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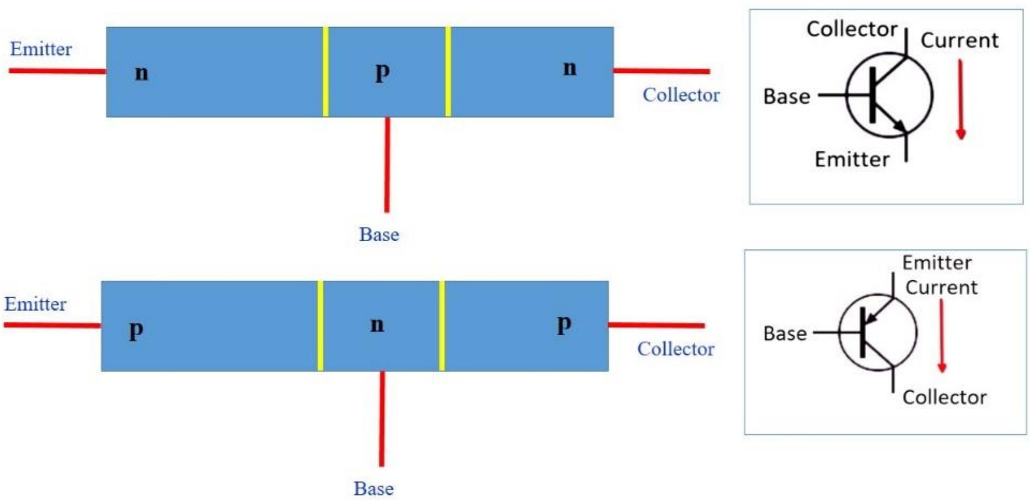
Topic:

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Active, Cut-off & Saturation regions Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line & Q- point.

TRANSISTOR

N-P-N Transistor: We know that a transistor is a semiconductor device applied for switching or amplification purpose. Junction transistor is two type-(i) n-p-n (ii) p-n-p.If a layer of p-type material is sandwich between two n-type layers, the transistor is called n-p-n transistor.

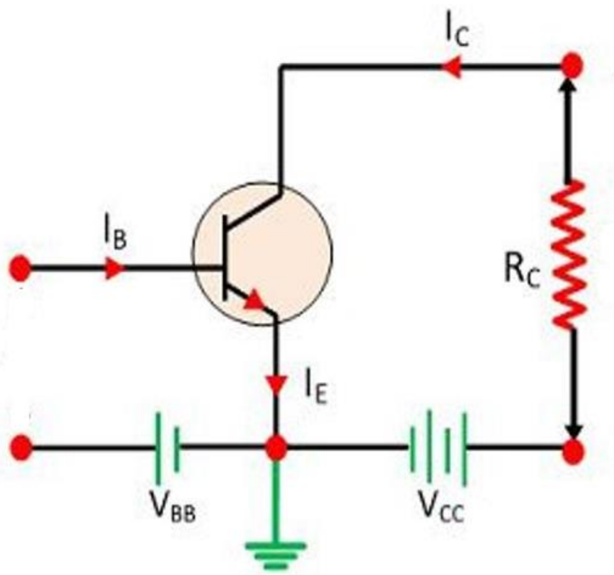
P-N-P Transistor: Whereas, a layer of n-type material is sandwich between two p-type layers, the transistor is called p-n-p transistor.



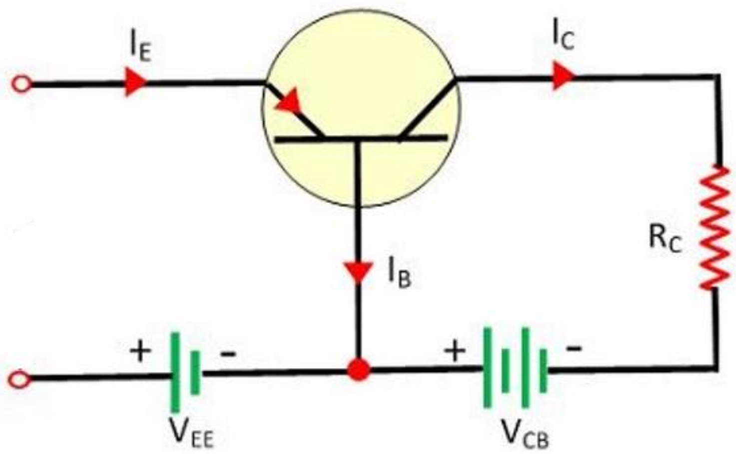
Characteristics of CB, CE and CC Configurations:A junction transistor has got three terminals-emitter, base and collector as well as it can be used as a two-port network with one one of three terminals common to both input and output. Therefore, we have three different configuration or mode of connection of transistor.

(i) Common Emitter (CE) Mode: When the emitter of a transistor is common to both input and output circuits, the transistor is called common emitter configuration (CE) or grounded emitter mode.

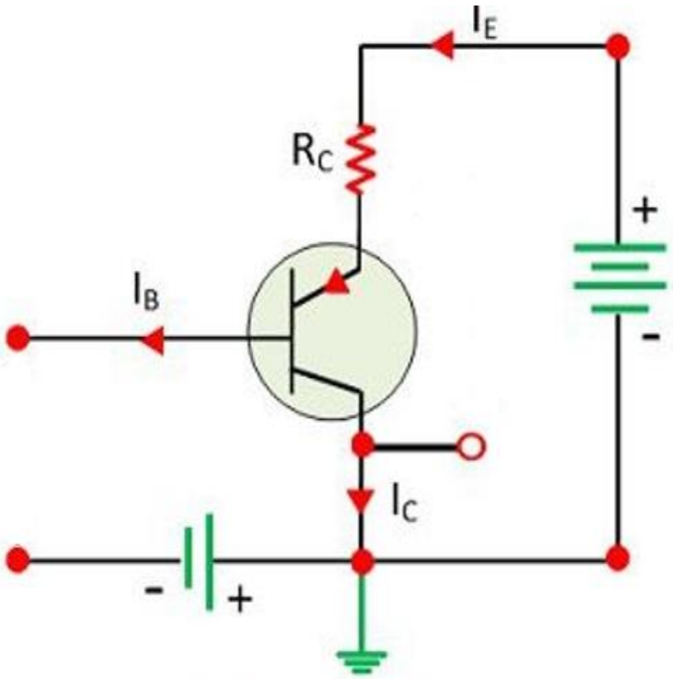
(ii) Common base (CB) Mode:When the base of a transistor is common to both input and output circuits, the transistor is called common emitter configuration (CE) or grounded emitter mode.
(iii) Common collector (CC) Mode:When the collector terminal of a transistor is common to both input and output circuits, the transistor is called common emitter configuration (CE) or grounded emitter mode.



n-p-n Transistor with Common Emitter (CE) Configuration

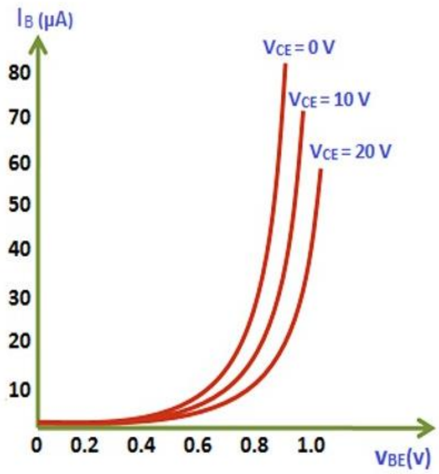


n-p-n Transistor with Common Base (CB) Configuration

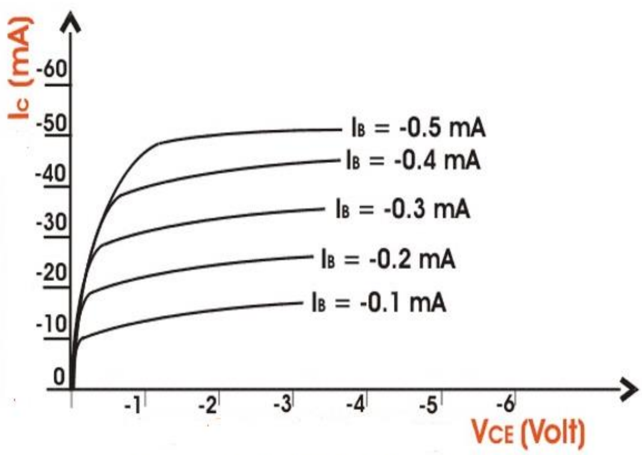


n-p-n Transistor with Common Collector (CC) Configuration

Common Emitter Input and Output Characteristics



Common Emitter Input Characteristics



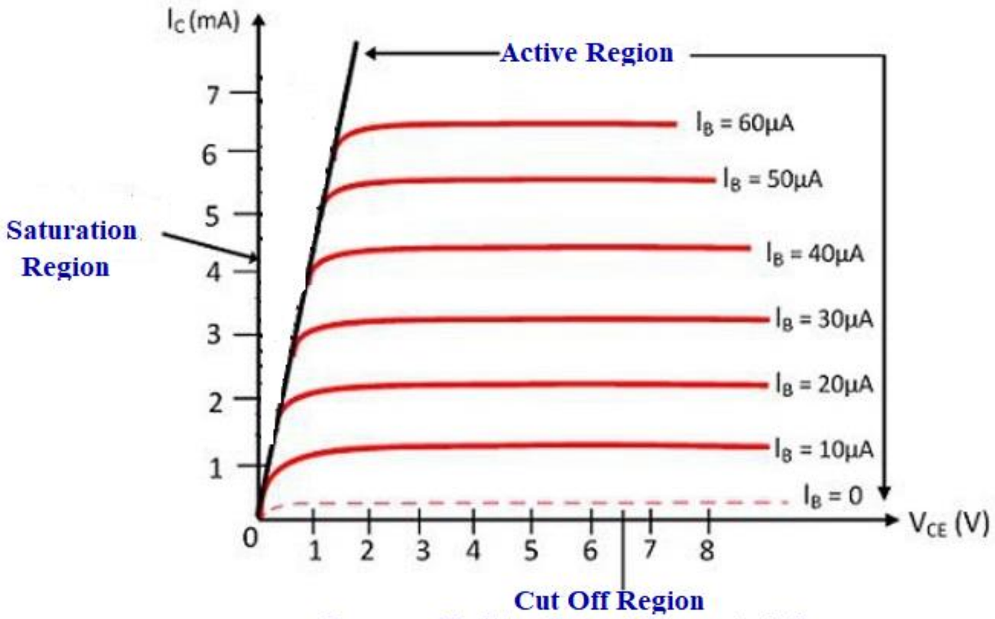
Common Emitter Output Characteristics

(i) Common Emitter Input Characteristics

For Common Emitter (CE)input Characteristics, we plot $I_B\ (\mu A)\ vs\ V_{BE}\ (Volt)$ where Collector to Emitter voltage (V_{CE}) become constant. The characteristics curve are similar to that of forward biased p-n junction diode. For, constantV_{BE} ,I_B decreases with increase in V_{CE} . Increase in V_{CE} decreases the effective base width. As a result, the recombination base current decreases.

(ii) Common Emitter Output Characteristics

For Common Emitter (CE)input Characteristics, we plot $I_C\ (mA)\ vs\ V_{CE}\ (Volt)$ where the base current (I_B) become constant. Here, we get three region-(i) Active (ii) Saturation (iii) Cut-off Region.



Common Emitter Output Characteristics

Active Region:

In active region, the emitter base junction is forward bias and the collector base junction is reverse bias.This region is from, right to the ordinate $V_{CE} = V_{CEsat}$ and above the characteristics for $I_B = 0$.In this region the curves are straight and equispaced. In this region I_C increases rapidly with V_{CE} by considering the relation,

$$I_c = \beta I_B + (\beta + 1) I_{CBO}$$

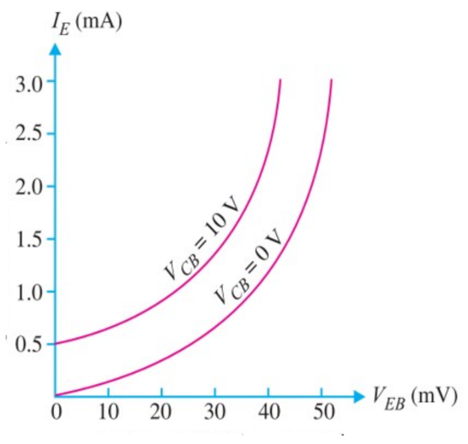
Cut off Region:

The cut off region is defined, $I_E = 0$, $I_B = -I_{CBO}$ and $I_C = I_{CBO}$. In cut off region, the emitter base junction is reverse bias and the collector base junction is reverse bias.

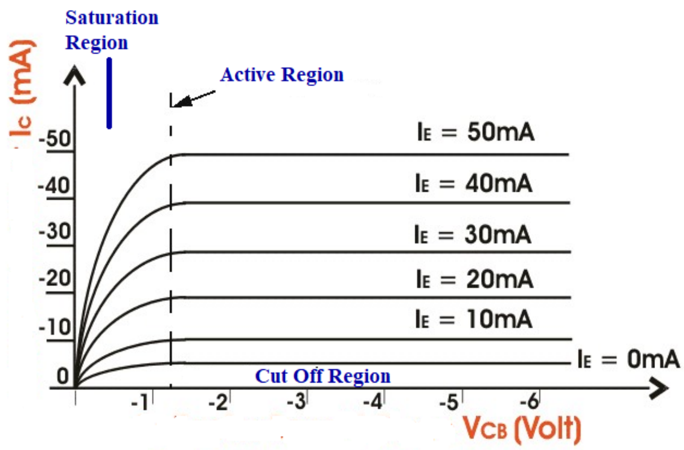
Saturation Region:

In saturation region, the emitter base junction is forward bias and the collector base junction is forward bias by at least the cutin voltage. This region is from, left of the ordinate $V_{CE} = V_{CEsat}$ where all the curves merge and fall rapidly towards origin is the saturation region.In this region, the collector current becomes almost independent of base current, for a given load and collector supply.

Common Base Input and Output Characteristics



Common Base Input Characteristics



Common Base Output Characteristics

(i) *Common Base Input Characteristics*

For Common Base (CB)input Characteristics, we plot $I_E\ (mA)\ vs\ V_{EB}\ (Volt)$ where Collector to Base voltage (V_{CB}) become constant. The characteristics curve are similar to that of forward biased p-n junction diode. For, constantV_{EB} ,I_E increases with increase in V_{CB} . Increase in V_{CB} increases the width of the depletion region of the collector base junction increases. This the effective base width.

(ii) *Common BaseOutput Characteristics*

For Common Base (CB)input Characteristics, we plot $I_C\ (mA)\ vs\ V_{CB}\ (Volt)$ where the emitter current (I_E) become constant. Here, we get three region-(i) Active (ii) Saturation (iii) Cut-off Region.

Active Region:

In active region, the emitter base junction is forward bias and the collector base junction is reverse bias. At the lower end of the active region, $I_E = 0$ and the collector current is simply I_{CBO}. Now,I_E , *increases* above zero, the I_C is given by

$$I_{c} = \alpha I_E + I_{CBO} \approx \alpha I_E$$

In this region, the I_C is almost independent of V_{CB}

Cut off Region:

The cut off region is defined the region right to the ordinate $V_{CB} = 0$ and below the characteristics for $I_E = 0$, is Cut-off region.In cut off region, the emitter base junction is reverse bias and the collector base junction is reverse bias.

Saturation Region:

In saturation region, the emitter base junction is forward bias and the collector base junction is forward bias. This region is from, left of the ordinate $V_{CB} = 0$ and above the characteristics $I_E = 0$is the saturation region.

Transistor (α and β) and Current Gain: The collector current consists of two components, the collector to base reverse saturation current and the predominant portion representing a part of the emitter current reaching the collector. Therefore,

$$I_c = \alpha I_E + I_{CBO}$$

Where, [$\alpha = transistor\ alpha$]

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

If we take $I_{CBO}$is very very less than I_c

Therefore, $I_c = \alpha I_E$

$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E} \Big| V_{CB=Constant}$$

We know that, $I_E = I_B + I_C$

Therefore, $I_c = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

$$I_c = \beta I_B + (\beta + 1) I_{CBO}$$

Therefore, $\beta = \frac{\alpha}{1-\alpha}$[This is the relation between α and β]

$$\beta_{dc} = \frac{I_C}{I_B} = h_{FE}$$

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B} \Big| V_{CE=Constant} = h_{fe}$$

Transistor Load Line & Q-point:

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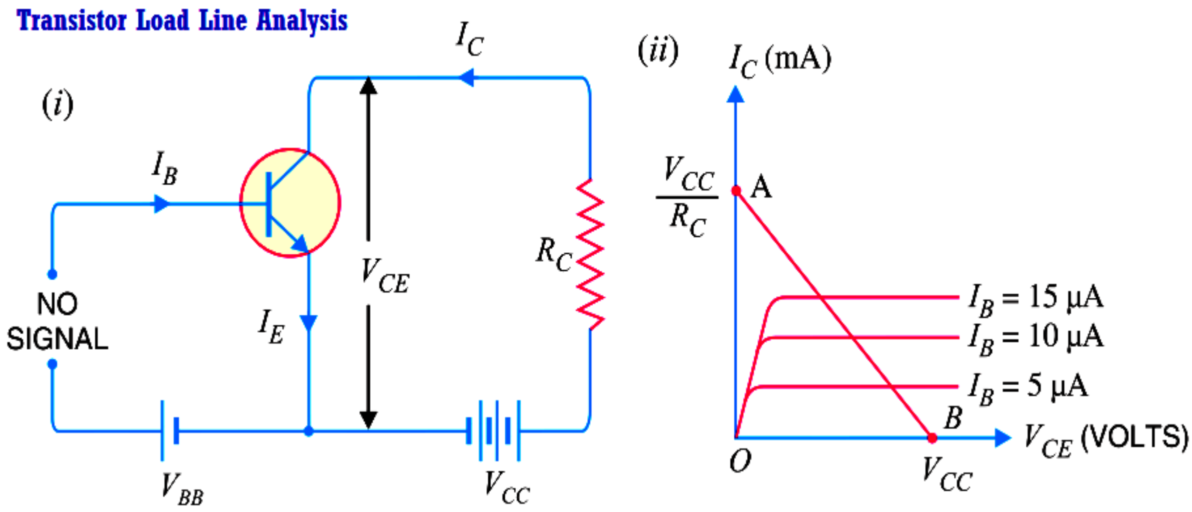
For better operation and stability of circuit of transistor we have to require the determination of the collector current for various collector-emitter voltages.It can be done by load line analysis.

The resistance R_C connected to the transistor circuit is called load or load resistance therefore, the line is called the load line.



From the analysis of circuit,

$$V_{CC} = I_C R_C + V_{CE}$$

This equation represent a straight line in V_{CE}-I_C plane. It is called d.c load line. To find the **Q**-point this d.c. load line is plotted on the output characteristics curves as a line connecting the points **(0,** $\frac{V_{CC}}{R_C}$**) and (**V_{CC}, I_C**)**. The coordinates of the points intersecting the load line and the characteristics curve to a fixed value of input current gives the actual d.c. value of collector current (I_C) flowing through the circuit and the d.c. value of collector to emitter voltage (V_{CE})operating across the transistor. The point is called **Q-point**.

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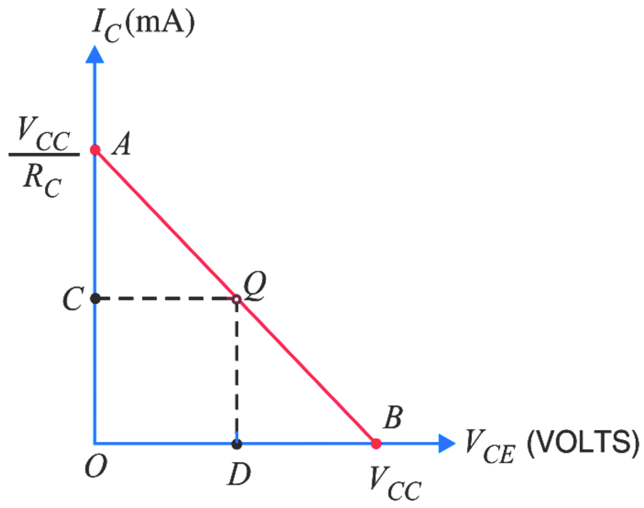

Frequently Asked Questions:

1. *Draw the circuit symbol and diagram of n-p-n and p-n-p transistor.*
2. *With proper circuit symbol, explain CE, CB,CC mode of p-n-p and n-p-n transistor.*
3. *With proper circuit diagram explain load line and Q-point*
4. *Explain* $\beta_{dc}, \beta_{ac}, \alpha_{dc}, \alpha_{ac}$.
5. ***Prove the relation:*** (i) $I_c = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

(ii) $I_c = \beta I_B + (\beta + 1) I_{CBO}$

6. *With proper circuit symbol, explain CE, CB,CC mode input and output characteristics of transistor.*

Numerical:

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References:

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(vi) *https://www.quora.com/(Images are taken only for class teaching)*
(vii) *https://www.researchgate.net/(Images are taken only for class teaching)*