Transistors

A **Transistor** is a three terminal semiconductor device that regulates current or voltage flow and acts as a switch or gate for signals.

Ex: BJT,FET.

❖Advantages

There are many advantages of a transistor such as −

- High voltage gain.
- Lower supply voltage is sufficient.
- Most suitable for low power applications.
- Smaller and lighter in weight.
- Mechanically stronger than vacuum tubes.
- No external heating required like vacuum tubes.
- Very suitable to integrate with resistors and diodes to produce ICs.

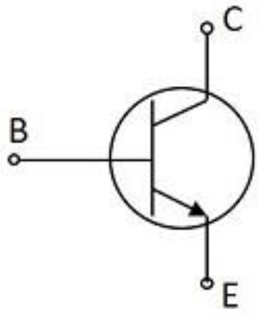
Bipolar junction transistor (BJT)

The Transistor is a three terminal solid state device which is formed by connecting two diodes back to back. Hence it has got **two PN junctions**. Three terminals are drawn out of the three semiconductor materials present in it.

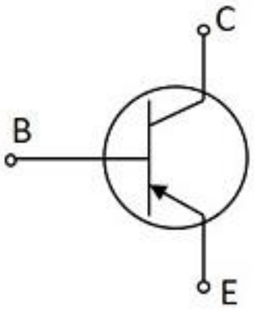
- This type of connection offers two types of BJT.
- They are **PNP** and **NPN** which means an N-type material between two P types and the other is a P-type material between two N-types respectively.

The symbols of PNP and NPN transistors are as shown below.

The three terminals drawn from the transistor indicate **Emitter, Base and Collector terminals**



Symbol of NPN transistor



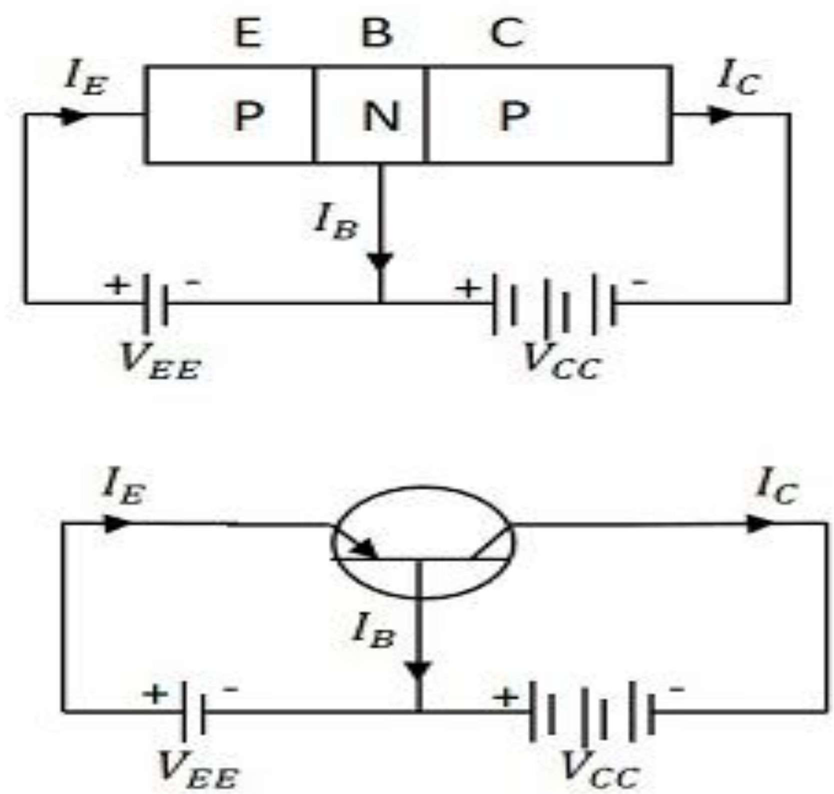
Symbol of PNP transistor

Construction of PNP & NPN Transistors

Emitter	Base	Collector
The left hand side of the above shown structure can be understood as **Emitter**. As this emits electrons, it is called as an Emitter. This is simply indicated with the letter **E**.	The middle material in the above figure is the **Base**. This is indicated by the letter **B**.	The right side material in the above figure can be understood as a **Collector**. This is indicated by the letter **C** .
This has a **moderate size** and is **heavily doped**. Its main function is to **supply** a number of **majority carriers**, i.e. either electrons or holes.	This is **thin** and **lightly doped**. Its main function is to **pass** the majority carriers from the emitter to the collector.	This is **a bit larger** in size than emitter and base. It is **moderately doped**. Its name implies its function of **collecting the carriers**.

Operation of PNP Transistor

The operation of a PNP transistor can be explained by having a look at the following figure, in which emitter-base junction is forward biased and collector-base junction is reverse biased.



P-N-P Transistor biasing

▪The voltage $\mathbf{V_{EE}}$ provides a positive potential at the emitter which repels the holes in the P-type material and these holes cross the emitter-base junction, to reach the base region. There a very low percent of holes recombine with free electrons of N-region. This provides very low current which constitutes the base current $\mathbf{I_B}$. The remaining holes cross the collector-base junction, to constitute collector current $\mathbf{I_C}$, which is the hole current.

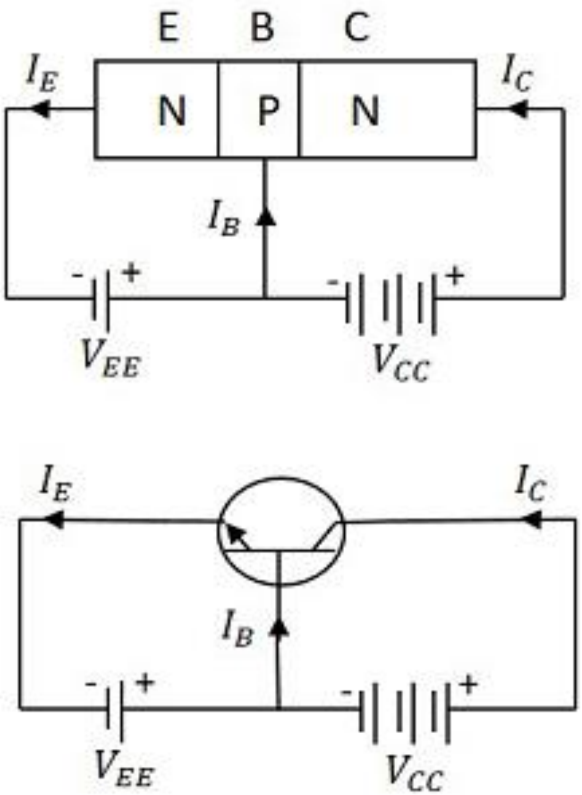
▪As a hole reaches the collector terminal, an electron from the battery negative terminal fills the space in the collector. This flow slowly increases and the electron minority current flows through the emitter, where each electron entering the positive terminal of $\mathbf{V_{EE}}$, is replaced by a hole by moving towards the emitter junction. This constitutes emitter current $\mathbf{I_E}$.

Conclusion:

- **The conduction in a PNP transistor takes place through holes.**
- **The collector current is slightly less than the emitter current.**
- **The increase or decrease in the emitter current affects the collector current.**

Operation of NPN Transistor

The operation of an NPN transistor can be explained by having a look at the following figure, in which emitter-base junction is forward biased and collector-base junction is reverse biased.



N-P-N Transistor biasing

The voltage $\mathbf{V_{EE}}$ provides a negative potential at the emitter which repels the electrons in the N-type material and these electrons cross the emitter-base junction, to reach the base region. There a very low percent of electrons recombine with free holes of P-region. This provides very low current which constitutes the base current $\mathbf{I_B}$. The remaining holes cross the collector-base junction, to constitute the collector current $\mathbf{I_C}$.

- As an electron reaches out of the collector terminal, and enters the positive terminal of the battery, an electron from the negative terminal of the battery $\mathbf{V_{EE}}$ enters the emitter region. This flow slowly increases and the electron current flows through the transistor.

Conclusion:

- **The conduction in a NPN transistor takes place through electrons.**
- **The collector current is higher than the emitter current.**
- **The increase or decrease in the emitter current affects the collector current.**

Configurations of Transistor

Any transistor circuit can be designed using three types of configuration. Three configurations of the transistor are based on the connection of the transistor terminal. The three types of transistor circuit configurations are:

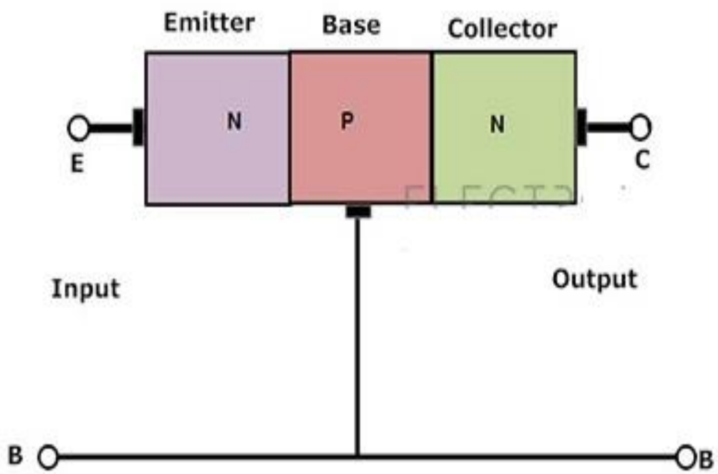
1. Common Emitter Transistor
2. Common Base Transistor
3. Common Collector Transistor.

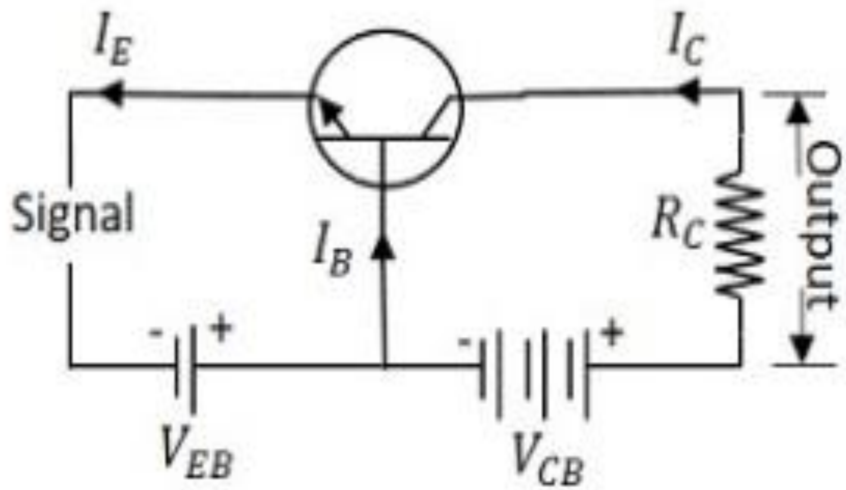
Each of these three circuit configurations has its own characteristics curve. Based on the requirement the type will be chosen for the circuit.

In every configuration, the emitter junction is forward biased and the collector junction is reverse biased.

Common Base (CB) Configuration of Transistor

The name itself implies that the Base terminal is taken as common terminal for both input and output of the transistor.





•Here the input is applied between the base and emitter terminals and the corresponding output signal is taken between the base and collector terminals with the base terminal grounded.

•Here the input parameters are V_{EB} and I_E and the output parameters are V_{CB} and I_C.

•The input current flowing into the emitter terminal must be higher than the base current and collector current to operate the transistor, therefore the output collector current is less than the input emitter current.

This type of configuration has high resistance gain i.e. ratio of output resistance to input resistance is high.

The voltage gain for this configuration of circuit is given as

$$A_V = V_{out}/V_{in} = (I_C*R_L) / (I_E*R_{in})$$

The Current gain in common base configuration is given as

$$\alpha = \text{Output current/Input current}$$

$$\alpha = I_C/I_E$$

The common base circuit is mainly used in single stage amplifier circuits, such as microphone pre amplifier or radio frequency amplifiers because of their high frequency response.

Input Characteristics (CB configuration)

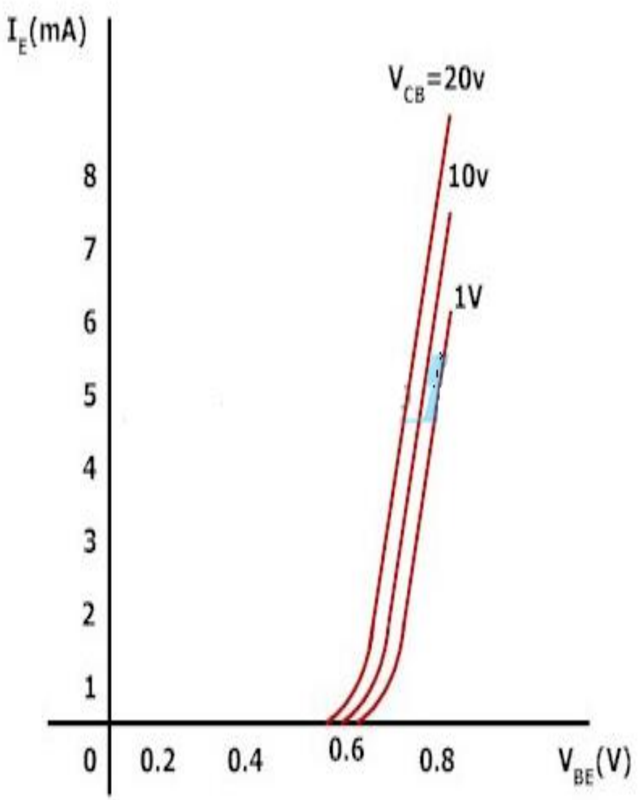
- Input characteristics are obtained between input current and input voltage with constant output voltage.

- First keep the output voltage V_{CB} constant and vary the input voltage V_{EB} for different points then at each point record the input current I_E value.

- Repeat the same process at different output voltage levels.

- Now with these values we need to plot the graph between I_E and V_{EB} parameters.

- The equation to calculate the input resistance R_{in} value is given below.



$R_{in} = V_{EB} / I_E$ (when V_{CB} is constant)

Output Characteristics (CB configuration)

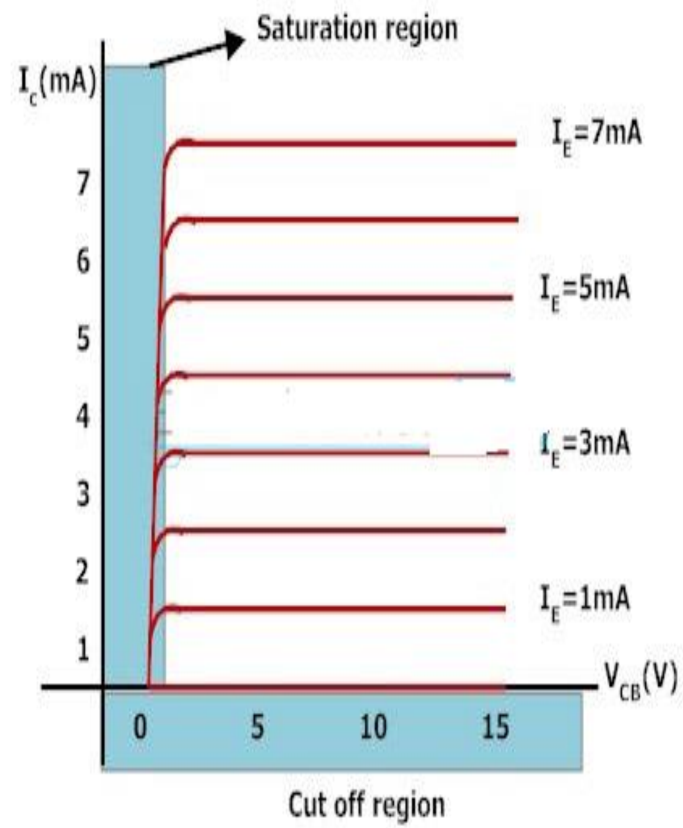
•The output characteristics are obtained between output current and output voltage with constant input current.

•First keep the emitter current constant and vary the V_{CB} value for different points, now record the I_C values at each point.

•Repeat the same process at different I_E values.

•Finally we need to draw the plot between V_{CB} and I_C at constant $I_{E.}$.

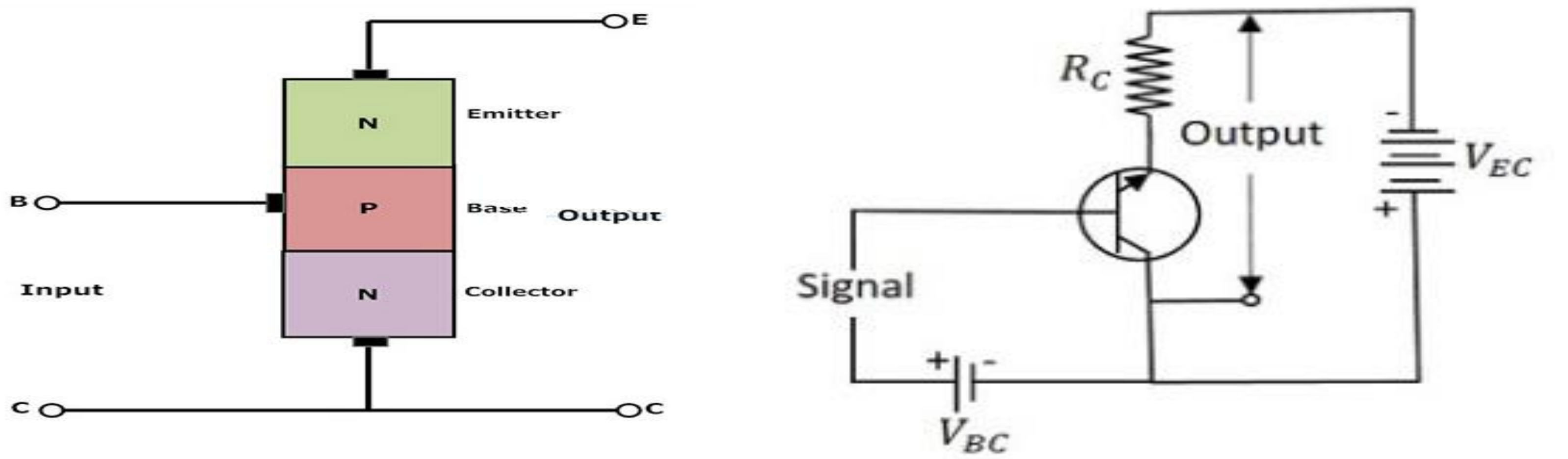
•The equation to calculate the output resistance value is given below.



$R_{out} = V_{CB} / I_C$ (when I_E is constant)

Common Collector (CC) Configuration of Transistor

In this configuration we use collector terminal as common for both input and output signals.



•In this configuration the input signal is applied between the base-collector region and the output is taken from the emitter-collector region.

•Here the input parameters are VBC and IB and the output parameters are VEC and IE.

•Here also the emitter current is equal to the sum of collector current and the base current.
Ie=Ic+Ib

The common collector configuration has high input impedance and low output impedance.

The Current gain in common collector configuration is given as

$$A_i = \text{output current/Input current}$$

$$A_i = I_E/I_B$$

$$A_i = (I_C + I_B)/I_B$$

$$A_i = (I_C/I_B) + 1$$

$$A_i = \beta + 1$$

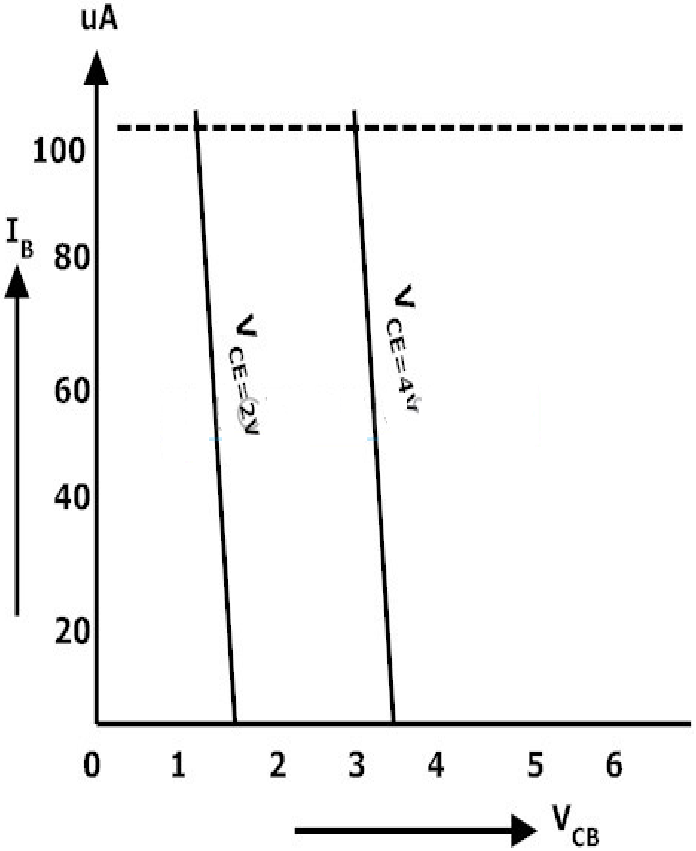
Input Characteristics (CC configuration)

•The input characteristics of a common-collector configuration are obtained between inputs current I_B and the input voltage V_{CB} at constant output voltage V_{EC}

•Keep the output voltage V_{EC} constant at different levels and vary the input voltage V_{BC} for different points

•Repeat the same process at different output voltage levels.

•we need to draw a graph between the parameters of V_{BC} and I_B at constant V_{EC}.



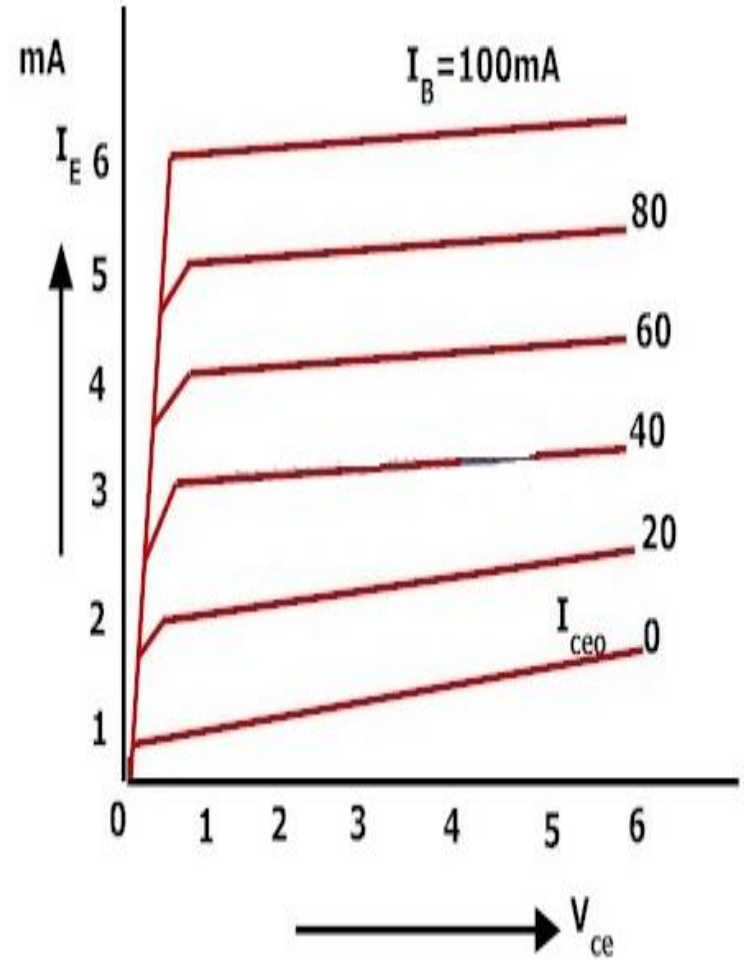
Output Characteristics (CC configuration)

•The output characteristics of a common collector circuit are obtained between the output voltage V_{EC} and output current I_E at constant input current I_B.

•we keep the I_B at constant value and we will vary the V_{EC} value for various points, now we need to record the value of I_E for each point..

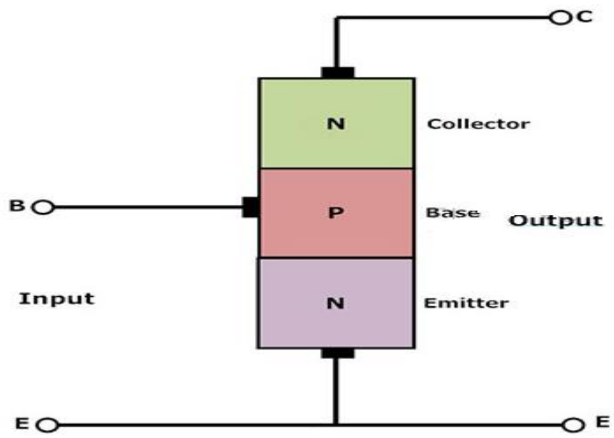
•Repeat the same process at different I_B values.

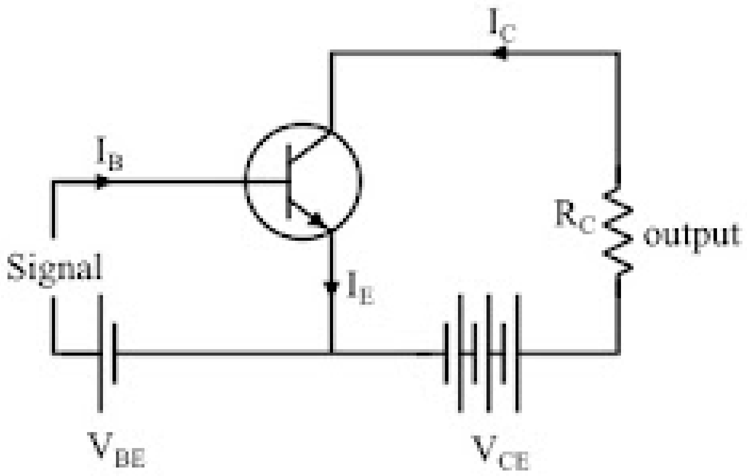
•we need to plot the graph between the parameters of I_E and V_{CE} at constant values of I_B.



Common Emitter (CE) Configuration of Transistor

The name itself implies that the **Emitter** terminal is taken as common terminal for both input and output of the transistor.





•Here the input is applied between base-emitter region and the output is taken between collector and emitter terminals. In this configuration the input parameters are V_{BE} and I_B and the output parameters are V_{CE} and I_C.

•In this configuration the emitter current is equal to the sum of small base current and the large collector current. i.e. $I_E = I_C + I_B$.

•We know that the ratio between collector current and emitter current gives current gain alpha in Common Base configuration similarly the ratio between collector current and base current gives the current gain beta in common emitter configuration.

Now let us see the relationship between these two current gains.

$$\text{Current gain } (\alpha) = I_C/I_E$$

$$\text{Current gain } (\beta) = I_C/I_B$$

$$\text{Collector current } I_C = \alpha\, I_E = \beta I_B$$

This configuration is mostly used one among all the three configurations. It has medium input and output impedance values. It also has the medium current and voltage gains. But the output signal has a phase shift of 1800 i.e. both the input and output are inverse to each other.

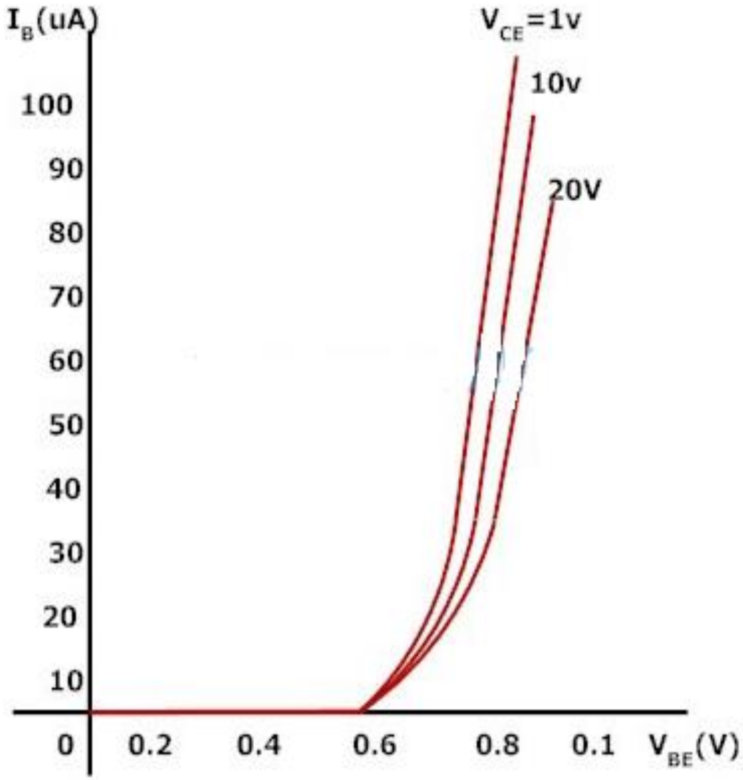
Input Characteristics (CE configuration)

•The input characteristics of common emitter configuration are obtained between input current I_B and input voltage V_{BE} with constant output voltage V_{CE}

•Keep the output voltage V_{CE} constant and vary the input voltage V_{BE} for different points, now record the values of input current at each point.

•Repeat the same process at different output voltage levels.

•We need to draw a graph between the values of I_B and V_{BE} at constant V_{CE}.



The equation to calculate the input resistance R_{in} is given below.

$R_{in} = V_{BE}/I_B$ (when V_{CE} is at constant)

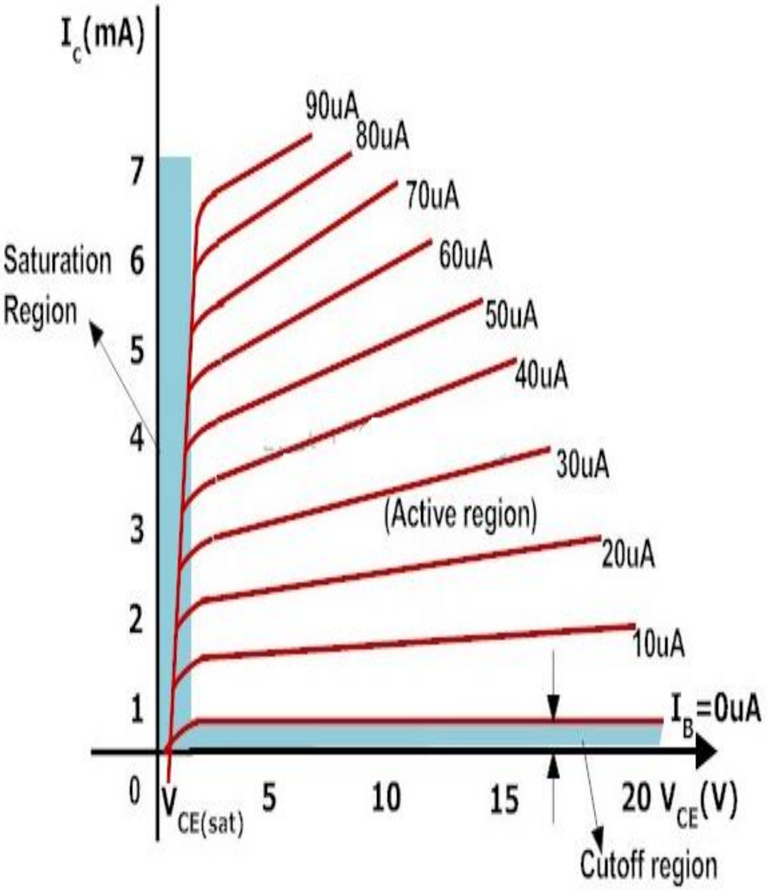
Output Characteristics (CE configuration)

•The output characteristics of common emitter configuration are obtained between the output current I_C and output voltage V_{CE} with constant input current I_B.

•Keep the base current I_B constant and vary the value of output voltage V_{CE} for different points, now note down the value of collector I_C for each point.

•Plot the graph between the parameters I_C and V_{CE} in order to get the output characteristics of common emitter configuration.

The equation to calculate the output resistance from this graph is given below.



$R_{out} = V_{CE}/I_C$ (when I_B is at constant)

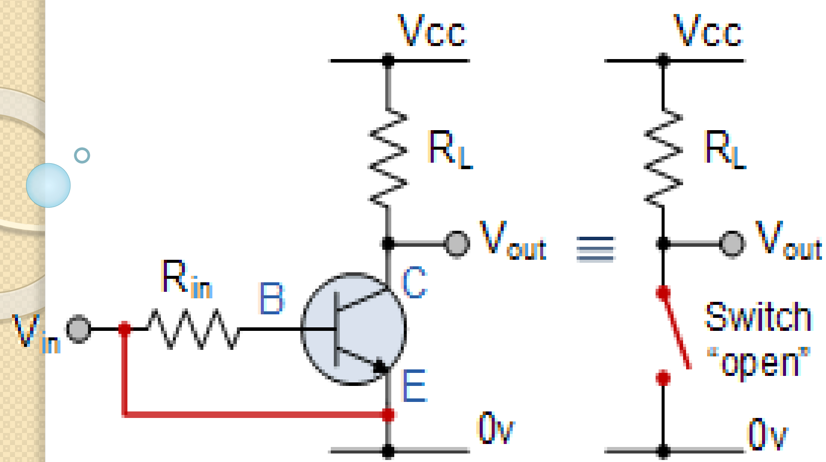
Transistor as a Switch

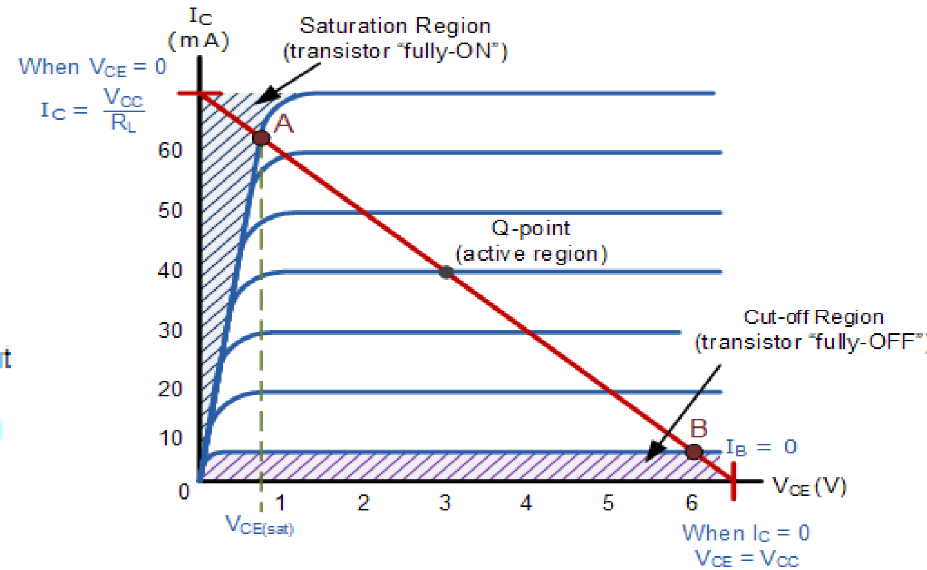
•A transistor can be used as a **solid state** switch. If the transistor is operated in the **saturation** region then it acts as closed **switch** and when it is operated in the **cut off region** then it behaves as an open switch.

•The transistor operates as a **Single Pole Single Throw (SPST)** solid state switch. When a zero input signal applied to the base of the transistor, it acts as an open switch. If a positive signal applied at the input terminal then it acts like a closed switch.

•When the transistor operating as switch, in the cut off region the current through the transistor is zero and voltage across it is maximum, and in the saturation region the transistor current is maximum and voltage across is zero. Therefore, both the on – state and off – state power loss is zero in the transistor switch.

Circuit diagram





Cut Off State (Open Switch)	Saturation State (Closed Switch)
The input is grounded i.e. at zero potential.	The input is connected to V_{CC}.
The V_{BE} is less that cut – in voltage 0.7 V.	Base – Emitter voltage is greater than cut – in voltage (0.7 V).
Both emitter – base junction and collector – base junction are reverse biased.	Both the base – emitter junction and base – collector junction are forward biased.
The transistor is fully – off acting as open switch.	The transistor is fully – ON and operates as closed switch.
The collector current I_C = 0 A and output voltage $V_{out} = V_{CC}$.	The collector current is maximum Ic=Vcc/RL