Transistors

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TRANSISTORS

"The building blocks of electronics world"

History of transistors

In 1906, an American inventor and physicist, Lee De Forest, made the vacuum tube triode or audion as he called it.

- Used in radios
- Used in early computers

The first transistor

In 1947, John Bardeen and Walter Brattain deviced - the first "point contact" transistor.

Transistor Definition

- Transistor is an electronic device made of three layers of semiconductor material that can act as an insulator and a conductor.

- The three layered transistor is also known as the bipolar junction transistor.

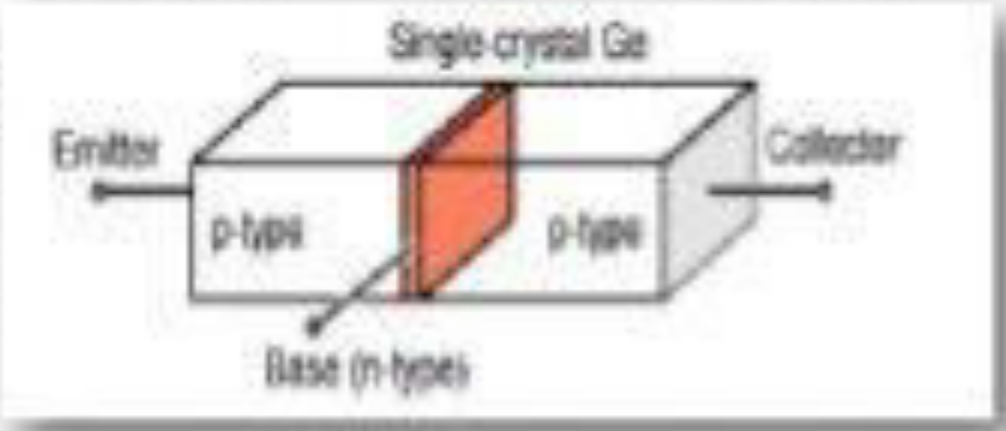
Bipolar Junction Transistors (BJT's)

- The term bipolar refers to the use of both holes and electrons as charge carriers in the transistor structure

- There are two types of BJTs, the NPN and PNP

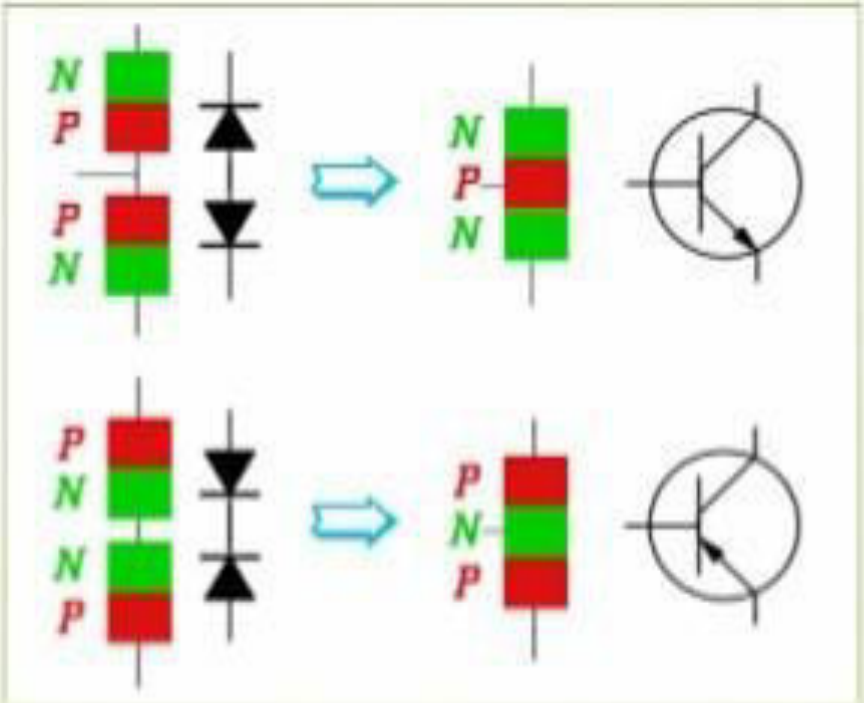
Regions of a transistor

- A transistor has three regions namely,
- Emitter- heavily doped
- Base- lightly doped
- Collector- moderately doped

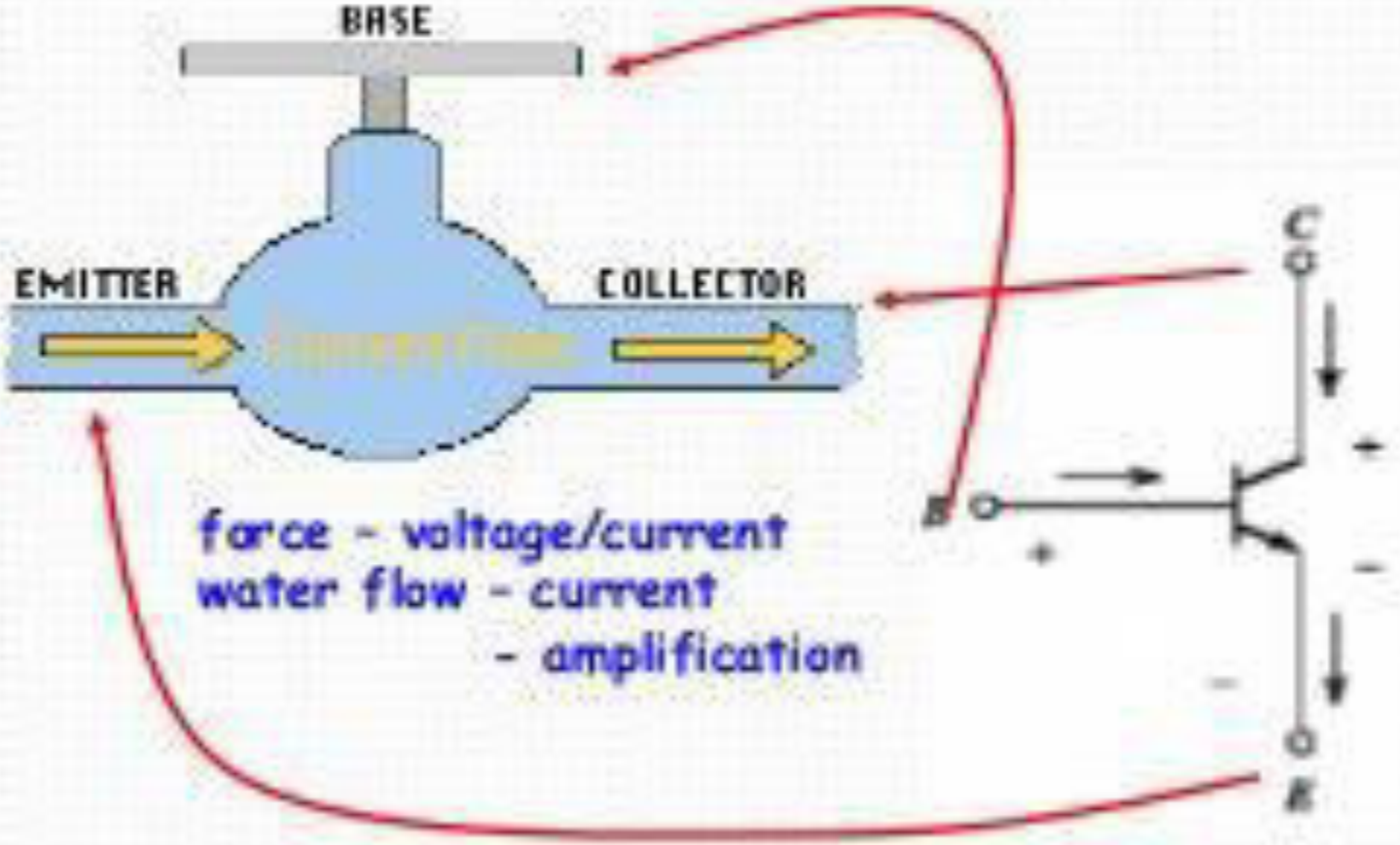


Bipolar junction transistor (BJT)

- A Bipolar Transistor essentially consists of a pair of PN Junction Diodes that are joined back-to-back.
- It is called **bi**polar because conduction channel uses both majority and minority carriers for main electric current. It is the First type of transistor to be commercially mass-produced.

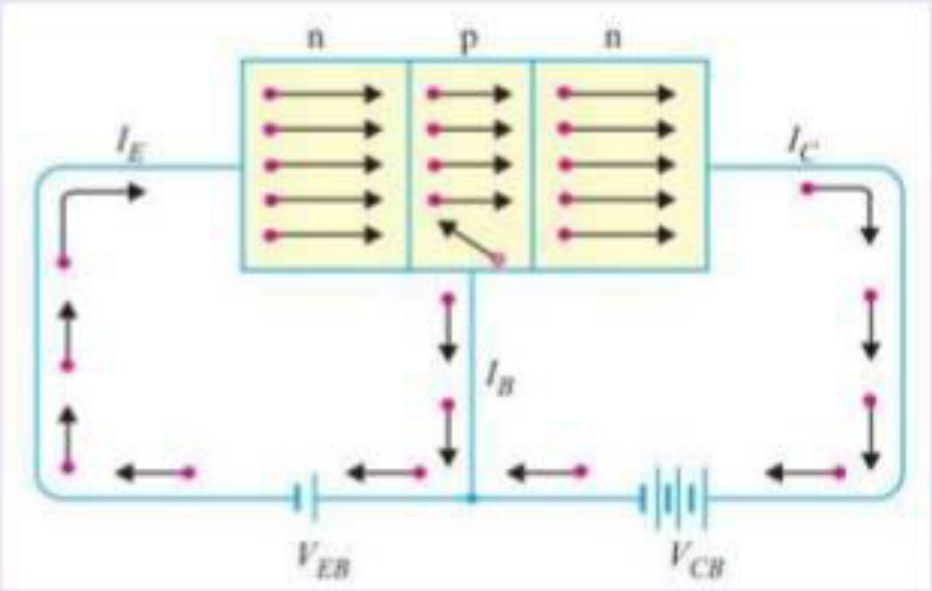


Transistor operation



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

Transistor Operation

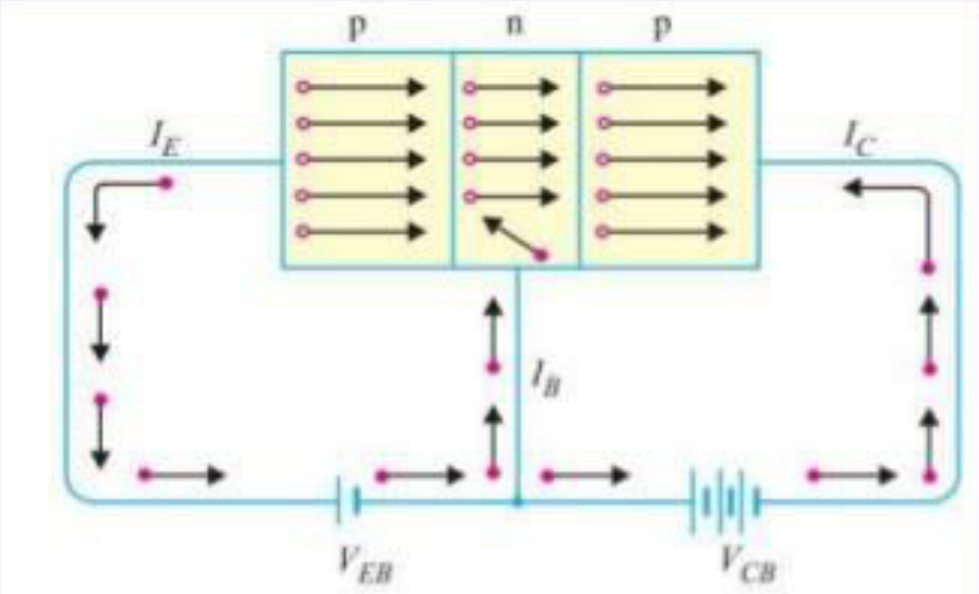
1) Working of npn transistor:

- ✓ 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.

$$I_E = I_B + I_C$$

Transistor Operation

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

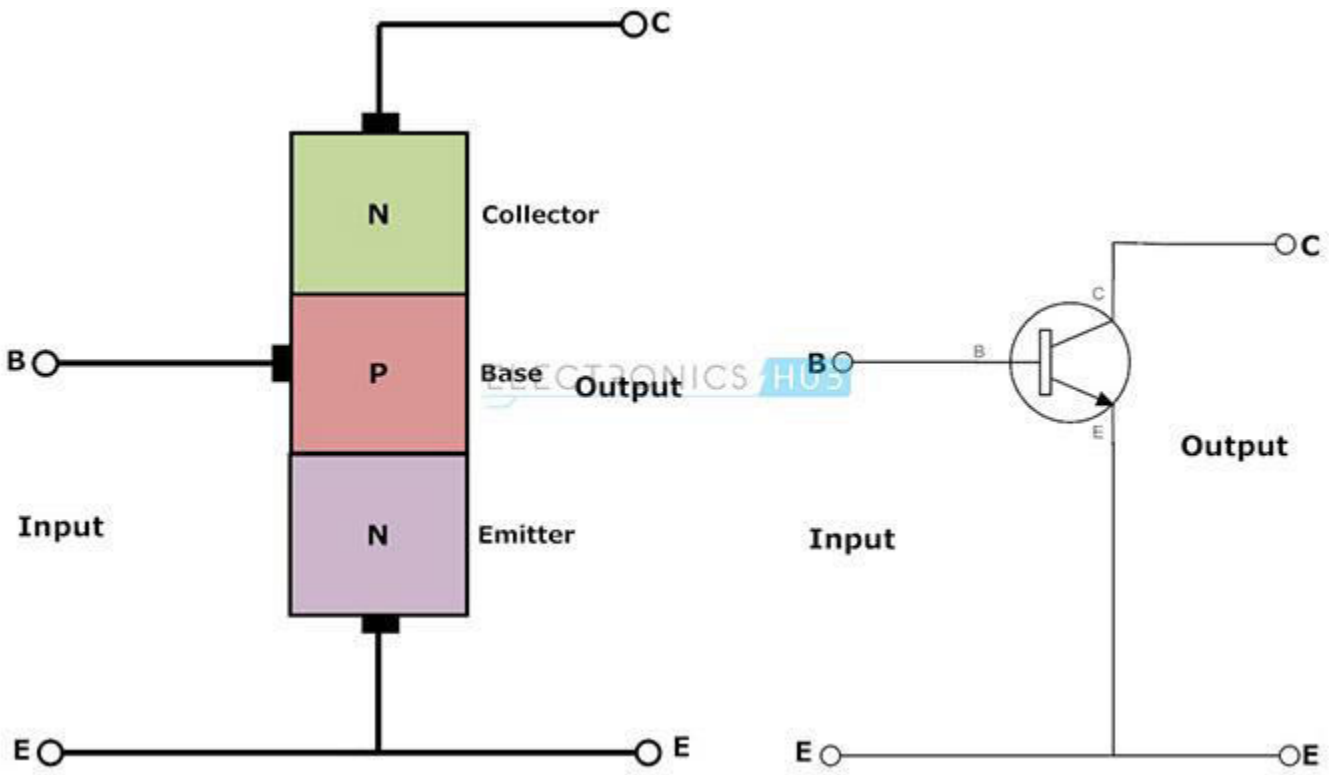
  → Both junctions are reverse biased.

Transistor Connection

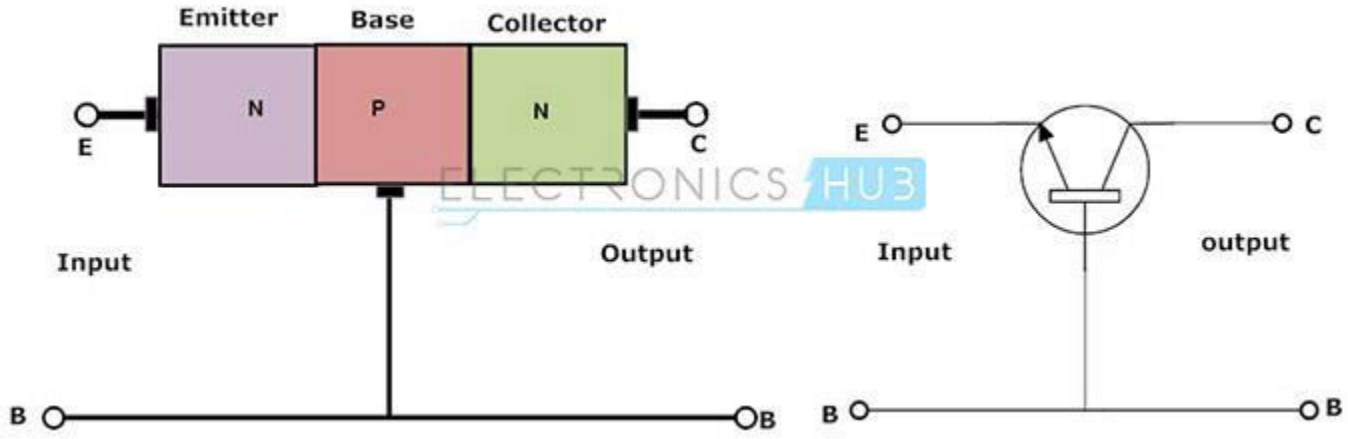
- Transistor can be connected in a circuit in following three ways-

1) Common Base
2) Common Emitter
3) Common Collector

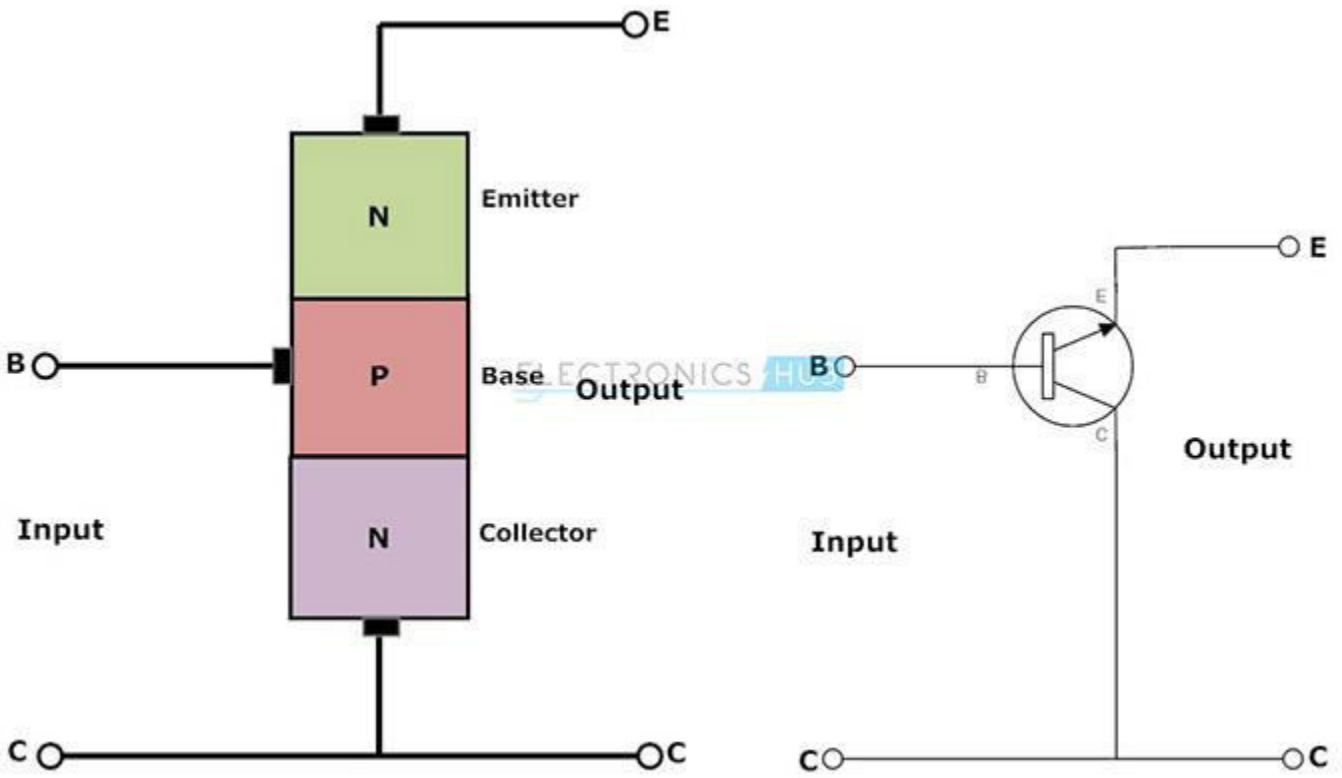
Common emitter configuaration OR mode



Common Base Configuaration OR mode

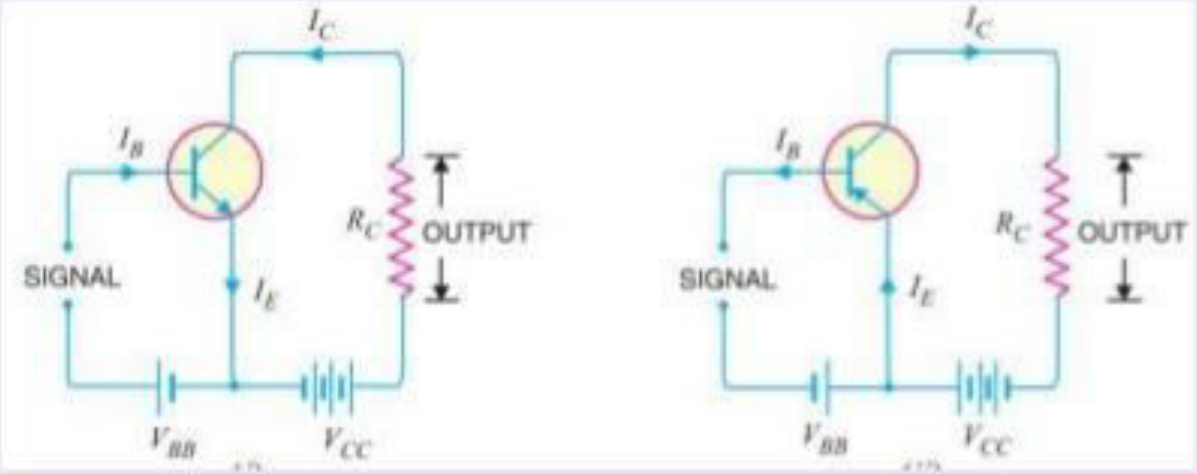


Common collector Configuaration OR mode



Common Emitter Connection

- The common-emitter terminology is derived from the fact that the emitter is common to both the input and output sides of the configuration.



- First Figure shows common emitter npn configuration and second figure shows common emitter pnp configuration.

Common Emitter Connection

- Base Current amplification factor (β) :
- In common emitter connection input current is base current and output current is collector current.
- The ratio of change in collector current to the change in base current is known as base current amplification factor, β.

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

- Normally only 5% of emitter current flows to base, so amplification factor is greater than 20. Usually this range varies from 20 to 500.

Relation Between β and α

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

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

$$I_E = I_B + I_C$$

$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1 - \alpha}$$

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

Expression for Collector Current

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

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

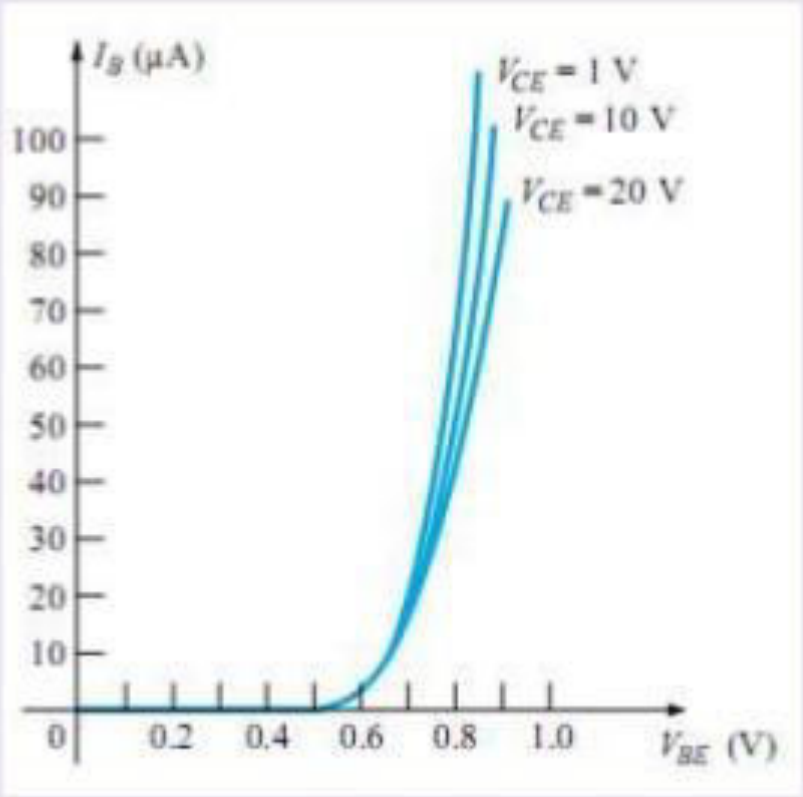
$$I_E(1-\alpha) = I_B + I_{CBO}$$

$$I_E = \frac{I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha}$$

$$I_C \; ; \; I_E = *(\beta + 1) I_B + (\beta + 1) I_{CBO}$$

Characteristics of common emitter configuration

- <u>Input Characteristics:</u>



→ V_{BE} vs I_B characteristics is called input characteristics.

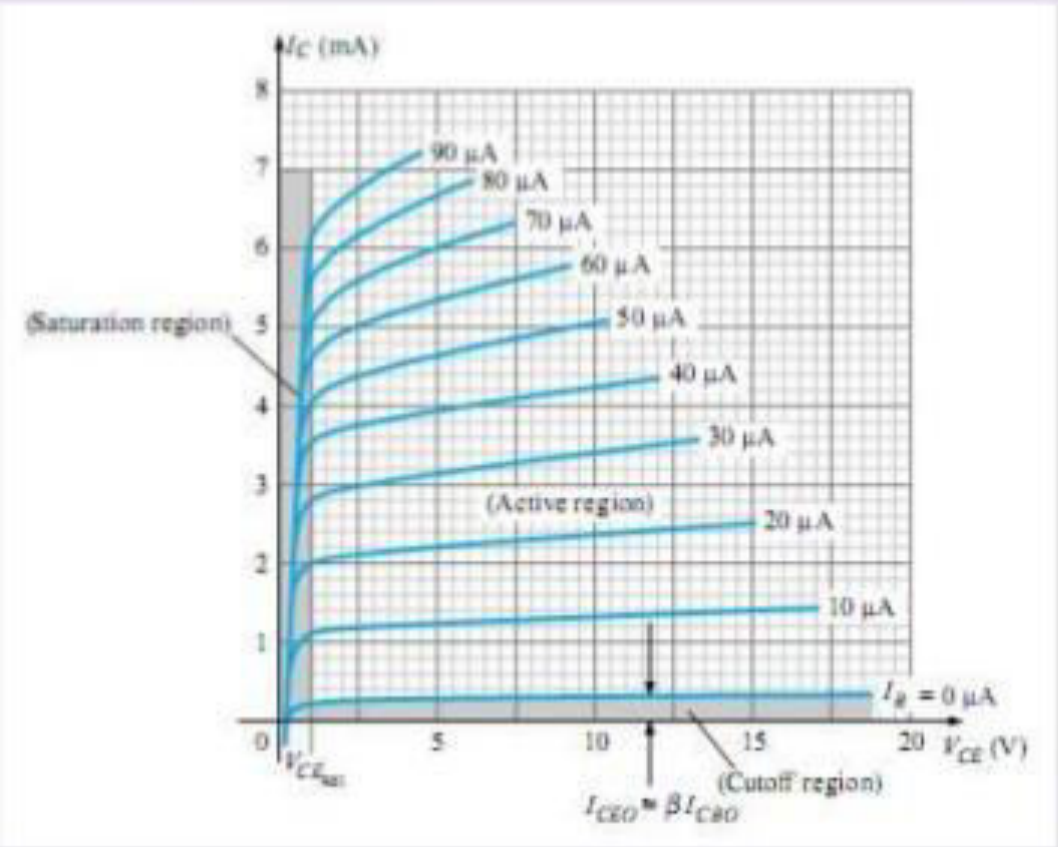
→ I_B increases rapidly with V_{BE}. It means input resistance is very small.

→ I_E almost independent of V_{CE}.

→ I_B is of the range of micro amps.

Characteristics of common emitter configuration

- <u>Output Characteristics:</u>



→ V_{CE} vs I_c characteristics is called output characteristics.

→ I_C varies linearly with V_{CE}, only when V_{CE} is very small.

→ As, V_{CE} increases, I_C becomes constant.

Input and Output Resistance of common emitter conf.

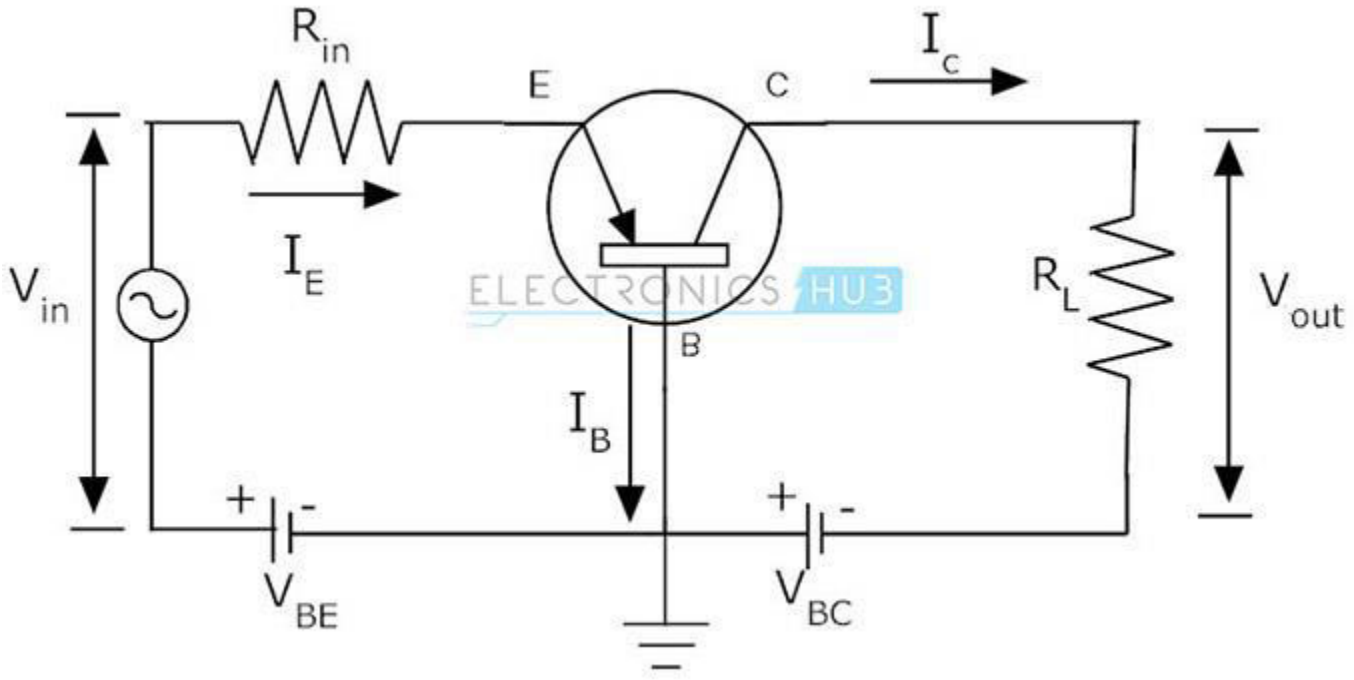
- Input Resistance: The ratio of change in emitter-base voltage to the change in base current is called Input Resistance.

$$r_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

- Output Resistance: The ratio of change in collector-emitter voltage to the change in collector current is called Output Resistance.

$$r_0 = \frac{\Delta V_{CE}}{\Delta I_C}$$

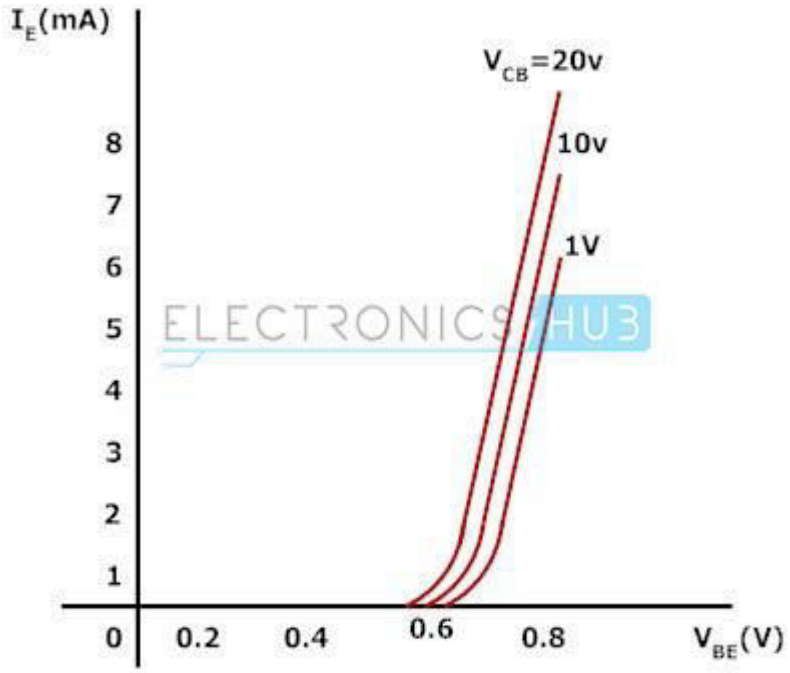
Common base configuaration connection diagram



Input characteristics

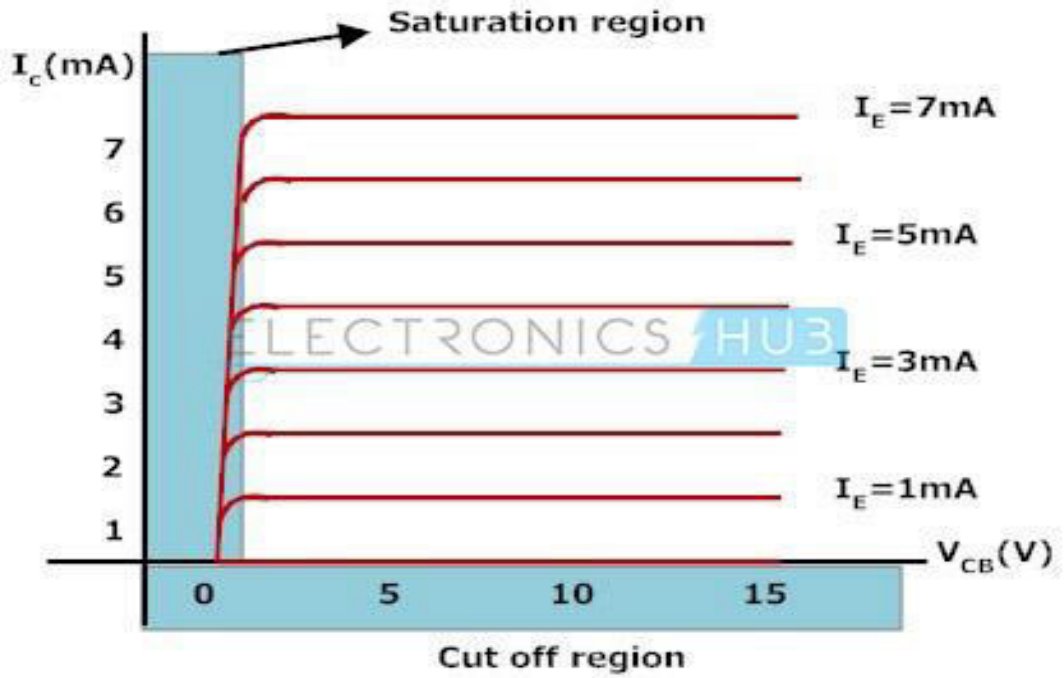
The below figure show the input characteristics of common base configuration. The equation to calculate the input resistance R_{in} value is given below.

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

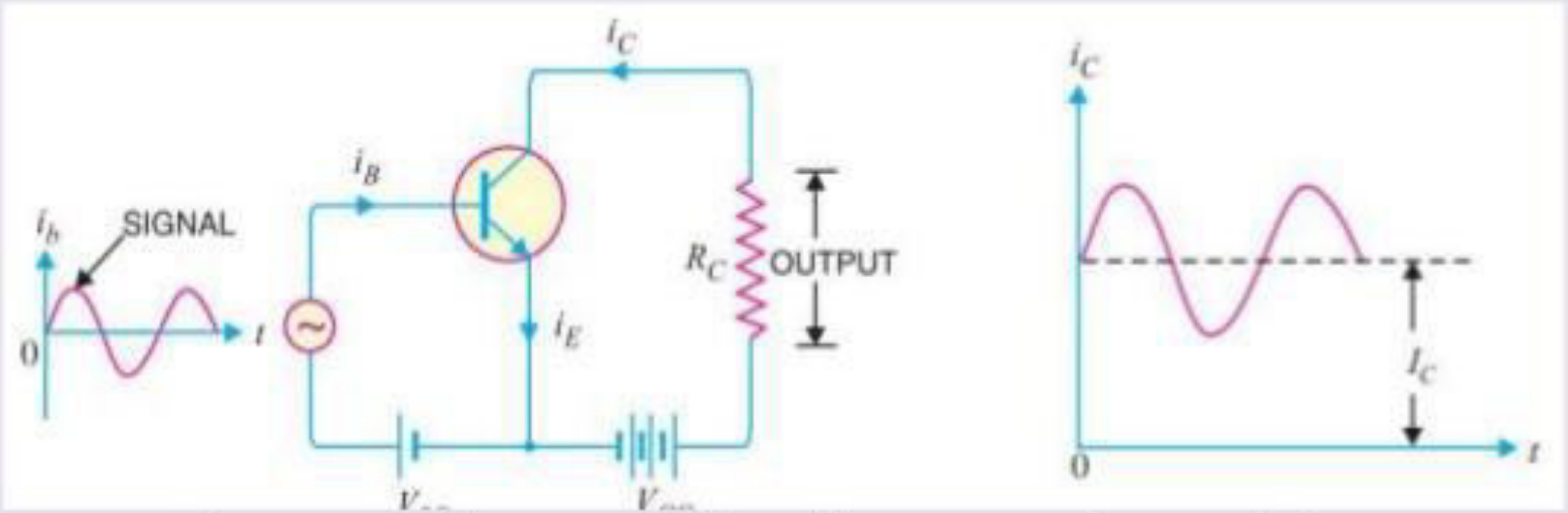


output characteristics

- The below figure show the output characteristics of common base configuration. The equation to calculate the output resistance value is given below.
- $R_{out} = V_{CB} / I_C$ (when I_E is constant)



Transistor as an amplifier in CE conf.



- Figure shows CE amplifier for npn transistor.
- Battery V_{BB} is connected with base in-order to make base forward biased, regardless of input ac polarity.
- Output is taken across Load R

Transistor as an amplifier in CE conf.

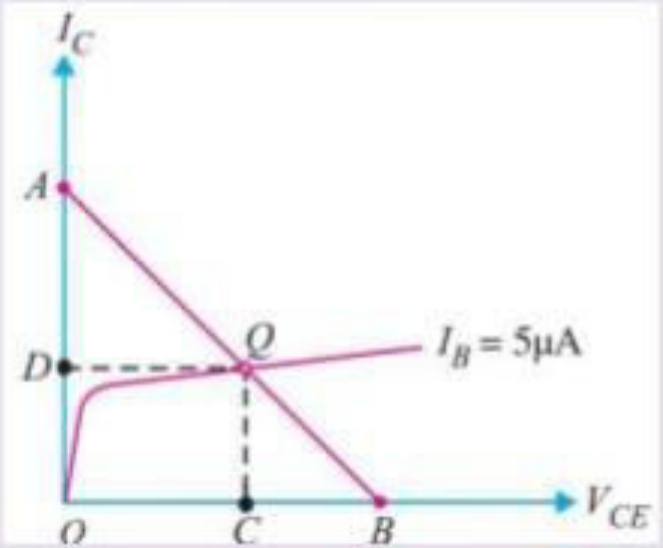
- During positive half cycle input ac will keep the emitter-base junction more forward biased. So, more carrier will be emitted by emitter, this huge current will flow through load and we will find output amplified signal.
- During negative half cycle input ac will keep the emitter-base junction less forward biased. So, less carrier will be emitted by emitter. Hence collector current decreases.
- This results in decreased output voltage (In opposite direction).

Operating Point

The zero signal values of I_C and V_{CE} are known as the **operating point.**

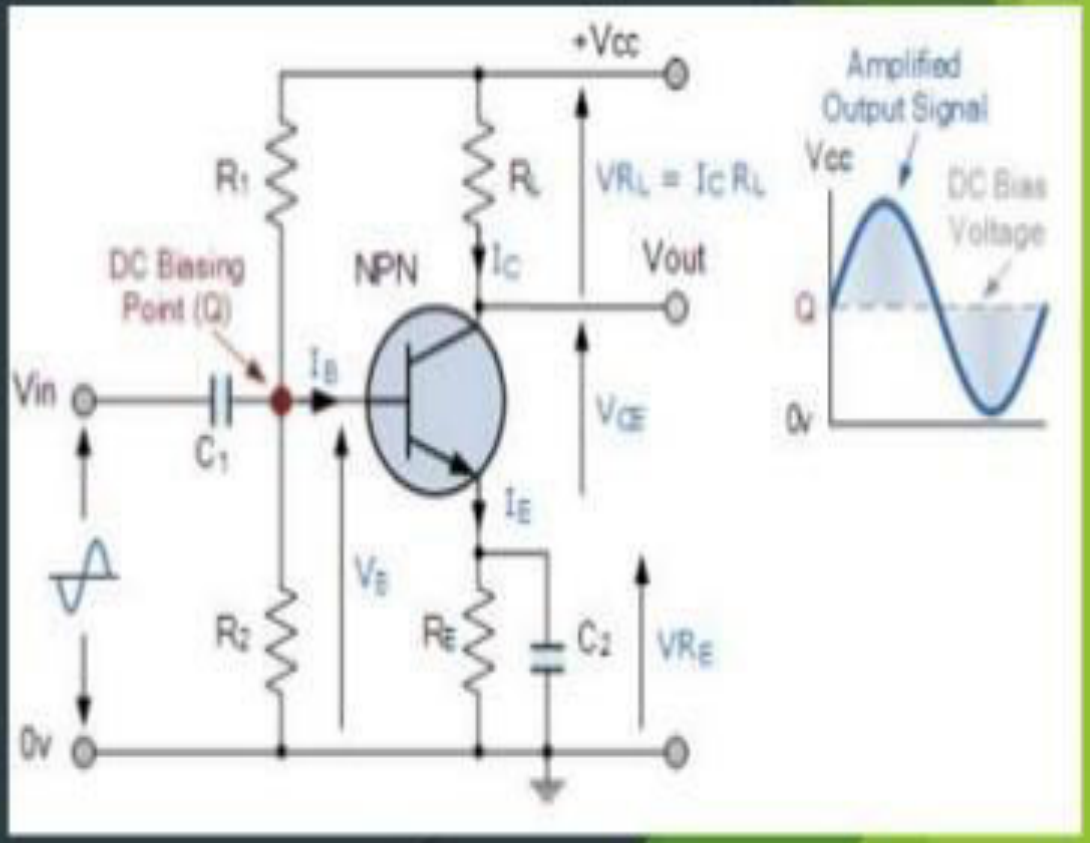
→It is called operating point because variation of I_C takes place about this point.

→ It is also called quiescent point or Q-point.

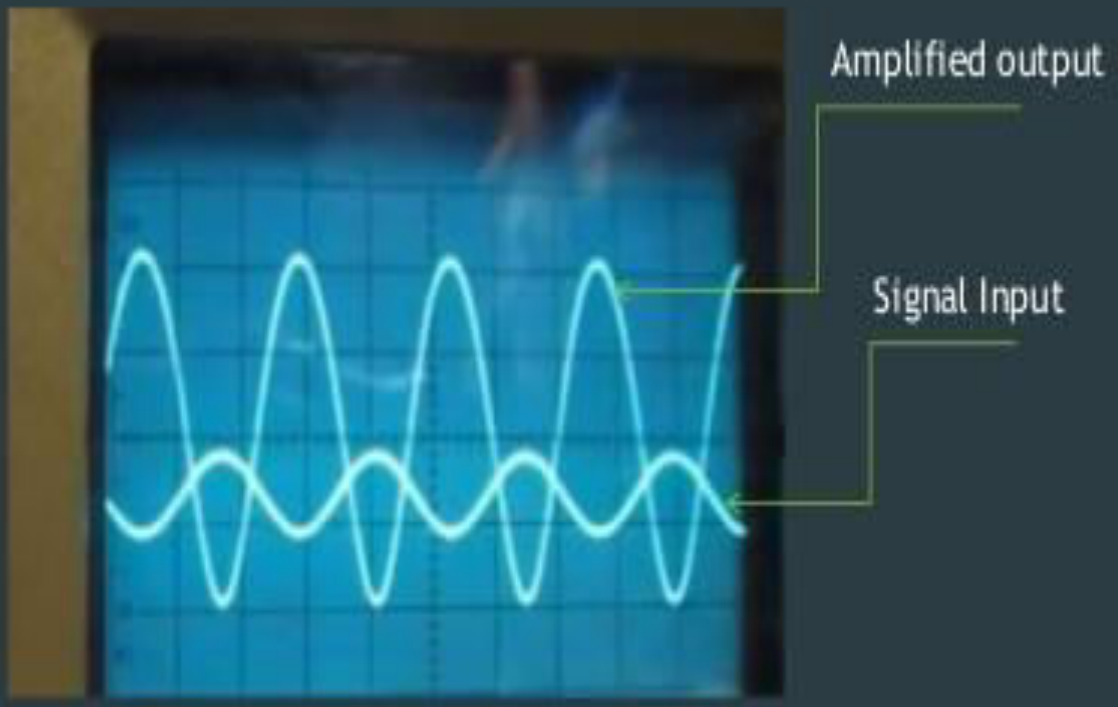


Common Emitter Amplifier

- a common emitter amplifier is typically used as a voltage amplifier
- Input is applied to base ,output is taken across collector and the emitter is grounded.
- Features:
  - Moderate /high input impedance.
  - Moderate output impedance.
  - High Voltage Gain
  - High Currant Gain.
  - Output is Inverted



Experimental Output of CE



Thank you