Electronic Devices

Lecture 11
Bipolar Junction Transistor

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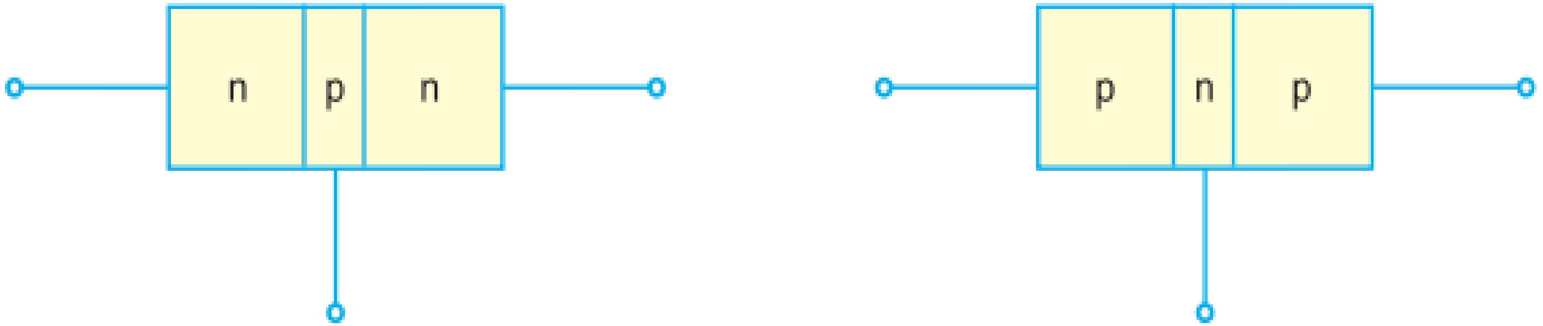
The Bipolar Junction Transistor

- It is a three terminal element device formed from 2 junctions which share a common semiconductor layer.
- There are two junction, so transistor can be considered as two diode connected back to back.
- The middle section is thin than other.



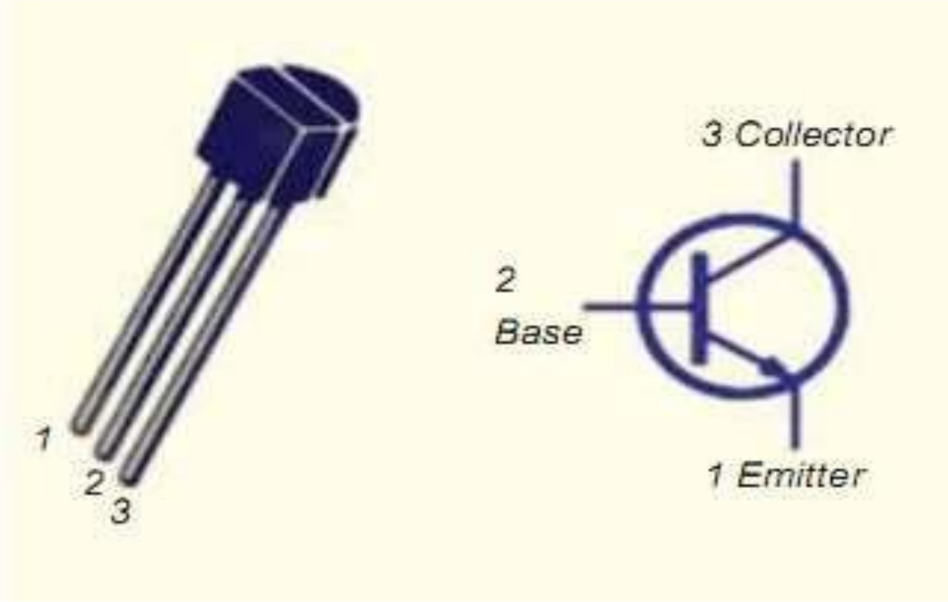
NPN Transistor PNP Transistor

- BJT is very important electronic device because we use it as:

Amplifier-Switch-logic circuits

The Bipolar Junction Transistor

- Transistor has three section of doped semiconductor.
- The section one side is called “Emitter” and the opposite side is called “Collector”.
- The middle section is called “Base”.



The Bipolar Junction Transistor

- ***Emitter:***

➢ The section of one side that supplies carriers is called emitter.

➢ Emitter is heavily doped so it can inject large amount of carriers into the base.

➢ Emitter is always forward biased to base so it can supply carrier.

➢ For “NPN transistor” emitter supply electrons to its junction.

➢ For “PNP transistor” emitter supply holes to its junction.

The Bipolar Junction Transistor

- ***Collector:***

➢ The section on the other side that collects carrier is called collector.

➢ For “NPN transistor” collector receives electrons to its junction.

➢ For “PNP transistor” collector receives holes to its junction.

➢ Collector is moderately doped.

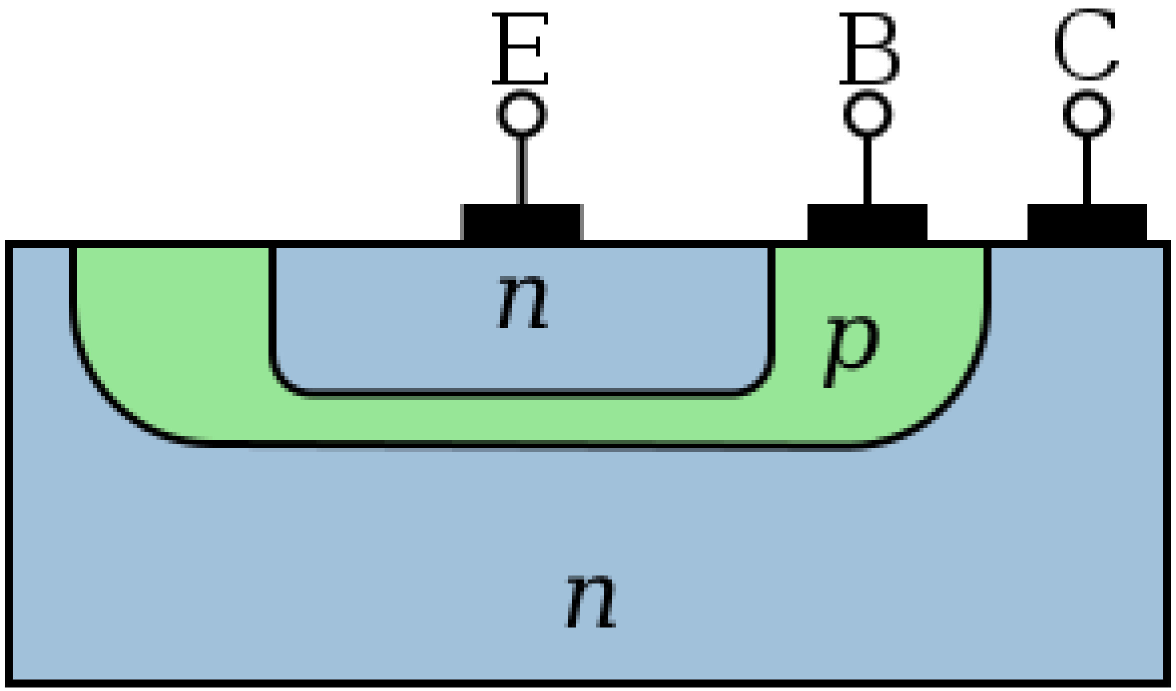
- ***Base:***

➢ The middle section which forms two P-N junction between emitter and collector is called Base.

➢ The Base is much thinner than other region.

➢ Base is lightly doped so it can pass most of the carrier to the collector.

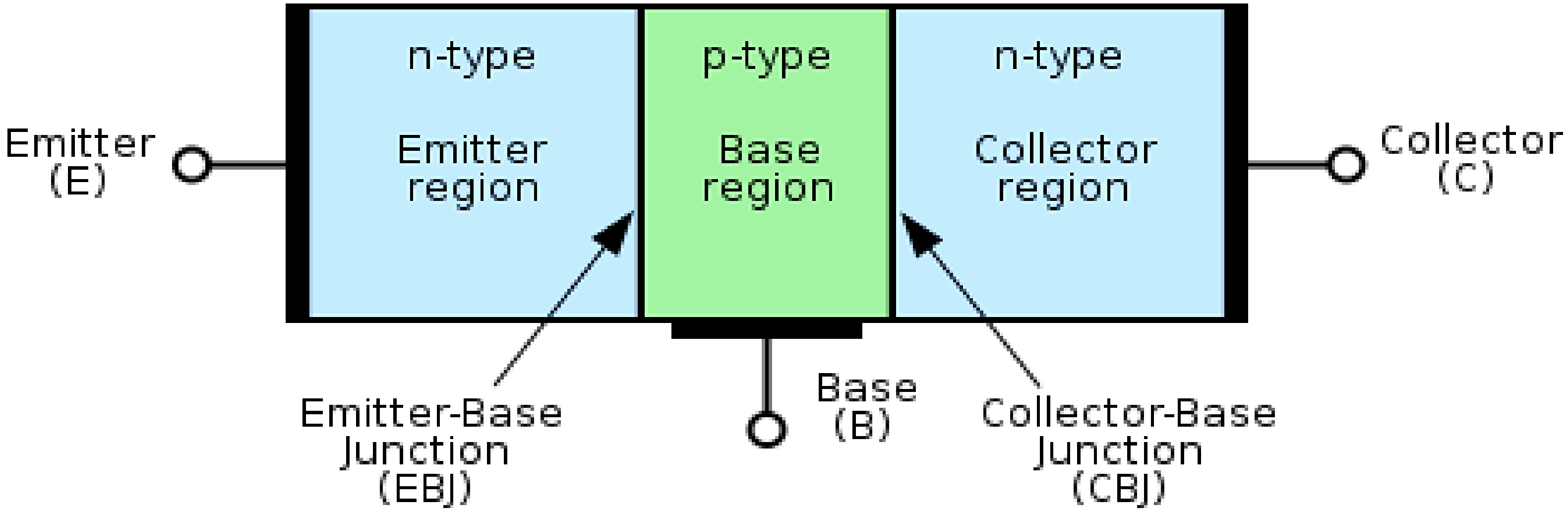
Physical Structure of BJT



Cross-section of an NPN BJT

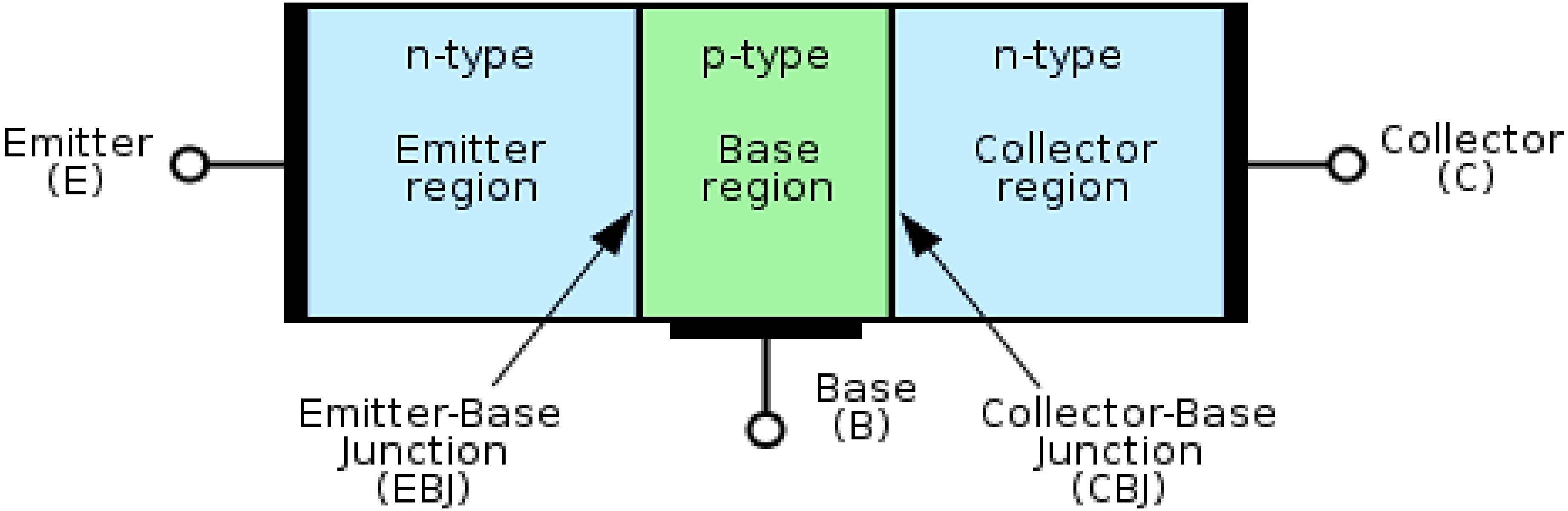
The Bipolar Junction Transistor

- 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 (Active/ Amplifier).
- The resistance of emitter diode is very small (forward) and resistance of collector diode is high (reverse).

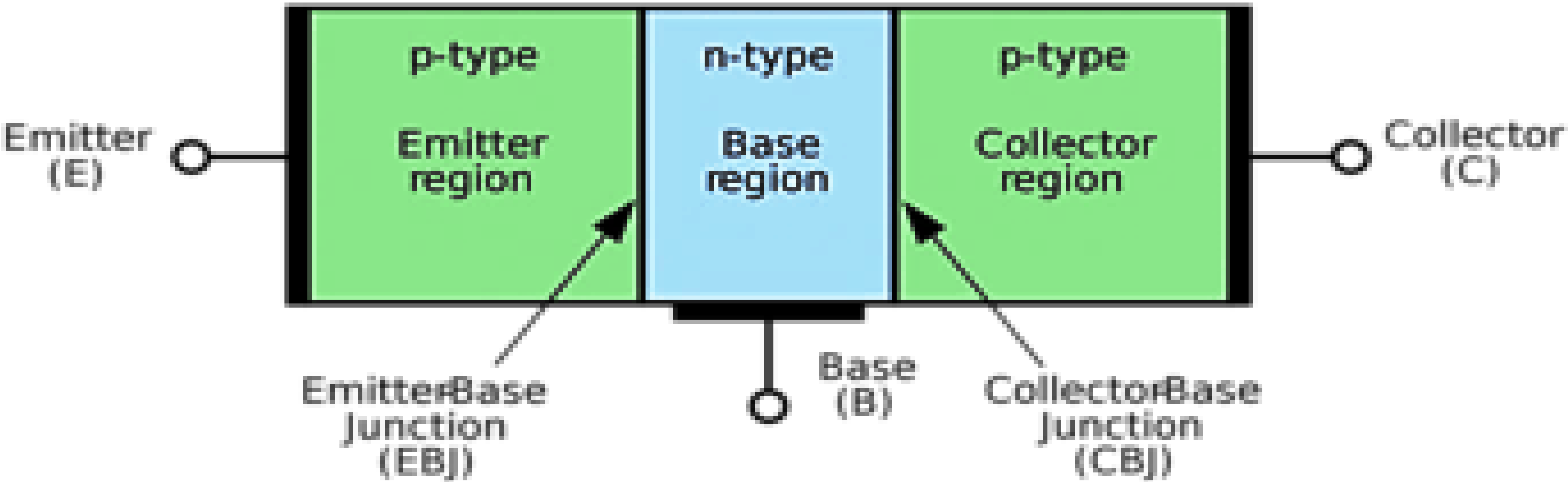


The Bipolar Junction Transistor

➢ Unbiased NPN Transistor



➢ Unbiased PNP Transistor

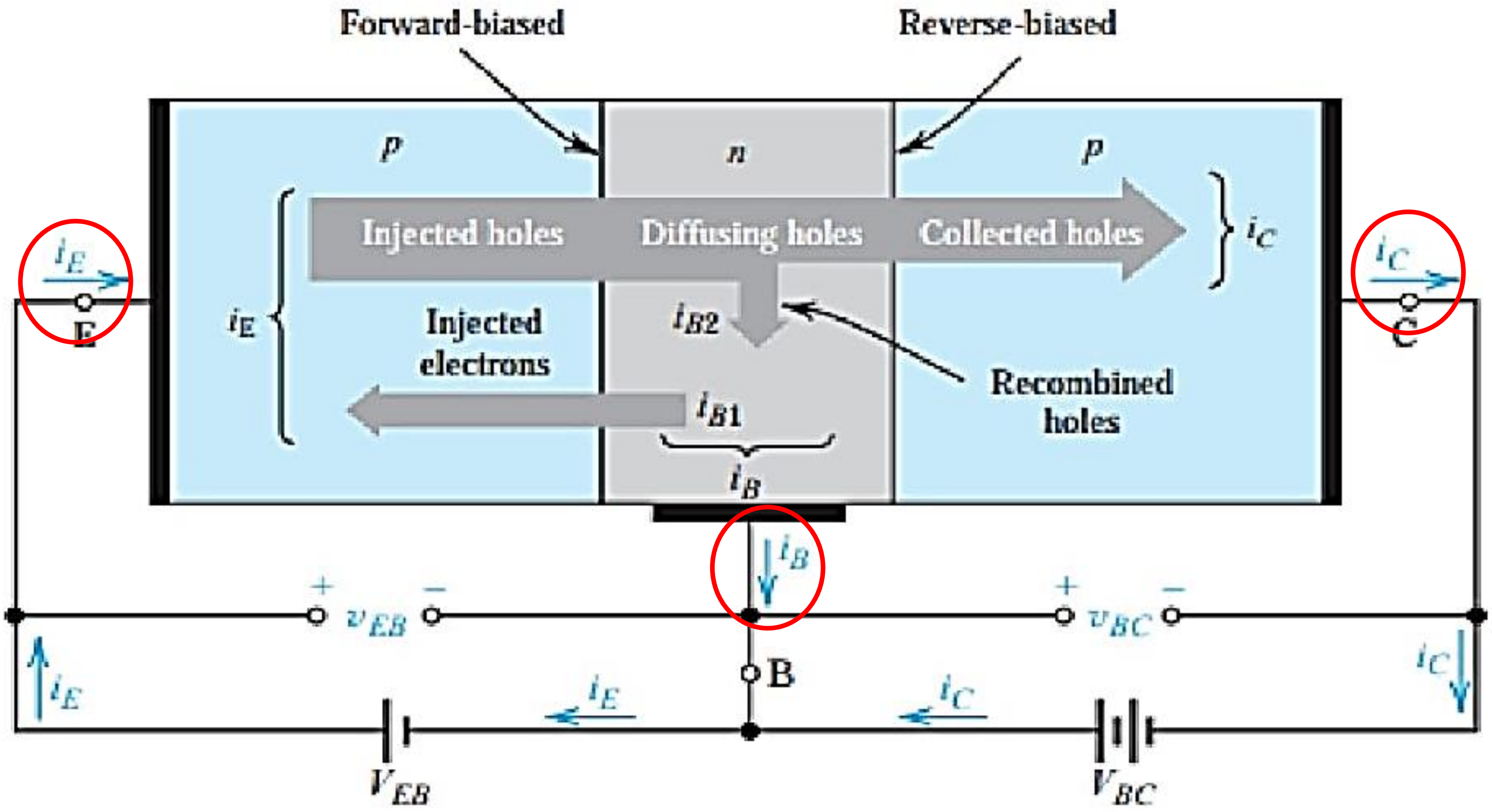


The Bipolar Junction Transistor

- Depending upon the bias condition (Forward or Reverse) of each of the two junction (E-B or C-B) different modes of operation of the BJT are obtained.

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Reverse Active	Reverse	Forward
Saturation	Forward	Forward

Operation of Transistor in the Active Mode (PNP)



Operation of Transistor in the Active Mode (PNP)

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

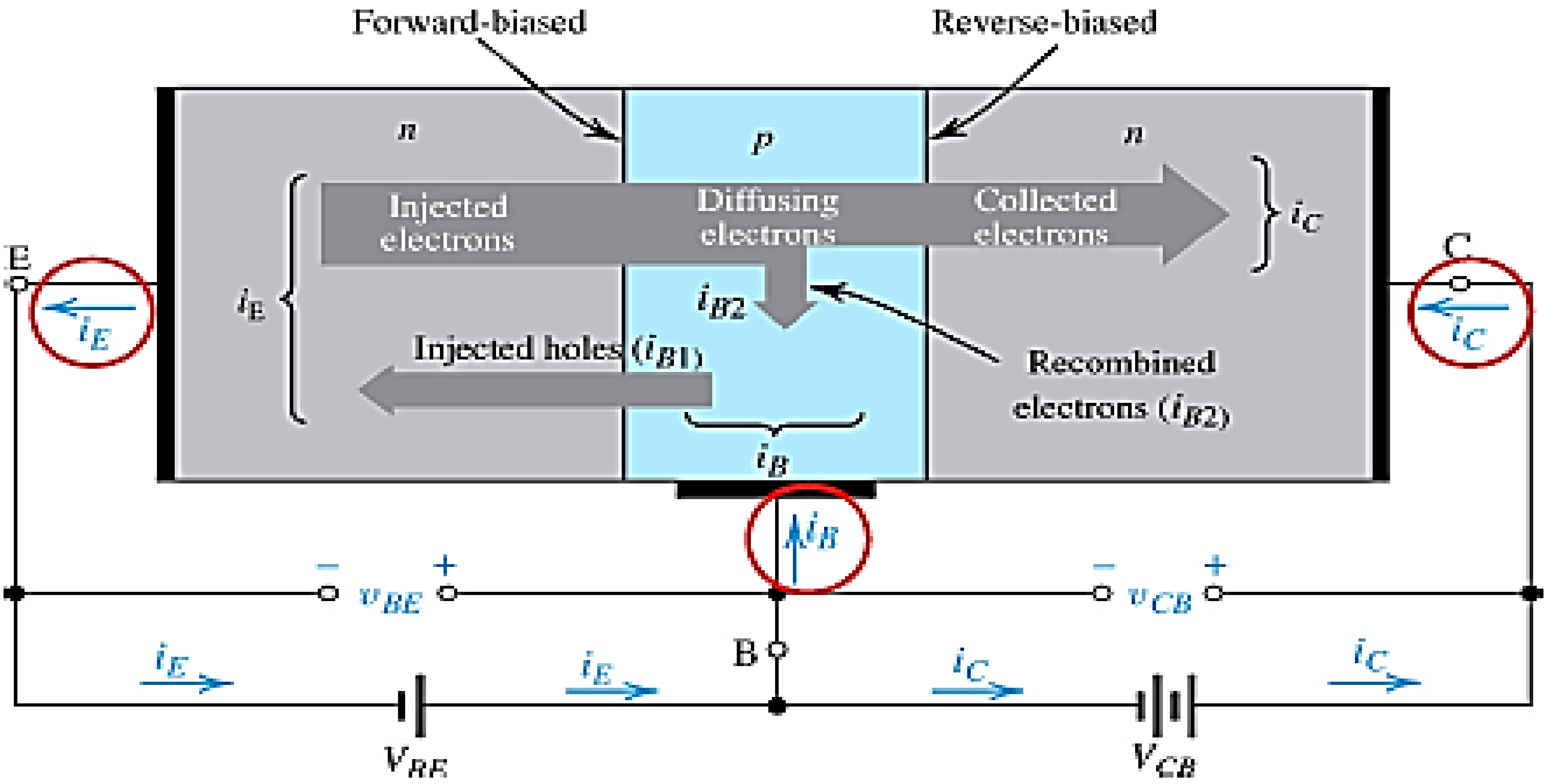
- The forward bias in the emitter-base junction causes holes to move toward base. This constitute emitter current, IE.

- 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.

Operation of Transistor in the Active Mode (NPN)



Operation of Transistor in the Active Mode (NPN)

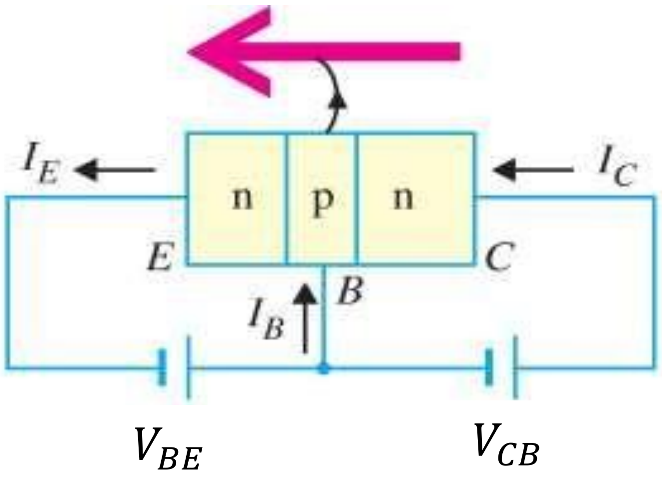
- Forward bias Is applied to emitter- base junction and reverse bias is applied to collector- base junction.

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

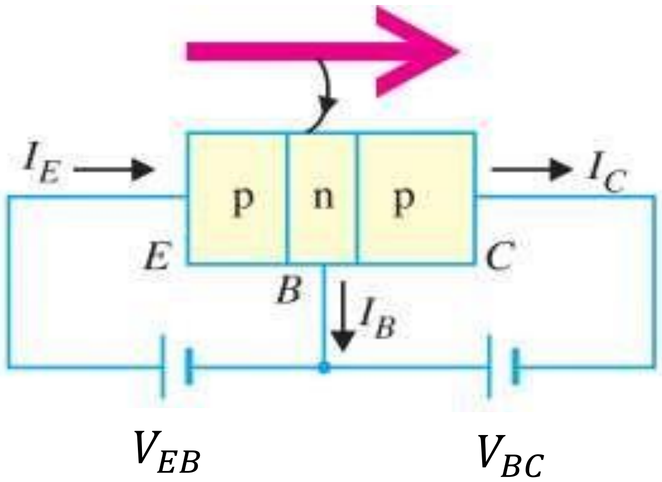
- As this electrons flow toward p-type base, they try to recombine with holes. As base is lightly doped only few electrons recombine with holes within the base.

- These recombined electrons constitute small base current.

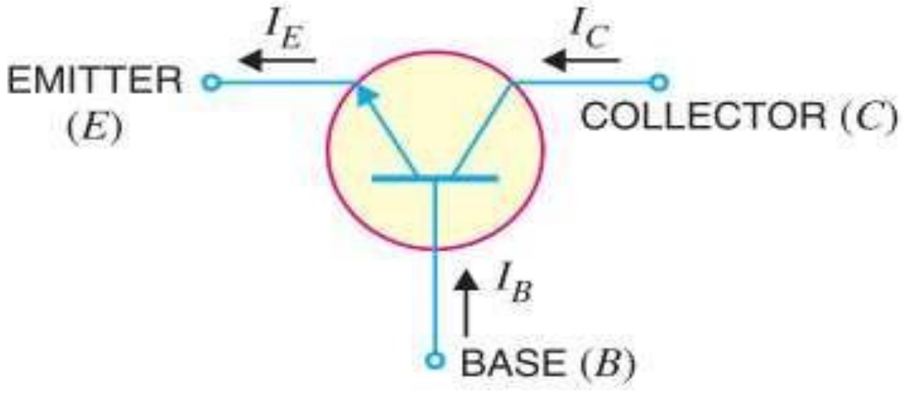
- The remainder electrons crosses base and constitute collector current.



I_E
I_C
n
p
n
E
C
B
I_B
V_{BE}
V_{CB}

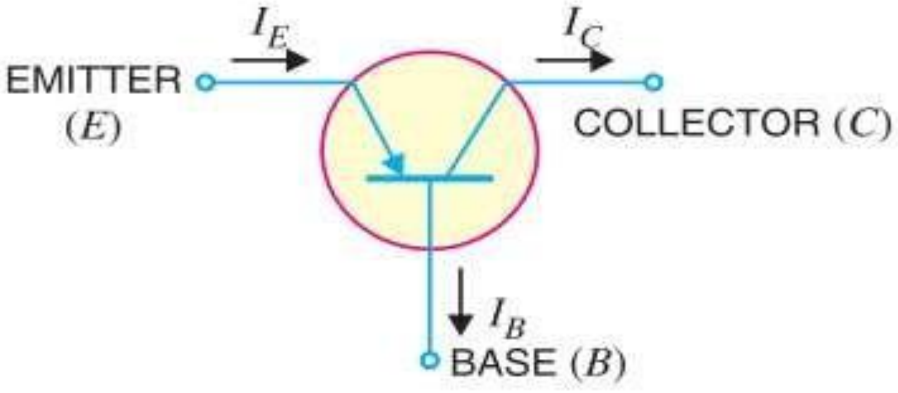


I_E
I_C
p
n
p
E
C
B
I_B
V_{EB}
V_{BC}



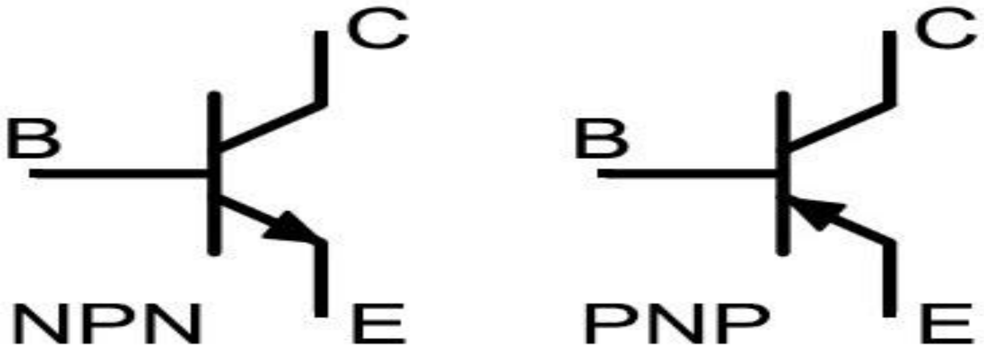
I_E
I_C
EMITTER
(E)
COLLECTOR (C)
I_B
BASE (B)

(i)



I_E
I_C
EMITTER
(E)
COLLECTOR (C)
I_B
BASE (B)

(ii)



C
B
NPN
E
C
B
PNP
E

BJT Current Equations

$$I_E = I_B + I_C$$

Active Mode

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

$$I_E = (1 + \boldsymbol{\beta}) I_B$$

$$I_C = \frac{\boldsymbol{\beta}}{(1 + \boldsymbol{\beta})} I_E$$

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

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

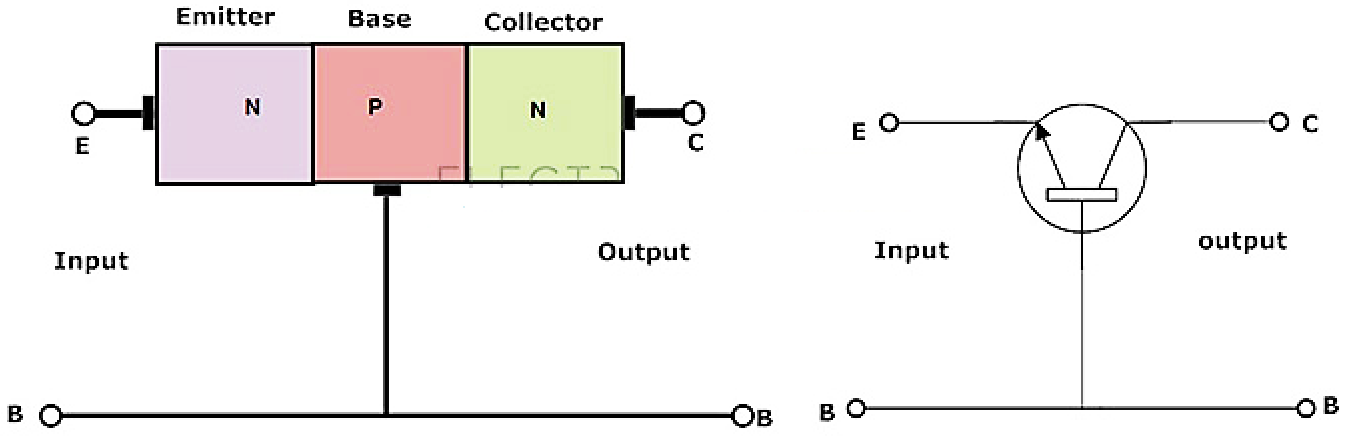
$\boldsymbol{\beta}$ Common Emitter Current Gain 50<$\boldsymbol{\beta}$<300

$\boldsymbol{\alpha}$ Common Base Current Gain $\boldsymbol{\alpha} < 1, \quad \boldsymbol{\alpha} = 0.95 : 0.99$

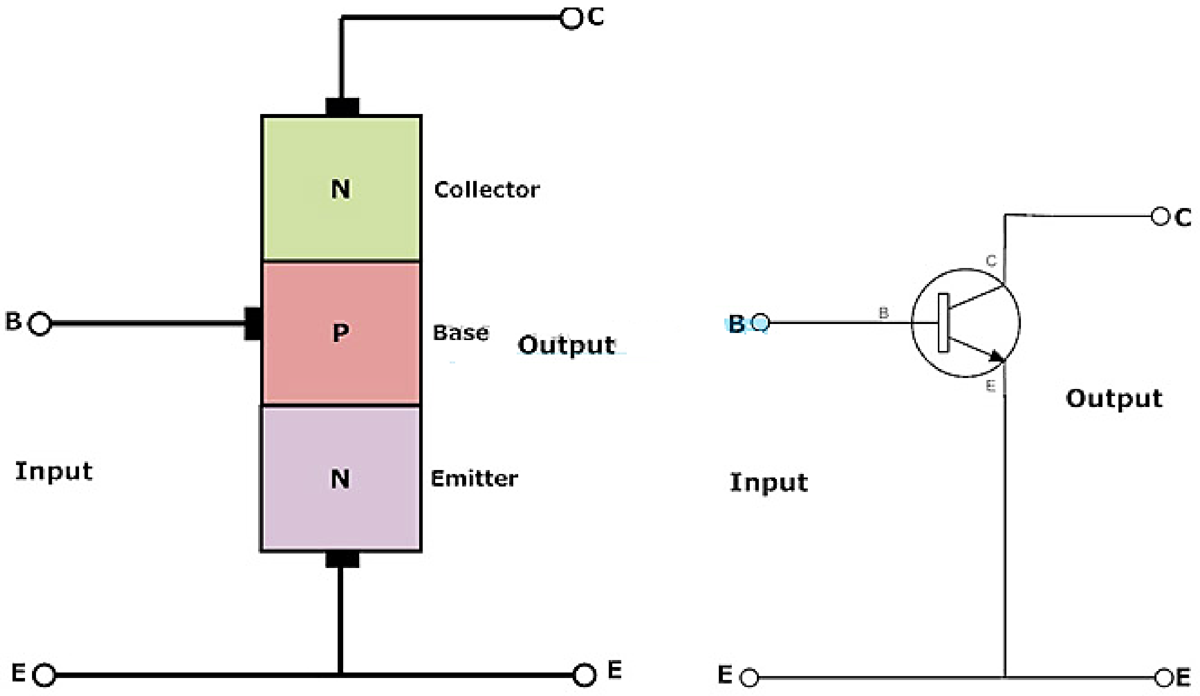
Different BJT Configurations

- Common Base
- Common Emitter
- Common Collector

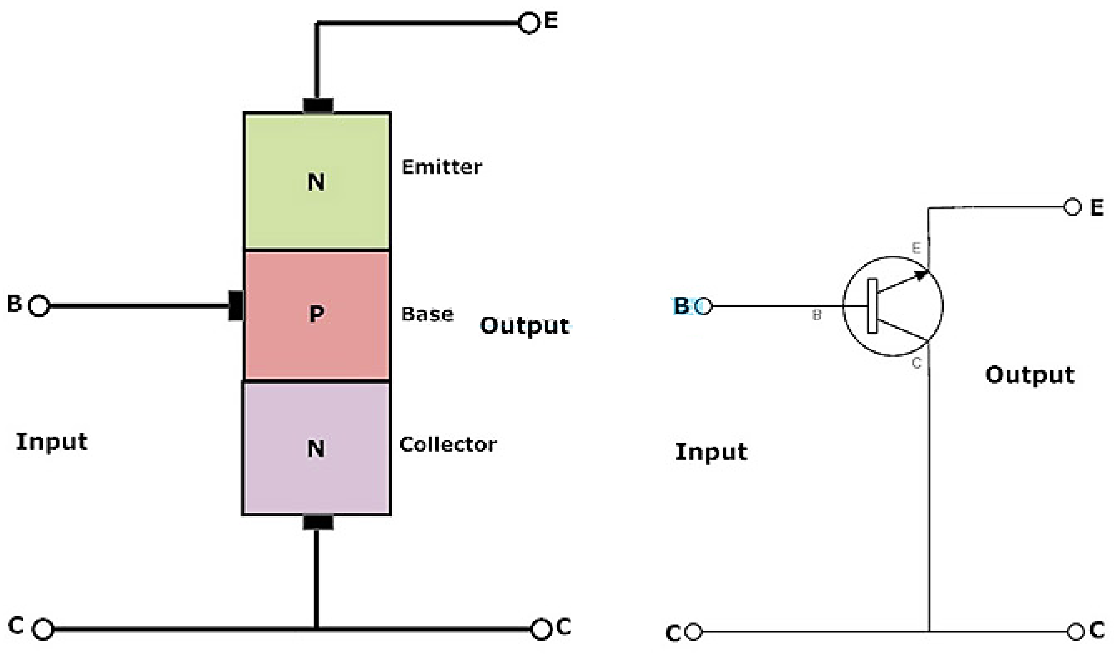
Different BJT Configurations



Common Base (CB)

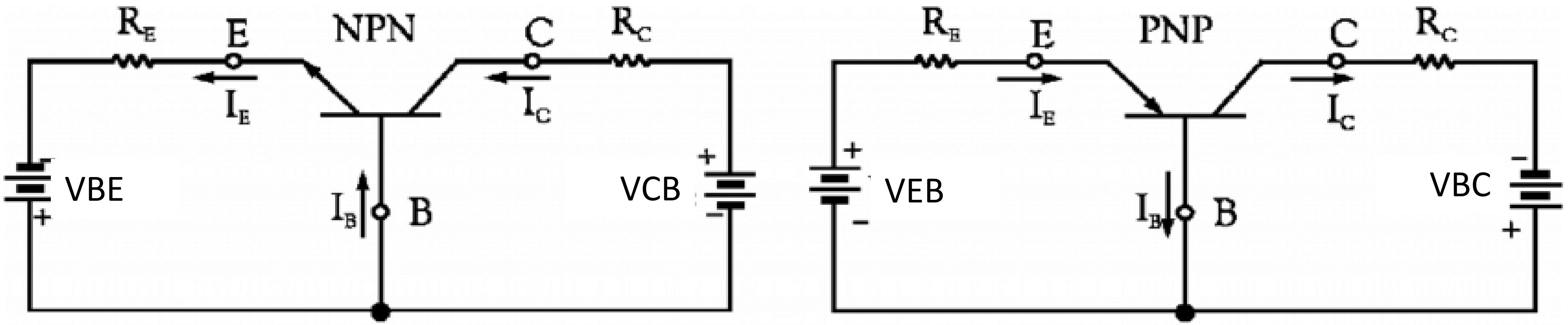


Common Emitter (CE)



Common Collector (CC)

Common Base "CB"



(a) Common-base NPN transistor circuit. (b) Common-base PNP transistor circuit.

- The common-base terminology is derived from the fact that the base is common to both the input and output sides of the configuration.
- Active mode: E-B junction (Forward) , C-B junction (Reverse)

- NPN: VBE, VCB

- PNP: VEB, VBC

Common Base "CB"

- Current amplifier Factor **α**:

The ratio of change in collector current to the change in emitter current at constant VCB is known as current amplification factor (Current gain) **α**.

$$I_C = \boldsymbol{\alpha} I_E \qquad\qquad \boldsymbol{\alpha} = \frac{\triangle I_C}{\triangle I_E}$$

- Practical value of a is less than unity, but in the range of 0.95 to 0.99.

- Total emitter current does not reach the collector terminal, because a small portion of it constitute base current. So,

$$I_E = I_B + I_C$$

Common Base “CB”

- Also, collector diode is reverse biased, so very few minority carrier passes the collector-base junction which actually constitute leakage current, I_{CBo}.

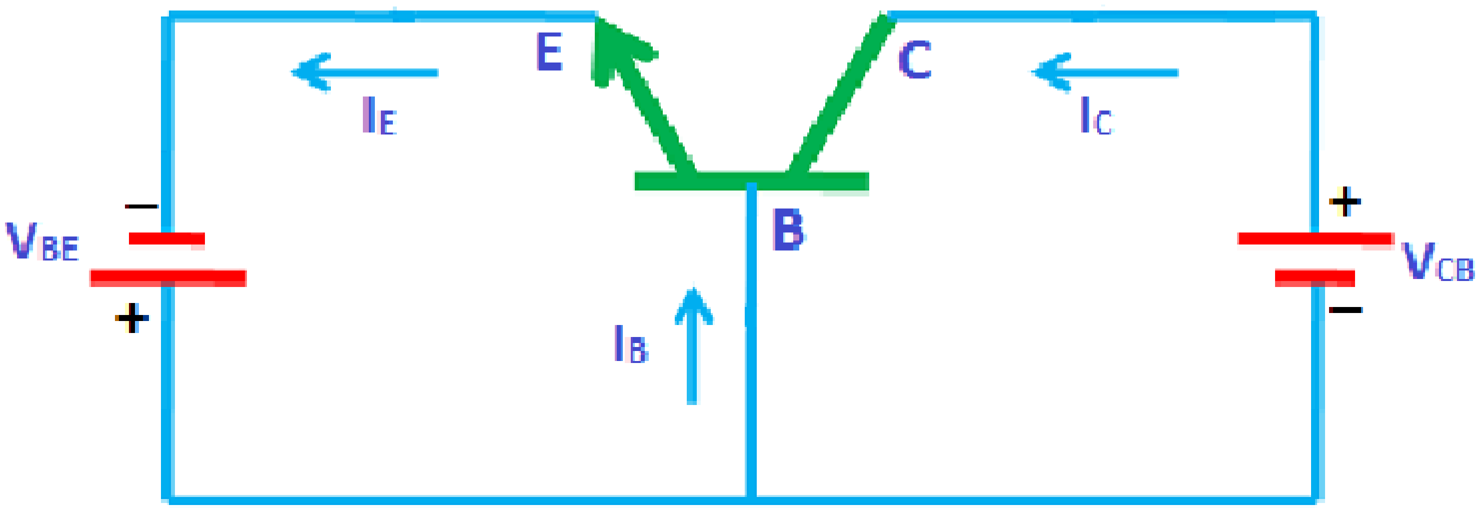
- So, collector current constitute of portion of emitter current $\boldsymbol{\alpha} I_E$ and leakage current I_{CBo} .

$$I_C = \boldsymbol{\alpha} I_E + I_{CBo}$$

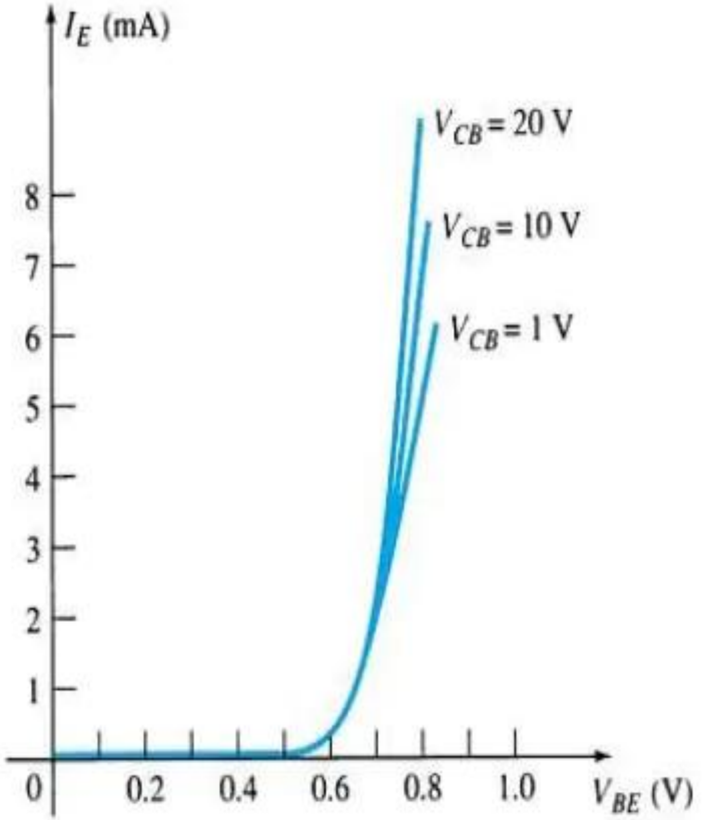
$$\begin{aligned} I_C &= \alpha (I_C + I_B) + I_{CBO} \\ I_C (1-\alpha) &= \alpha I_B + I_{CBO} \\ I_C &= \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha} \end{aligned}$$

Input Characteristics of Common Base Configuration (NPN)

- V_{BE} vs I_E characteristics is called input characteristics.
- I_E increases rapidly with V_{BE}.
  It means **input resistance is very small.**
- I_E almost independent of V_{CB}.

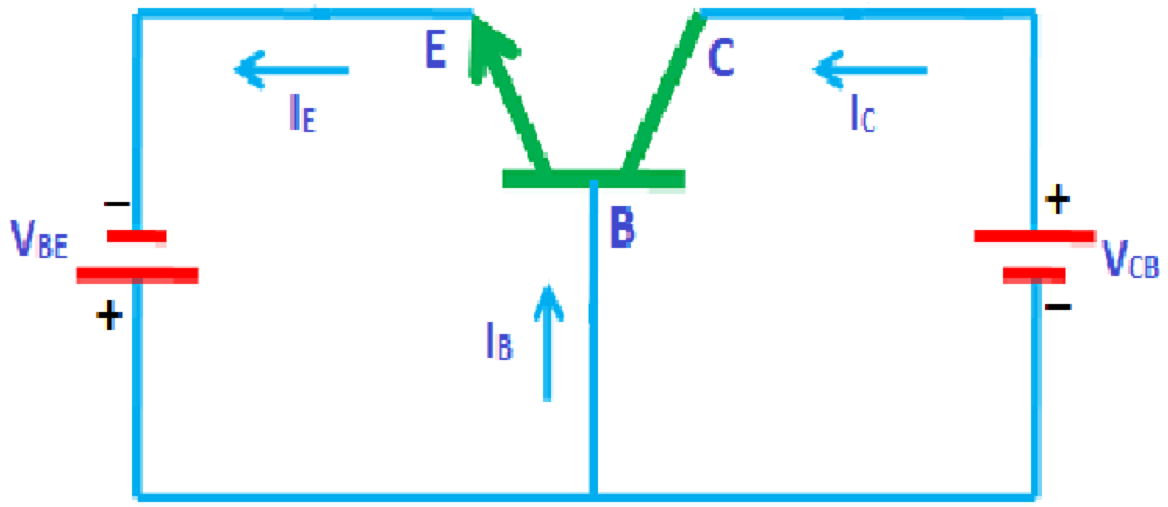


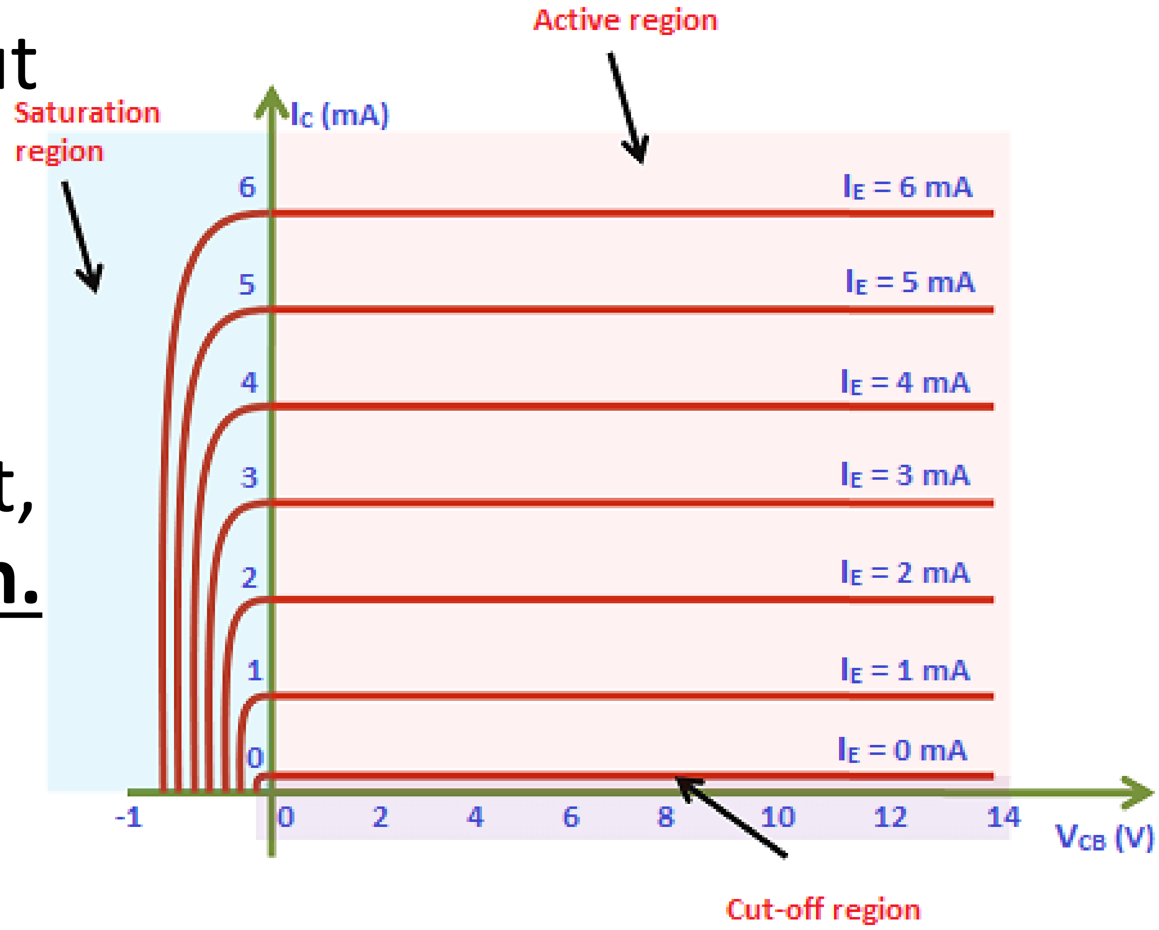
Input Characteristics



Output Characteristics of Common Base Configuration(NPN)

- V_{CB} vs I_C characteristics is called output characteristics.
- I_C varies linearly with V_{CB} ,only when V_{CB} is very small.
- As, V_{CB} increases, I_C becomes constant, It means **output resistance is very high.**





O/P characteristics CB configuration

Input, Output Resistance and gain of CB

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

$$r_i = \frac{\triangle V_{BE}}{\triangle I_E} \quad \text{(Low)}$$

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

$$r_o = \frac{\triangle V_{CB}}{\triangle I_C} \quad \text{(High)}$$

- **Current gain:** $$Ai = \boldsymbol{\alpha} = \frac{\triangle I_C}{\triangle I_E} \quad \text{(low less than unity)}$$
- **Voltage gain:** $$Av = \frac{I_C x r_o}{I_E x r_i} \quad \text{(High)}$$