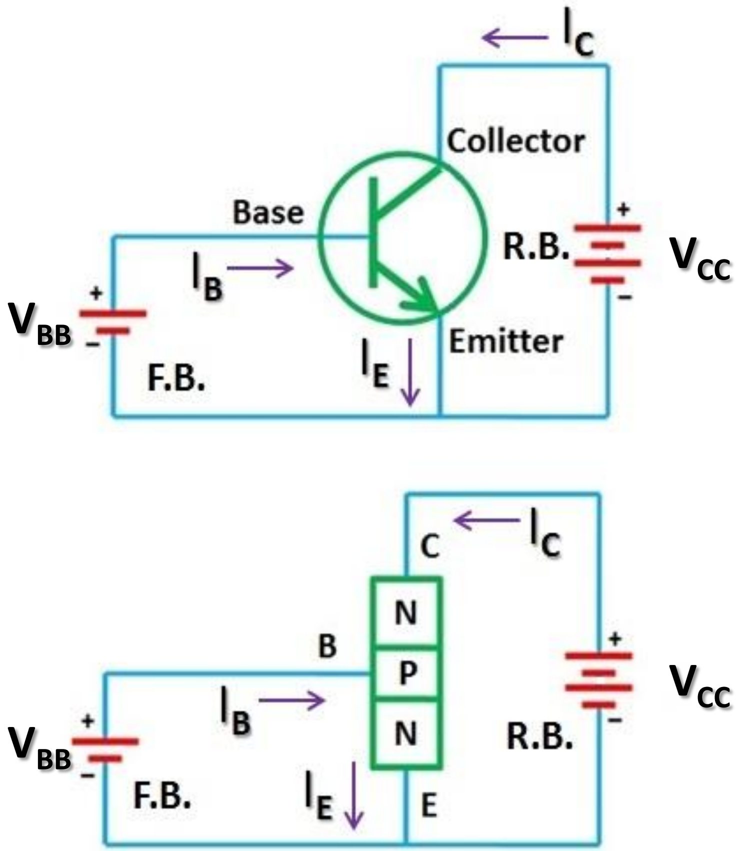
UNIT 3

Bipolar Junction Transistor

Common-Emitter Configuration

NPN- Common Emitter (CE) Configuration



$I_E = I_C + I_B$

Since I_B is very small
$I_C \approx I_E$ (approx.)

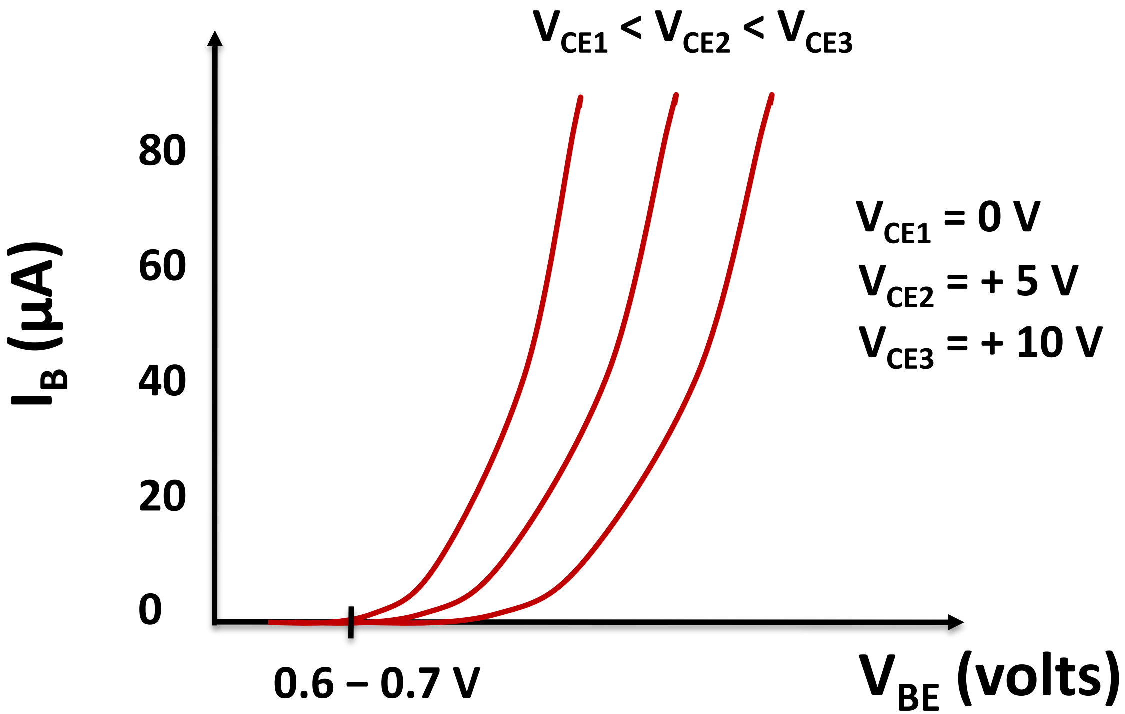
- CE Configurations have different voltage arrangements for NPN and PNP, such that
  - For Active Region operation of CE Configuration-----
    - Input Section is always Forward Biased (F.B.) &
    - Output Section is always Reverse Biased (R.B.)

Current-Voltage (I-V) Characteristics of NPN – CE configuration

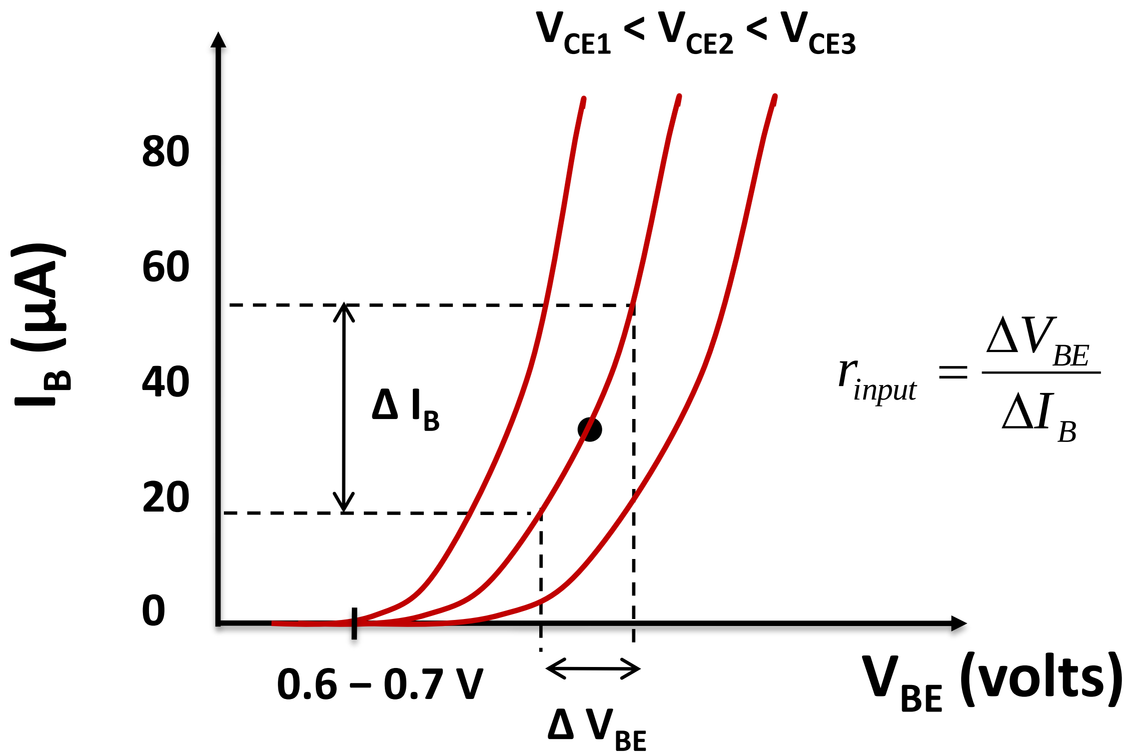
- **Input (or Base) Static Characteristics:**

- Input Current (I_B) vs Input Voltage (V_{BE})

-@ Constant value of Collector-Emitter Voltage (V_{CE}) for each curve



Input (or Base) Static Characteristics



$$r_{input} = \frac{\Delta V_{BE}}{\Delta I_B} \qquad (@\ V_{CE} = \text{Constant})$$

- **Dynamic Input Resistance (r_{input}) can be calculated from I/P characteristics**
- **It varies with the point of measurement**
- **Typical values of r_{input} are ≈ 1 KΩ**
- **So, Input Resistance of CE config. is although Low but higher than that of CB Config.**

Input (or Base) Static Characteristics

- **Represents simply the Forward Characteristics of Base-Emitter Diode (@ various Collector-Emitter Voltages)**
- Threshold Voltage below which I_B is Very Small

  ---- 0.6 – 0.7 V (Si) and 0.1 – 0.2 V (Ge) materials

- If V_{CE} = 0 (Collector shorted to Emitter) & Base-Emitter Jn. Forward Biased, Input characteristics are simply of a Forward-Biased PN-Diode
- I_B = 0 if both V_{BE} & V_{CE} are Zero (i.e. Both Jn. are shorted)

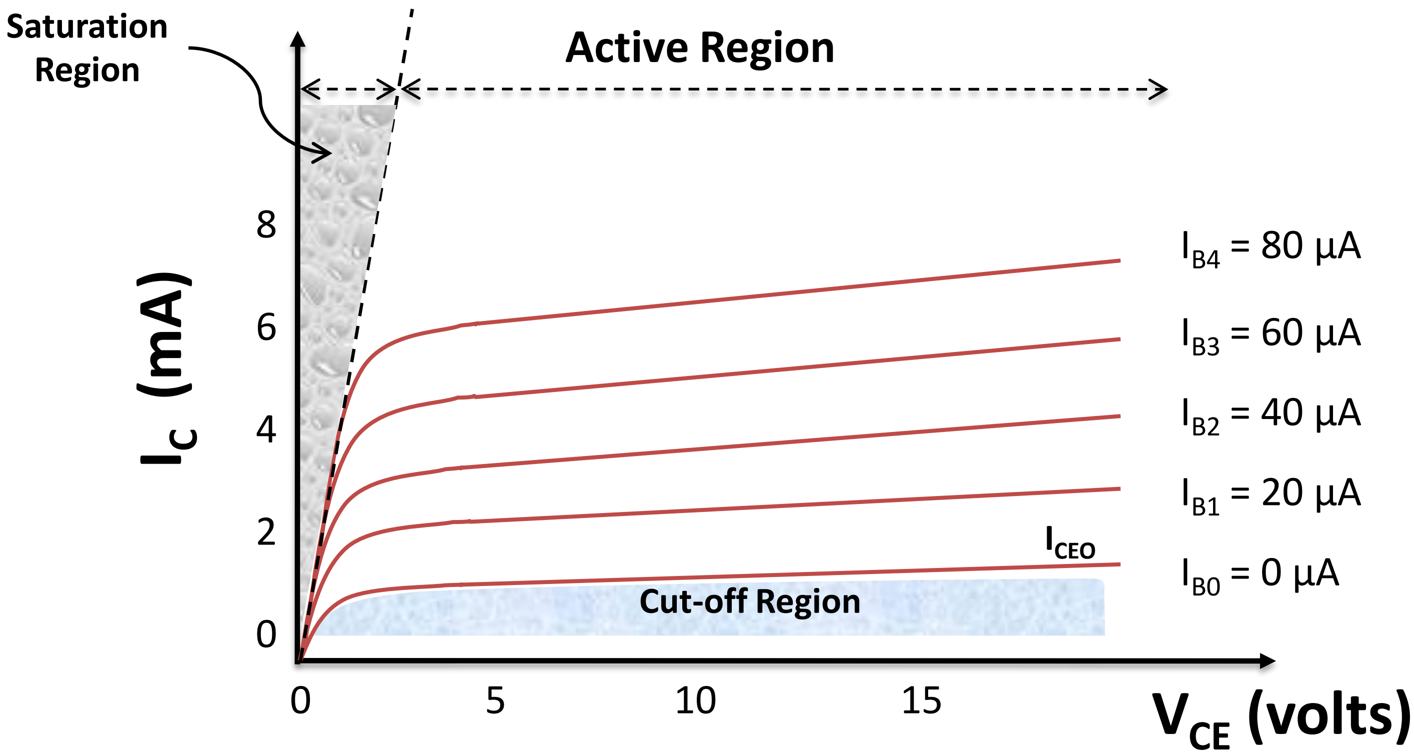
- **I_B decreases with increase in V_{CE} (@ constant V_{BE}), due to modulation of Base width ("Early Effect")**
- So, Input Curves will shift towards right as $\mathbf{V_{CE}}$ Increases.

Current-Voltage (I-V) Characteristics of NPN – CE configuration

- **Output (or Collector) Static Characteristics:**

  - Output Current (I_C) vs Output Voltage (V_{CE})

  -@ Constant value of Base Current (I_B) for each curve



Output (or Collector) Static Characteristics

- **Divided into 3 Regions: - Active Region, - Saturation Region, - Cutoff Region**

	Active Region	Saturation Region	Cutoff Region
Base-Emitter	Forward Biased	Forward Biased	Reverse Biased
Collector-Emitter	Reverse Biased	Forward Biased	Reverse Biased

Active Region:

- Area between the "Saturation & Cutoff Regions"
- Input Current is now I_B, and Output current is now I_C
- I_B is very small (in tens of µA), however I_C is Large (in mA)
- This results in Amplification of current-**Transistor Amplifying Action**
- **Current Equations are:**

$$I_E = I_C + I_B \qquad \& \qquad I_C = \alpha_{dc} I_E + I_{CO} \qquad (1)$$

So,
$$I_C = \alpha_{dc} (I_C + I_B) + I_{CO} \qquad (2)$$

Or,
$$(1 - \alpha_{dc}) I_C = \alpha_{dc} I_B + I_{CO} \qquad (3)$$

Relation Between α_{dc} and β_{dc}

$$I_C = \frac{\alpha_{dc}}{1-\alpha_{dc}} I_B + \frac{1}{1-\alpha_{dc}} I_{CO} \qquad (4)$$

- **Let us define β_{dc} as "Common-Emitter dc Current Gain" or simply "dc beta"**

$$\beta_{dc} = \frac{I_C - I_{CEO}}{I_B} \approx \frac{I_C}{I_B} \quad (\text{as } I_{CEO} << I_C) \qquad \beta_{dc} = \frac{\alpha_{dc}}{1-\alpha_{dc}} \qquad (5)$$

- **and "Reverse Leakage Current between Collector & Emitter as I_{CEO}**

$$I_{CEO} = \frac{1}{1-\alpha_{dc}} I_{CO} \qquad (6)$$

- **where, $I_{CO} = I_{CBO}$ (since $\alpha_{dc} \approx 0.95$, $I_{CEO} >> I_{CBO}$) is Reverse Leakage Current between Collector & Base**

$$I_C = \beta_{dc} I_B + I_{CEO} = \beta_{dc} I_B + (1+\beta_{dc}) I_{CO} \approx \beta_{dc} I_B \quad \text{as } I_B >> I_{CO} \qquad (7)$$

Relation Between α and β

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CO}$$ **(4.1)**

- **Let us define β as "Small Signal Common-Emitter ac Current Gain" or simply "ac or dynamic beta"**

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad (\text{@ Constant } V_{CE}) \qquad \beta = \frac{\alpha}{1-\alpha}$$ **(5.1)**

- **and "Reverse Leakage Current between Collector & Emitter as I_{CEO}**

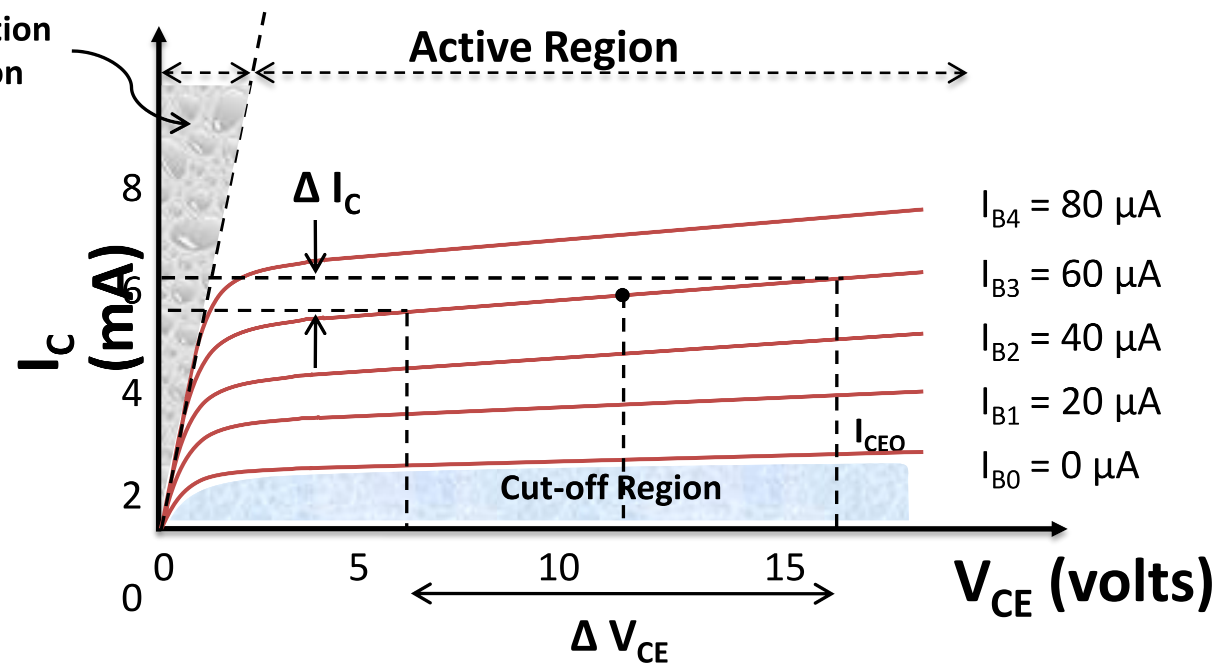
$$I_{CEO} = \frac{1}{1-\alpha} I_{CO}$$ **(6.1)**

- **where, $I_{CO} = I_{CBO}$ (since $\alpha_{dc} \approx 0.95$, $I_{CEO} >> I_{CBO}$) is Reverse Leakage Current between Collector & Base, Therefore,**

$$I_C = \beta I_B + I_{CEO} = \beta I_B + (1+\beta) I_{CO} \approx \beta I_B \qquad \text{as } I_B >> I_{CO}$$ **(7.1)**

Output (or Collector) Static Characteristics

$$r_{output} = \frac{\Delta V_{CE}}{\Delta I_C} \qquad (@\ I_B = \text{Constant})$$



- **Dynamic Output Resistance (r_{output}) can be calculated from O/P characteristics ≈ 20 KΩ**
- **So, Output Resistance of CE config. is Quite Large, but not that large of CB Config. Since α is not perfectly constant ≈ 0.98 (usually range between 0.90 – 0.995), hence even small variation in it can cause large Variations in the values of β (as per relation (5)/(5.1))**

Output (or Collector) Static Characteristics

Saturation Region:

- Both B-E and C-E Junctions are Forward –Biased

- As V_{CB} becomes few tens of a Volt (such that $V_{CE} < V_{BE}$),
    - I_C decreases rapidly as V_{CE} decreases
- I_C is almost independent of I_B

Cutoff Region:

- **Both B-E and C-E Junctions are Reverse –Biased**
- Only Reverse Leakage/Saturation Current $I_{CEO} = (1+\beta)\ I_{CBO}$ flows in the output circuit

Parameters from Output Characteristics

$$r_{output} = \frac{\Delta V_{CE}}{\Delta I_C} \quad \left(@\ I_B = \text{Constant}\right)$$

$$\beta_{dc} = \frac{I_C}{I_B} \quad (@\ V_{CE} = \text{Constant})$$

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad (@\ V_{CE} = \text{Constant})$$