Electronic Devices

Lecture 12
Bipolar Junction Transistor

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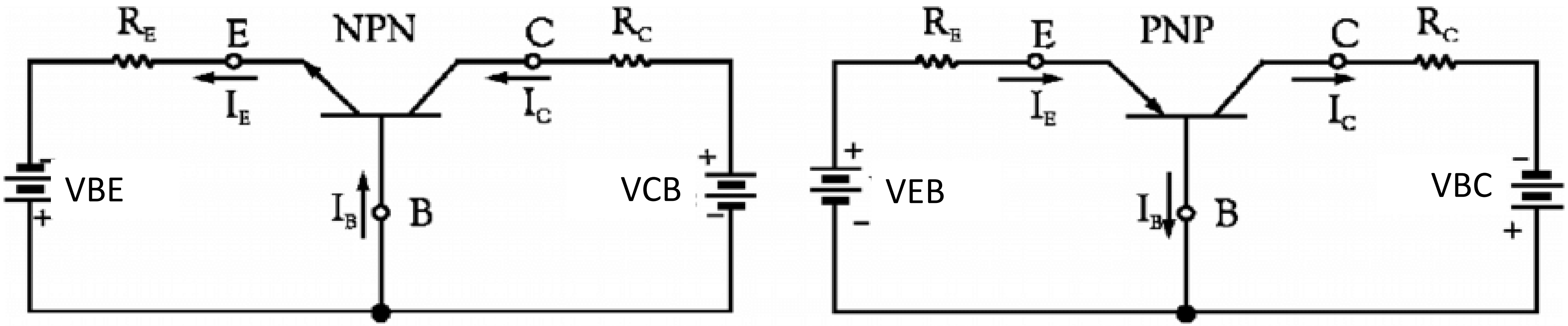
Different BJT Configurations

- Common Base
- Common Emitter
- Common Collector

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}.

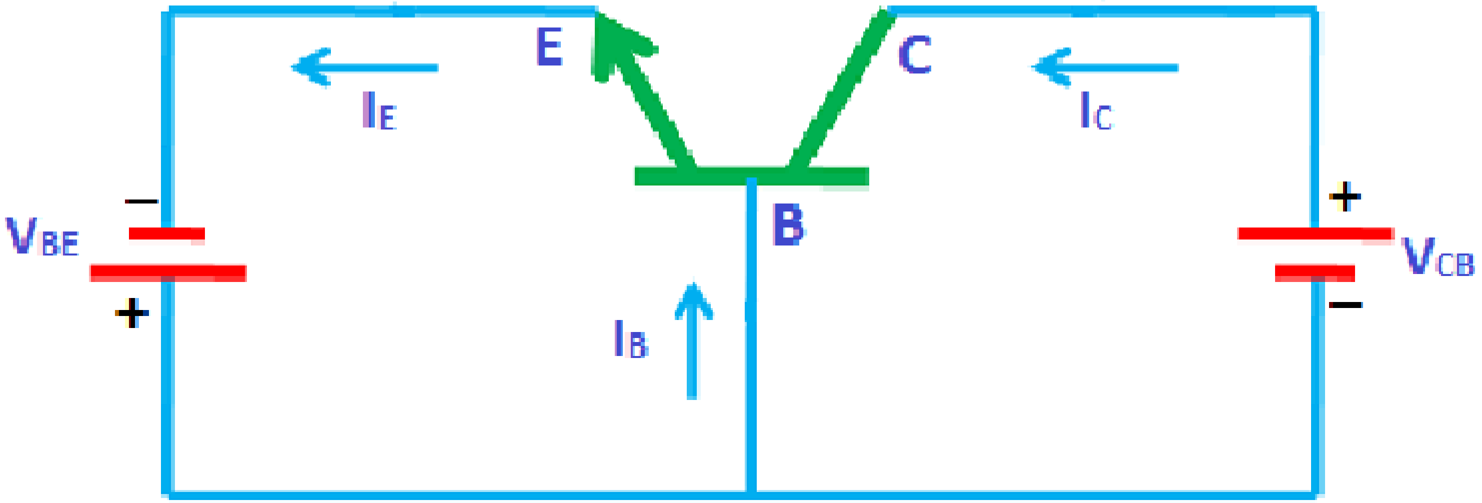
- So, collector current constitute of portion of emitter current $\boldsymbol{\alpha} I_E$ and leakage current I_{CBo} .

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

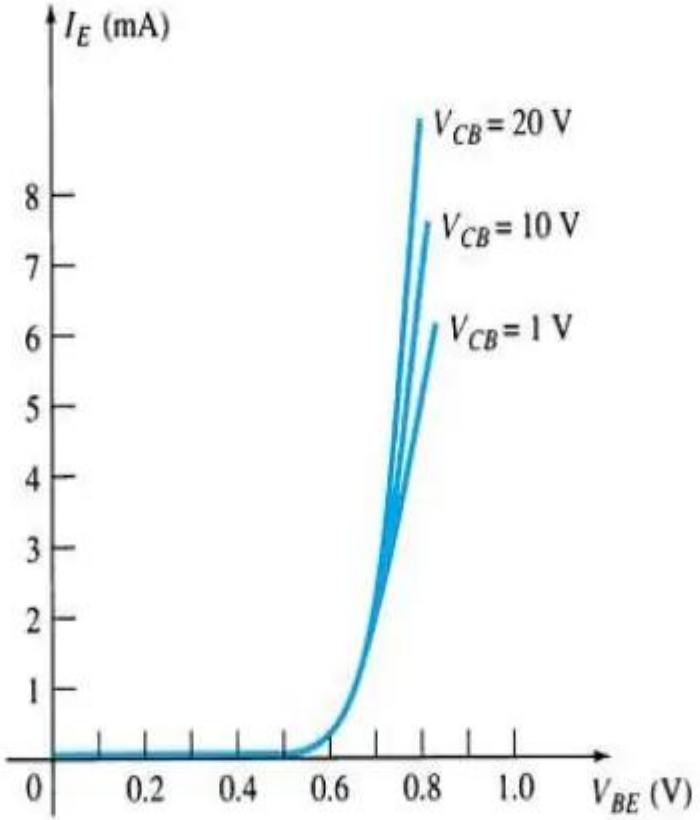
$$\begin{aligned} I_C &= \alpha (I_C + I_B) + I_{CBO} \\ I_C (1 - \alpha) &= \alpha I_B + I_{CBO} \\ I_C &= \frac{\alpha}{1 - \alpha} I_B + \frac{I_{CBO}}{1 - \alpha} \end{aligned}$$

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}.

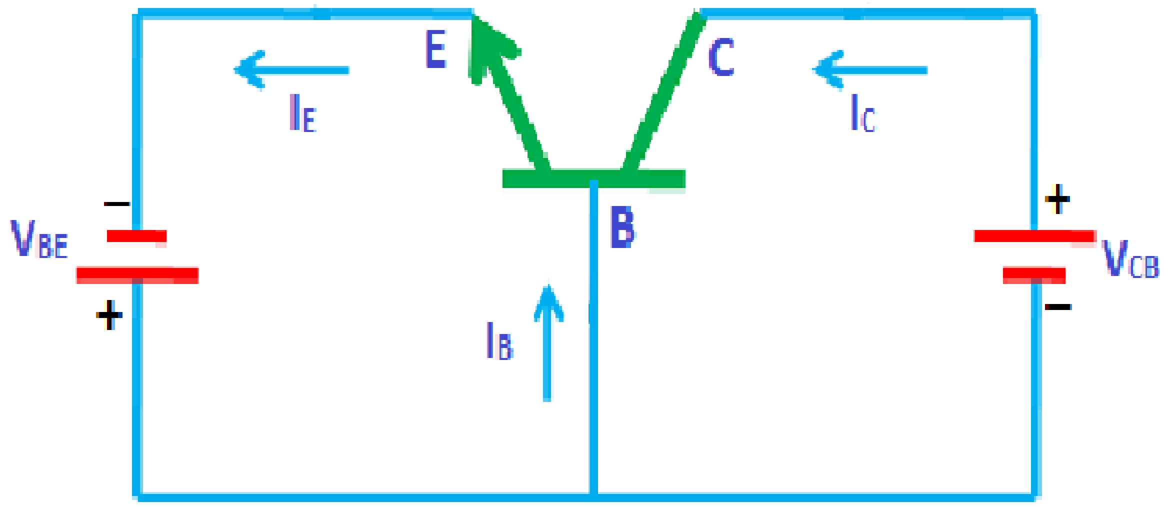


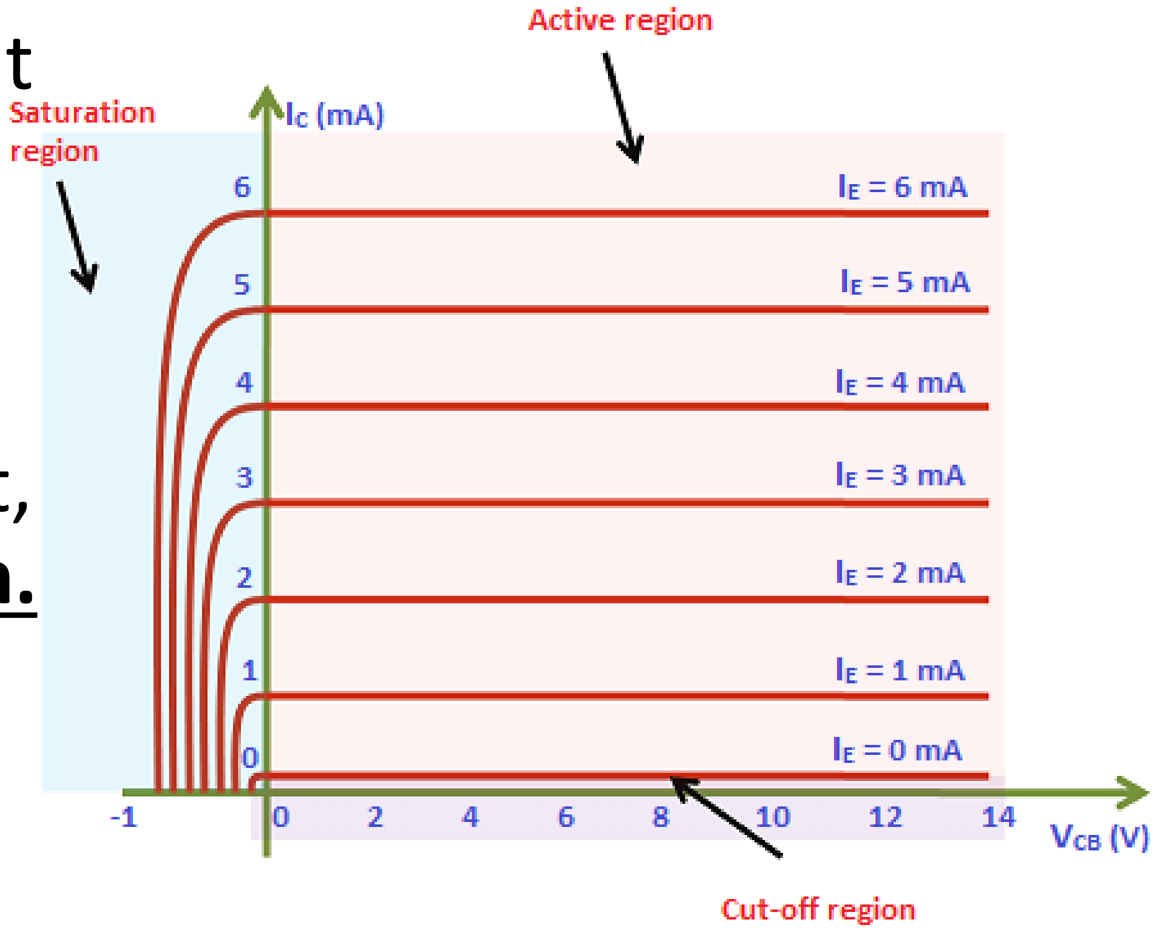
Input Characteristics



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.

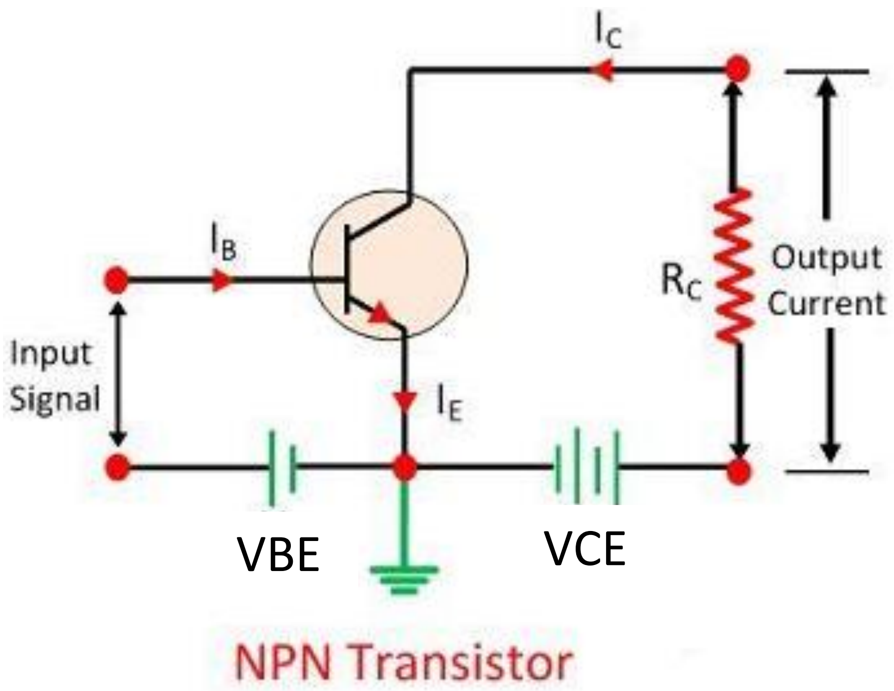
$$r_i = \frac{\triangle V_{BE}}{\triangle I_E} \quad \text{(Low)}$$

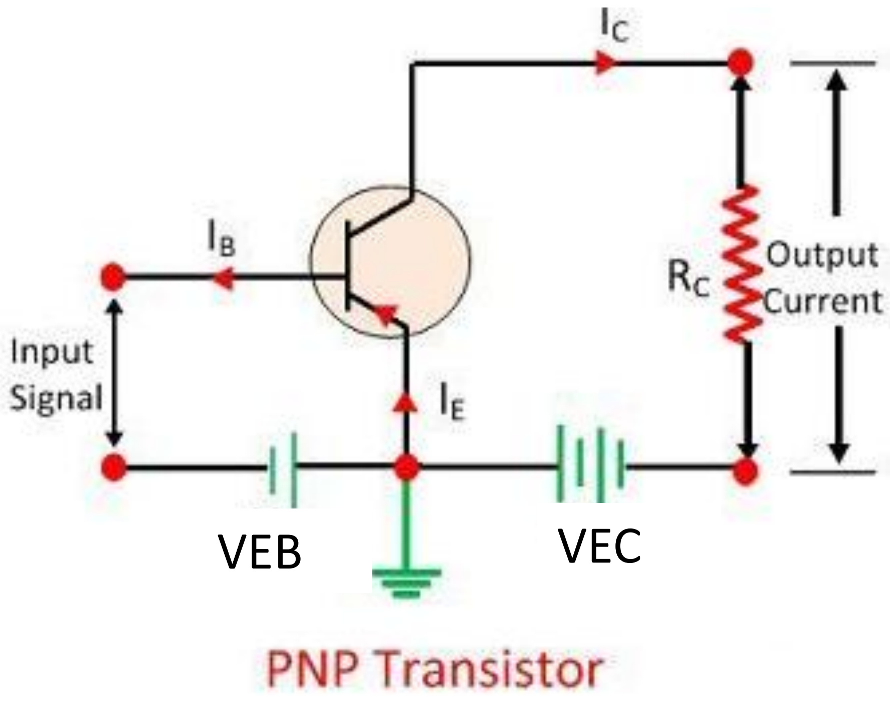
- **Output Resistance**: The ratio of change in collector-base voltage to the change in collector current is called Output Resistance.

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

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

Common Emitter "CE"





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

- NPN: VBE, VCE

- PNP: VEB, VEC

Common Emitter “CE”

- Base Current amplification factor **β** :

In common emitter connection input current is base current and output current is collector current.

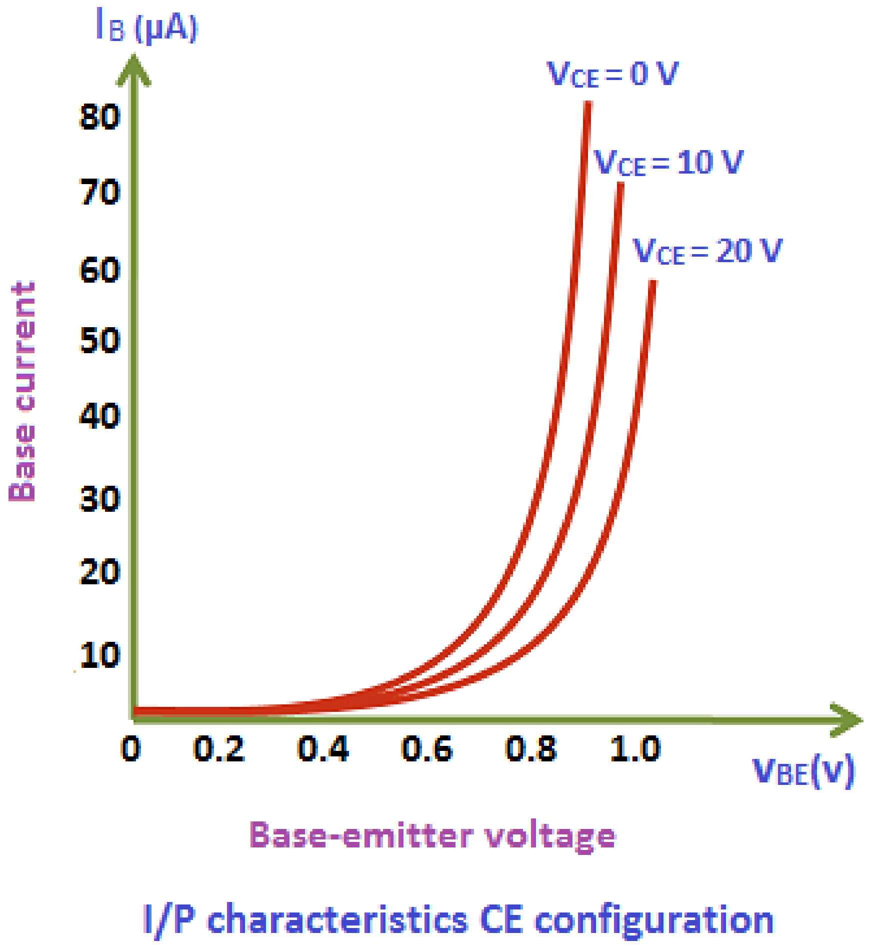
The ratio of change in collector current to the change in base current is known as base current amplification factor, **β** .

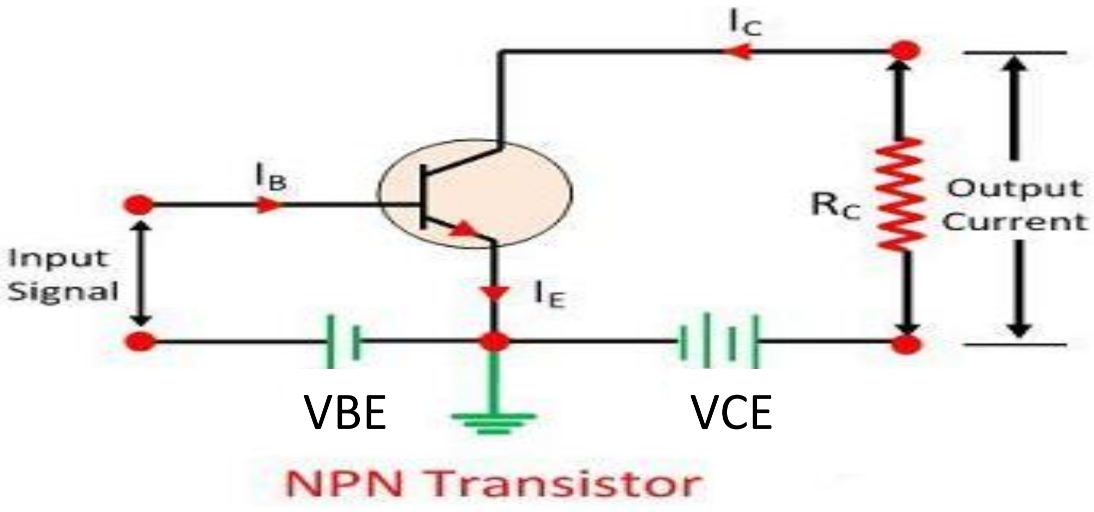
$$\boldsymbol{\beta} = \frac{\triangle I_C}{\triangle I_B}$$

Normally only 5% of emitter current flows to base, so amplification factor is greater than 50. Usually this range varies from 50 to 500.

Input Characteristics of Common Emitter Configuration (NPN)

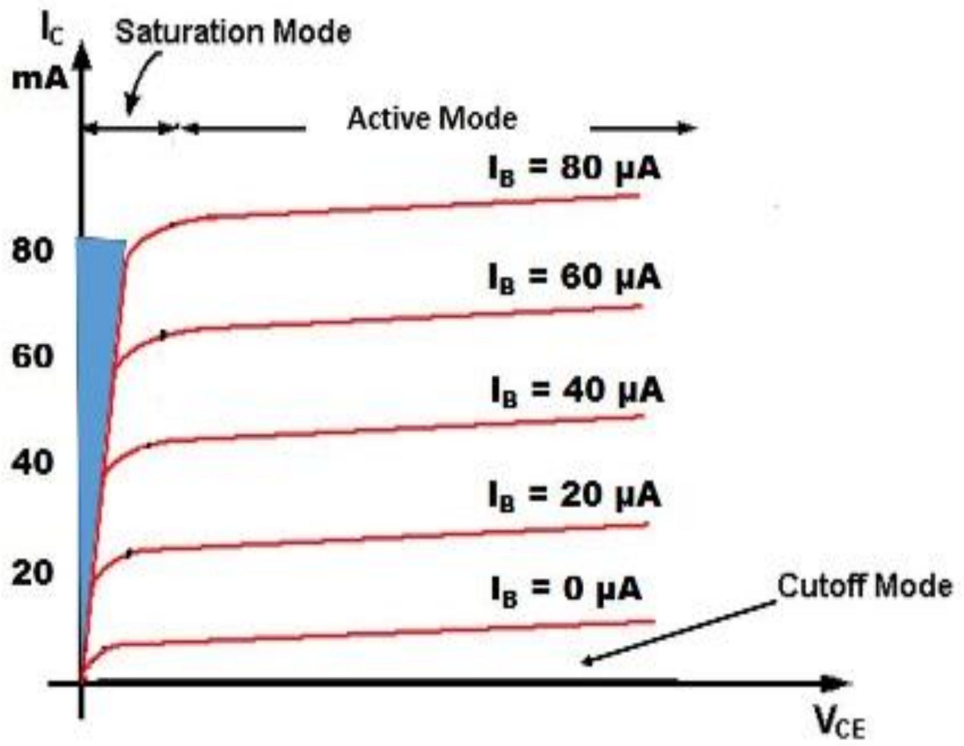
- V_{BE} vs I_B characteristics is called input characteristics.
- I_B increases rapidly with V_{BE} . It means **input resistance is relatively small.**
- I_B almost independent of V_{CE}.
- I_B is of the range of micro amps.

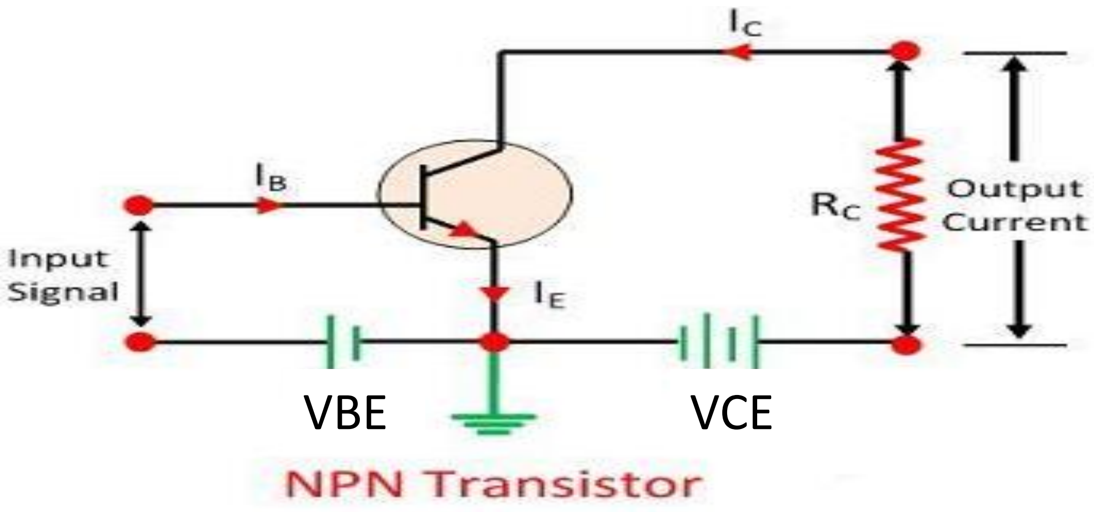




Output Characteristics of Common Emitter Configuration(NPN

- 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. It means **output resistance is high.**





Input, Output Resistance and gain of CE Conf.

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

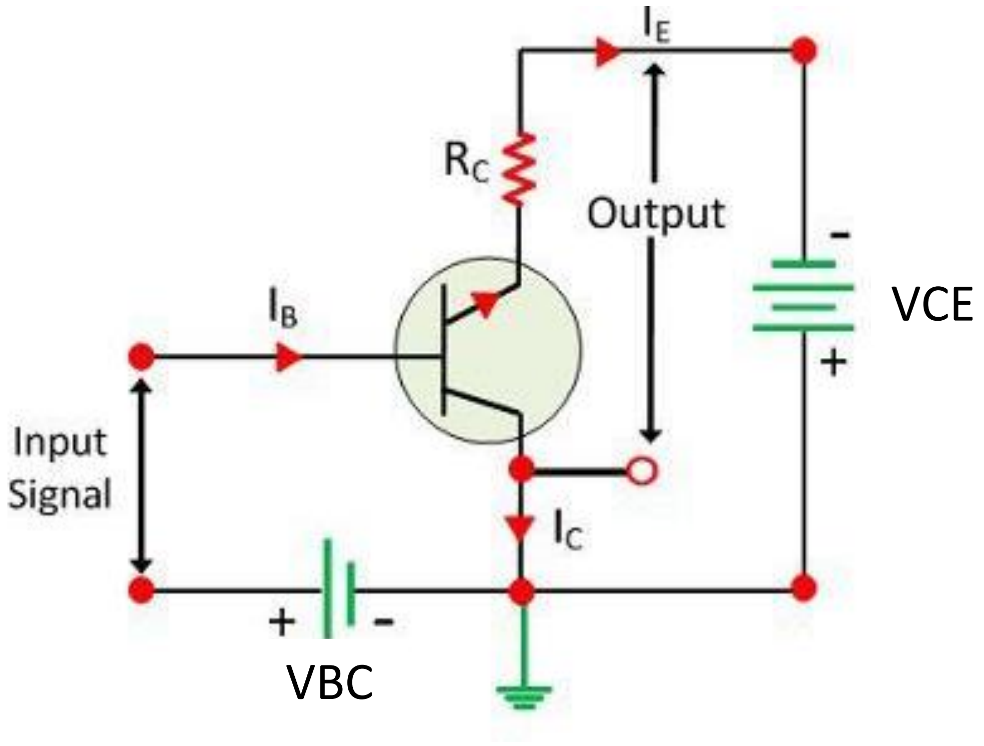
$$r_i = \frac{\triangle V_{BE}}{\triangle I_B} \text{ (relatively Low)}$$

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

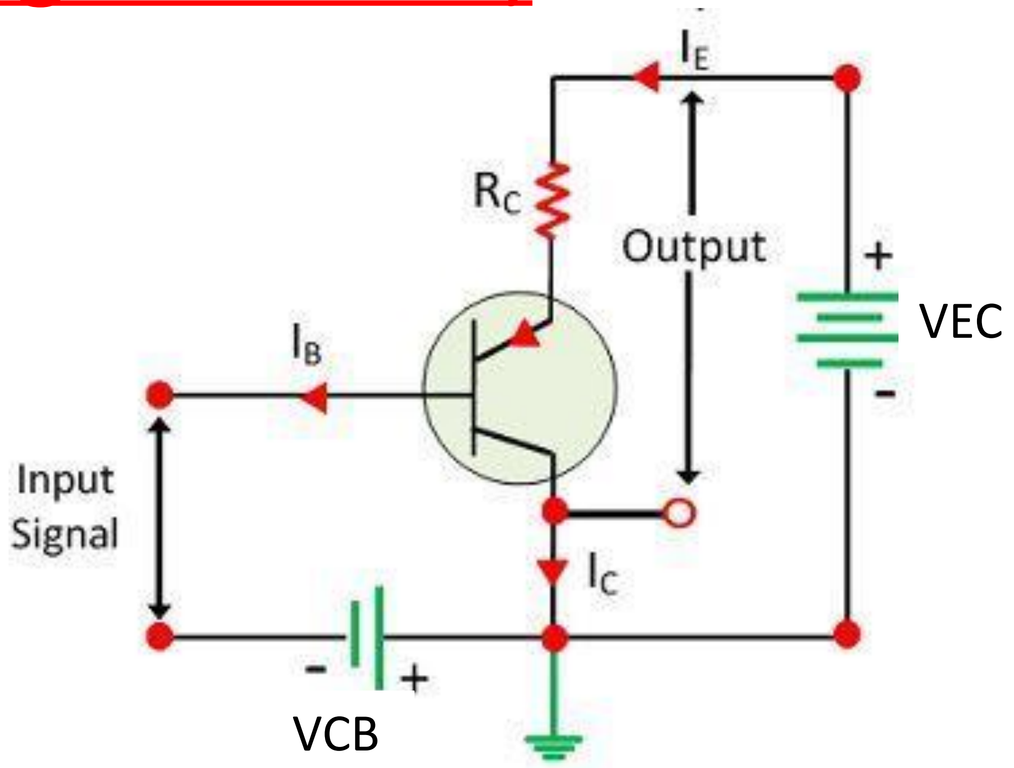
$$r_o = \frac{\triangle V_{CE}}{\triangle I_C} \text{ (High)}$$

- **Current gain:** $Ai = \boldsymbol{\beta} = \frac{\triangle I_C}{\triangle I_B}$ (relatively High/Medium)
- **Voltage gain:** $Av = \frac{I_C x r_o}{I_B x r_i}$ (relatively High/ Medium)

Common Collector “CC” (Voltage Follower)



NPN Transistor



PNP Transistor

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

- NPN: VBC, VCE

- PNP: VCB, VEC

Input, Output Resistance and gain of CC Conf.

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

$$r_i = \frac{\triangle V_{BC}}{\triangle I_B} \text{ (High)}$$

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

$$r_o = \frac{\triangle V_{CE}}{\triangle I_E} \text{ (Low)}$$

- **Current gain:** $I_E = (1 + \boldsymbol{\beta})I_B$ $\quad Ai = \boldsymbol{\beta}+1 = \frac{\triangle I_E}{\triangle I_B}$ (High)

- **Voltage gain:** $Av = \frac{I_E x r_o}{I_B x r_i}$ (unity/Low)

Comparison of Transistor Configurations

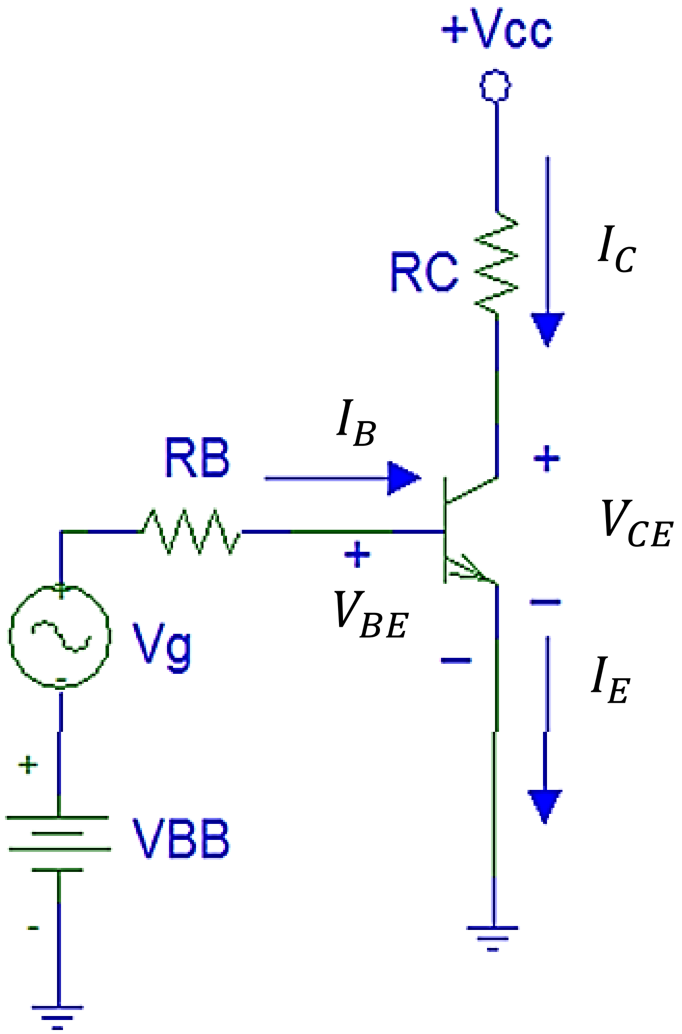
Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Shift	0^{o}	180^{o}	0^{o}
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

BJT Biasing

- Transistor Biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.
- The analysis or design of a transistor amplifier requires knowledge of both the dc and ac response of the system. In fact, the amplifier increases the strength of a weak signal by transferring the energy from the applied DC source to the weak input ac signal The analysis or design of any electronic amplifier therefore has two components:

❑The dc portion and

❑The ac portion



BJT Biasing

- During the design stage, the choice of parameters for the required dc levels will affect the ac response.
- Biasing: Application of dc voltages to establish a fixed level of current and voltage.

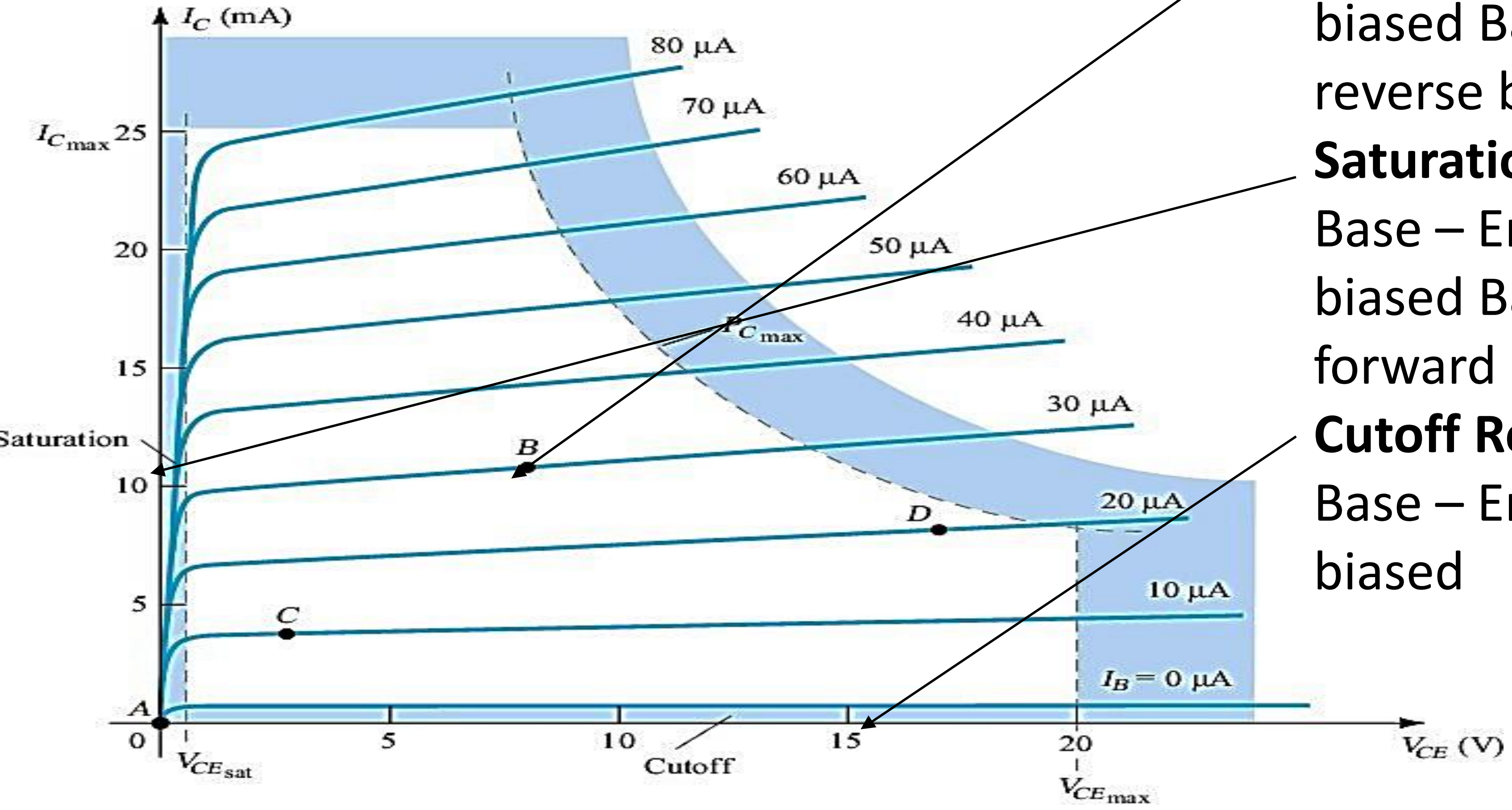
Purpose of the DC biasing circuit

- To turn the device "ON"
- To place it in operation in the region of its characteristic where the device

operates most linearly .

- Proper biasing circuit which it operate in linear region and circuit have centered Q-point or midpoint biased
- Improper biasing cause:
  - Distortion in the output signal.
  - Produce limited or clipped at output signal.

Operating Point " Q-Point"



Active or Linear Region Operation

base – Emitter junction is forward biased Base – Collector junction is reverse biased Good operating point

Saturation Region Operation

Base – Emitter junction is forward biased Base – Collector junction is forward biased

Cutoff Region Operation

Base – Emitter junction is reverse biased

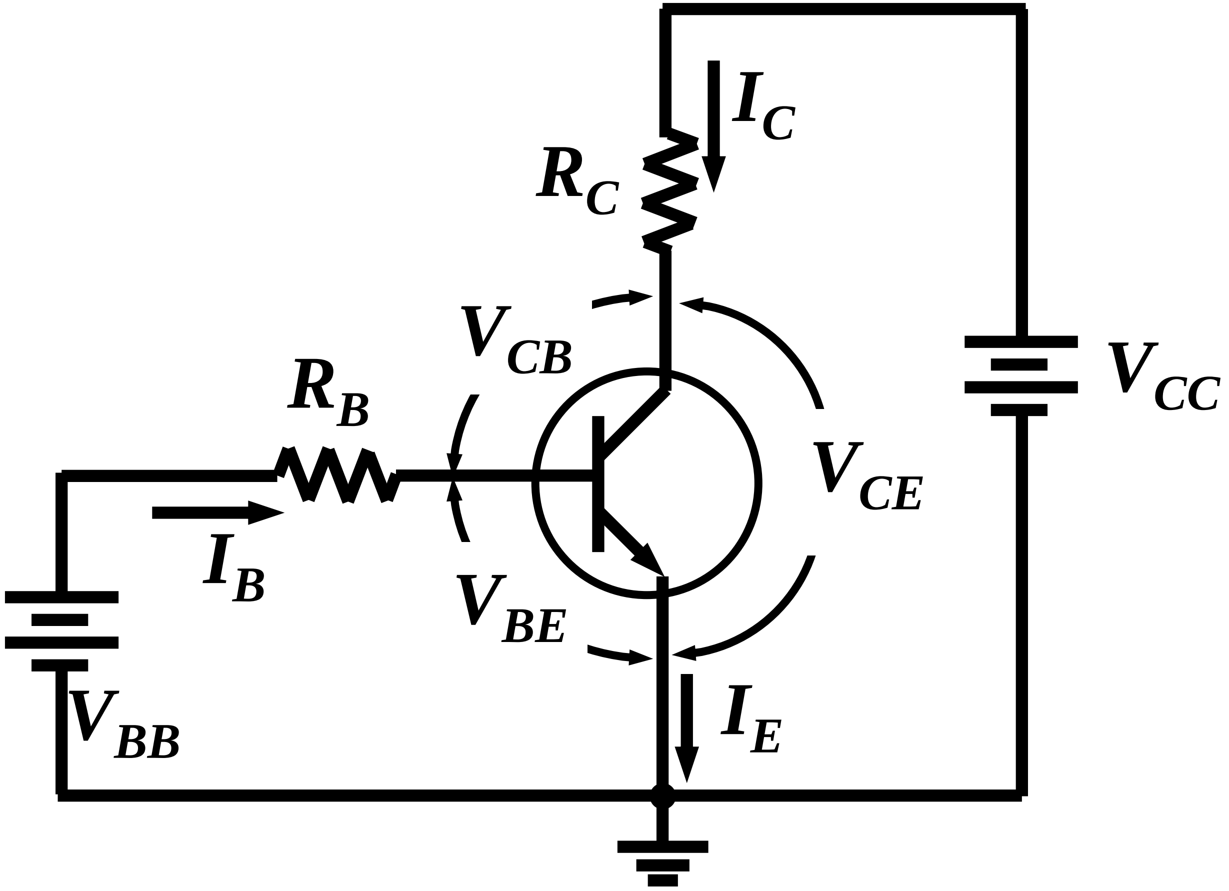
Important basic relationship

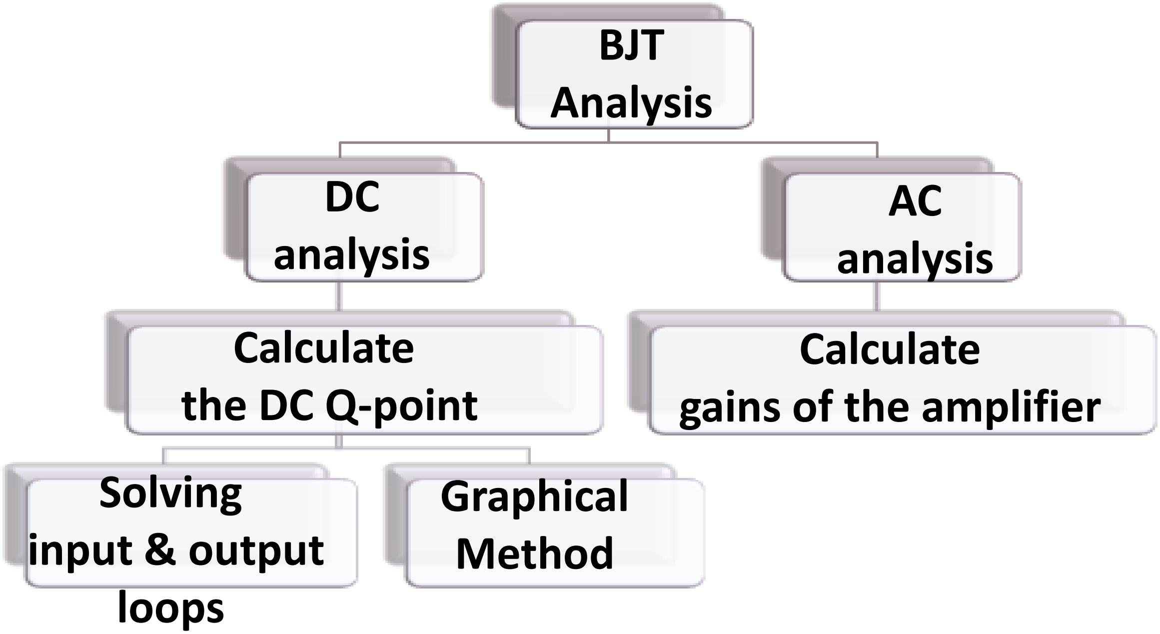
$$I_E = I_B + I_C$$

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

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

$$V_{CB} = V_{CE} - V_{BE}$$

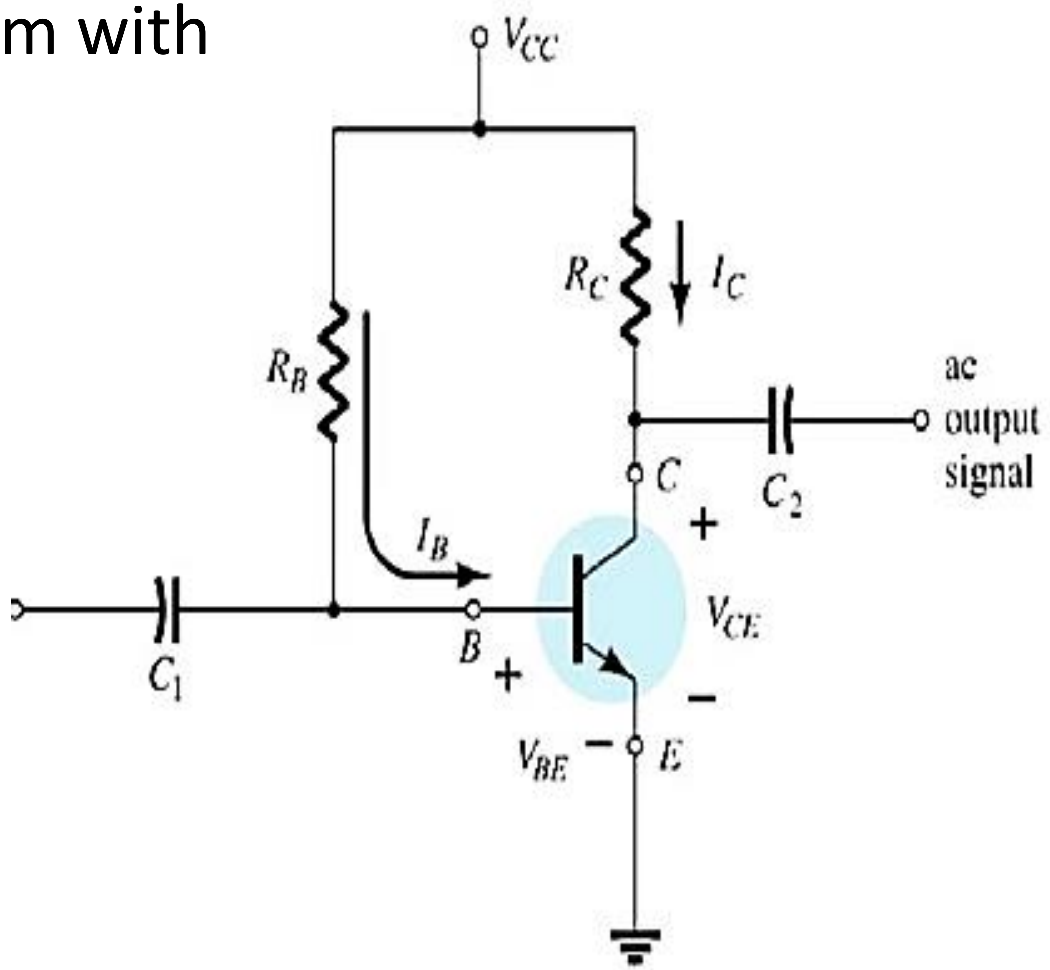




- **DC Biasing Circuits**
- Fixed-bias circuit
- Emitter-stabilized bias circuit
- Voltage divider bias circuit
- DC bias with voltage feedback

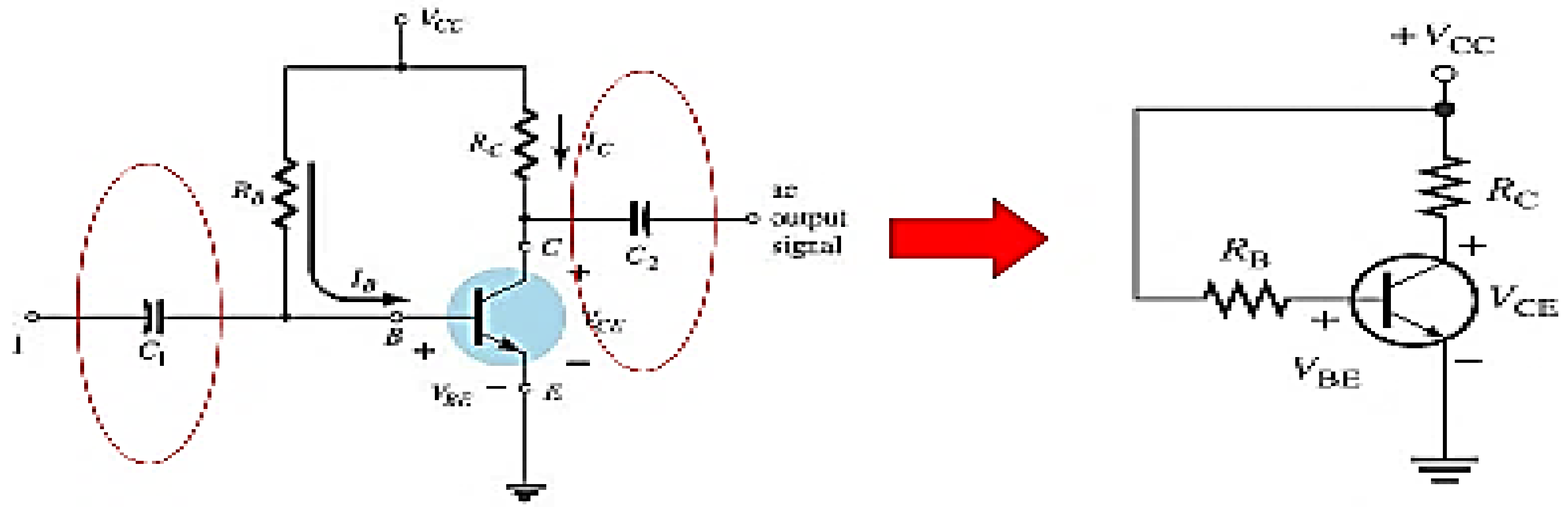
Fixed Bias circuit

- This is common emitter (CE) configuration
  - 1st step: Locate capacitors and replace them with an open circuit
  - 2nd step: Locate 2 main loops which;
    - **BE loop (input loop)**
    - **CE loop(output loop)**



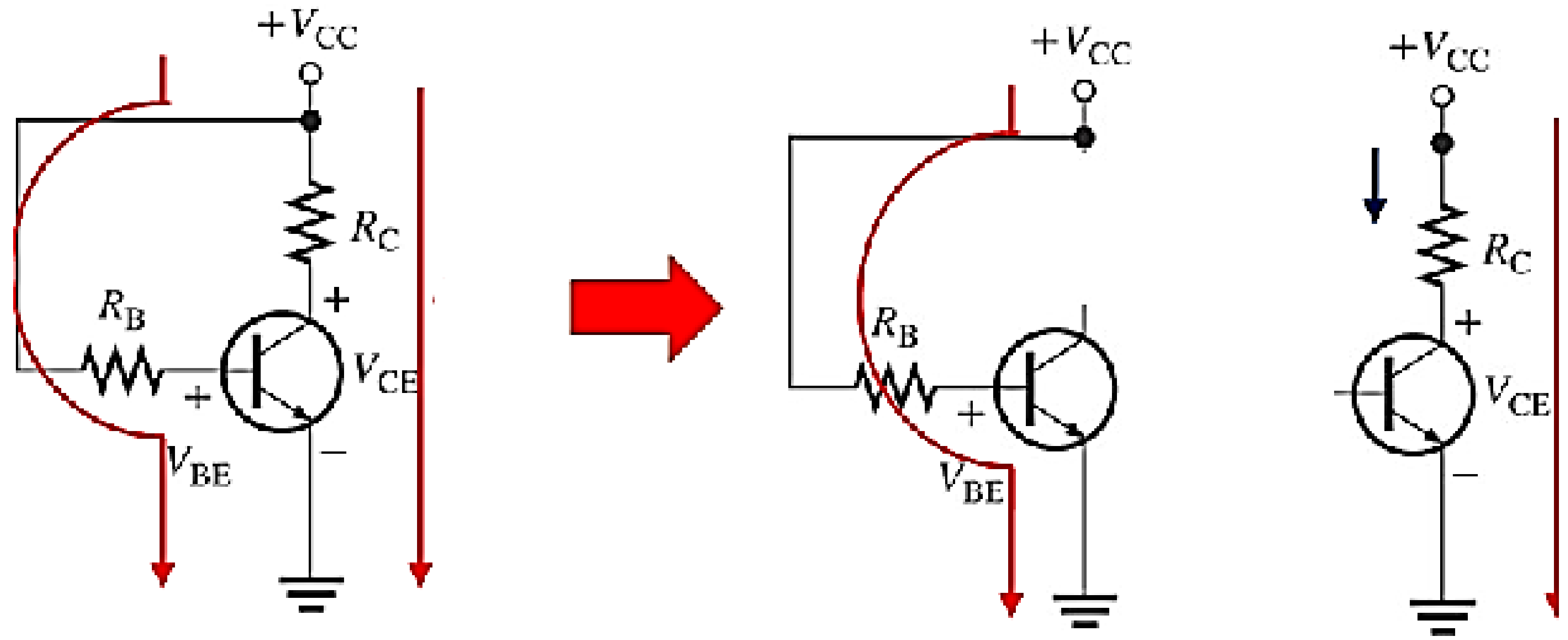
Fixed Bias circuit

- 1st step: Locate capacitors and replace them with an open circuit



Fixed Bias circuit

- 2nd step: Locate 2 main loops.



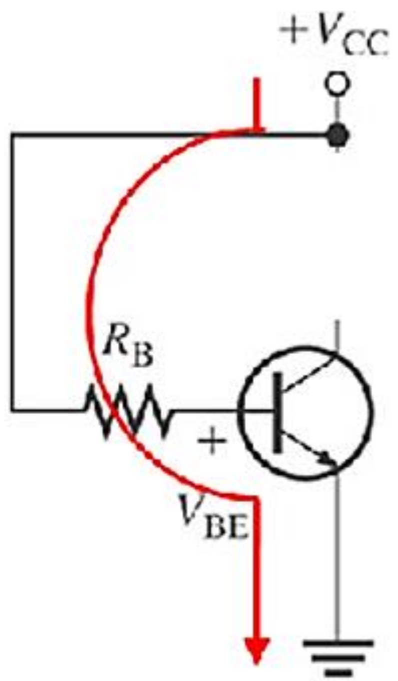
Fixed Bias circuit

- BE Loop Analysis

From KVL:

$$-V_{cc} + R_B I_B + V_{BE} = 0$$

$$I_B = \frac{V_{cc} - V_{BE}}{R_B}$$



- CE Loop Analysis

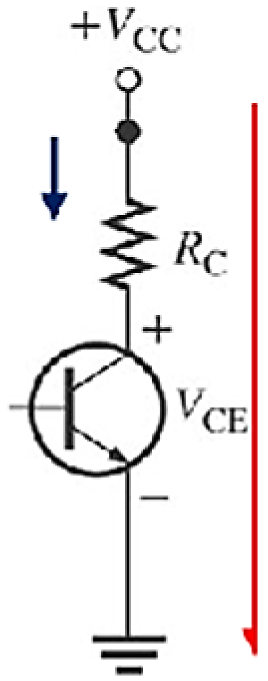
From KVL:

$$-V_{cc} + R_c I_C + V_{CE} = 0$$

$$V_{CE} = V_{cc} - R_c I_C$$

$$I_C = \beta I_B$$

$$I_C = \beta\left(\frac{V_{cc} - V_{BE}}{R_B}\right)$$



Note that R_c does not affect the value of Ic

Fixed Bias circuit

- The transistors base current, I_B remains constant for given values of Vcc, and therefore the transistors operating point must also remain fixed. Hence referred as fixed biasing.
- This two resistor biasing network is used to establish the initial operating region of the transistor using a fixed current bias.

- **DISADVANTAGE**
  - Unstable – because it is too dependent on β and produce width change of Q-point
  - For improved bias stability , add emitter resistor to dc bias.