BIPOLAR JUNCTION TRANSISTOR

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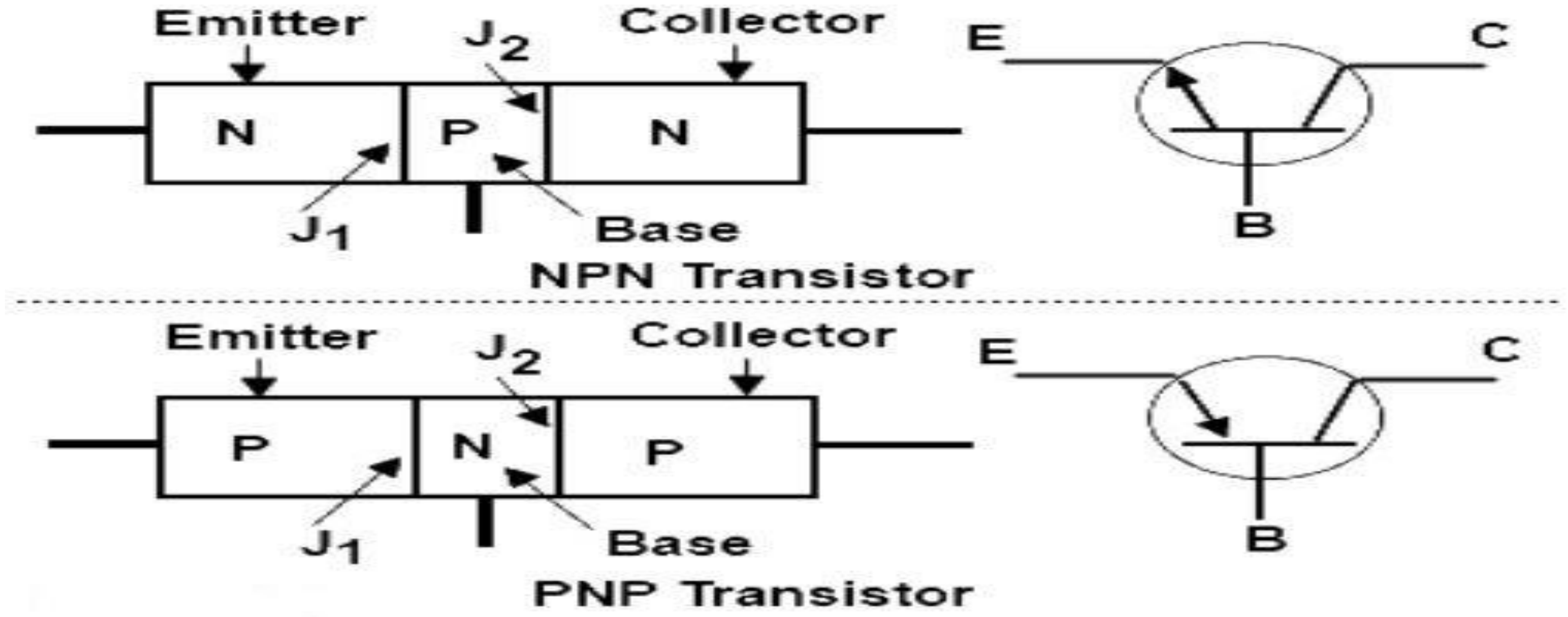
- A Bipolar Junction Transistor (BJT) is a three-terminal semiconductor device consisting of two p-n junctions which are able to amplify or magnify a signal.
- The three terminals of the BJT are the base, the collector and the emitter.
- A BJT is a type of transistor that uses both electrons and holes as charge carriers.
- It is a current controlled device.



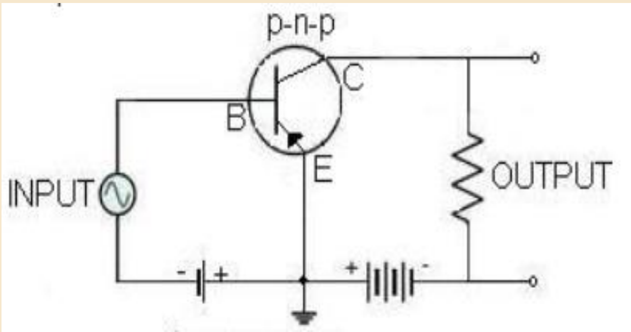
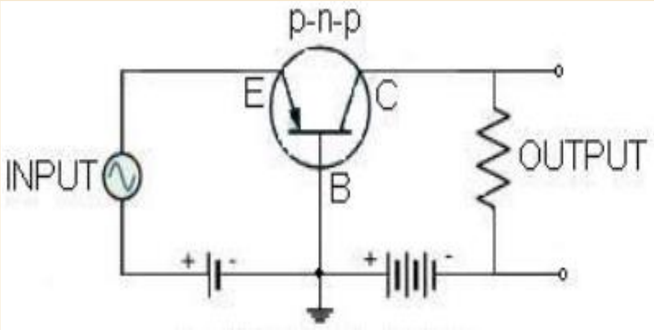
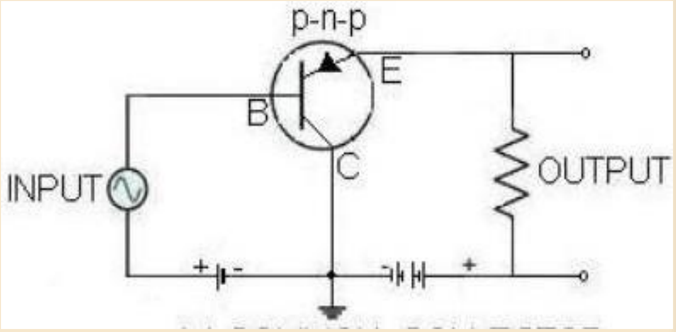
BIPOLAR JUNCTION TRANSISTOR

- 2 Junctions of Transistor **Emitter Base Junction** and **Collector Base Junction.**
- Biasing of these Junction and Modes of operation

EMITTER BASE JUNCTION	COLLECTOR BASE JUNCTION	REGION OF OPERATION
FORWARD BIASED	REVERSE BIASED	ACTIVE REGION
FORWARD BIASED	FORWARD BIASED	SATURATION REGION
REVERSE BIASED	REVERSE BIASED	CUTOFF REGION
REVERSE BIASED	FORWARD BIASED	INVERTED REGION

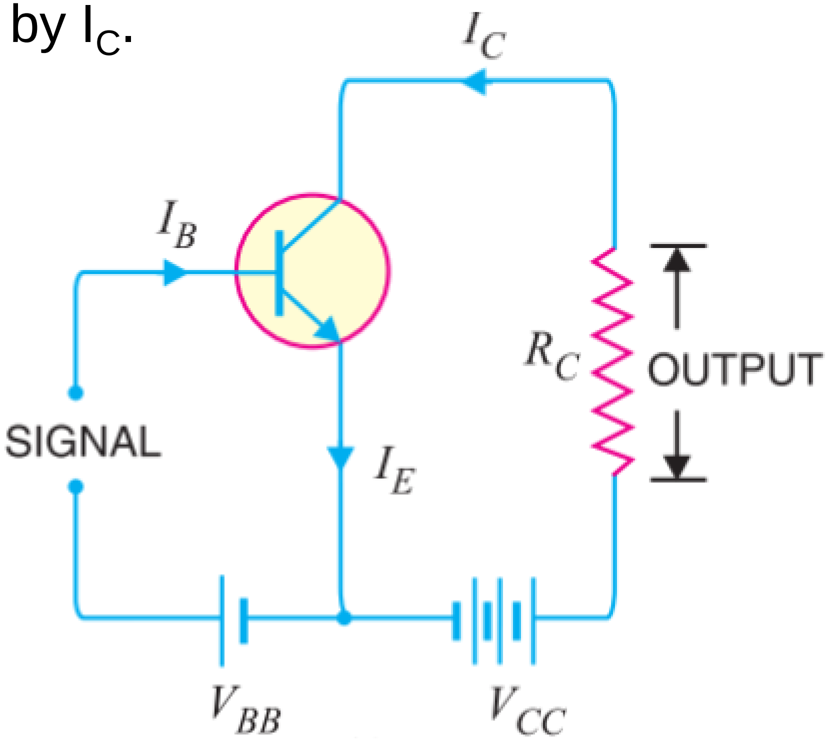
BIPOLAR JUNCTION TRANSISTOR

- The BJT transistors have three types of configurations. They are
- COMMON-EMITTER Configuration
- COMMON-BASE Configuration
- COMMON-COLLECTOR Configuration

CHARACTERISTICS	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
CIRCUIT			
INPUT VOLTAGE APPLIED BETWEEN	BASE & EMITTER	EMITTER & BASE	BASE & COLLECTOR
OUTPUT VOLTAGE APPLIED BETWEEN	COLLECTOR & EMITTER	COLLECTOR & BASE	EMITTER & COLLECTOR
INPUT & OUTPUT CURRENT	I_B & I_C	I_E & I_C	I_B & I_E

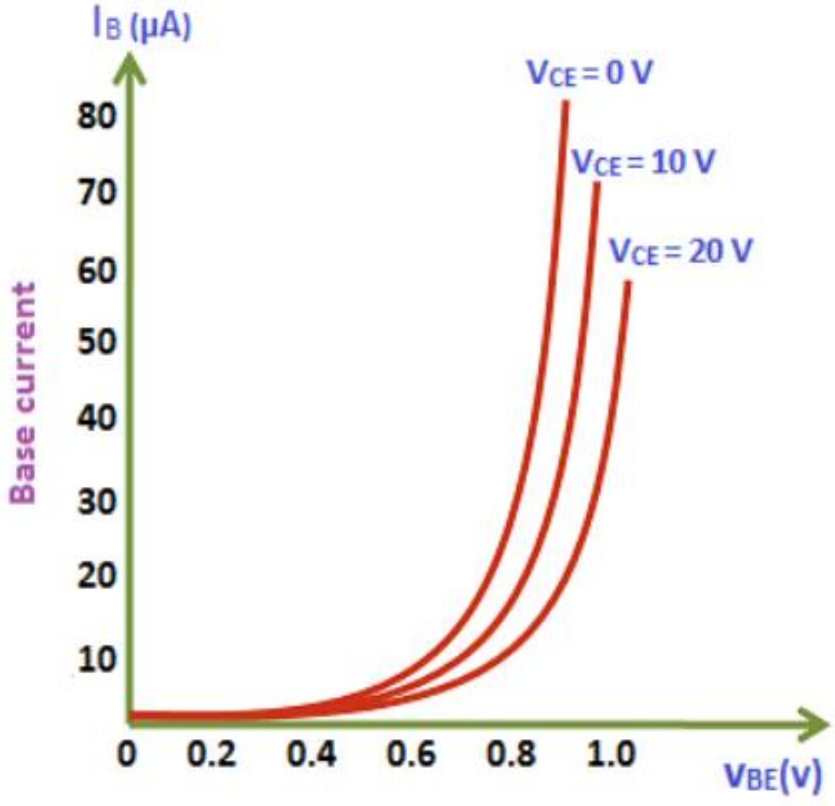
COMMON EMITTER CONFIGURATION

- In CE Configuration Emitter Terminal common to both Input and Output.
- Input signal is fed at Base terminal and Output is taken across Collector terminal
- The supply voltage between base and emitter is denoted by V_{BE} while the supply voltage between collector and emitter is denoted by V_{CE}.
- In common emitter (CE) configuration, input current or base current is denoted by I_B and output current or collector current is denoted by I_C.



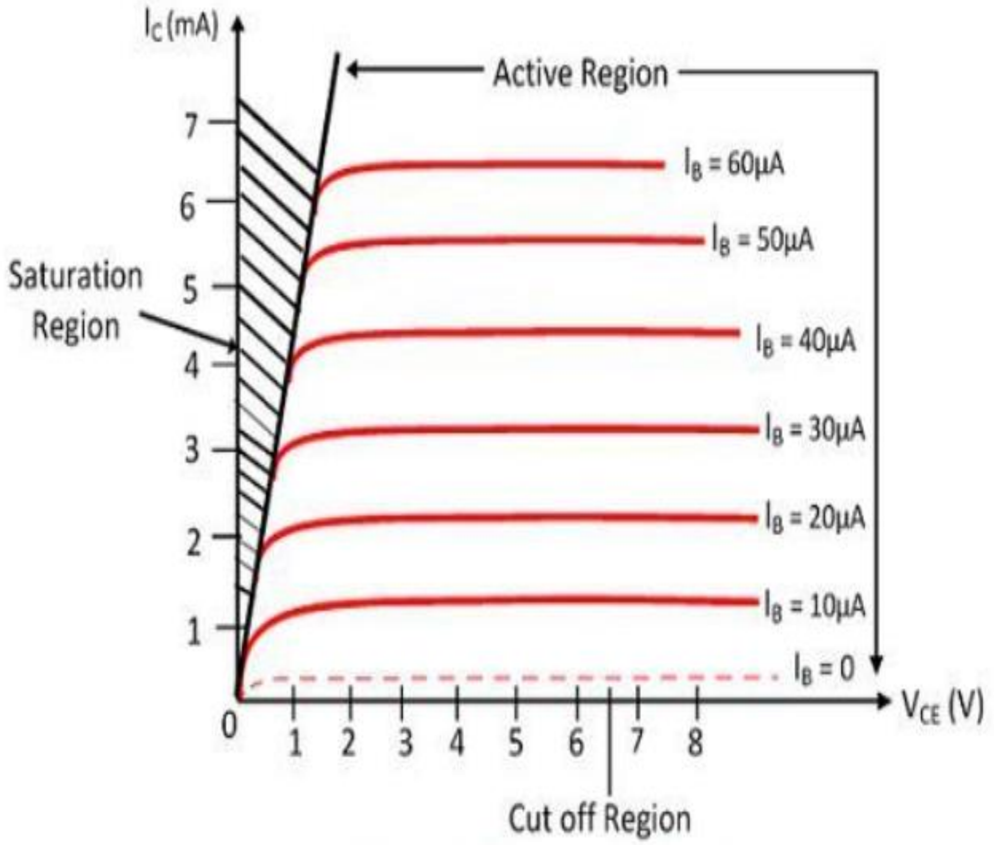
Input Characteristics – CE Configuration

- The input characteristics describe the relationship between input current or base current (IB) and input voltage or base-emitter voltage (VBE).
- The input current or base current (IB) is taken along y-axis (vertical line) and the input voltage (VBE) is taken along x-axis (horizontal line).
- The input characteristics of the CE configuration is same as the characteristics of a normal pn junction diode.
- The input current in CE configuration is measured in microamperes (μA)



Output Characteristics – CE Configuration

- The output characteristics describe the relationship between output current (IC) and output voltage (VCE).
- The output current or collector current (IC) is taken along y-axis (vertical line) and the output voltage (VCE) is taken along x-axis (horizontal line).
- The value of the collector current IC increases with the increase in VCE at constant voltage IB, the value β of also increases.
- When the VCE falls, the IC also decreases rapidly.



TRANSISTOR BIASING

What is Transistor Biasing?

- Transistor Biasing is the process of setting a transistor's DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.
- If the transistor is to operate correctly as a linear amplifier, it must be properly biased around its Operating point called **Quiescent point.**
- The correct biasing point for a bipolar transistor, lies between Saturation region or Cutoff region along its DC load line.
- This central operating point is called the **Quiescent Operating Point** or **Q-point**

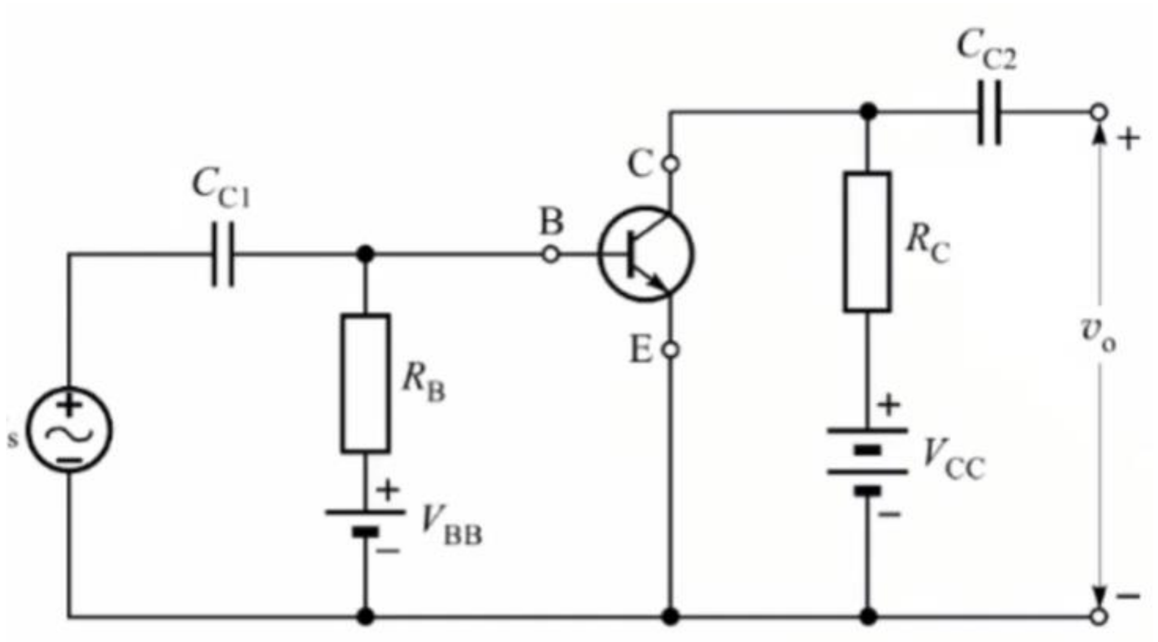
What is Need for DC biasing?

- If a signal of very small voltage is given to the input of BJT, it cannot be amplified. Because, for a BJT, to amplify a signal, two conditions have to be met.
  - The input voltage should exceed cut-in voltage for the transistor to be ON.
  - The BJT should be in the active region, to be operated as an amplifier.

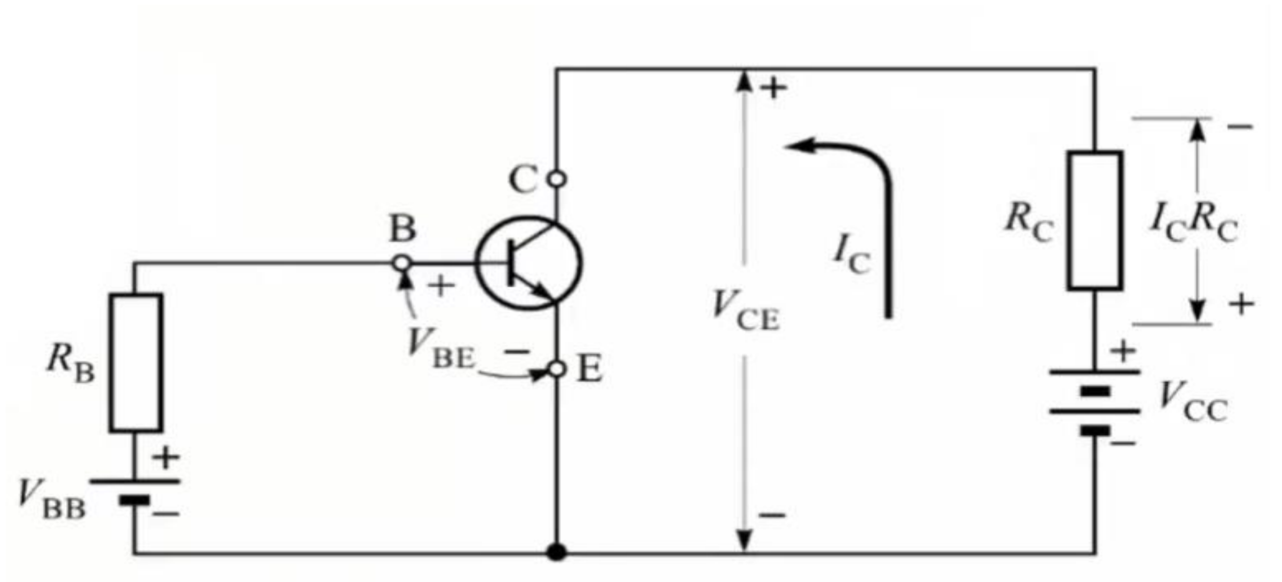
- If appropriate DC voltages and currents are given through BJT by external sources, BJT operates in active region and AC signals are amplified.
- DC voltage and currents are so chosen that the transistor remains in active region for entire input AC cycle.

DC LOAD LINE

- A DC load line is the load line of the DC equivalent circuit, defined by reducing the reactive components to zero (replacing capacitors by open circuits and inductors by short circuits).
- It is used to determine the correct DC operating point, often called the **Q point**.
- No input is applied to the input and Capacitors are removed. (**Quiescent Condition**)

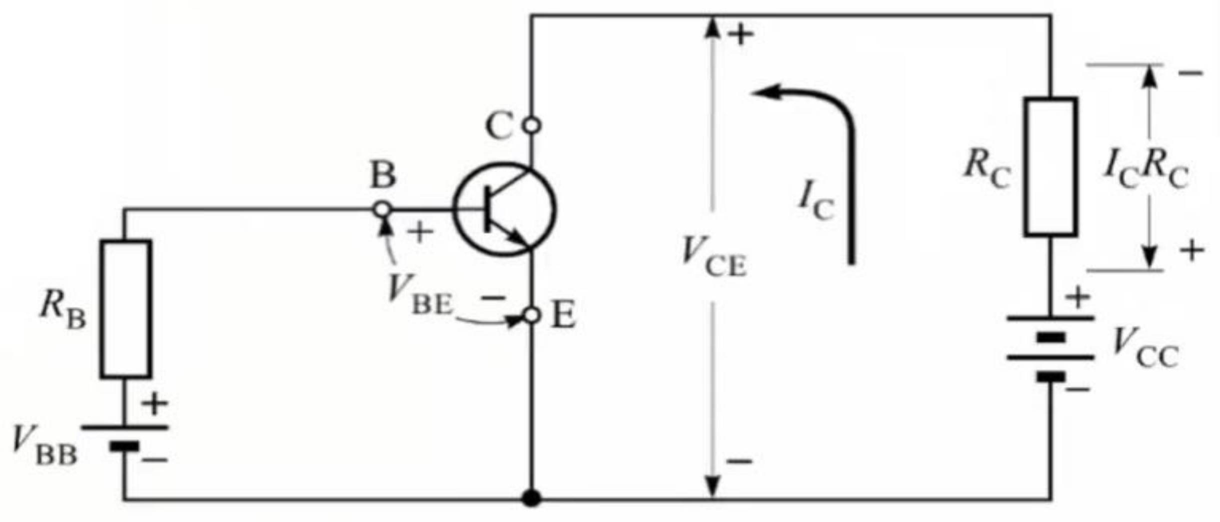


CE AMPLIFIER



CE AMPLIFIER QUIESCENT CONDITION

DC LOAD LINE



Applying KVL at Output Side (Collector)

$$V_{CC} - I_C R_C - V_{CE} = 0 \tag{1}$$

$$V_{CC} = I_C R_C + V_{CE}$$

$$I_C R_C = V_{CC} - V_{CE}$$

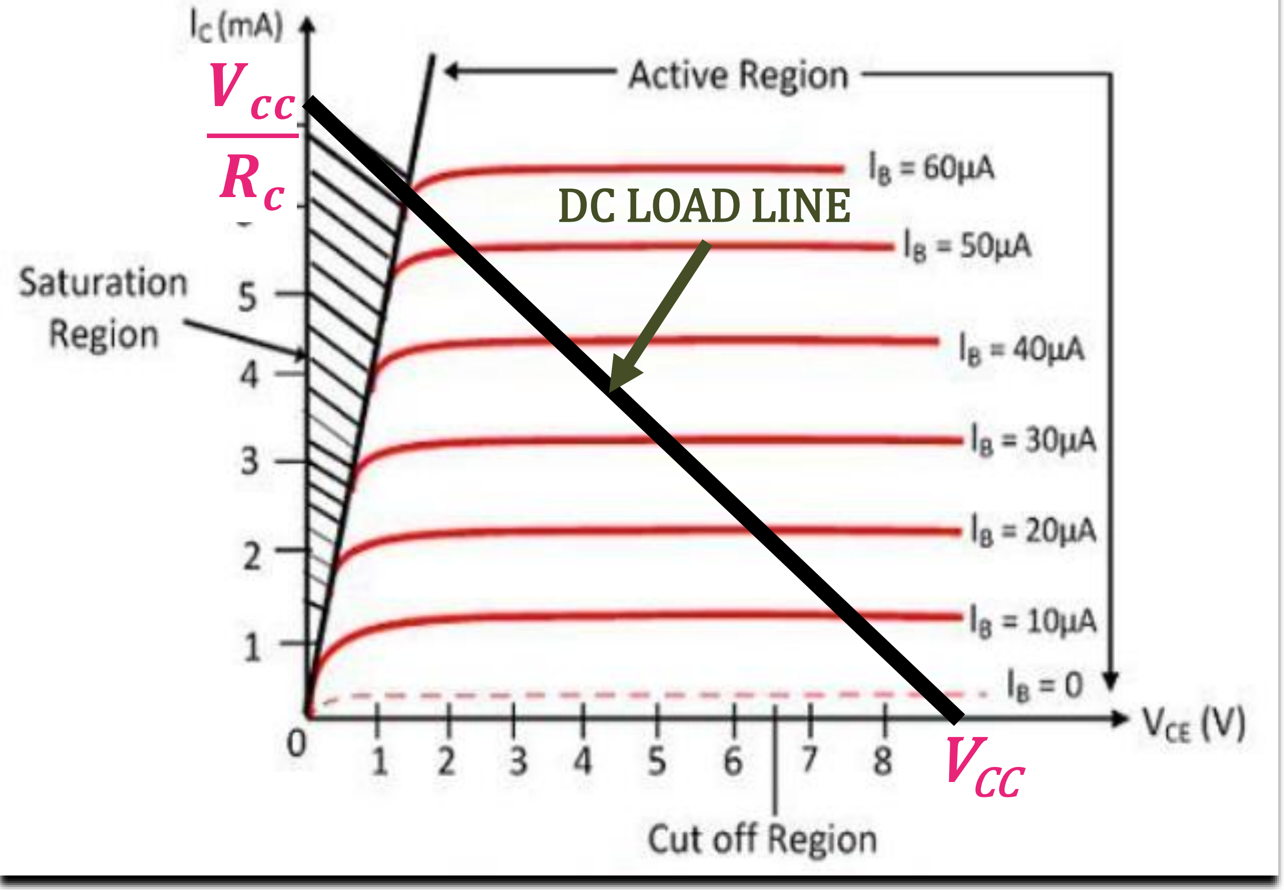
$$I_C = \frac{V_{cc} - V_{CE}}{R_c}$$

$$I_c = \left(\frac{-1}{R_c}\right)V_{CE} + \frac{V_{cc}}{R_c} \tag{2}$$

EQUATION OF STRAIGHT LINE

Y = mX + C

DC LOAD LINE



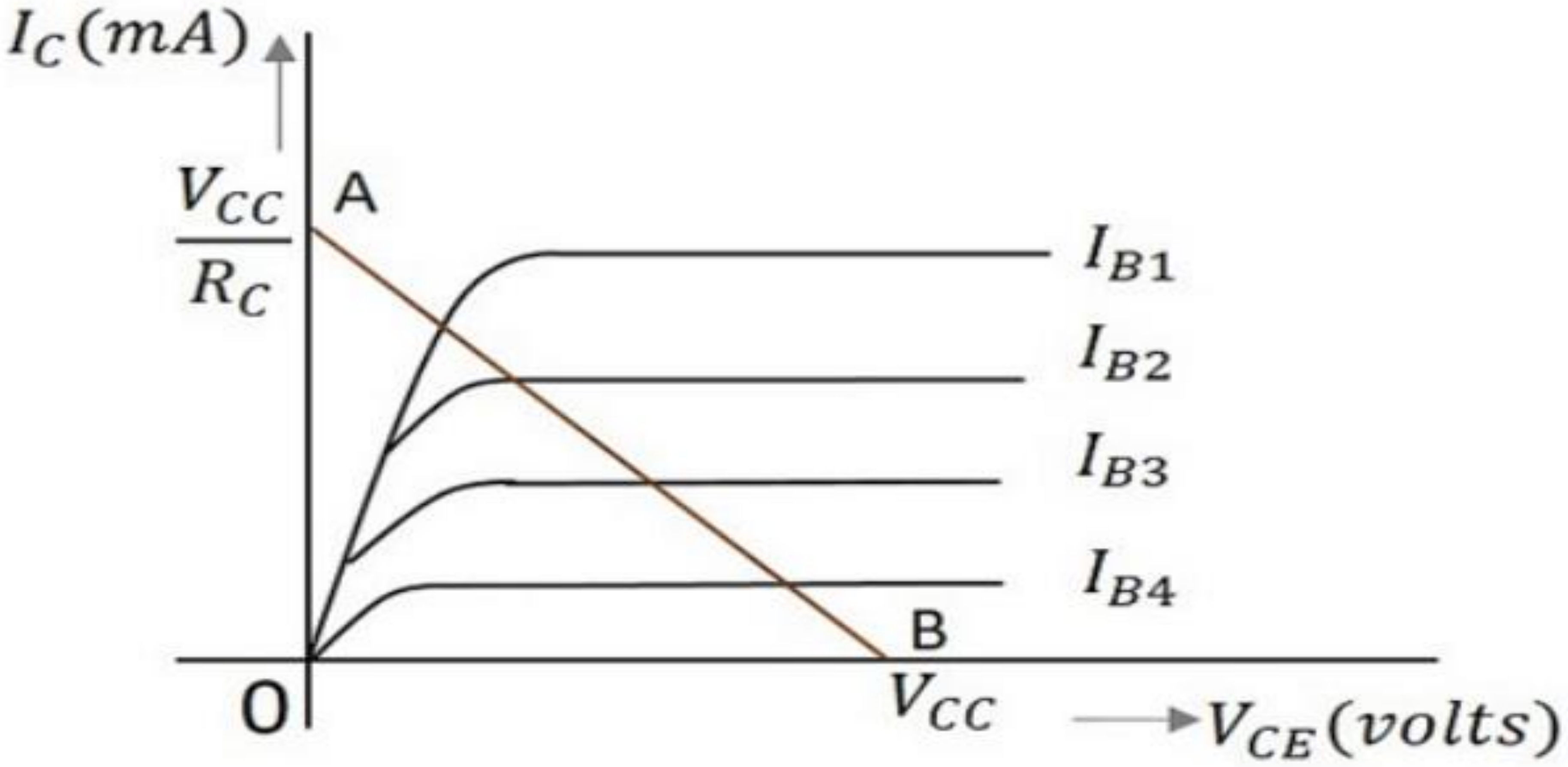
$$m = \left(\frac{-1}{R_c}\right) \quad c = \frac{v_{cc}}{R_c}$$

$$At\ X\ axis,\ Ic = 0,\ V_{CC} = V_{CE}$$

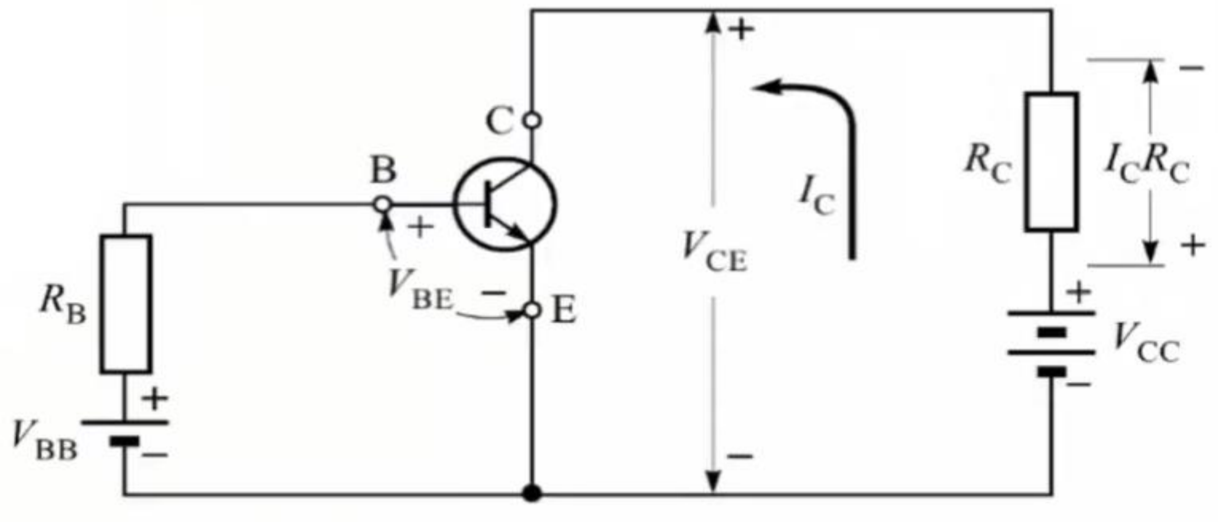
$$At\ Y\ axis,\ V_{CE} = 0,\ V_{CC} = I_C R_C,\ I_C = \frac{V_{cc}}{R_c}$$

*The DC load line is a graph of all values of I_C and V_{CE}. If we plot the graph will get the slope line and that line is called the **DC load line.***

DC LOAD LINE



DC LOAD LINE



Applying KVL at Input Side (Base)

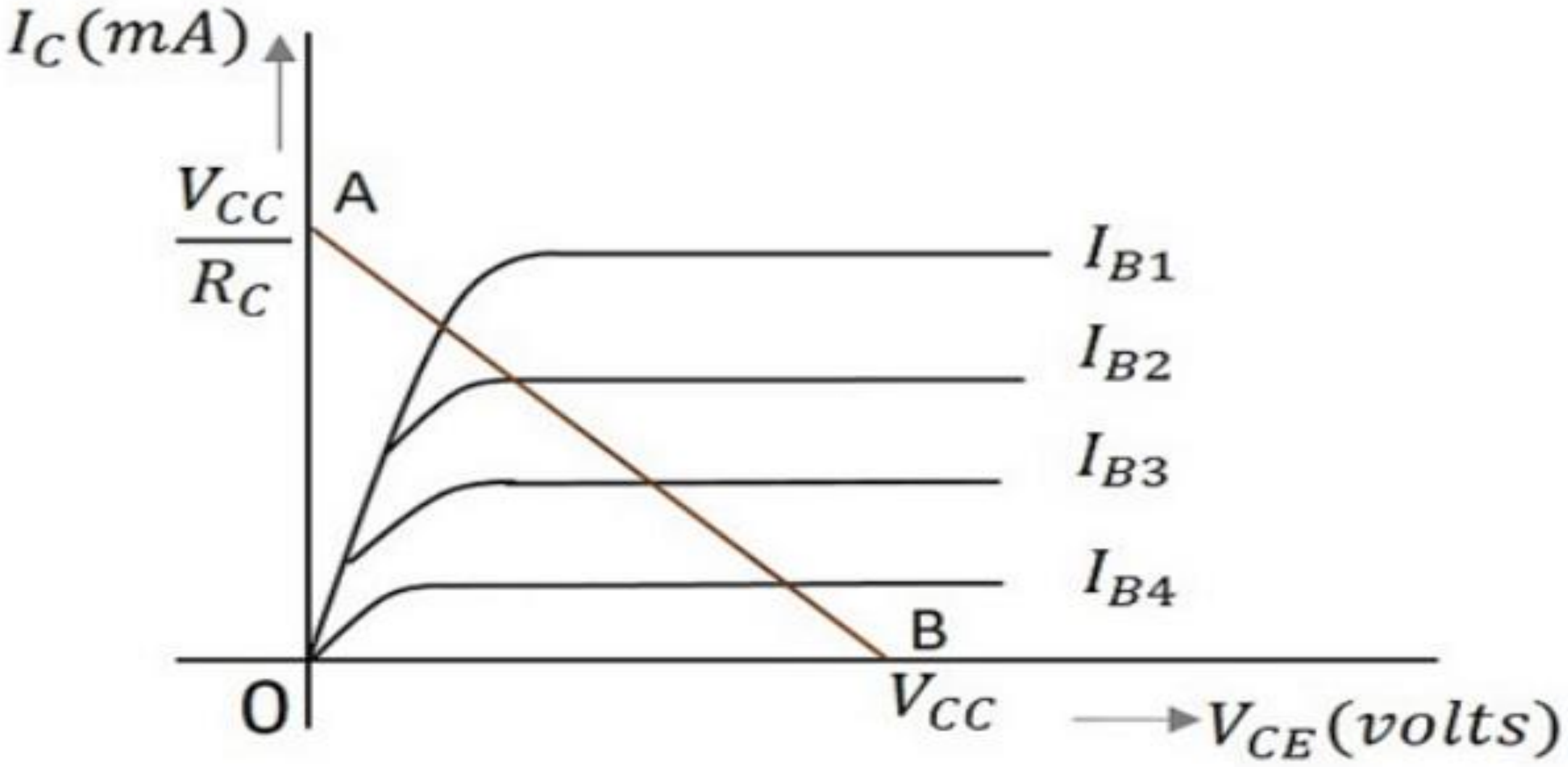
$$V_{BB} = I_B R_B + V_{BE}$$

$$I_B R_B = V_{BB} - V_{BE}$$

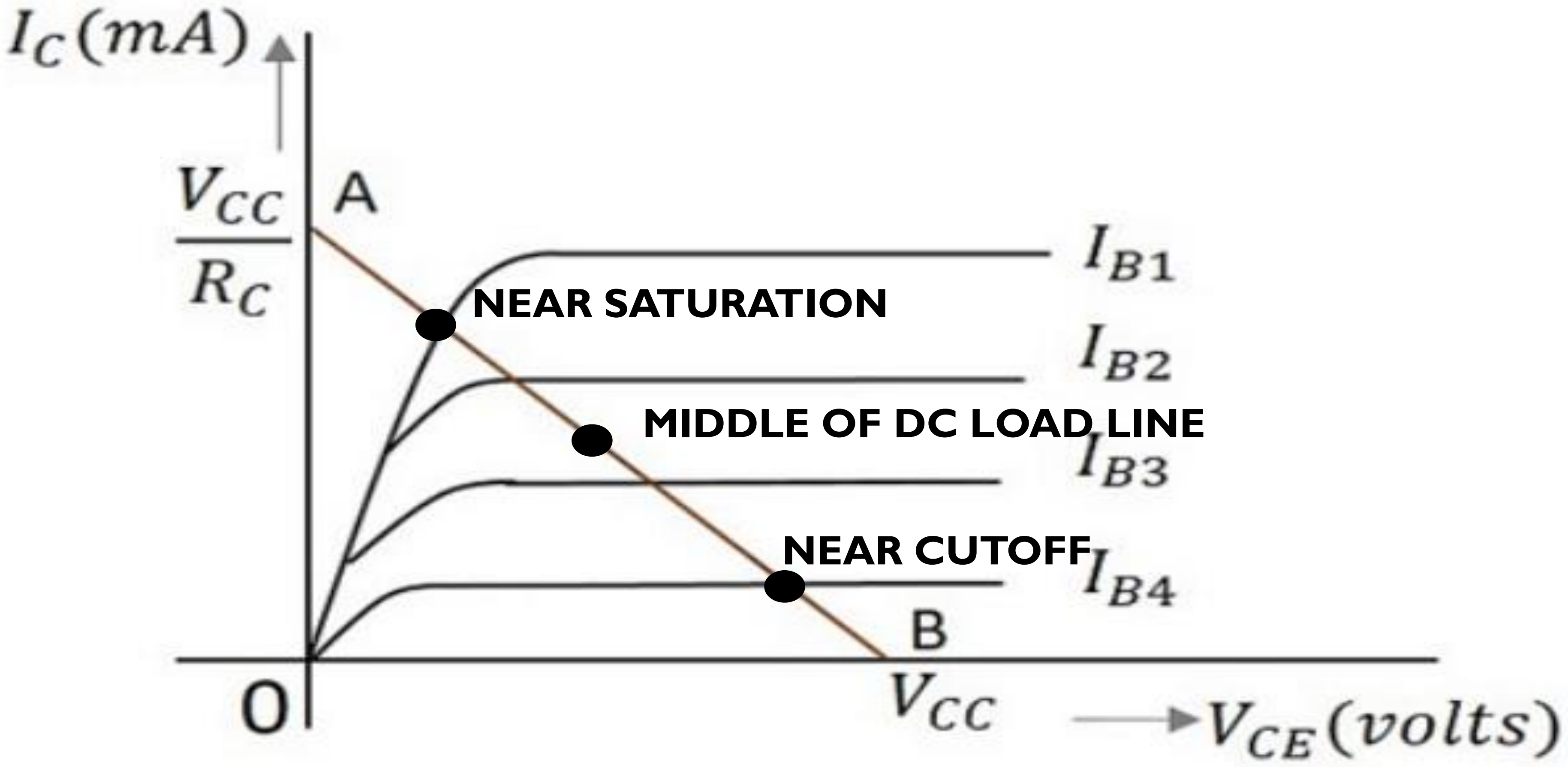
$$\boxed{I_B = \frac{V_{BB} - V_{BE}}{R_B}} \quad 3$$

$$I_B \approx \frac{V_{BB}}{R_B}$$

DC LOAD LINE

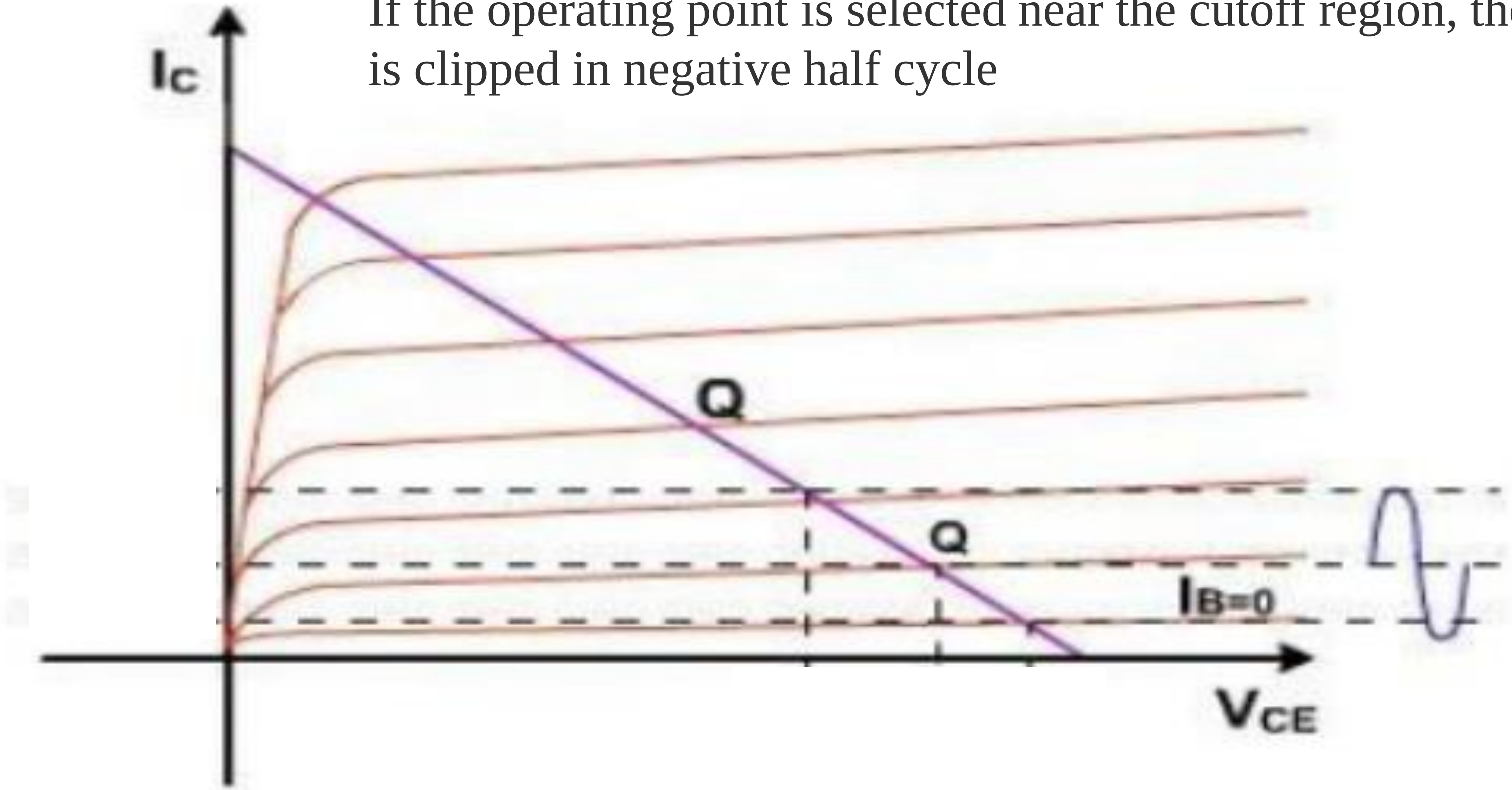


- For a circuit to amplify the signal properly, the transistor is to be biased at an operating point so that no distortion at amplified output signal.
- Assume operating points at different regions on DC load line.
  - Near cut off
  - Near Saturation
  - Middle of DC load line

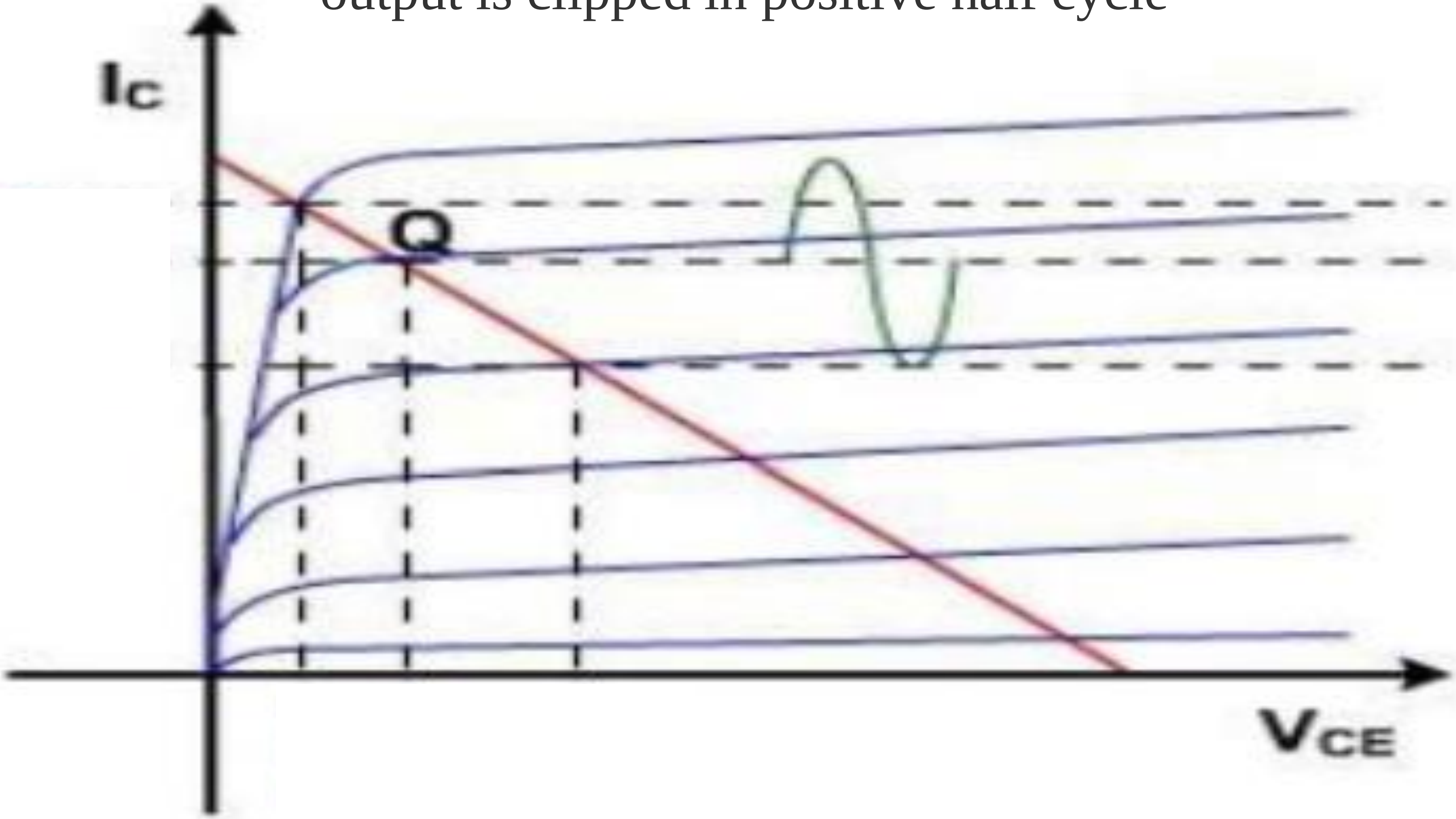


$I_C(mA)$
$\frac{V_{CC}}{R_C}$
A
I_{B1}
NEAR SATURATION
I_{B2}
MIDDLE OF DC LOAD LINE
I_{B3}
NEAR CUTOFF
I_{B4}
B
O
V_{CC}
$V_{CE}(volts)$

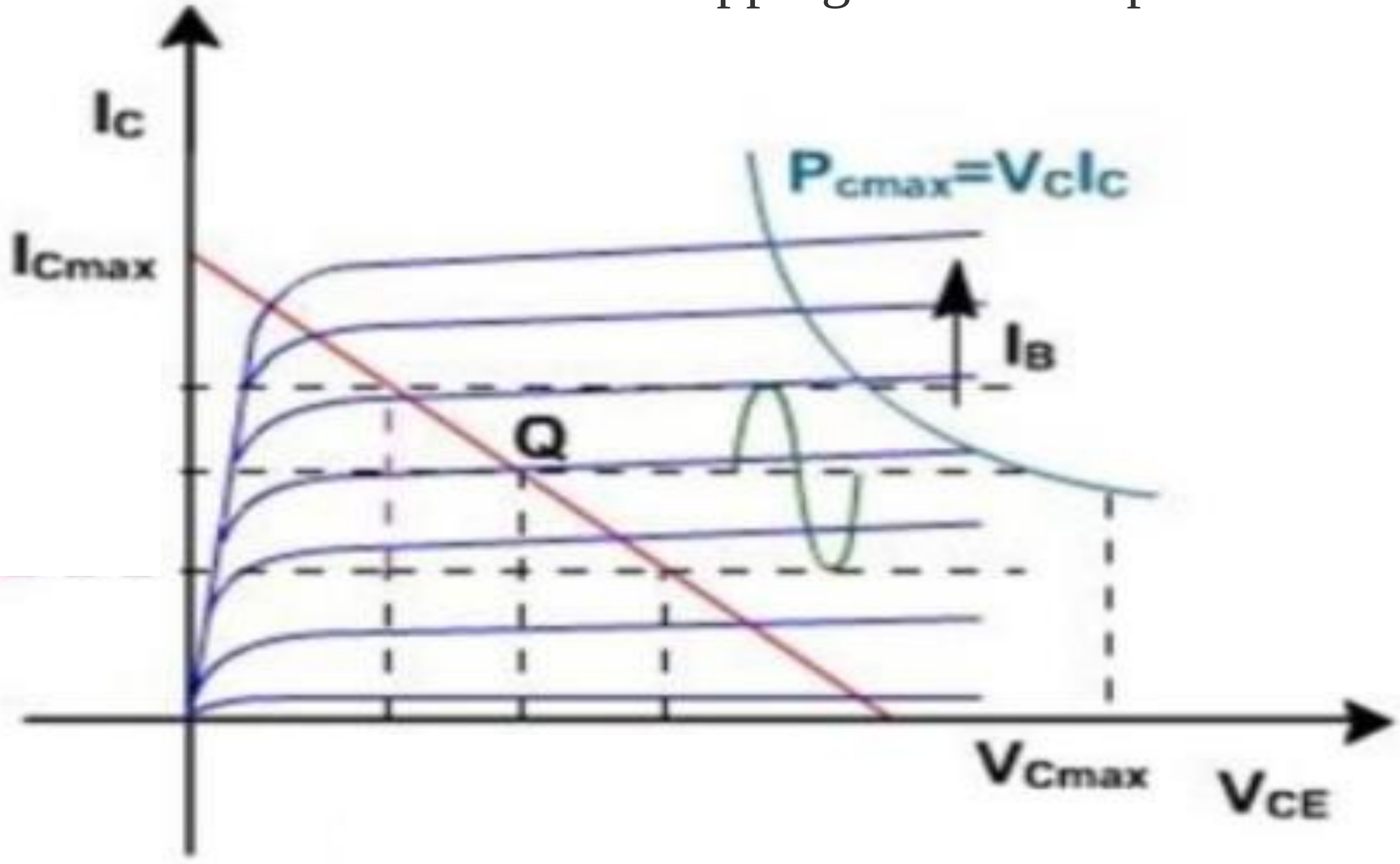
If the operating point is selected near the cutoff region, the output is clipped in negative half cycle

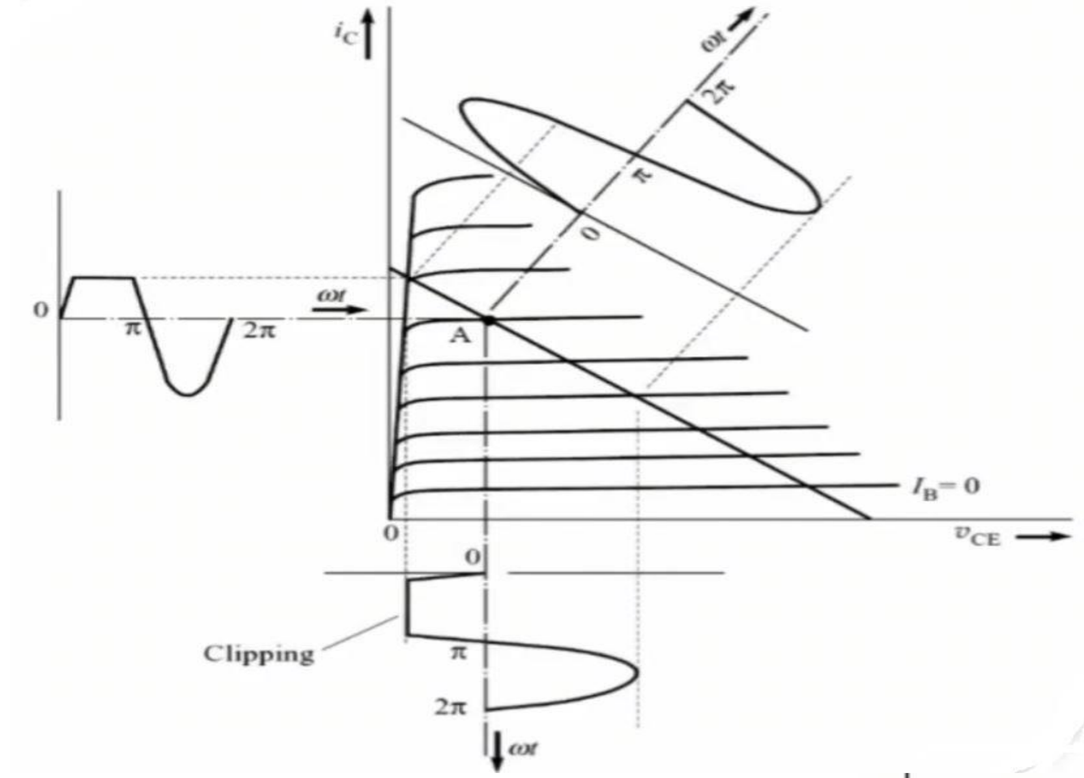


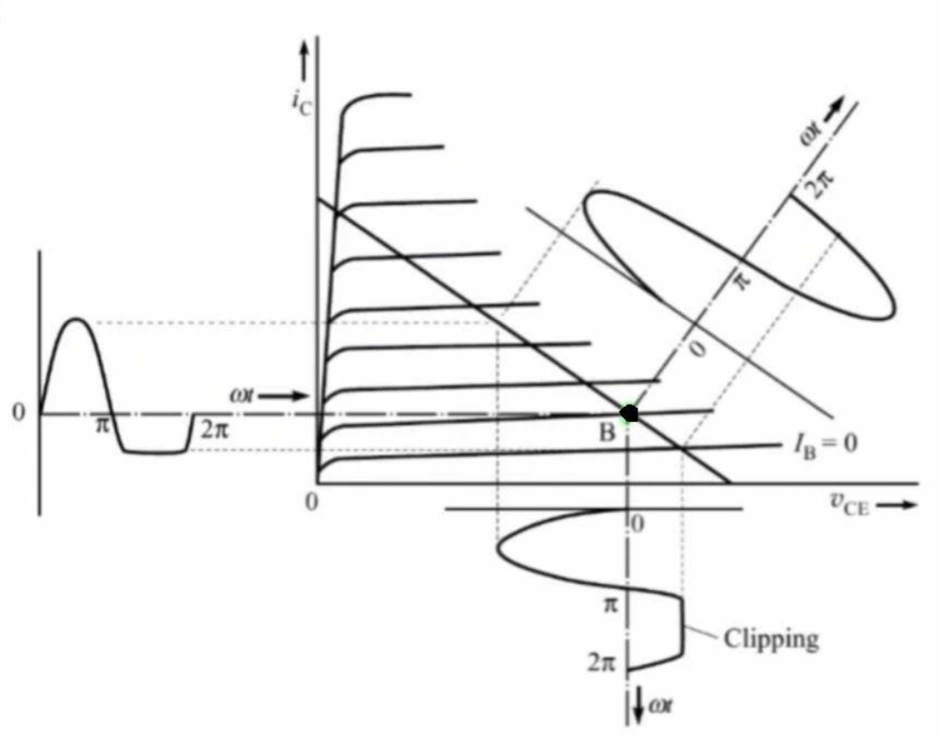
If the operating point is selected near the saturation region, the output is clipped in positive half cycle

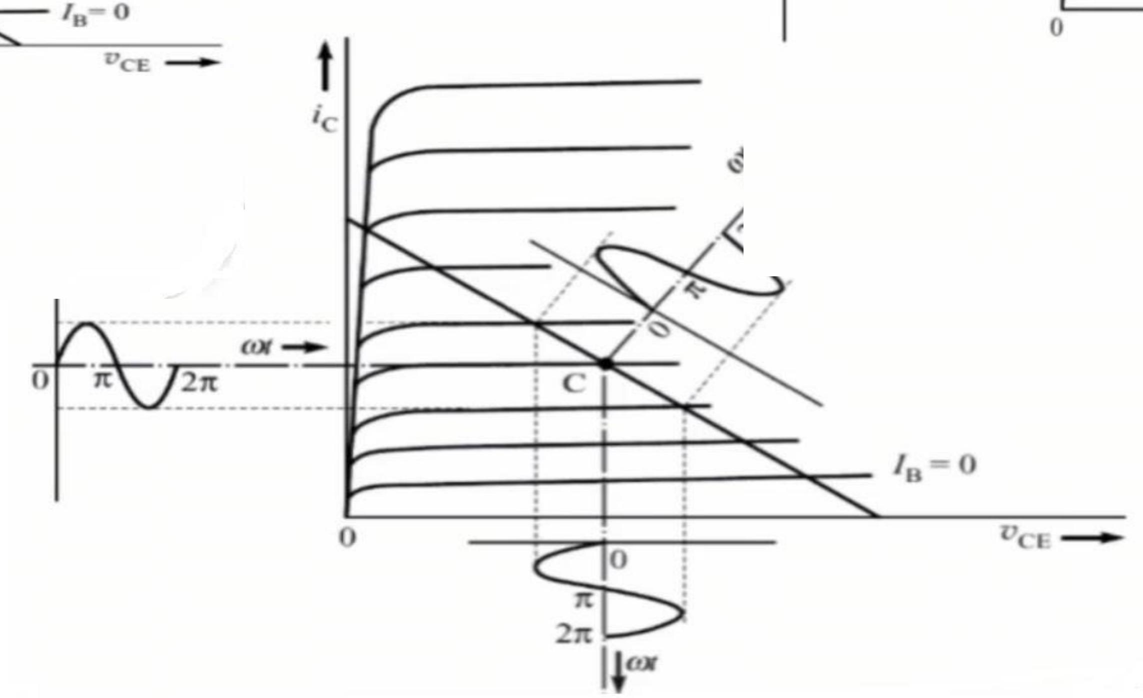


If the operating point is selected in the middle of active region, then there is no clipping and the output follows input faithfully




iC
ωt
2π
π
0
ωt
0
π
2π
A
IB = 0
0
vCE
0
Clipping
π
2π
ωt


iC
ωt
2π
π
0
ωt
0
π
2π
B
IB = 0
0
vCE
0
π
Clipping
2π
ωt


iC
π
0
ωt
0
π
2π
C
IB = 0
0
vCE
0
π
2π
ωt

Need For Bias Stabilization?

- Transistor parameters are temperature dependent
- Parameters like β for transistor changes from one unit to the other.
- The process of making operating point independent of temperature, parameter variations or transistor replacement is called **Bias Stabilization.**

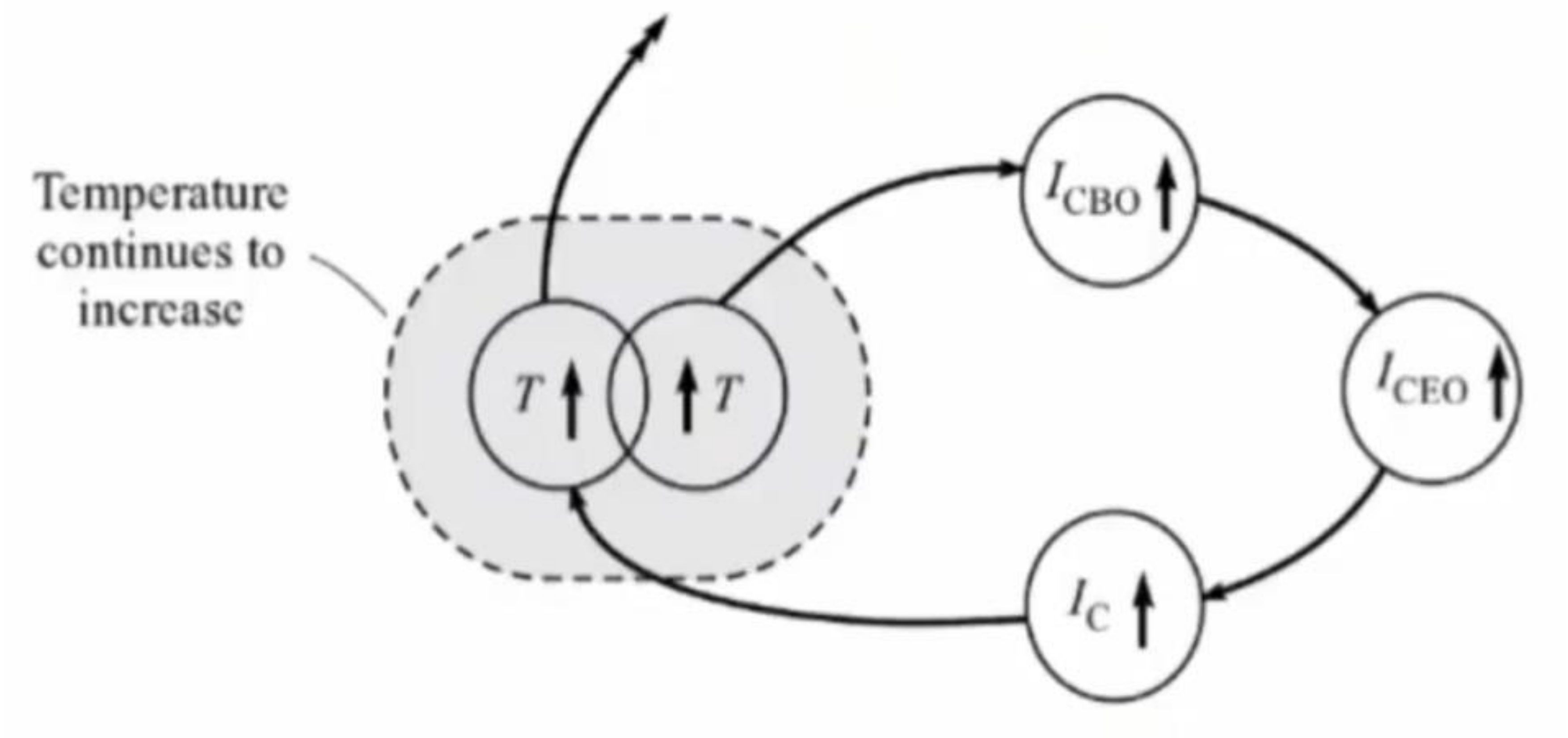
Need For Bias Stabilization?

Temperature Dependence of I_C

$$Ic = \beta I_B + I_{CEO} \qquad I_{CE0} = (1+\beta)I_{CBO}$$

- Reverse saturation current $\boldsymbol{I_{CBO}}$ doubles for every **10 degree** rise in temperature.
- So $\boldsymbol{I_{CE0}}$ increases $\boldsymbol{\beta + 1}$ times of $\boldsymbol{I_{CBO}}$.
- $\boldsymbol{I_C}$ dependent on $\boldsymbol{I_{CE0}}$, so $\boldsymbol{I_C}$ also increases $\boldsymbol{\beta + 1}$ times of $\boldsymbol{I_{CBO}}$.
- Power dissipation of transistor, $\boldsymbol{P = V_C I_C}$.
- So power dissipation at the junction Increases with collector current, which further increases temperature.
- The process repeats and excess heat may even burn or destroy transistor, and the situation is described as **Thermal Runaway.**

Need For Bias Stabilization?



Need For Bias Stabilization?

- $\boldsymbol{V_{BE}}$ is temperature dependent, $\boldsymbol{V_{BE}}$ changes at the rate of **2.5mV/degree.**
- So as $\boldsymbol{V_{BE}}$ varies, $\boldsymbol{I_B}$ varies, which increases I_C due to which Q-point shift will happen.
- From transistor to transistor the current amplification factor $\boldsymbol{\beta}$ and the Base emitter voltage $\boldsymbol{V_{BE}}$ varies.
- So if a transistor is replaced then the Collector current varies and Q-point shifts from initial position.

Requirements of Biasing Circuits

- Operating point is to be fixed in the middle of the Active region to protect the signal from distortion.
- Stabilize the collector current against the variations of temperature.
- Making the operating point independent of transistor parameters.