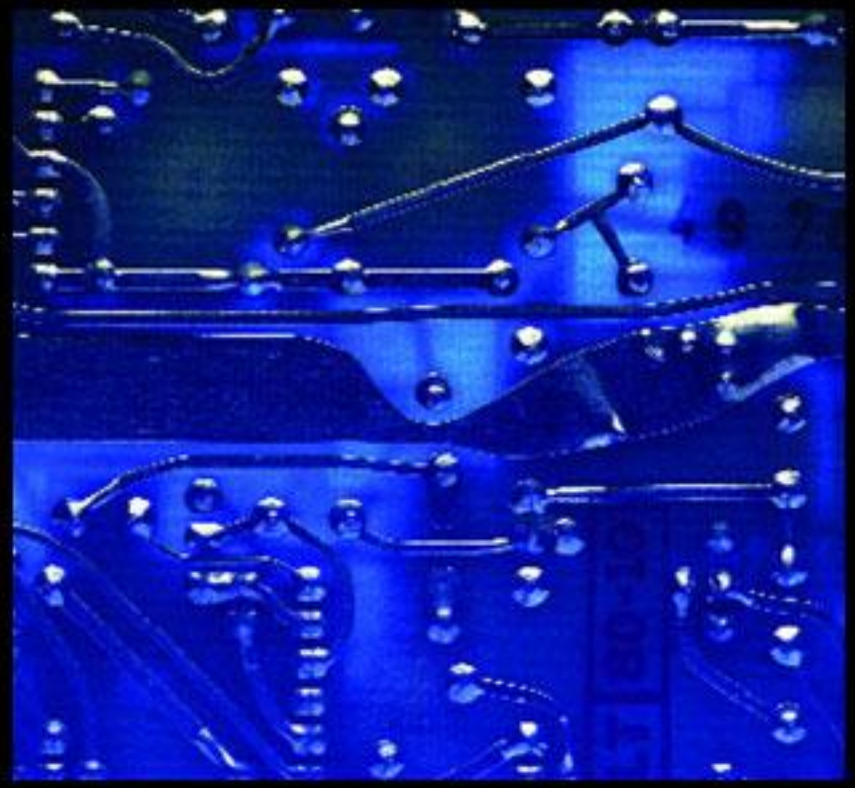
Electronic Devices and Circuit Theory

Tenth Edition



BOYLESTAD

PEARSON

Chapter 3:
Bipolar Junction Transistors

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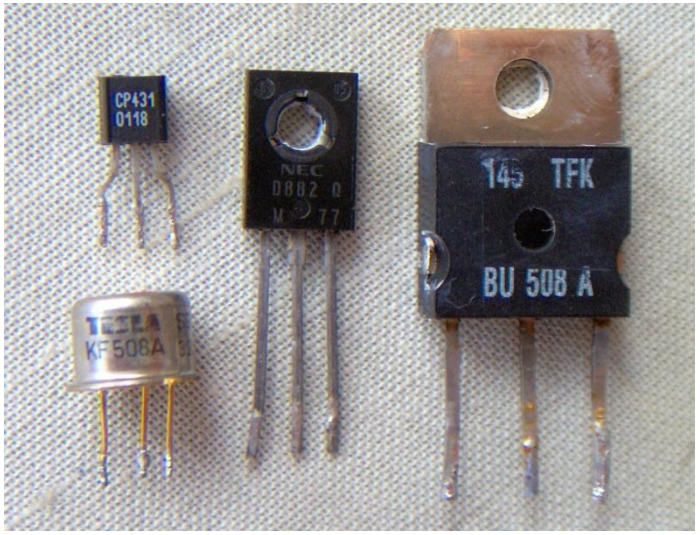
Transistor Construction

There are two types of transistors:

- ***pnp***
- ***npn***

The terminals are labeled:

- **E - Emitter**
- **B - Base**
- **C - Collector**



•The ***npn*** BJT consists of three semiconductor regions: the emitter region (*n type), the* base region (*p type), and the collector region (n type).*

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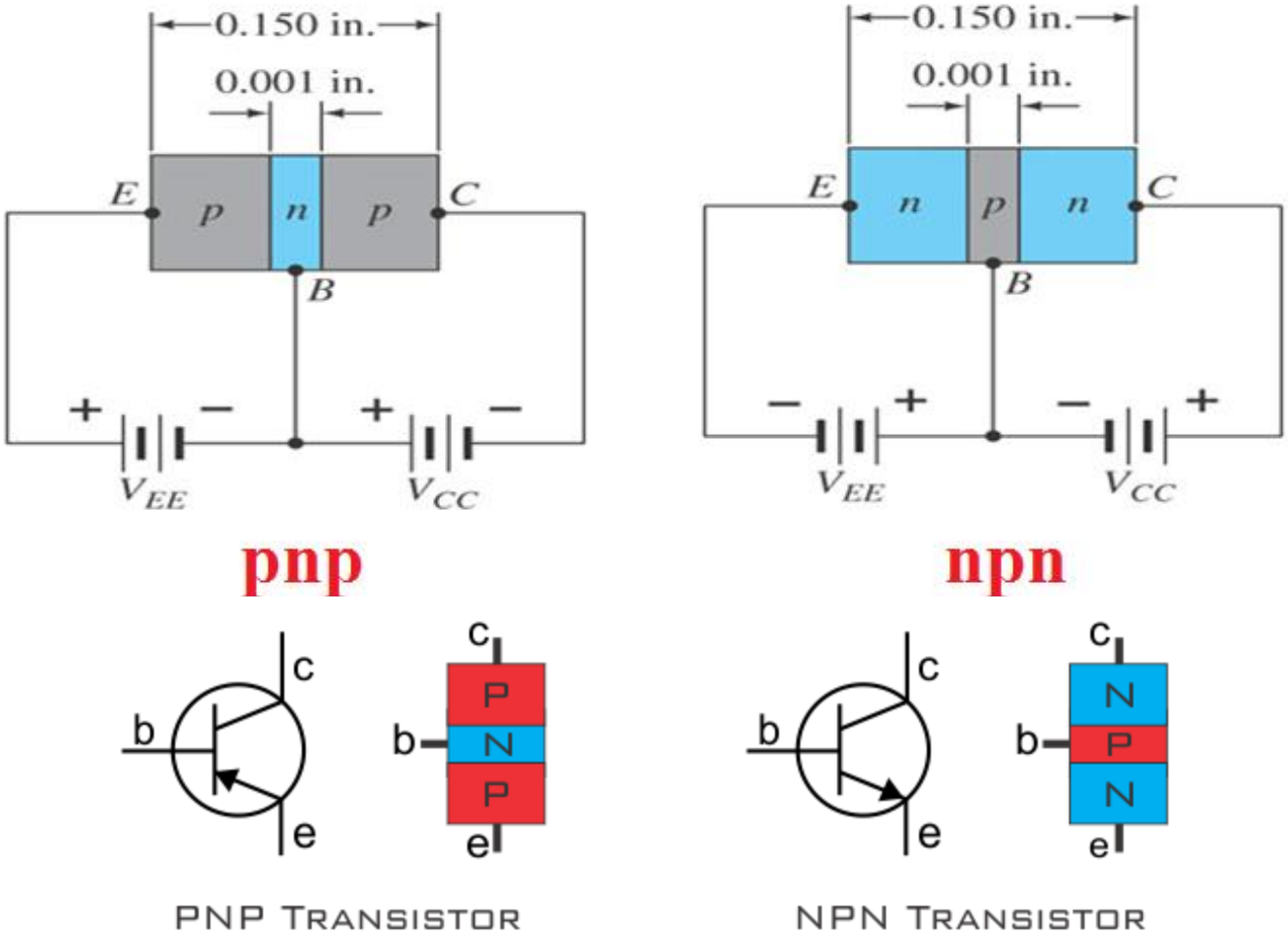
Transistor Construction



The transistor consists of two *pn junctions, the* **emitter–base junction (EBJ) and the collector–base junction (CBJ).**

Transistor Construction

- **Emitter**: The portion on one side of transistor that supplies charge carriers (i.e. electrons or holes) to the other two portions.
- The emitter is a heavily doped region.
- Emitter of PNP transistor supplies hole charges to its junction with the base. Similarly, the emitter of NPN transistor supplies free electrons to its junction with the base.

Transistor Construction

- **Collector** is the portion on the other side of the transistor (i.e. the side opposite to the emitter) that collects the charge carriers (i.e. electrons or holes).
- The doping level of the collector is in between the heavily doping of emitter and the light doping of the base.
- **Base:** The middle portion which forms two PN junctions between the emitter and the collector is called the base.
- The base of transistor is thin, as compared to the emitter and is a lightly doped portion.
- The function of base is to control the flow of charge carrier.

BJT Modes Of Operation

- There are two junctions in bipolar junction transistor.
- Each junction can be forward or reverse biased independently.
- Thus there are different modes of operations:

  Forward Active.

  Cut off.

  Saturation.

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

BJT Modes Of Operation

FORWARD ACTIVE

- Emitter-base junction is forward biased and collector-base junction is reverse biased.
- The BJT can be used as an amplifier and in analog circuits.

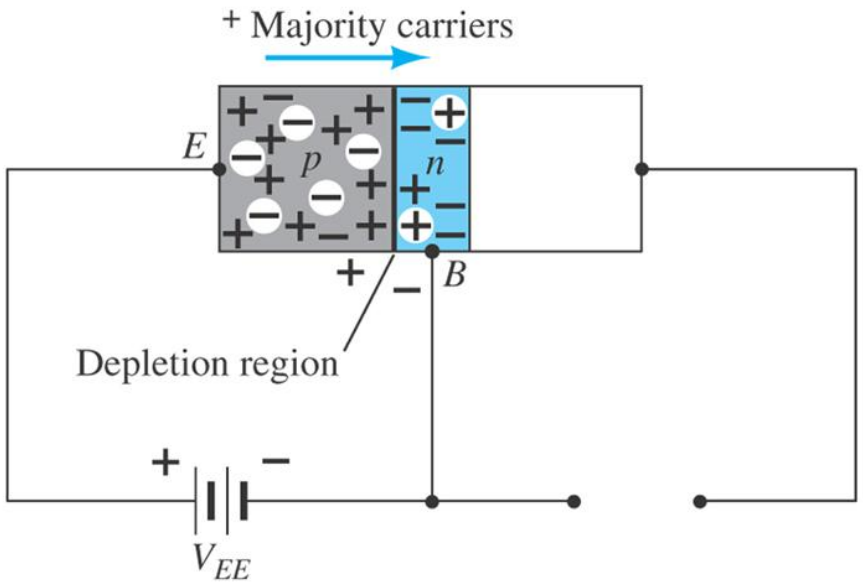
CUTT OFF

- When both junctions are reverse biased it is called cut off mode.
- In this situation there is nearly zero current and transistor behaves as an open switch.

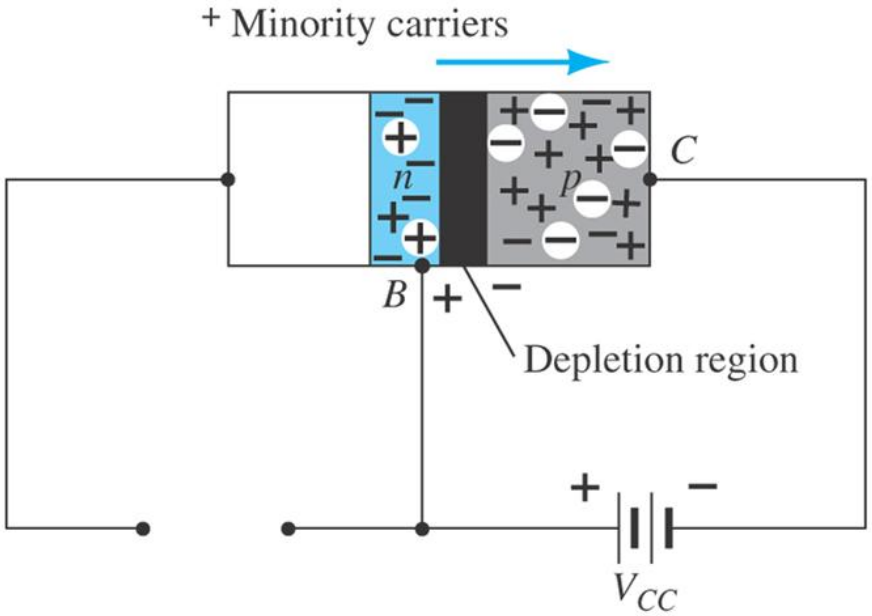
SATURATION

- In saturation mode both junctions are forward biased.
- Large collector current flows with a small voltage across collector base junction.
- Transistor behaves as an closed switch.

Operation of pnp transistor in active mode



Forward-biased junction of a pnp transistor.

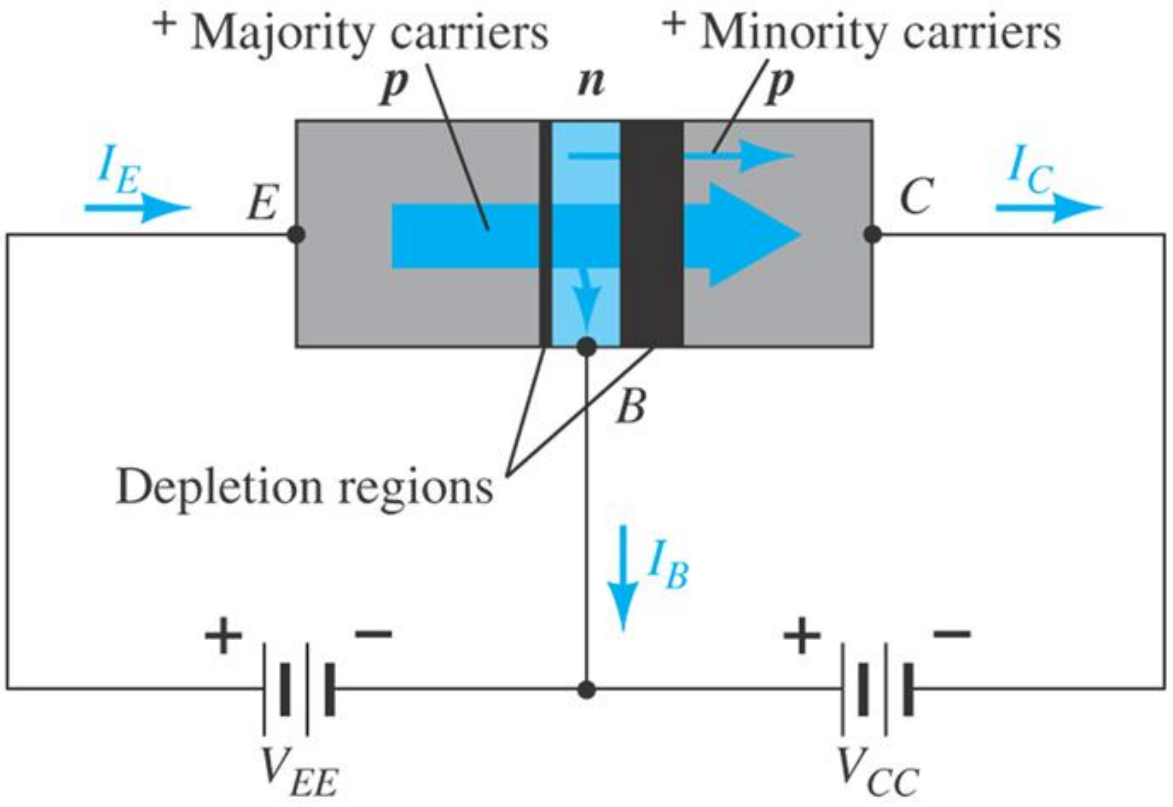


Reverse-biased junction of a pnp transistor

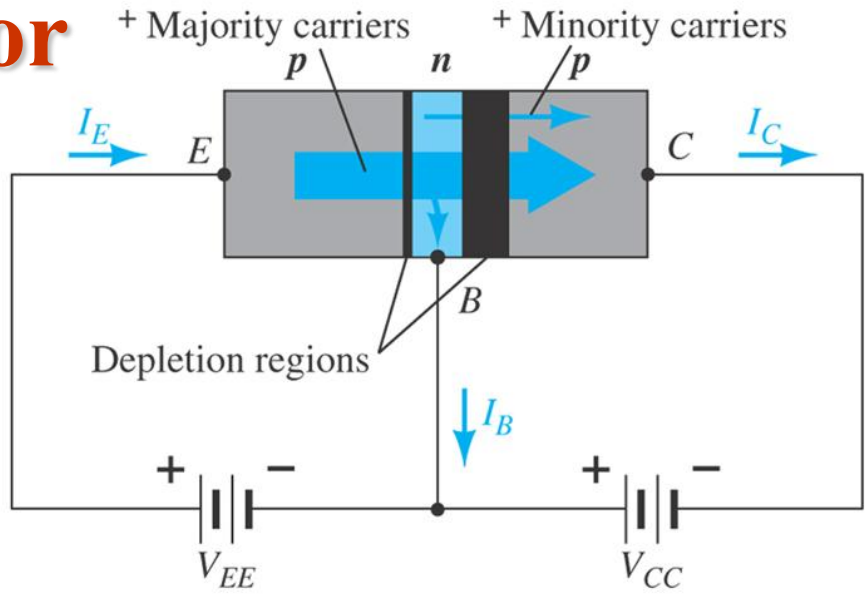
Operation of pnp transistor in active mode

With the external sources, V_{EE} and V_{CC}, connected as shown:

- **The emitter-base junction is forward biased**
- **The base-collector junction is reverse biased**



Currents in a Transistor



Emitter current is the sum of the collector and base currents:

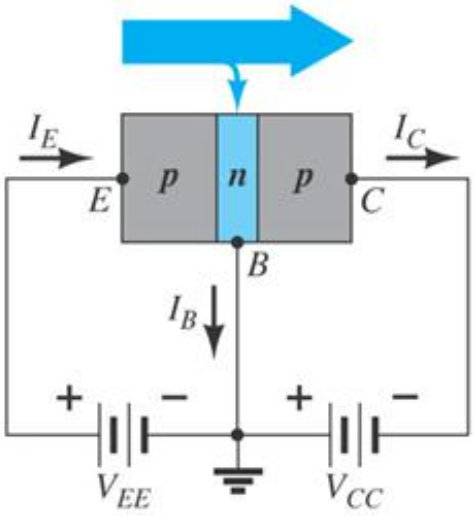
$$I_E = I_C + I_B$$

The collector current is comprised of two currents:

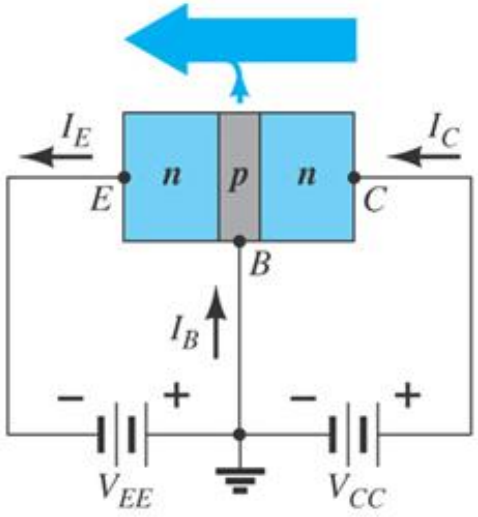
$$I_C = I_{C_{majority}} + I_{CO_{minority}}$$

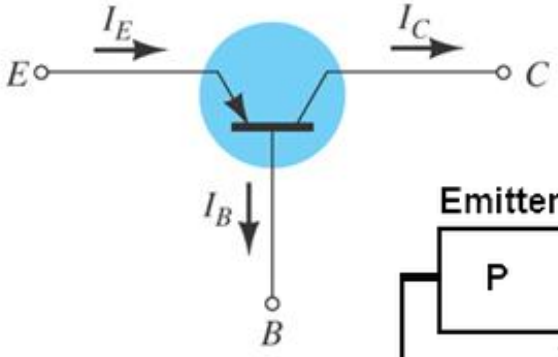
The minority current is called the leakage current and is given by the symbol I_{CO} (I_C current with emitter terminal *O*pen).

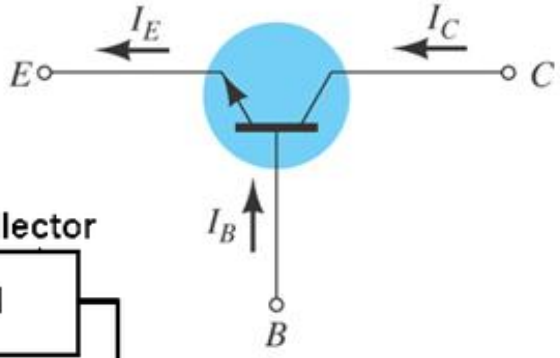
Common Base Configuration

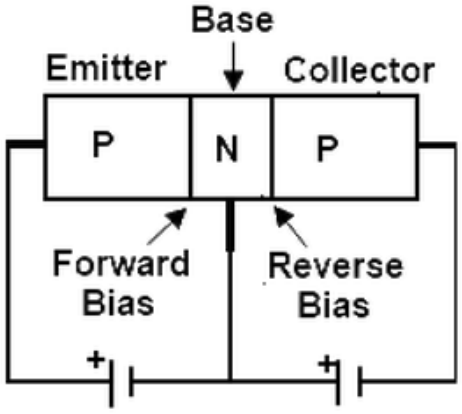


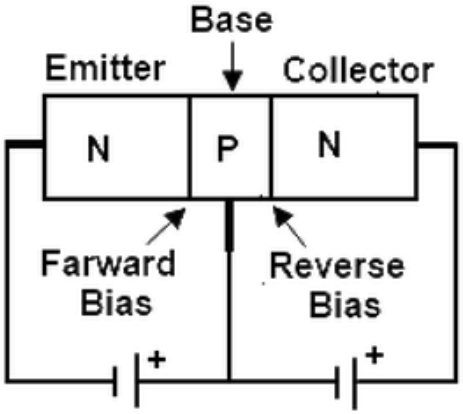
The base is common to both input (emitter–base) and output (collector–base) of the transistor.







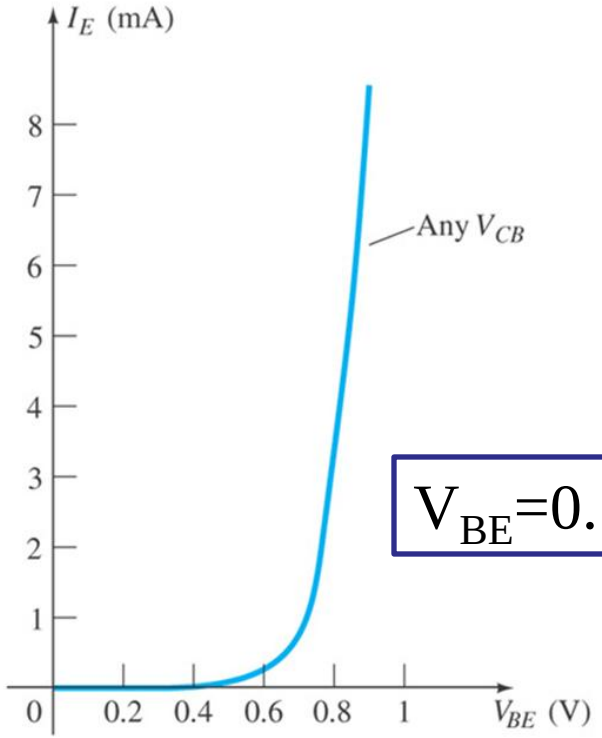




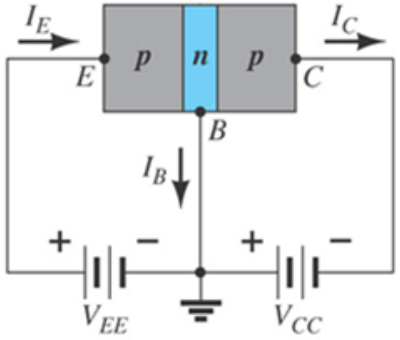
Common-Base Configuration

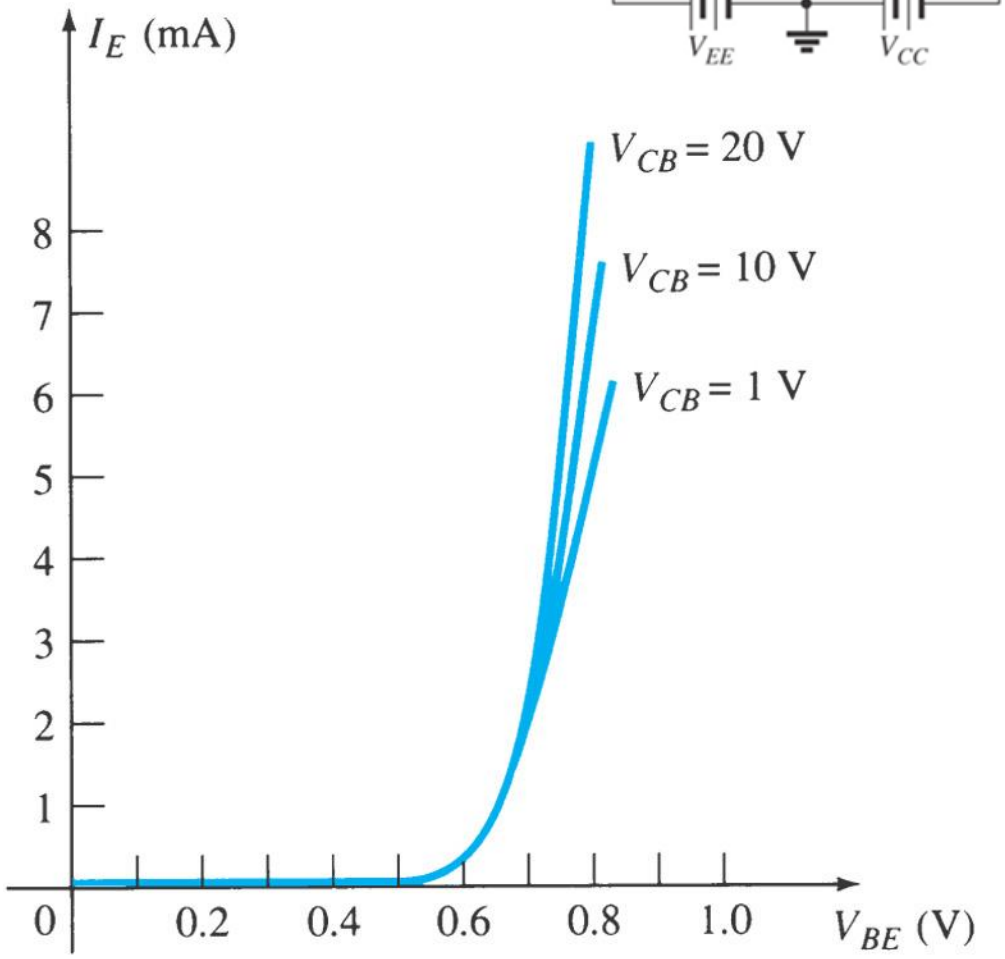
Input Characteristics

This curve shows the relationship between of input current (I_E) to input voltage (V_{BE}) for three output voltage (V_{CB}) levels.

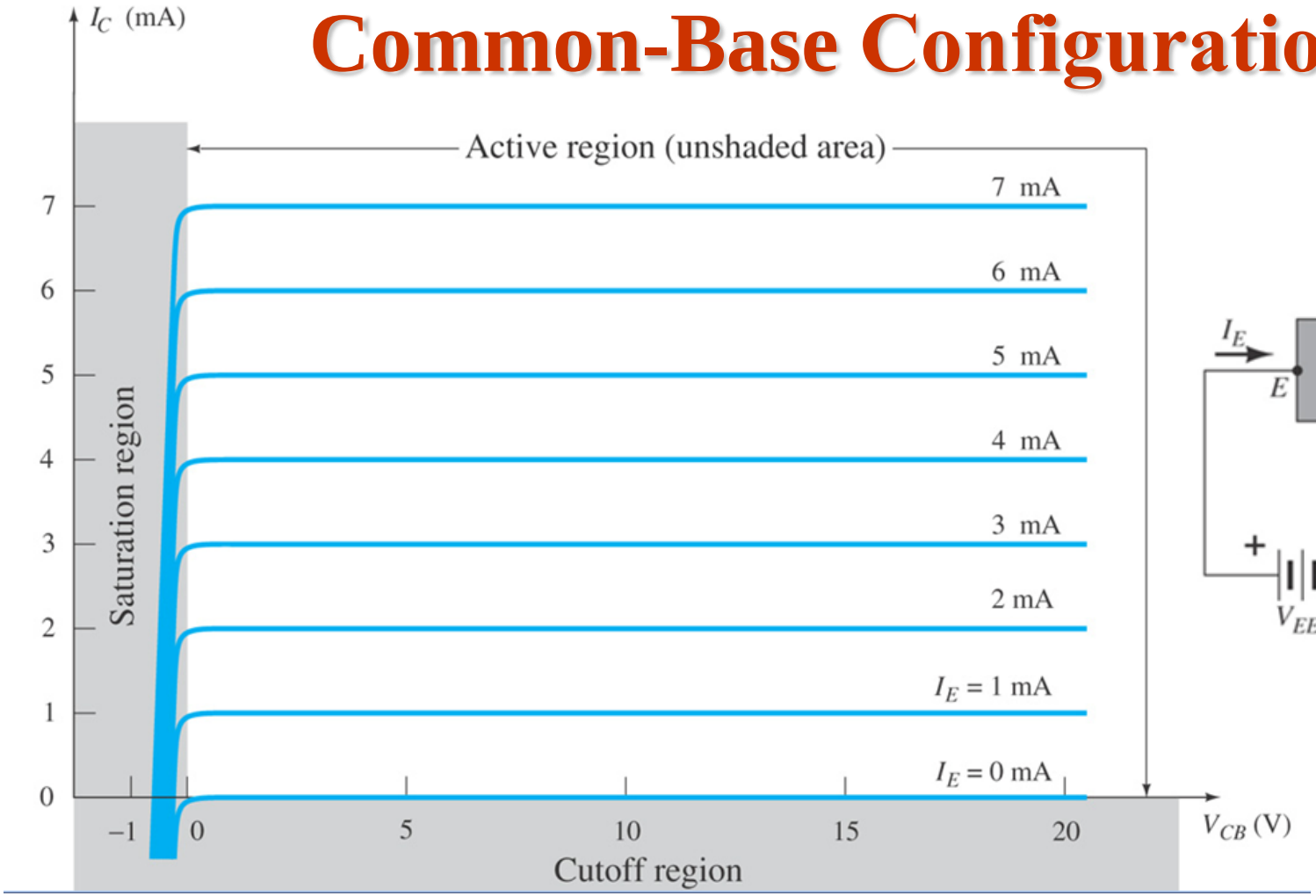


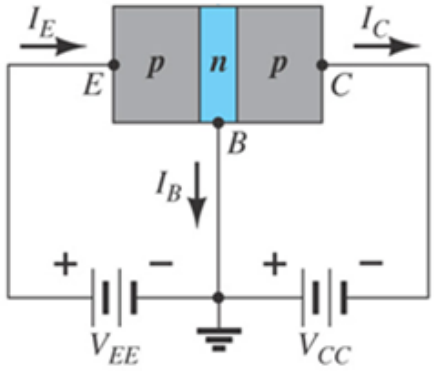
V_{BE}=0.7 V





Common-Base Configuration



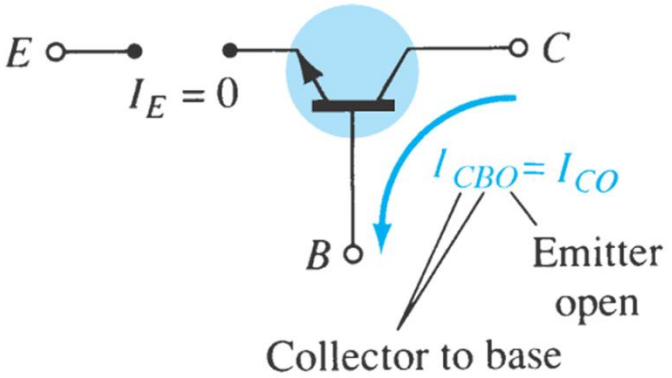


Output Characteristics

This graph demonstrates the output current (I_C) to an output voltage (V_{CB}) for various levels of input current (I_E).

Operating Regions

- **Active** – Operating range of the amplifier. It is noticed that I_E is approximately equal to I_C ($I_C \approx I_E$).
- **Cutoff** – the region where the collector current is approximately 0A ($I_C = I_{CBO}$). The amplifier is basically off. There is voltage, but little current.



- **Saturation** – Region to the left of $V_{CB}=0$. Note the exponential increase in collector current as the voltage V_{CB} increases toward 0 V. There is current but little voltage.

Approximations

Emitter and collector currents:

$$I_C \cong I_E$$

Base-emitter voltage:

$$V_{BE} = 0.7\,\text{V} \quad (\text{for Silicon})$$

Alpha (α)

Alpha (α) is the ratio of I_C to I_E:

$$\alpha_{dc} = \frac{I_C}{I_E}$$

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

Ideally: α = 1

In reality: α is between 0.9 and 0.998

Alpha (α) in the AC mode:

$$\alpha_{ac} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}=\text{constant}}$$