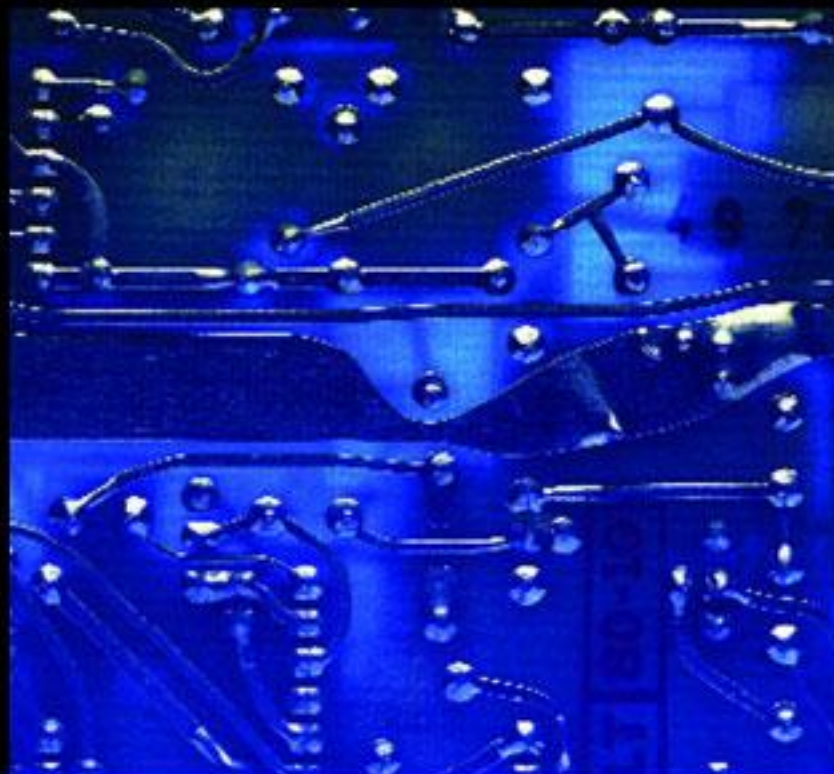
# ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION



BOYLESTAD

PEARSON

## Chapter 3:
## Bipolar Junction Transistors

Islamic University of Gaza

**Dr. Talal Skaik**

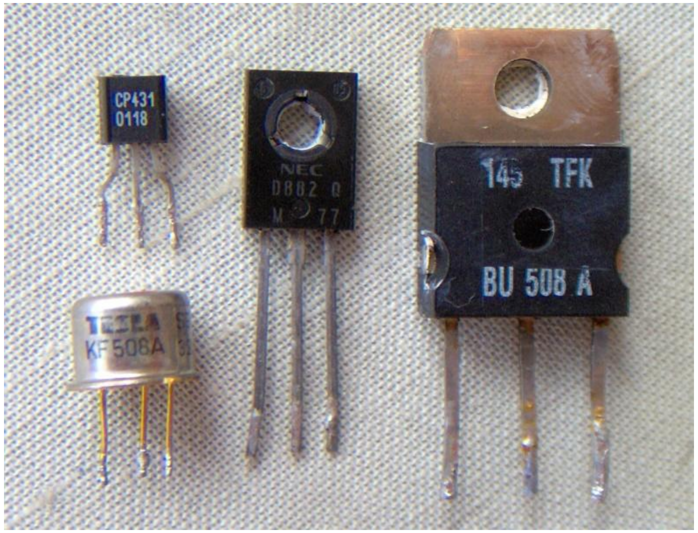
# Transistor Construction

**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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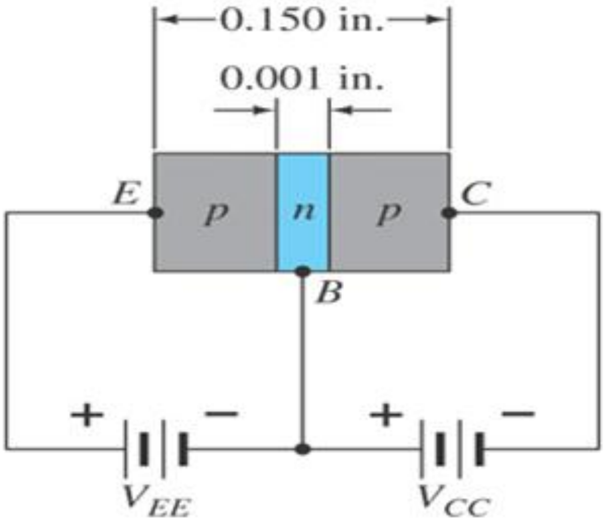
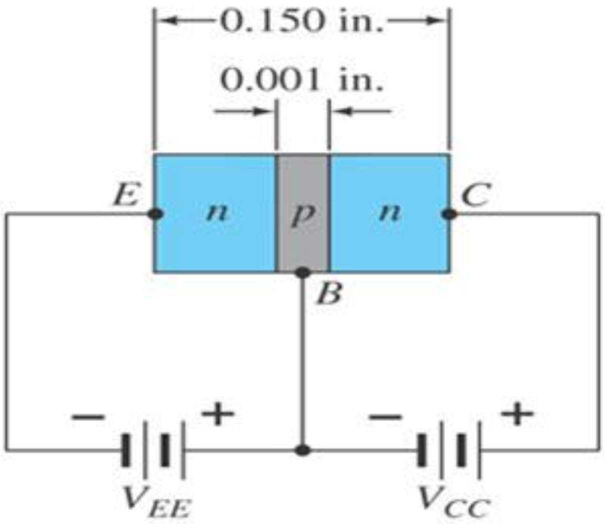
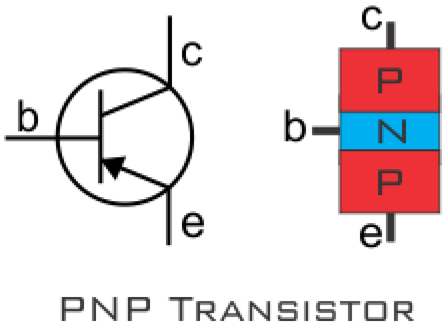
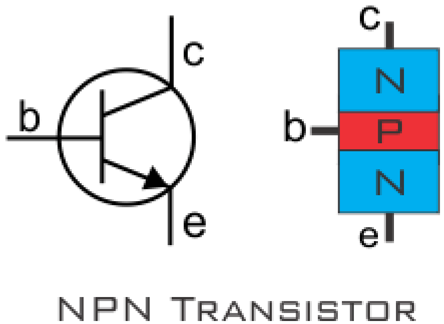
# Transistor Construction




**pnp** **npn**




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.

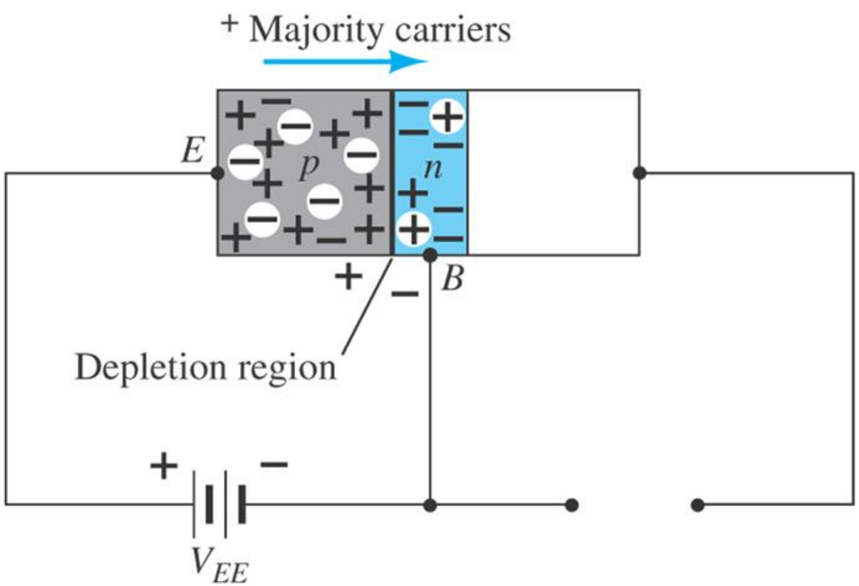
**CUTT OFF**

- 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.

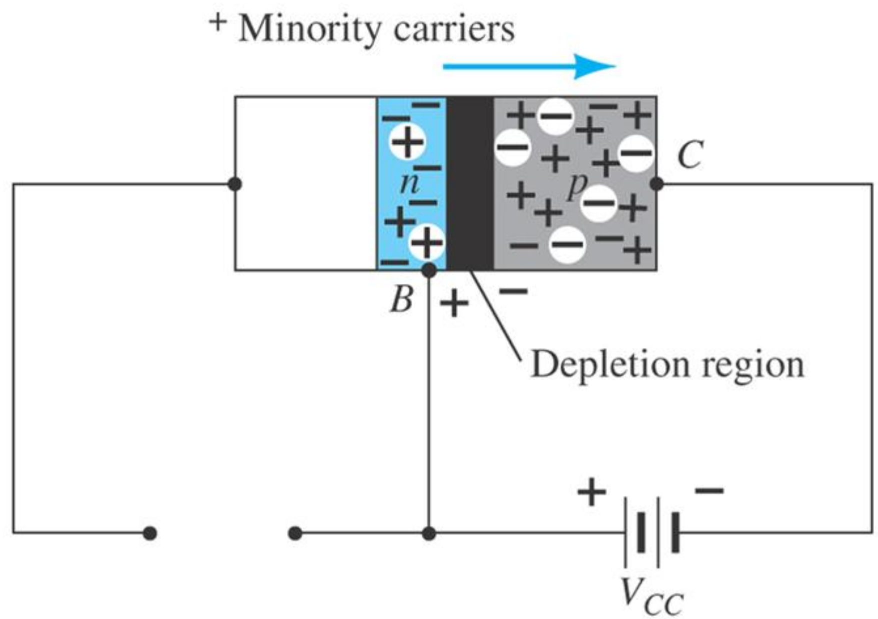
**SATURATION**

- 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.**

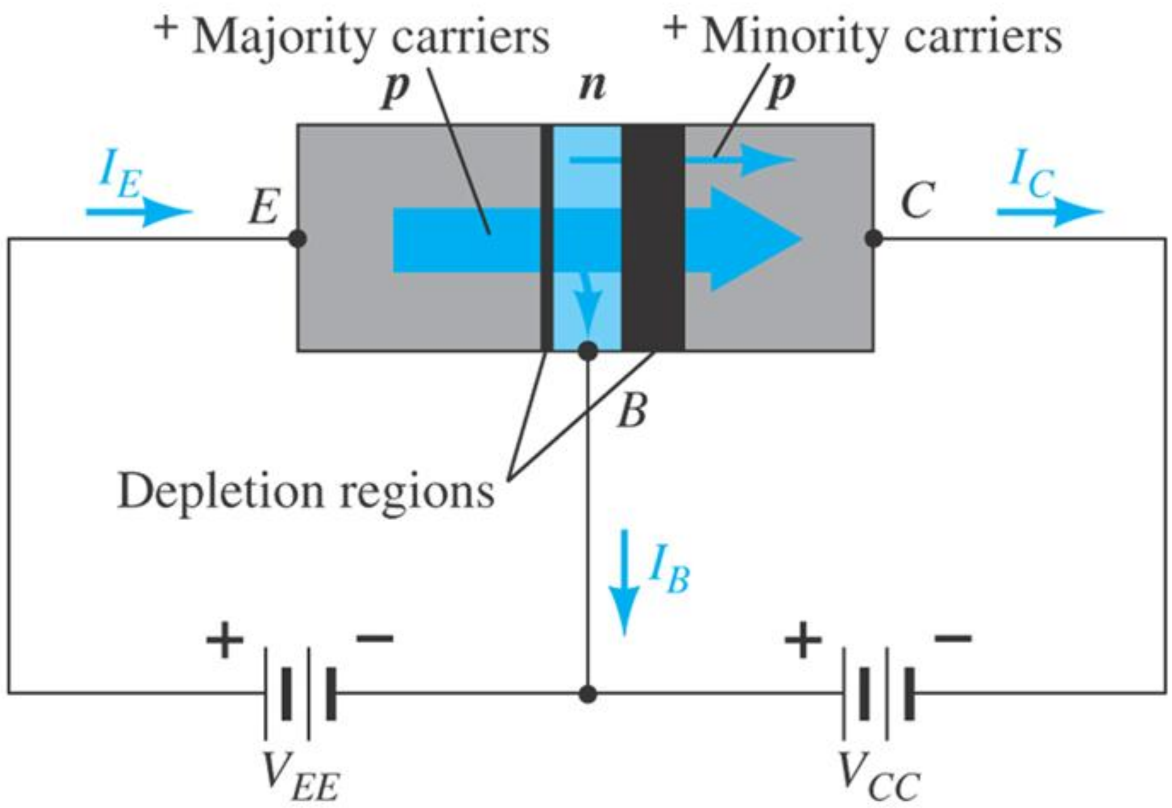



**Reverse-biased junction of a pnp transistor**

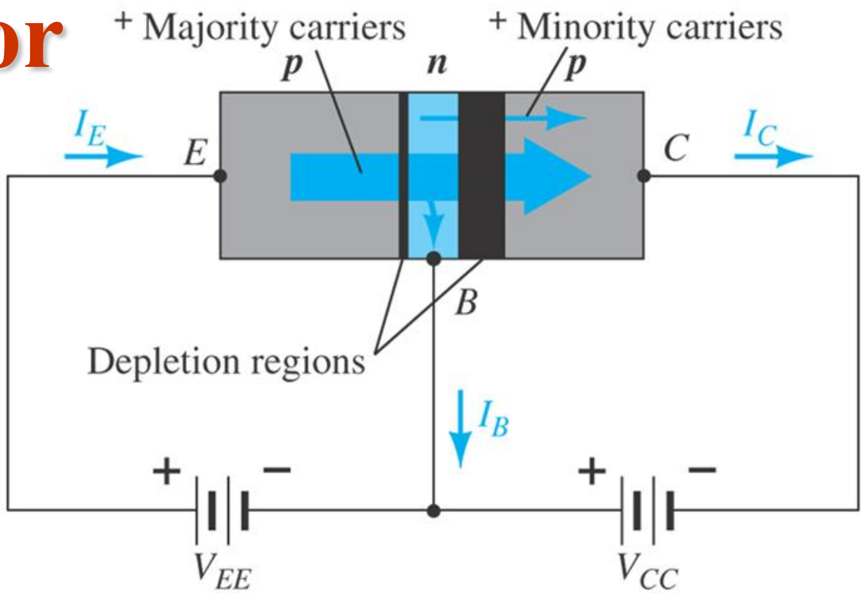
# Operation of pnp transistor in active mode

**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:

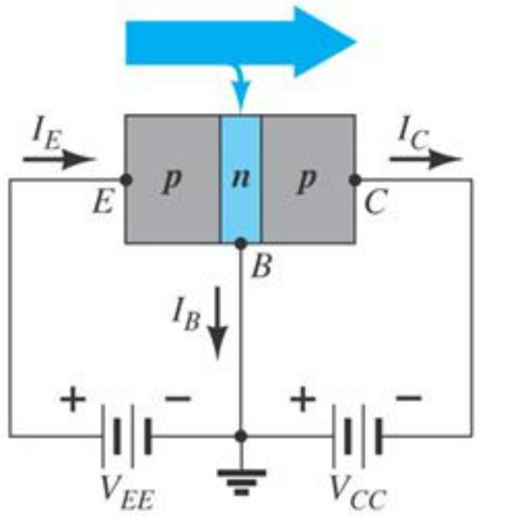
$$\mathbf{I_E = I_C + I_B}$$

The collector current is comprised of two currents:

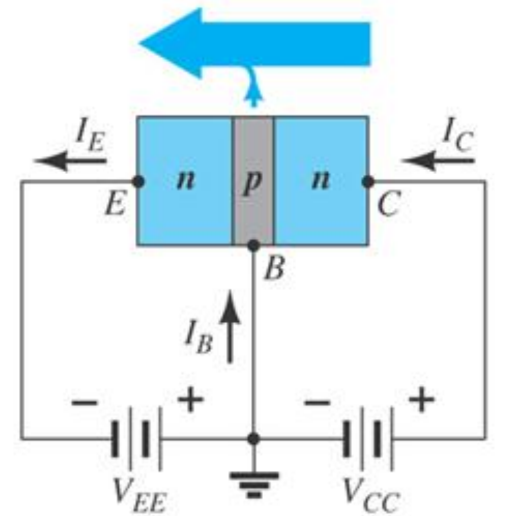
$$\mathbf{I_C = I_{C_{majority}} + I_{CO_{minority}}}$$

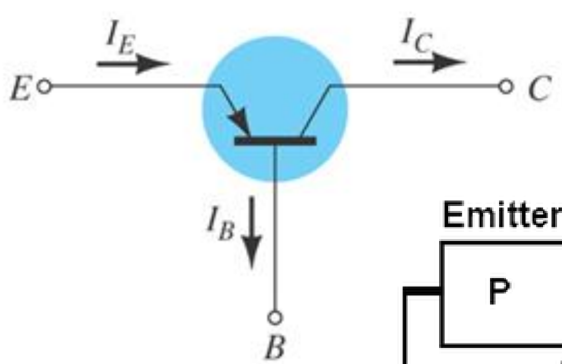
The minority current is called the leakage current and is given by the symbol $I_{CO}$ ($I_C$ current with emitter terminal ***O***pen).

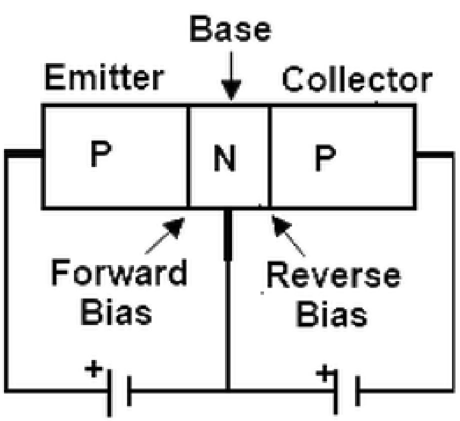
# Common Base Configuration

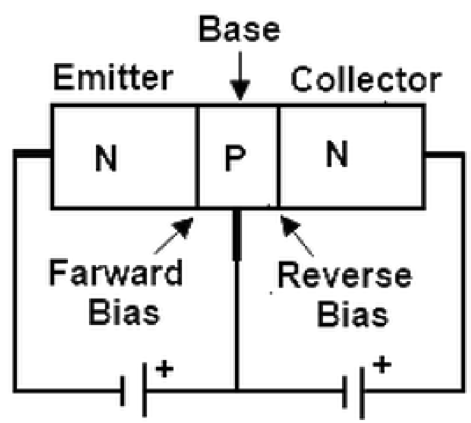


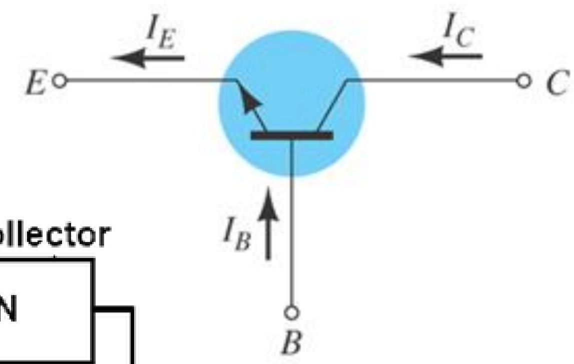

**The base is common to both input (emitter–base) and output (collector–base) of the transistor.**



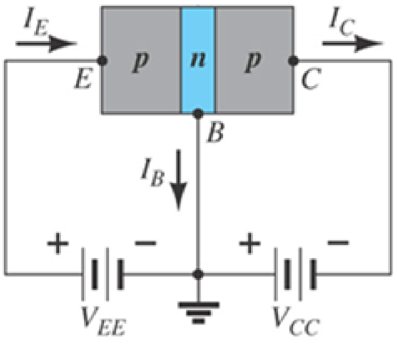



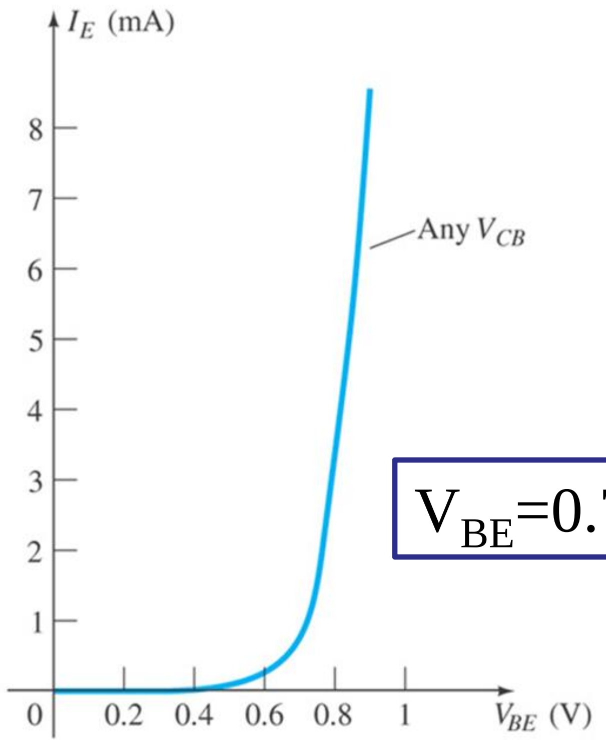



# Common-Base Configuration

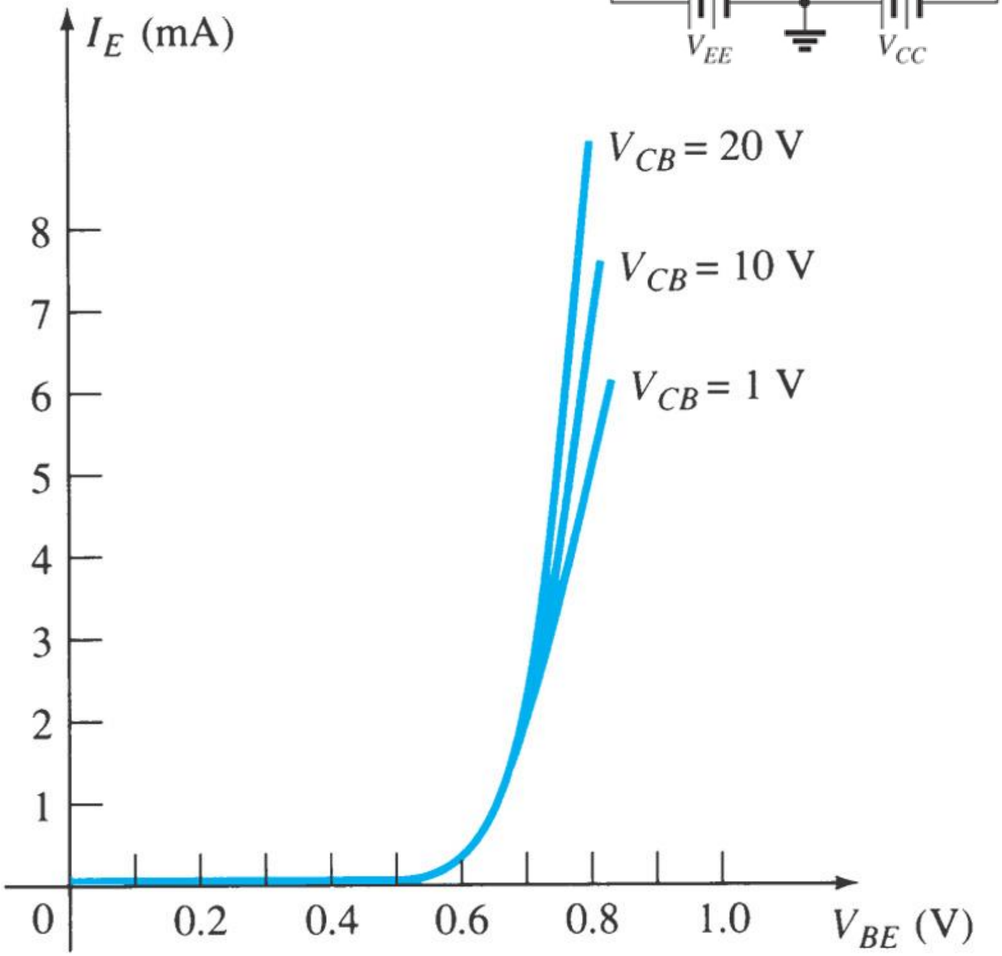



## Input Characteristics

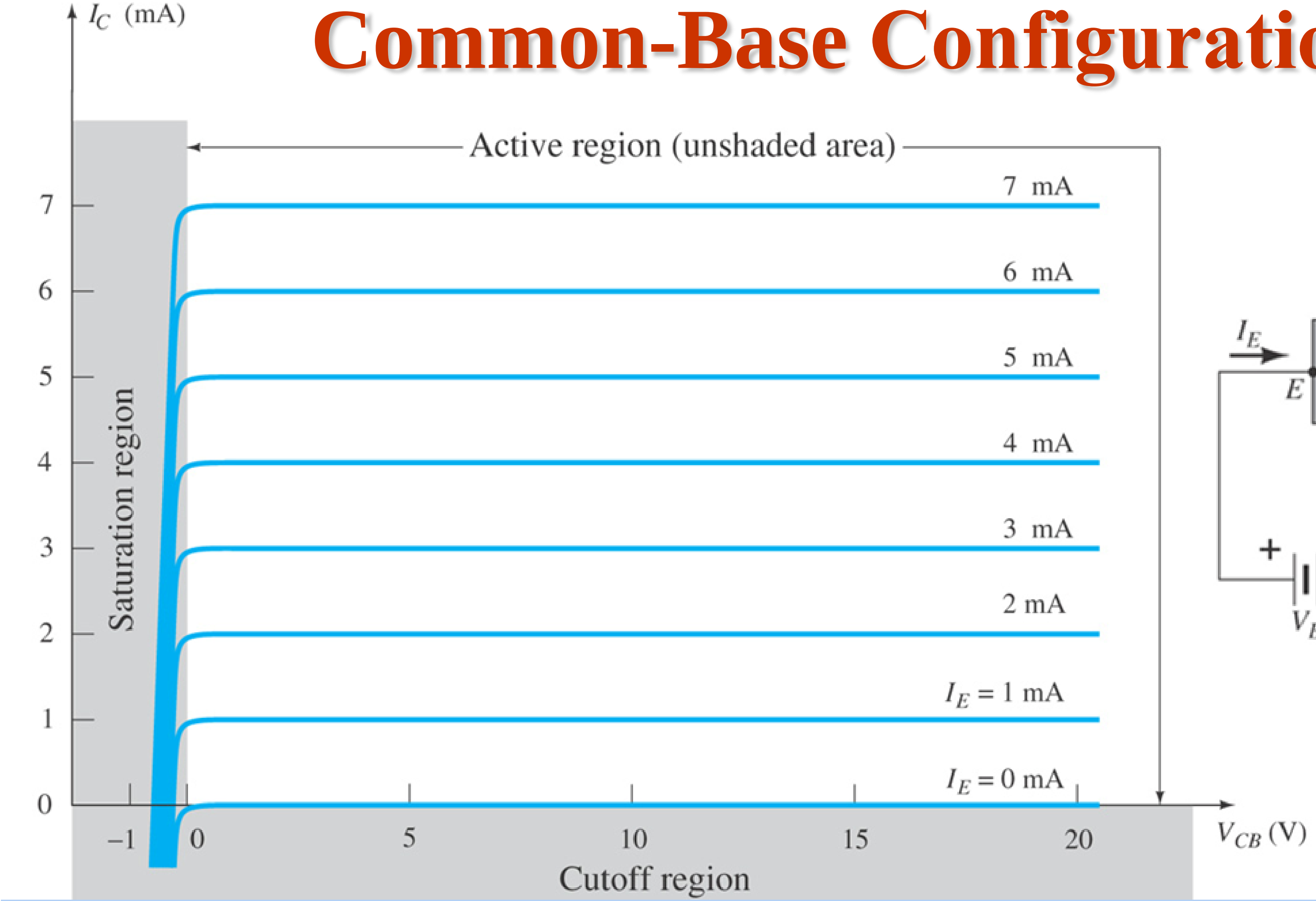
This curve shows the relationship between of input current ($I_E$) to input voltage ($V_{BE}$) for three output voltage ($V_{CB}$) levels.

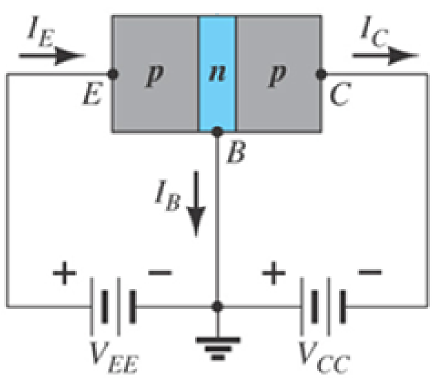



$V_{BE}$=0.7 V



# Common-Base Configuration



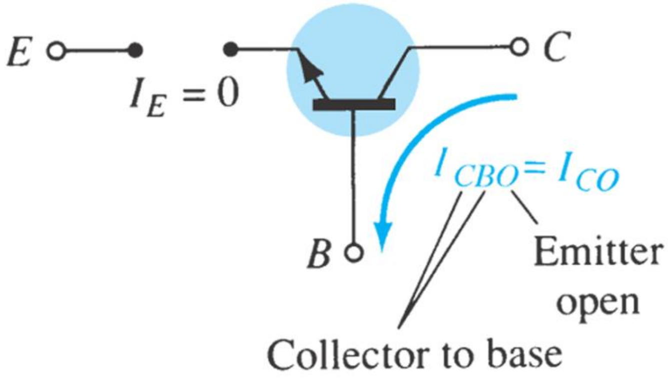




## Output Characteristics

**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:**

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

# Alpha (α)

**Alpha ($\alpha$) is the ratio of $I_C$ to $I_E$:**

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

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

**Ideally: α = 1**
**In reality: α is between 0.9 and 0.998**

**Alpha ($\alpha$) in the AC mode:**

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