Chapter 3: Bipolar Junction Transistors

Islamic University of Gaza

Dr. Talal Skaik
Transistor Construction

There are two types of transistors:

- **pnp**
- **nnp**

The terminals are labeled:

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

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

<table>
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<th>Mode</th>
<th>EBJ</th>
<th>CBJ</th>
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<td>Saturation</td>
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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

![Diagram of pnp transistor in active mode](image-url)
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:

\[ I_C = I_{C_{\text{majority}}} + I_{C_{\text{minority}}} \]

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

\[ V_{BE} = 0.7 \text{ V} \]
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:

\[ I_C \approx I_E \]

Base-emitter voltage:

\[ V_{BE} = 0.7 \text{ V (for Silicon)} \]
Alpha ($\alpha$)

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

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

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

Ideally: $\alpha = 1$
In reality: $\alpha$ is between 0.9 and 0.998

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

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