Transistor and their Characteristics – Lesson-1 Junction Transistor
1. Junction Transistor

Definition

The \textit{transferred-resistance or transistor} is a multi-junction device that is capable of

- Current gain
- Voltage gain
- Signal-power gain
Bipolar junction transistor

- Invented in 1948 by Bardeen, Brattain and Shockley

- Contains three adjoining, alternately doped semiconductor regions: Emitter (E), Base (B), and Collector (C)

- The middle region, base, is very thin compared to the diffusion length of minority carriers

- Two kinds: npn and pnp
Bipolar junction transistor – BJT

Definition

The Bipolar junction transistor is an active device that works as a voltage-controlled current source and whose basic action is control of current at one terminal by controlling voltage applied at other two terminals.
Bipolar Junction Transistor Representation

NPN

PNP
2. **Transistor Current Components**
As shown, the currents are positive quantities when the transistor is operated in forward active mode.

\[ I_E = I_B + I_C \quad \text{and} \quad V_{EB} + V_{BC} + V_{CE} = 0 \quad V_{CE} = -V_{EC} \]
Meaning of Forward biasing

- When the p side is applied +ve and n side negative in a junction and applied voltage is greater than a threshold 0.65 V for Silicon (Si)
Meaning of Reverse biasing

- When the p side is applied -ve and n side +ve in a junction and applied voltage is between 0 to a breakdown voltage
3. Transistor as Amplifier
Three configurations

BJT Common Base configuration

PJNP

(a) Common base

(b) Common emitter

(c) Common collector
Six Problems

- Draw circuits of CB, CE, CC configurations for npn and pnp transistors
- Show current directions
nnp transistor in a simple circuit, known as ‘common-emitter’ amplifier
Characteristics of Transistor Amplifier in three regions of operations
Input or driving Point Characteristics of Common Base transistor Amplifier

Saturation region
(a) Common base

Active region

Saturation region
(b) Common emitter

Input or driving Point Characteristics of Common Emitter transistor Amplifier
Output Collector Characteristics of Common Base transistor Amplifier

Active region

Saturation region

Cut-off region

Output Collector Characteristics of Common Emitter transistor Amplifier

Active region

Saturation region

Cut-off region
First Approximation Relationship between $I_C$ and $I_E$

- $I_C \approx I_E$

BJT Common Base configuration
The collector current is being controlled by the B-E voltage, or the current in the one part of the device is being controlled by the voltage in another part - transistor action

Since the B-E junction is forward biased, holes from the base are injected into the emitter. However, these injected holes do not contribute to the collector current and are therefore not part of the transistor action.

To design a useful device, we need mathematical expressions for the minority carrier concentrations shown in the figure above.

There are three modes of operation we must consider:

- **Forward-active (B-E FB, B-C RB)**
- **Cut-off (B-E RB, B-C RB)**
- **Saturation (B-E FB, B-C FB)**
### BJT biasing modes

![Diagram showing BJT biasing modes with V_{EB} (pnp) and V_{BE} (nnp) axes.]

<table>
<thead>
<tr>
<th>Biasing Mode</th>
<th>Biasing Polarity E–B Junction</th>
<th>Biasing Polarity C–B Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturation</td>
<td>Forward</td>
<td>Forward</td>
</tr>
<tr>
<td>Active</td>
<td><strong>Forward</strong></td>
<td><strong>Reverse</strong></td>
</tr>
<tr>
<td>Inverted</td>
<td>Reverse</td>
<td>Forward</td>
</tr>
<tr>
<td>Cutoff</td>
<td>Reverse</td>
<td>Reverse</td>
</tr>
</tbody>
</table>
Cut-off defined as region of characteristics $I_C = 0$

- In the cut-off region, the base emitter and collector base junctions of transistor are reverse biased $I_C \approx I_E \approx 0$
Saturation- region – defined as region of characteristics left of \( V_{CB} = 0 \) and \( I_C \) increase exponentially with \( V_{CB} \) increases toward 0

- In the saturation region, the base emitter and collector base junctions of transistor are forward biased
Active - region – defined as region of characteristics right of $V_{CB} = 0$ and $I_C$ first increases exponentially with $V_{CB}$ increases toward 0.7 V in Si transistor and then becomes constant

- In the active region region, the base emitter and collector base junctions of transistor are forward and reversed biased respectively $I_C \approx I_E \neq 0$ and is in mA $I_C$
Operation in the *forward-active* mode

B-E junction is forward biased so electrons can be injected from the emitter to the base, B-C junction is reverse biased.
4. Transistor Construction
BJT structure - three regions, two p-n junctions, three terminals (emitter, base, collector)
Construction

- Devices can be p-n-p, or n-p-n structures
- Width of the base is small compared to the minority carrier length and is about 1/150 of total width, number of free carriers are small as doping level is 1/10th or less compared to collector)
- Emitter is normally heavily doped, the collector has light doping
Summary

We learnt

- (i) pnp transistor
- (ii) npn transistor
- (iii) Current Components
- (iv) Three configurations - Common base, common emitter and Common collector
We learnt

- (v) Three regions - cut-off, saturation and active
- (vi) Transistor construction
End of Lesson 1