**Transistor**

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage.

The Bipolar Transistor basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. Three terminals of the transistor are emitter(E), base(B), and collector(C).

**Common Emitter Configuration**

The input signal is applied between the base and emitter, while the output is taken from the emitter load as shown. This type of configuration is commonly known as a Voltage Amplifier or Emitter Follower circuit. The emitter follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance.

**Transistor Function**

The transistor’s have two basic functions: “switching” (digital electronics) or “amplification” (analog electronics).

**Transistor Configuration**

- **Common base configuration**: No current gain but voltage gain
- **Common Emitter Configuration**: Current gain and Voltage gain
- **Common Collector Configuration**: Current gain but no voltage gain

**Common Base Configuration**

The base connection is common to both the input signal and the output signal with the input signal being applied between the base and the emitter terminals. The corresponding output signal is taken from between the base and the collector terminals as shown with the base terminal grounded.

**Common Emitter Configuration**

In the Common Emitter configuration, the input signal is applied between the base and emitter, while the output is taken from between the collector and the emitter as shown.

**Common Collector Configuration**

In the Common Collector or grounded collector configuration, the collector is now common through the supply. The input signal is connected directly to the base, while the output is taken from the emitter load as shown. This type of configuration is commonly known as a Voltage Amplifier or Emitter Follower circuit. The emitter follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance.

**Common Emitter Characteristics**

- **Input Characteristics**: It is the curve between base current $I_b$ and base-emitter voltage at constant collector-emitter voltage.
- **Output Characteristics**: It is the curve between collector current $I_c$ and collector-emitter voltage at constant base current $I_b$. 
Transistor Characteristics Regions

Bipolar Transistor has mainly three reasons.

1. **Active Region** - the transistor operates as an amplifier.
2. **Saturation** - the transistor is "fully-ON" operating as a switch.
3. **Cut-off** - the transistor is "fully-OFF" operating as a switch.

Relations of Current amplification factor

The ratio of change in collector current to the change in emitter current at constant collector-base voltage is known as current amplification factor.

\[ \alpha = \frac{I_C}{I_E} \]

The ratio of change in collector current to the change in base current is known as base current amplification factor.

\[ \beta = \frac{I_C}{I_B} \]

\[ I_C = \alpha I_E = \beta I_B \]

\[ I_E = I_C + I_B \]

\[ \alpha = \frac{\beta}{\beta + 1} \]

How Transistor acts as an Amplifier?

A transistor BE junction has a low resistance due to forward bias and the BC junction has a high resistance due to reverse bias. A transistor amplifies current because the collector current is equal to the base current multiplied by the current gain.

Let us consider the following circuit

An ac voltage, \( V_{in} \), is superimposed on the dc bias voltage \( V_{BB} \). DC bias voltage \( V_{CC} \) is connected to the collector through the collector resistance, \( R_C \).

The ac input voltage produces an ac base current, which results in a much larger ac collector current. The ac collector current produces an ac voltage across \( R_C \), thus producing an amplified, but inverted, reproduction of the ac input voltage in the active region.

Field Effect Transistor

JFET Operation

With no external Gate voltage ( \( V_G = 0 \) ), and a small voltage ( \( V_{DS} \) ) applied between the Drain and the Source, maximum saturation current ( \( I_{DSS} \) ) will flow through the channel from the Drain to the Source restricted only by the small depletion region around the junctions.

If a small negative voltage ( \( V_{GS} \) ) is now applied to the Gate the size of the depletion layer begins to increase reducing the overall effective area of the channel and thus reducing the current flowing through it, a sort of "squeezing" effect takes place. So by applying a reverse bias voltage increases the width of the depletion region which in turn reduces the conduction of the channel.

Since the PN-junction is reverse biased, little current will flow into the gate connection. As the Gate voltage ( \( V_{GS} \) ) is made more negative, the width of the channel decreases until no more current flows between the Drain and the Source and the FET is said to be "pinched-off" (similar to the cut-off region for a BJT).

JFET Characteristics

**Ohmic Region** - When \( V_{GS} = 0 \) the depletion layer of the channel is very small and the JFET acts like a voltage controlled resistor.

**Cut-off Region** - This is also known as the pinch-off region were the Gate voltage, \( V_{GS} \) is sufficient to cause the JFET to act as an open circuit as the channel resistance is at maximum.

**Saturation or Active Region** - The JFET becomes a good conductor and is controlled by the Gate-Source voltage, \( V_{GS} \) while the Drain-Source voltage, \( V_{DS} \) has little or no effect.

**Breakdown Region** - The voltage between the Drain and the Source, \( V_{DS} \) is high enough to cause the JFET's resistive channel to break down and pass uncontrolled maximum current.
**FET Parameters**

**DC Drain Resistance** is the static or ohmic resistance of the channel and is given by \( R_{DS} = \frac{V_{DS}}{I_D} \).

**AC Drain Resistance** is the ratio of change in drain source voltage (\( \Delta V_{DS} \)) and change in drain current (\( \Delta I_D \)) at constant gate-source voltage \( V_{GS} \). It is also called the dynamic resistance and denoted as \( r_d \).

**Transconductance** \( g_m \) is the ratio of change in drain current (\( \Delta I_D \)) to the change in gate-source voltage (\( \Delta V_{GS} \)) at constant \( V_DS \).

**Amplification Factor** is defined as the ratio of change in \( V_{DS} \) to the change in \( V_{GS} \) at constant drain current and is denoted by \( \mu \).

---

**Comparison between BJT and FET**

<table>
<thead>
<tr>
<th>Field Effect Transistor (FET)</th>
<th>Bipolar Junction Transistor (BJT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low voltage gain</td>
<td>High voltage gain</td>
</tr>
<tr>
<td>2 High current gain</td>
<td>Low current gain</td>
</tr>
<tr>
<td>3 Very input impedance</td>
<td>Low input impedance</td>
</tr>
<tr>
<td>4 High output impedance</td>
<td>Low output impedance</td>
</tr>
<tr>
<td>5 Low noise generation</td>
<td>Medium noise generation</td>
</tr>
<tr>
<td>6 Fast switching time</td>
<td>Medium switching time</td>
</tr>
<tr>
<td>7 Easily damaged by static</td>
<td>Robust</td>
</tr>
<tr>
<td>8 Some require an input to</td>
<td>Requires zero input to turn it &quot;OFF&quot;</td>
</tr>
<tr>
<td>turn it &quot;OFF&quot;</td>
<td>Current controlled device</td>
</tr>
<tr>
<td>9 Voltage controlled device</td>
<td></td>
</tr>
<tr>
<td>10 Exhibits the properties of</td>
<td>11 More expensive than bipolar</td>
</tr>
<tr>
<td>a Resistor</td>
<td>Cheap</td>
</tr>
<tr>
<td>12 Difficult to bias</td>
<td>Easy to bias</td>
</tr>
</tbody>
</table>

---

**Classification of FET**