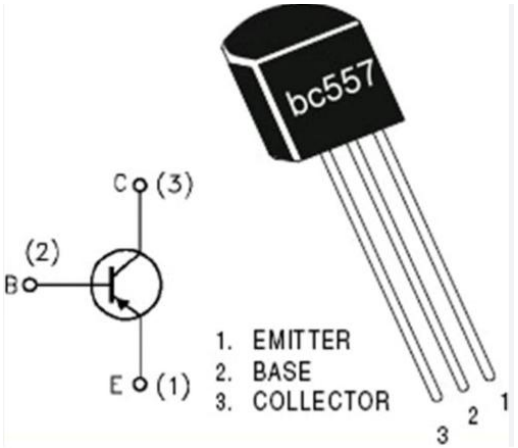
Transistor

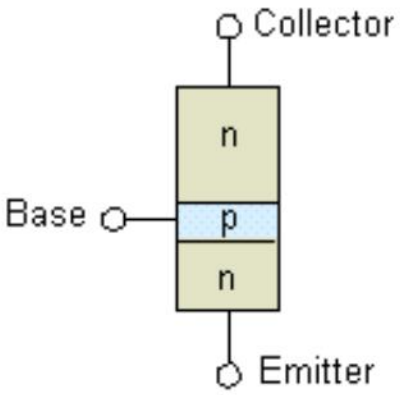
A **transistor** controls the flow of electrical current.
It has **three terminals**:

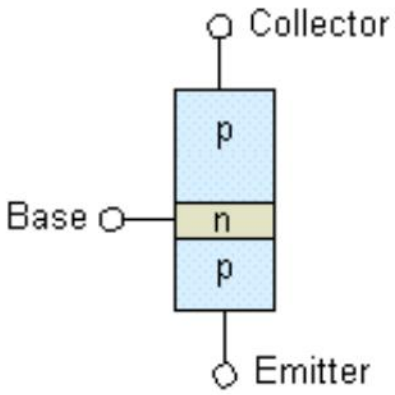
- **Base (B)** – input control terminal
- **Collector (C)** – where current enters
- **Emitter (E)** – where current leaves

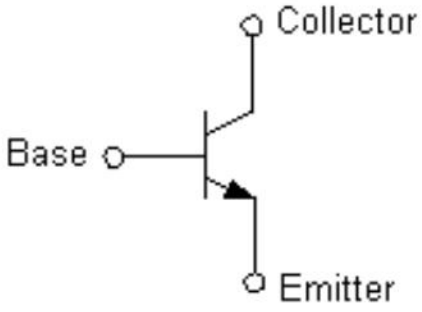
There are two main types:

- **NPN transistor** (most common)
- **PNP transistor**

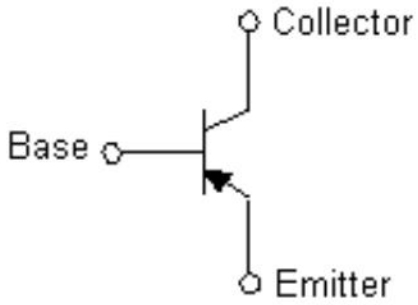








NPN transistor



PNP transistor

If a layer of n-type semiconductor is sandwiched between two p-type layers, the transistors are referred to as p-n-p type.

On the other hand if a layer of p-type material is sandwiched between two n-type layer , the transistor is called n-p-n transistor.

The central layer is made very thin and lightly doped as compared with two outer layers and is called base.

The emitter layer is heavily doped and collector layer is moderately doped.

The area of collector-base junction is made considerably larger than that of the emitter-base junction to handle more power at the collector base junction. So, if collector and emitter is interchanged normal transistor action cannot be obtained.

How It Works

Switching Mode

When used as a **switch**:

A **small current** at the **base** controls a **larger current** between the **collector and emitter**.

OFF state: No current flows into the base → no current from collector to emitter.

ON state: If base current flows → current freely flows from collector to emitter.

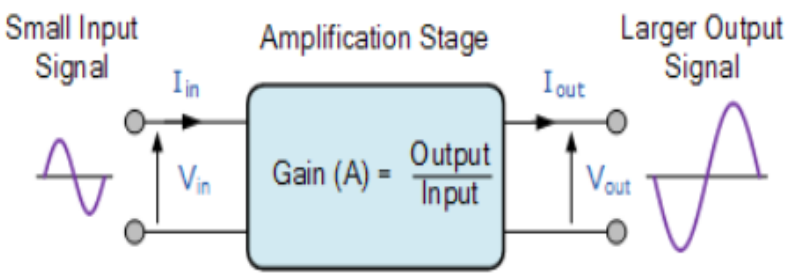
This is the basis of **digital logic** — transistors turning ON (1) or OFF (0) in circuits like CPUs, memory, and logic gates.

Amplifier Mode

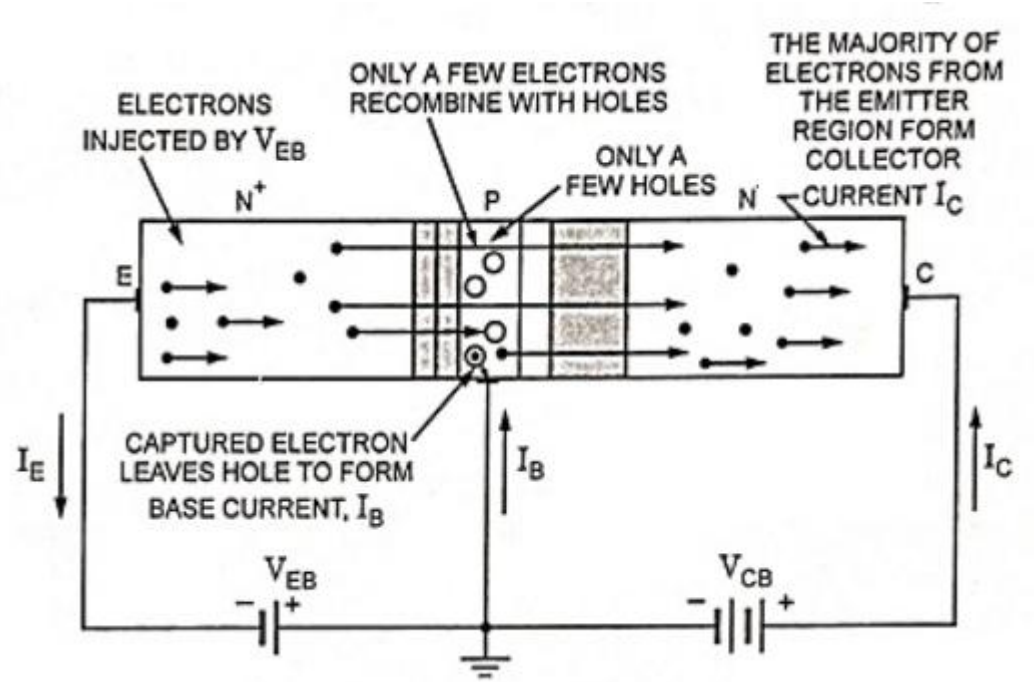
When used as an **amplifier**:

A **small input signal** at the base controls a **larger output current** through collector to emitter produces larger output signal.

e.g. audio amplifiers, RF amplifier.

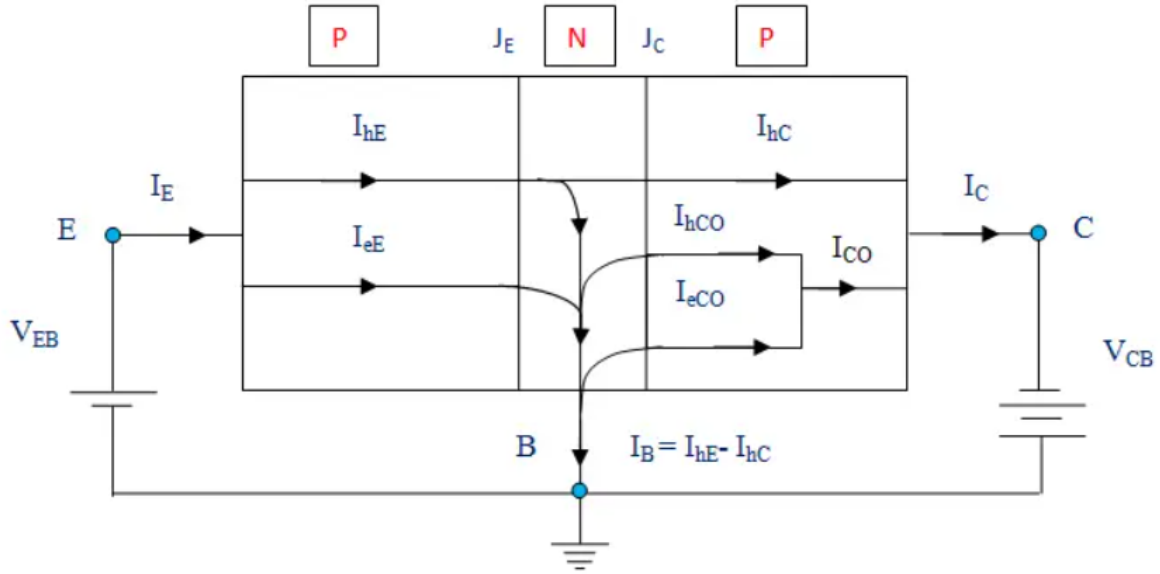


For normal operation of Transistor, emitter-base junction is forward biased and collector-base junction is reverse biased.



Transistor Current Components Definition:

The current components in a transistor include emitter current (IE), base current, and collector current.



Emitter Current (IE):

Emitter current (IE) is composed of hole current (IhE) and electron current (IeE), with hole current being dominant in PNP transistors.

- **Collector Current (IC)**: Collector current (IC) in a PNP transistor is influenced by the holes reaching the collector junction and can be equal to the reverse saturation current (ICO) when the emitter circuit is open.
- **Recombination in Base**: Holes recombine with electrons in the base, and remaining holes contribute to the hole current component (IhC) at the collector junction.

Transistor operation

The current arrives the transistor through the emitter and this current is called emitter current (I_E). This current consists of two constituents – **Hole current** (I_{hE}) and **Electron current** (I_{eE}). I_{eE} is due to passage of electrons from base to emitter and I_{hE} is due to passage of holes from emitter to base

$$I_E = I_{hE} + I_{eE}$$

The emitter region is heavily doped compared to the base, making the electron current negligible compared to the hole current. Therefore, the entire emitter current is due to the passage of holes from the emitter to the base.

- Some of the holes which are crossing the junction J_E (emitter junction) combines with the electrons present in the base (N-type). Thus, every holes crossing J_E will not arrive at J_C. The remaining holes will reach the collector junction which produces the hole current component, I_{hC}. There will be bulk recombination in the base and the current leaving the base will be

$$I_B = I_{hE} - I_{hC}$$

Electrons in the base lost due to recombination with holes injected across J_E are refilled by incoming electrons. The emitter injected Holes are minority carriers of base. These hole arriving at the collector junction (J_C) will cross into the collector region by the electric field present in the depletion region.

When the emitter circuit is open circuited, then $I_E = 0$ and $I_{hC} = 0$. In this condition, the base and collector will perform as reverse biased diode. Here, the collector current, I_C will be same as reverse saturation current (I_{CO} or I_{CBO})

$$I_{CO} = I_{hCO} + I_{eCO}$$

$I_C = \alpha I_E + I_{CO}$ Where α is defined as the fraction of total emitter current which represents holes which have travelled from the emitter across the base to the collector.