
EEE 1217

Analog Electronic Circuits

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PPT# 3: BJT



Transistor Construction

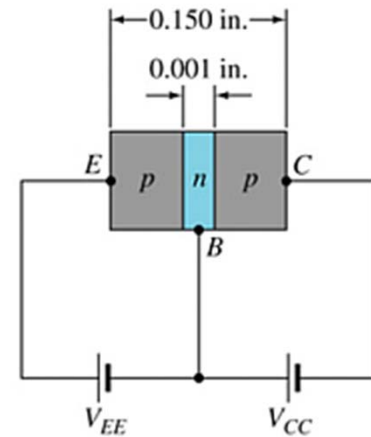
There are two types of transistors:

- *npn*
- *pnp*

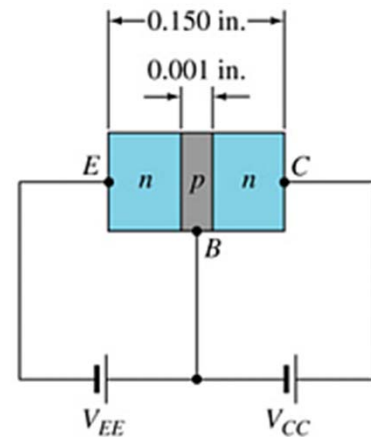
The terminals are labeled:

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

pnp



npn

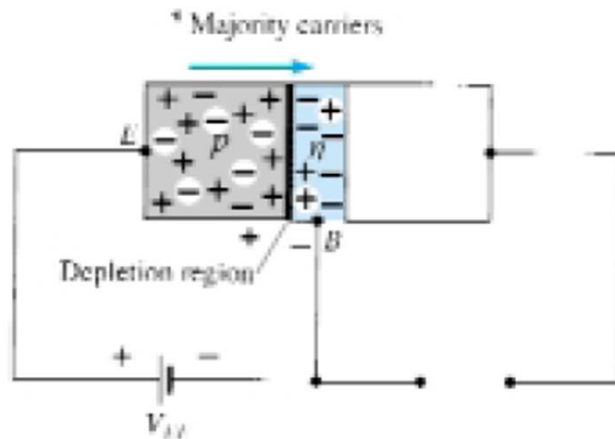


Transistor Construction

- dc biasing is necessary to establish the proper region of operation for ac amplification.
- **The** emitter layer is heavily doped, the base lightly doped, and the collector only lightly doped.
- The outer layers have widths much greater than the sandwiched *p*- or *n*-type material.
- For the transistors shown in Fig. the ratio of the total width to that of the center layer is $0.150/0.001 = 150:1$.
- The doping of the sandwiched layer is also considerably less than that of the outer layers (typically, 10^1 or less).
- This lower doping level decreases the conductivity of this material by limiting the number of “free” carriers.

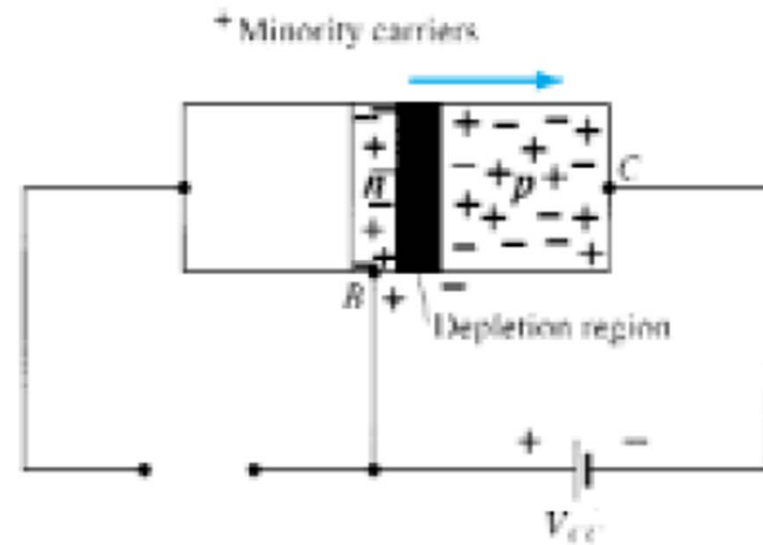


Transistor Operation



Forward-biased junction of a *pnp* transistor.

- *forward-biased diode*
- *heavy flow of majority carriers from the p- to the n-type material*



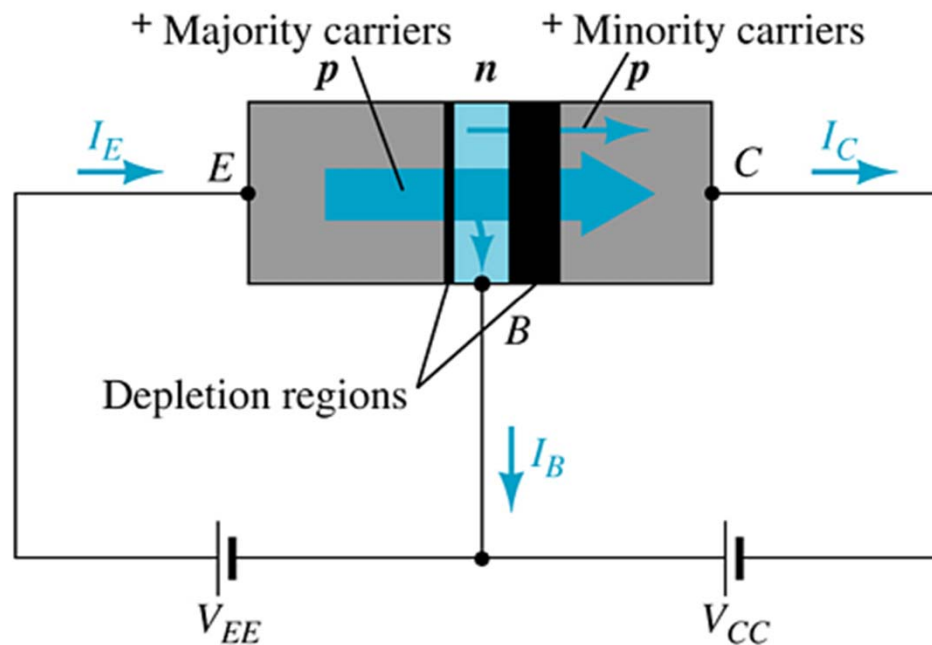
Reverse-biased junction of a *pnp* transistor.

- *forward-biased diode*
- *flow of minority carriers from the n- to the p-type material*

Transistor Operation

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



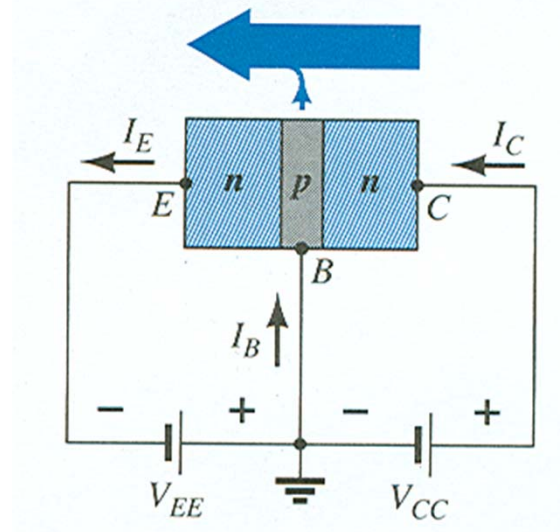
Currents in a Transistor

Emitter current is the sum of the collector and base currents:

$$I_E = I_C + I_B$$

The collector current is comprised of two currents:

$$I_C = I_{C_{\text{majority}}} + I_{C_{\text{minority}}}$$

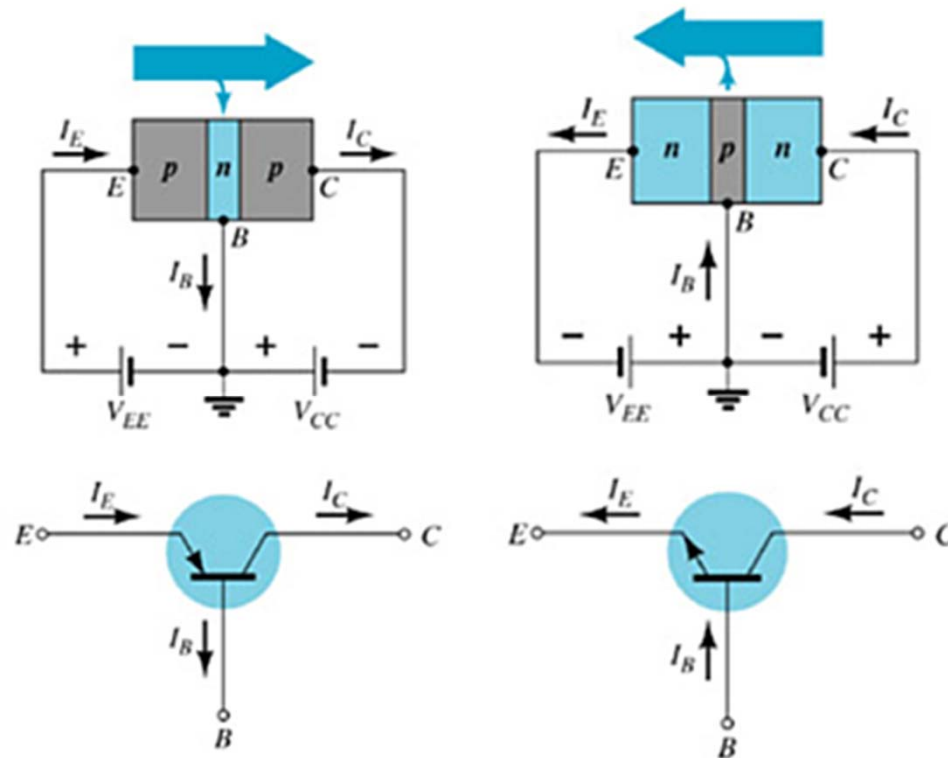


Transistor Operation

- **Active region**
 - ✓ **In the active region the collector-base junction is reverse-biased, while the base-emitter junction is forward-biased**
- **Cutoff region**
 - ✓ **In the cutoff region the collector-base and base-emitter junctions of a transistor are both reverse-biased.**
- **Saturation region**
 - ✓ **In the saturation region the collector-base and base-emitter junctions are forward-biased**



Common-Base Configuration

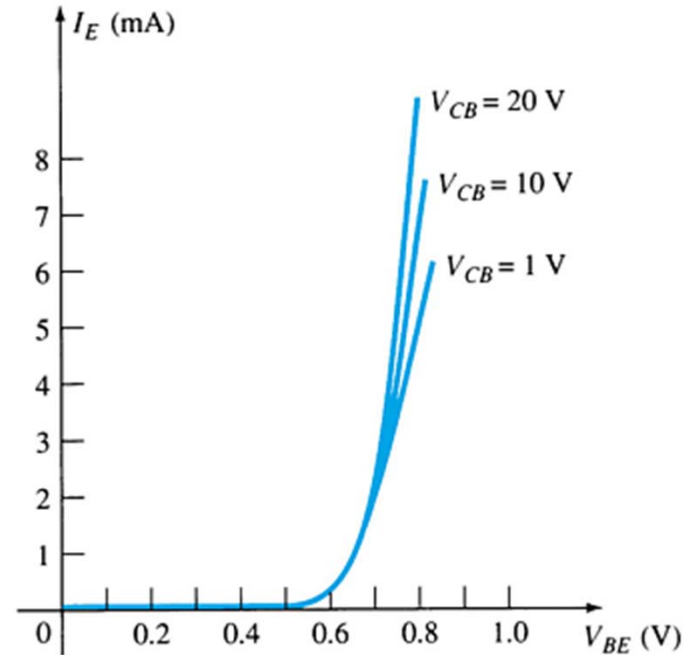


The base is common to both input (emitter–base) and output (collector–base) of the transistor.

Common-Base Amplifier

Input Characteristics

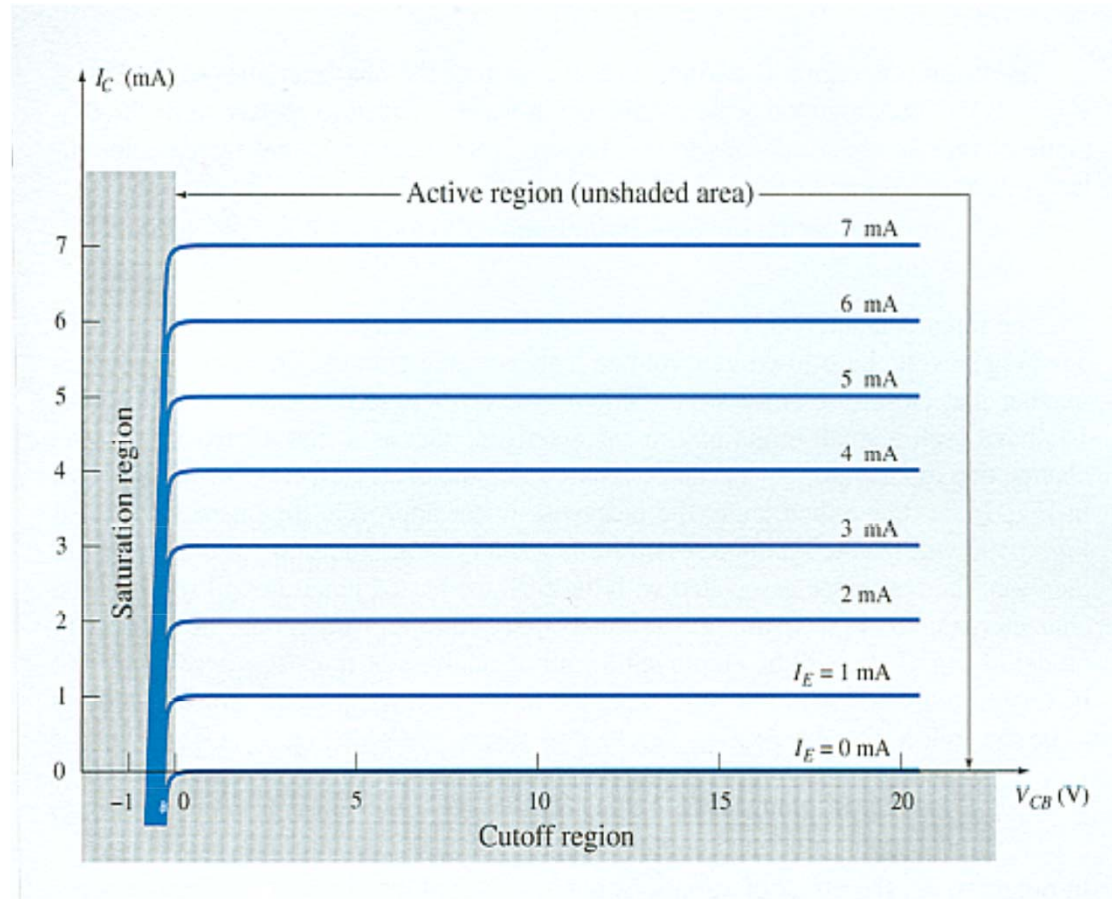
This curve shows the relationship between of input current (I_E) to input voltage (V_{BE}) for three output voltage (V_{CB}) levels.



Common-Base Amplifier

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.
- **Cutoff** – The amplifier is basically off. There is voltage, but little current.
- **Saturation** – The amplifier is full on. There is current, but little voltage.



Approximations

Emitter and collector currents:

$$I_C \cong I_E$$

Base-emitter voltage:

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



Alpha (α)

Alpha (α) is the ratio of I_C to I_E :

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

Ideally: $\alpha = 1$

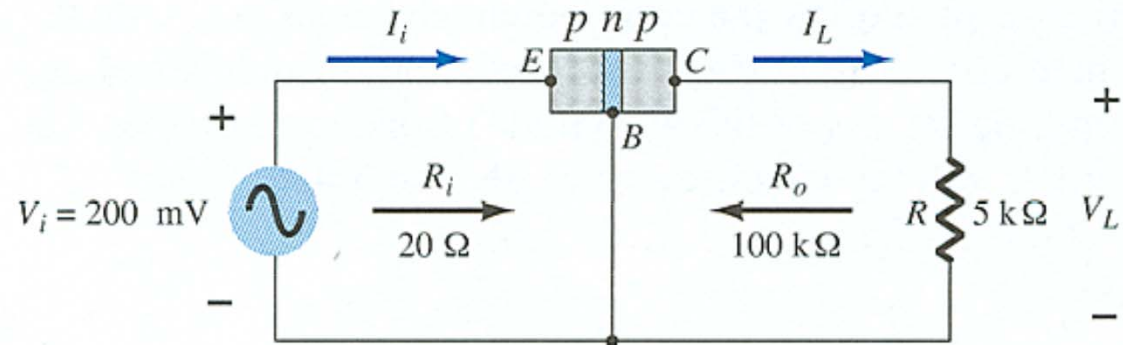
In reality: α is between 0.9 and 0.998

Alpha (α) in the AC mode:

$$\alpha_{\text{ac}} = \frac{\Delta I_C}{\Delta I_E}$$



Transistor Amplification



Currents and Voltages:

$$I_E = I_i = \frac{V_i}{R_i} = \frac{200\text{mV}}{20\Omega} = 10\text{mA}$$

$$I_C \cong I_E$$

$$I_L \cong I_i = 10\text{ mA}$$

$$V_L = I_L R = (10\text{ ma})(5\text{ k}\Omega) = 50\text{ V}$$

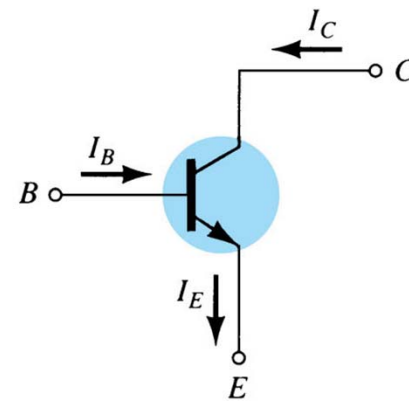
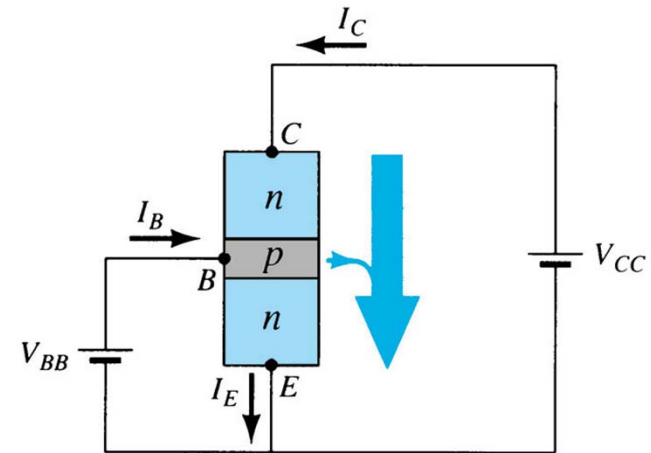
Voltage Gain:

$$A_v = \frac{V_L}{V_i} = \frac{50\text{V}}{200\text{mV}} = 250$$



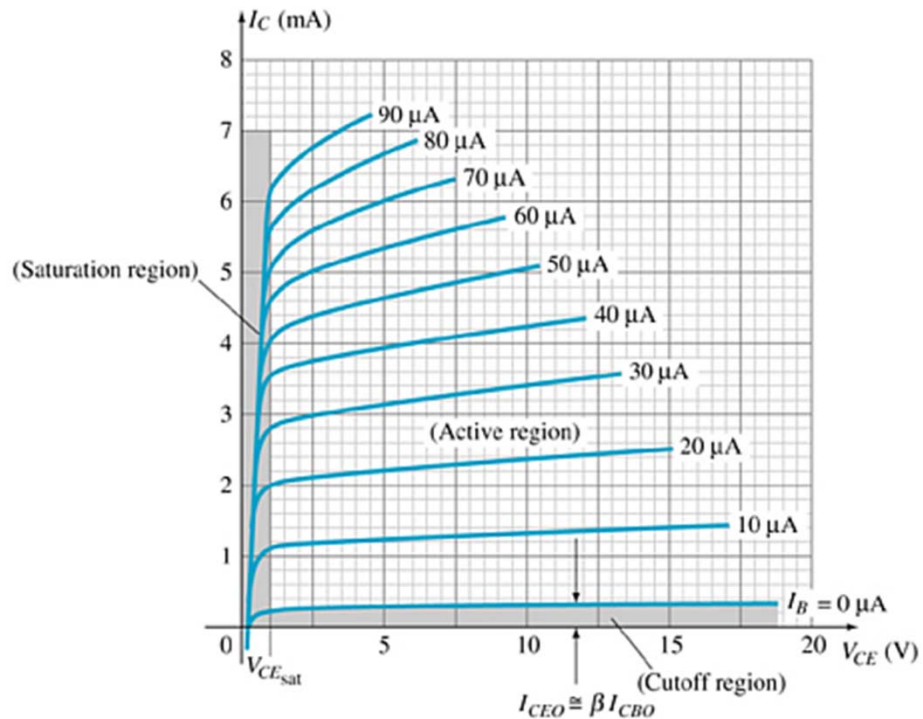
Common-Emitter Configuration

- The emitter is common to both input (base-emitter) and output (collector-emitter).
- The input is on the base and the output is on the collector.

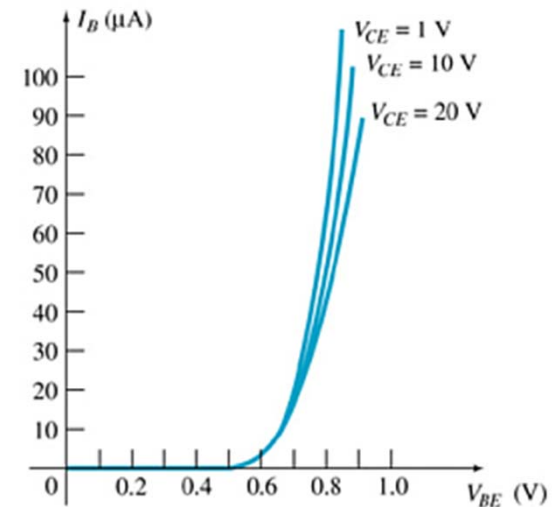


(a)

Common-Emitter Characteristics



Collector Characteristics



Base Characteristics



Common-Emitter Amplifier Currents

Ideal Currents

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E$$

Actual Currents

$$I_C = \alpha I_E + I_{CBO} \quad \text{where } I_{CBO} = \text{minority collector current}$$

I_{CBO} is usually so small that it can be ignored, except in high power transistors and in high temperature environments.

When $I_B = 0 \mu\text{A}$ the transistor is in cutoff, but there is some minority current flowing called I_{CEO} .

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha} \Big|_{I_B=0\mu\text{A}}$$



Beta (β)

β represents the amplification factor of a transistor. (β is sometimes referred to as h_{fe} , a term used in transistor modeling calculations)

In DC mode:

$$\beta_{dc} = \frac{I_C}{I_B}$$

In AC mode:

$$\beta_{ac} = \left. \frac{\Delta I_C}{\Delta I_B} \right|_{V_{CE} = \text{constant}}$$



Beta (β)

Relationship between amplification factors β and α

$$\alpha = \frac{\beta}{\beta + 1} \quad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

$$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

Relationship Between Currents

and dividing both sides of the equation by I_C will result in

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$I_C = \beta I_B$$

or

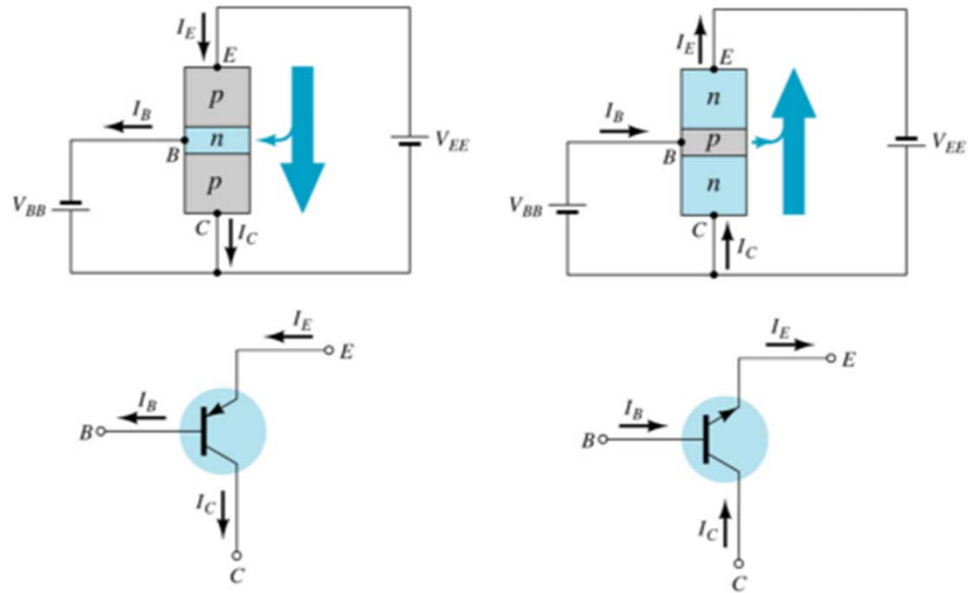
$$\beta = \alpha\beta + \alpha = (\beta + 1)\alpha$$

$$I_E = (\beta + 1)I_B$$



Common-Collector Configuration

The input is on the base and the output is on the emitter.



Common-Collector Configuration

The characteristics are similar to those of the common-emitter configuration, except the vertical axis is I_E .

