Name – Bishnupriya Jana
Dept. – physics
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Topic – Transistor

α and β of a transistor :-

The dc current gain of a transistor is denoted by α, which is defined as the ratio of collector current (I_c) to the emitter current (I_E) when the transistor is at Common base Connection.

$$\therefore \alpha = \frac{I_c}{I_E}$$

Small signal current gain of a transistor is denoted by α', which is defined as the ratio of change in collector current (ΔI_c) to the change in emitter current (ΔI_E) when collector to base voltage is constant.

$$\text{ie} \quad \alpha' = \frac{\Delta I_c}{\Delta I_E}\Big|_{V_{CB} \text{ is constant}}$$

The another dc current gain of a transistor is denoted by β, which is defined as the ratio of the collector current (I_c) to the base current (I_B) when the transistor is at common emitter connection.

$$\beta = \frac{I_c}{I_B}$$

The small signal current gain of a transistor is denoted by β', which is defined as ratio of change in collector current (ΔI_c) to the change in base current (ΔI_B) when collector to emitter voltage is constant.

$$\beta' = \frac{\Delta I_C}{\Delta I_B}\Big|_{V_{CB} \text{ is const.}}$$

Normally, the values of α lies between 0.95 to 0.99.
the values of β lies between 22 to 200.

1. Relation between α and β :-

If I_E be the emitter current
I_B be the base current
I_C be the collector current.

then $-I_E = I_B + I_C$.

Dividing by I_C on both sides, we get

$$-\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

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

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

Again

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

$$\Rightarrow \beta = \frac{\alpha}{1-\alpha}$$

2. Transistor leakage current :-

When one junction of a transistor is reverse biased with third terminal is open, the current of the transistor is known as transistor leakage current.

3. Common base current gain including leakage current :-

$$\alpha = \frac{\text{Actual oput}}{\text{Input current}}$$

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$$= -\frac{I_C - I_{CBO}}{I_E}$$

$\Rightarrow I_C = -\alpha I_E + I_{CBO}$ where $I_{CBO} \Rightarrow$ leakage current

I_C in terms of $\alpha \Rightarrow I_C = -\alpha I_E + I_{CBO}$

$\Rightarrow -\alpha I_E = I_C - I_{CBO}$

$\Rightarrow \alpha(I_B + I_C) = I_C - I_{CBO}$ as $I_E = -(I_B + I_C)$

$\Rightarrow I_C(\alpha - 1) = \alpha I_B + I_{CBO}$

$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

I_C in terms of $\beta \Rightarrow \alpha = \frac{\beta}{1+\beta}$

$\therefore \frac{\alpha}{1-\alpha} = \beta$ and $\frac{1}{1-\alpha} = \beta + 1$

thus,

$$\boxed{I_C = \beta I_B + (\beta+1) I_{CBO}}$$

4. Common emitter current gain including leakage current :-

$$\beta = \frac{I_C - I_{CEO}}{I_B}$$

$\therefore I_C = \beta I_B + I_{CEO}$ where $I_{CEO} \Rightarrow$ leakage curre

5. Show that, $I_{CEO} = (1+\beta) I_{CBO}$:-

Common base current gain with leakage current,

$$\alpha = \frac{I_C - I_{CBO}}{I_E}$$

$$\Rightarrow \alpha I_E = \alpha e - I_{CBO}$$

$$\Rightarrow (I_E + I_C)\alpha = I_C - I_{CBO}$$

$$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$$

Again $\alpha = \frac{\beta}{1+\beta}$ thus $\frac{\alpha}{1-\alpha} = \beta$

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

$$\therefore \boxed{I_C = \beta I_B + (\beta+1) I_{CBO}}$$

Where $I_{CEO} \Rightarrow$ transistor leakage current in CE mode.

$I_{CBO} \Rightarrow$ transistor leakage current in CB mode.

6. The value of α increases with the increasing reverse bias voltage of the collector junction - Why?

Ans:- With increasing reverse bias of the collector junction, the effective base width decreases. This reduces the possibility of recombination of the carriers injected from the emitter into the base, leading to the increase of α.

7. What is thermal runaway?

Ans:- If temperature increases then the leakage current within the transistor also increases. As a result of which more heat develops and again temperature increases, hence leakage current again increases. This process will continue in nature and finally, the transistor will or may burn out. This phenomena is known as "thermal runaway".

8. Two p-n junction diodes, joined externally in opposition do not from a transistor — explain.

Ans:- Two p-n junction diodes having metal leads and connected back to back will not make a transistor because then the base region will be thick. Again the contact potential at the metal conduction junction will not give the desired energy.

In a transistor, the emitter region is heavily doped and the collector region must be lightly doped. Moreover, in commercial transistor the area of the collector base junction is made considerably larger than that of the emitter - base junction.

When two diodes are joined back to back the above conditions are not obtained, hence it is impossible to make a transistor by joining two diodes back to back.