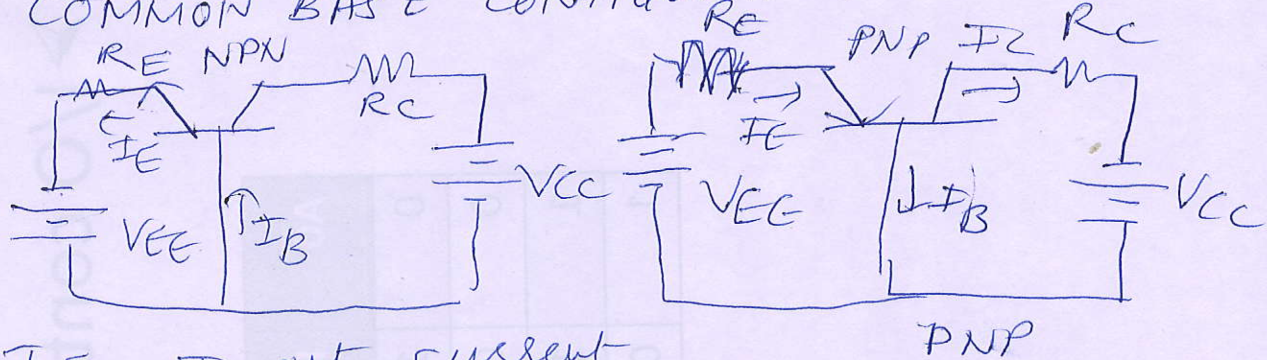
LECTURE 26TH OCT.

CURRENT GAINS:

(I) COMMON BASE CONFIGURATION:



I_E = Input current

I_C = output current

$$\text{current gain} = \frac{\text{Output current}}{\text{Input current}} = \frac{I_C}{I_E}$$

(i) Common base d.c. current gain α

– is defined as the ratio of collector current I_C to emitter current (I_E). It is designated as α, α_{DC} or h_{FB}.

$$\alpha = \frac{I_C}{I_E}$$

I_C is always less than I_E.

$\therefore$ current gain α is less than unity

α is made close to unity by making the width and doping level of base region as small as possible.

α ranges from 0.95 to 0.998

$$I_C = \alpha I_E$$

$$I_E = I_B + I_C$$

$$I_E = I_B + \alpha I_E$$

$$\therefore I_B = I_E - \alpha I_E$$

$$I_B = I_E(1-\alpha)$$

(ii) Common base a.c. current gain α_0:
It is defined as the ratio of small change in collector current (ΔI_C) to a small change in emitter current (ΔI_E) for a constant collector to base voltage (V_{CB}).

It is designated as α_0, α_{ac} or h_{fb}.

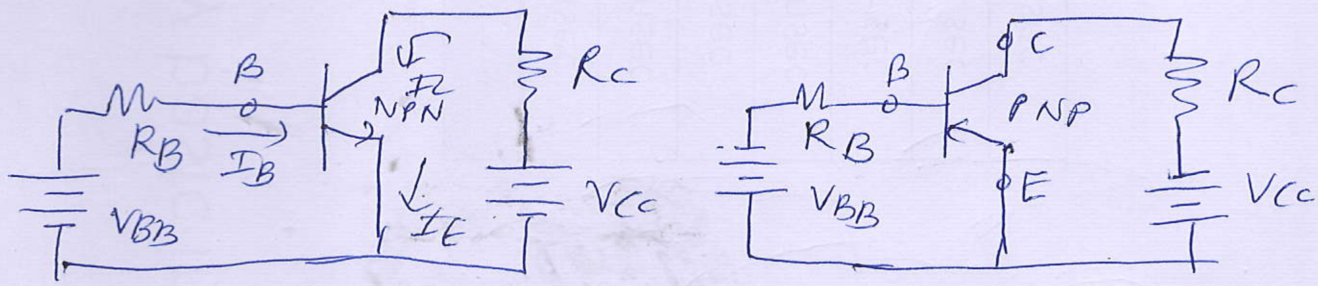
$$\alpha_0 = \frac{\Delta I_C}{\Delta I_E}$$

α_0 is also called CB short circuit current gain or small signal current gain.

For practical purposes $\alpha = \alpha_0$.

<u>Note:</u> current gain α is less than unity but it is still called current gain. It is because the output resistance of CB transistor is much higher than input resistance. This produces large voltage gain and hence large power gain.

(2) Common Emitter configuration current gain



I_B = Input current

I_C = Output current

current gain $= \frac{I_C}{I_B}$

(a) Common emitter d.c. current gain (β)
It is defined as the ratio of I_C to I_B.
It is designated as β, β_{dc} or h_{FE}.

$$\therefore \beta = \frac{I_C}{I_B}$$

$I_C > I_B$. $\therefore \beta >> 1$

β ranges from 20 to 250.

It is also called as large signal CE current gain.

(b) common emitter a.c. current gain (β_0)

It is defined as the ratio of small change in collector current (ΔI_C) to the small change in I_B (ΔI_B) for a constant collector to Emitter voltage (V_{CE})

It is designated as β_0, β_{ac} or h_{fe}

$$\beta_0 = \frac{\Delta I_C}{\Delta I_B}$$

For all practical purposes $\beta = \beta_0$.

Relation between current gain α and β

$$I_E = I_B + I_C$$ (divide by I_C on both sides)

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

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

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

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

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

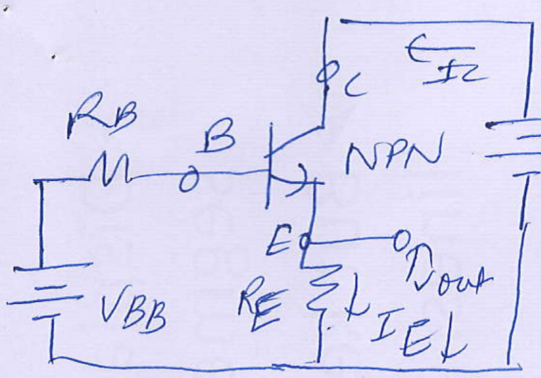
$$\alpha\beta + \alpha = \beta$$

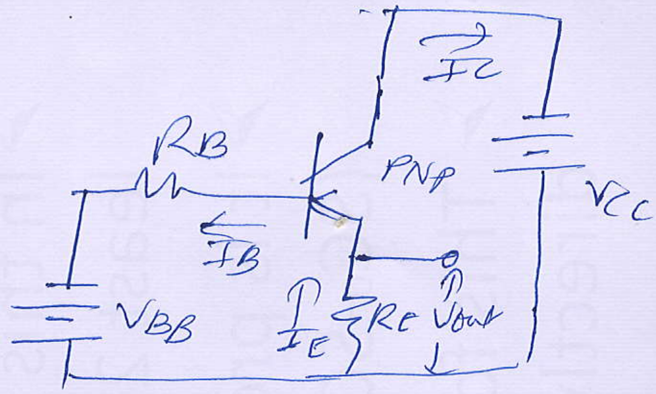
$$\alpha = \beta - \alpha\beta$$

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

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

(3) Current gain of CC configuration





Voltage V_{BB} forward biases the J_E junction (E-B) and Vcc reverse bias the collector-base junction (J_C) of the transistor.

I_B = input current

I_E = output current

current gain $= \frac{I_E}{I_B}$

$$\gamma = \frac{I_E}{I_B}$$

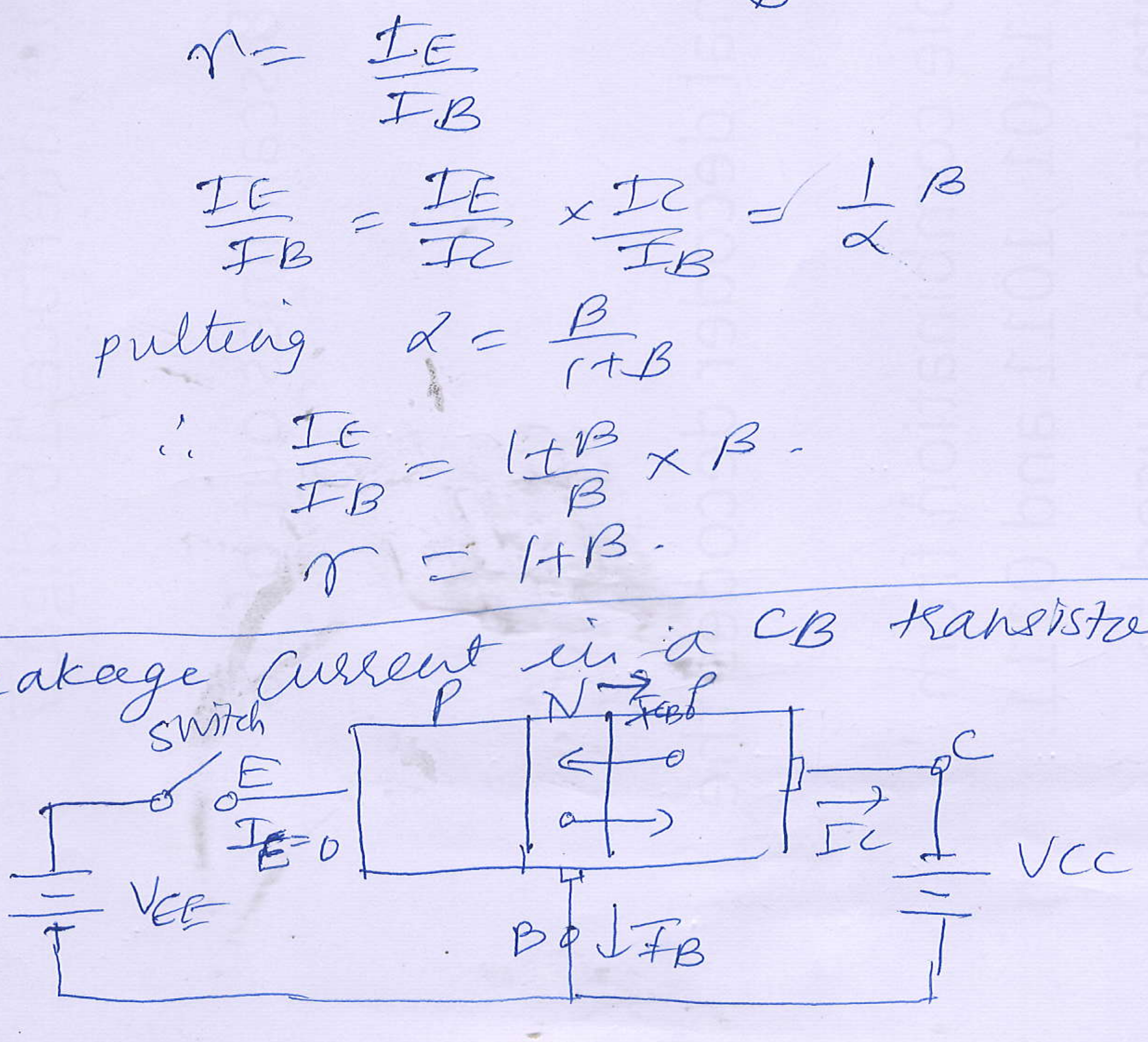
$$\frac{I_E}{I_B} = \frac{I_E}{I_C} \times \frac{I_C}{I_B} = \frac{1}{\alpha}\beta$$

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

$$\therefore \frac{I_E}{I_B} = \frac{1+\beta}{\beta} \times \beta.$$

$$\gamma = 1+\beta.$$

Leakage current in a CB transistor.



(i) Switch in 'closed' position
Forward bias voltage injects holes in the B region. The reverse bias voltage on the the J_C attracts the majority of holes from B region and constitute I_C. A small number of holes combine with the electrons in the B region and constitute I_B ; $\therefore I_E = I_C + I_B$.

(ii) Switch in 'OPEN' position:
It disconnects E from B and hence E-B junction is open-circuited. Thus $I_E = 0$ and therefore $I_B = I_C = 0$.

The CB junction is reverse biased due to holes injected from E. But this junction is forward bidsed due to thermally generated minority carriers (i.e. electrons in the P type collector region and holes in the N type B regions). The minority carriers diffuse across the C-B junction and hence produce a certain value of current known as leakage current.

This current is called the leakage current from C to B with E open and is designated as I_{CBO}. It is also known as reverse saturation current or collector cut-off current I_{CO}.

I_{CBO} or I_{CO} is similar to reverse saturation current in p-n junction
Direction of I_{CBO} is same as that of injected current.

I_C consists of 2 parts 6

(i) current produced by normal transistor action and is equal to αI_E and is due to majority carriers

(ii) The reverse saturation current I_{CO} produced by the thermally generated carriers or minority carriers.

$$\therefore I_C = \alpha I_E + I_{CO}$$

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

$$\alpha = \frac{I_C - I_{CO}}{I_C + I_B}$$

$$\alpha I_C + \alpha I_B = I_C - I_{CO}$$

$$I_C - \alpha I_C = \alpha I_B - I_{CO}$$

$$I_C(1-\alpha) = \alpha I_B - I_{CO}$$

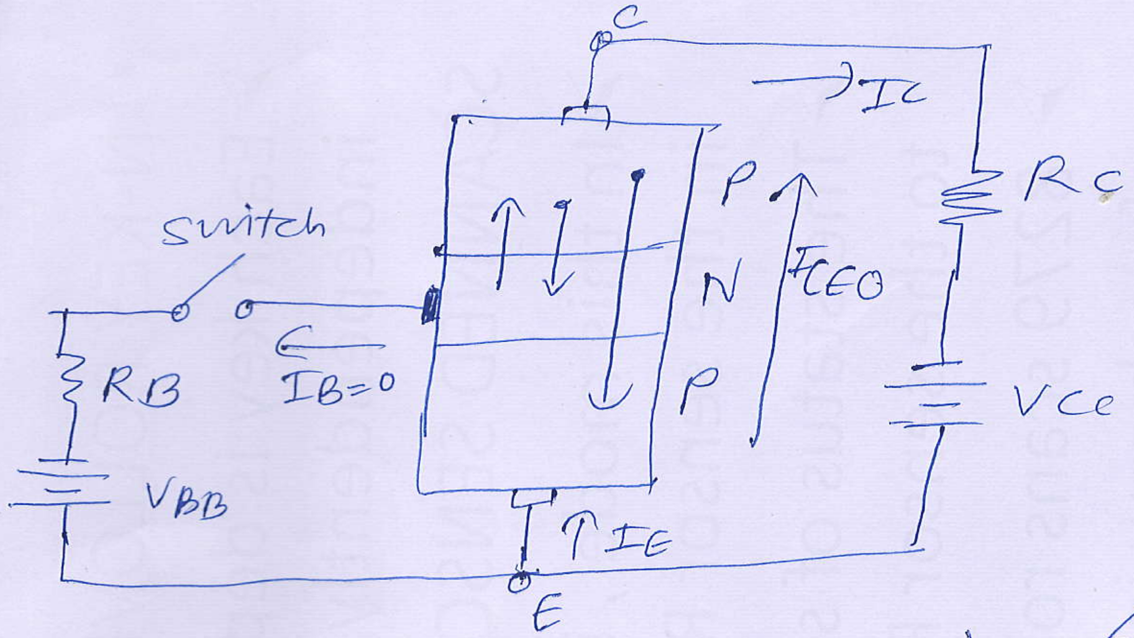
$$I_C = \frac{\alpha I_B}{1-\alpha} - \frac{I_{CO}}{1-\alpha}$$

Note: I_{CO} for Si transistors is in nA whereas for ~~Si~~ Ge transistors it is μA.
$\therefore$ cannot be neglected.

In both Si & Ge transistors I_{CO} is strongly temperature dependent. It doubles for every $10^\circ C$ increase in temperature.

As I_{CO} is less in Si transistors they can be used upto $200^\circ C$ whereas Ge transistors are limited to about $100^\circ C$ only.

Leakage current in a CE transistor



(i) Switch in closed position: (The description is same as for leakage current in CB transistor)

(ii) Switch in open position: Base is disconnected from the emitter. Hence the B-E junction is opened and $I_B=0$.

Under this condition, a leakage current flows from E to C terminal. This current is designated by I_{CEO}. This leakage current is not just due to the thermally generated carriers across C-B junction but also due to movement of electrons across the B-E junction. This flow of electrons slightly forward biases the B-E junction. It appears as if a base current equal to I_{CO} is being supplied to the transistor. This produces additional collector current equal to βI_{CO}.

Thus the total leakage current flowing through the transistor with Base open

$$I_{CEO} = I_{CO} + \beta I_{CO}$$
$$= (1+\beta) I_{CO}$$

The total $I_C = \beta I_B + I_{CEO}$

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

Note: As I_{CO} is temperature dependent, as temperature changes there is a change in I_C. As $\beta >> 1$ therefore CE transistor is more temperature dependent than CB transistor.

Base spreading resistance:

Width of B region is extremely small. Therefore the current which enters the B region across the E-B junction has a narrow path to reach the Base terminal. The resistance offered by this narrow base region is called base spreading resistance r_b'

The value of this resistance can be increased by increasing the reverse bias voltage V_{CB} across C-B junction.

r_b' is about 50 to 150 ohms. In some cases it may be as high as 1000 ohms.

Effect of r_b' is significant at high frequencies