Characteristics of BJT-2

Output Characteristics for Common Emitter configuration:

The output characteristic for transistor is a graph between output current and output voltage on the basis of different input current. In common Emitter configuration the output current is I_C and output voltage is V_{CE} and input current is I_B. So output characteristics for common emitter will be a graph between I_C and V_{CE} on the basis of different values of I_B.

For pnp transistor to work in active region emitter junction should be forward bias and collector junction should be reverse bias. For emitter junction forward bias V_{BE} should be negative, and to make collector junction reverse biased the voltage V_{CB} should be negative as well as greater than V_{BE} in magnitude i.e. $|V_{CB}| > |V_{BE}|$.

Here we have to apply V_{BE} in input side and V_{CE} on output side. On applying KVL between terminals of BJT we can find relation between voltages.

$V_{BE} + V_{CB} - V_{CE} = 0 \Rightarrow V_{CE} = V_{CB} + V_{BE}$

From equation $V_{CE} = V_{CB} + V_{BE}$, we can see that, if V_{BE} is negative (to make emitter junction of pnp forward bias) then to reverse bias the collector junction of pnp transistor V_{CE} should be negative.

Suppose for Si (pnp) transistor, $V_{BE} = -0.7V$, then to make V_{CB} negative and greater than V_{BE} (i.e. 0.7 v) the V_{CE} should be at least greater than 1.4 in magnitude and with negative sign. i.e. $V_{CE} = -1.42$ or

$|V_{CE}| > 1.4$

Means V_{CE} can be – 1.41,-1.42------------1.5 and so on

Therefore we can say that to make pnp (Si transistor) in active region V_{CE} should be negative and greater than 1.4V in magnitude.

Similarly to make a Si (pnp transistor) in saturation region the emitter junction and collector junction both should be forward bias. Means V_{BE} should be negative and to make V_{CB} positive and smaller in magnitude than V_{BE} (i.e. $|V_{CB}| < |V_{BE}|$), V_{CE} should be always negative and lower than V_{BE} in magnitude.

Suppose $V_{BE} = -0.7$ (for emitter junction Forward bias)

So for V_{CB} = +Ve and lower than V_{BE} in magnitude

[From $V_{CE} = V_{CB} + V_{BE}$

$V_{CB} = V_{BE} - V_{CE}$

= -0.7 – V_{CE}] V_{CE} can not be positive.

That means for pnp transistor in common emitter case to be in saturation region V_{BE} should be negative and V_{CB} should be positive and lower than V_{BE} in magnitude. And to make this, V_{CE} will be always negative.

So finally we can say to make a pnp transistor in active or saturation or in cut off V_{CE} will be always negative. Similarly for npn transistor it will be always positive.

So to draw an output characteristics graph for pnp transistors between I_C and V_{CE} only negative values of V_{CE} will be used.

As we have discussed for pnp common emitter transistor I_C should be function of V_{CE} and I_B means

$I_C = f(I_B, V_{CE})$.

We know $I_C = \alpha I_E + I_{CBO}(1 - e^{V_{CB}/\eta V_T})$ from common base configuration.

By using $I_E = I_C + I_B$ and $V_{CE} = V_{CB} + V_{BE}$

$$I_C = \alpha(I_C + I_B) + I_{CBO}(1 - e^{(V_{CE} - V_{BE})/\eta V_T})$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}(1 - e^{(V_{CE} - V_{BE})/\eta V_T})$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}(1 - e^{(V_{CE} - V_{BE})/\eta V_T})$$

$$I_C = \beta I_B + (\beta + 1) I_{CBO}(1 - e^{(V_{CE} - V_{BE})/\eta V_T})$$

Here we can see

$I_C = f(I_B, V_{CE})$

$$\beta = \frac{\alpha}{1-\alpha},\ (\beta+1)I_{CBO} = I_{CEO})$$

I_{CEO} means curent between collecor and emitter when base is open.

So general equation of BJT in common emitter configuration will be

$I_C = \beta I_B + I_{CEO}(1 - e^{(V_{CE} - V_{BE})/\eta V_T})$, This equation can be used to draw characteristics of BJT in common emitter configuration.

Active Region:

For active region emitter junction should be forward bias and collector junction should be reverse biased so βI_B will be present in the equation and $e^{(V_{CE}-V_{BE})/\eta V_T}$ will be neglected with respect to1, and equation for active region will be

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

So graph of I_C will be dependent on I_B and V_{CE} both, because on

$V_{CE}\uparrow \Rightarrow V_{CB}\uparrow \Rightarrow \alpha\uparrow \Rightarrow \beta\uparrow$ **(From base width modulation)**

(Means on increasing $V_{CE} \Rightarrow \beta$ will be increased) and as we know α varies from 0.92 to 0.99, for variation of α from 0.92 to 0.99, $\beta = \frac{0.92}{1-0.92} = \frac{0.92}{0.98} = 11.5, \beta = \frac{0.99}{1-0.99} = 99$,

So for α 0.92 to 0.99, β varies fro 11.5 to 99.

So variation in β with respect to V_{CE} is faster than variation in α. So slope of graph in common emitter will be greater than common base in active region.

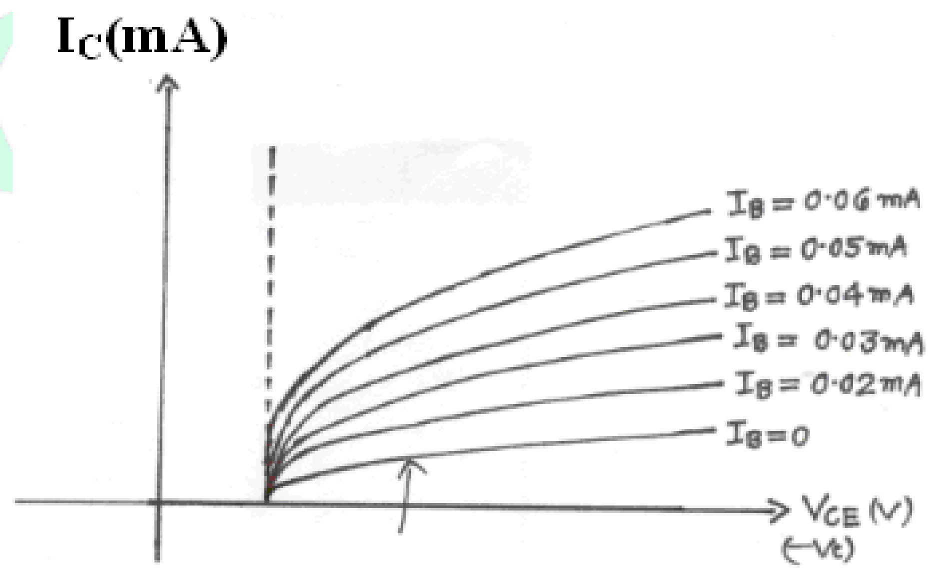

Figure-1(Active region)

Saturation region:

For BJT to be in saturation region emitter junction should be forward bias and collector junction should also be forward biased. For PNP transistor V_{BE} and V_{CB} both should be negative and $|V_{CB}| < |V_{BE}|$ is required for pnp in saturation region. For this V_{CE} will be always negative and

$|V_{CE}|<|V_{BE}|$.Due to emitter junction forward bias βI_B will be available in the equation and $e^{(V_{CE}-V_{BE})/\eta V_T}$ will be much greater than '1', so '1' will be neglected with respect to $e^{(V_{CE}-V_{BE})/\eta V_T}$ and current equation for pnp transistor in saturation region will be $I_C = \beta I_B + I_{CEO}(e^{(V_{CE}-V_{BE})/\eta V_T})$. From this equation it is conform that variation in V_{CE} is dominating over variation in I_B on values of I_C. So I_C will be approximately dependent on V_{CE} exponentially and independent of I_B and I_E. That means I_C is saturated with respect to I_B so this region is called saturation region

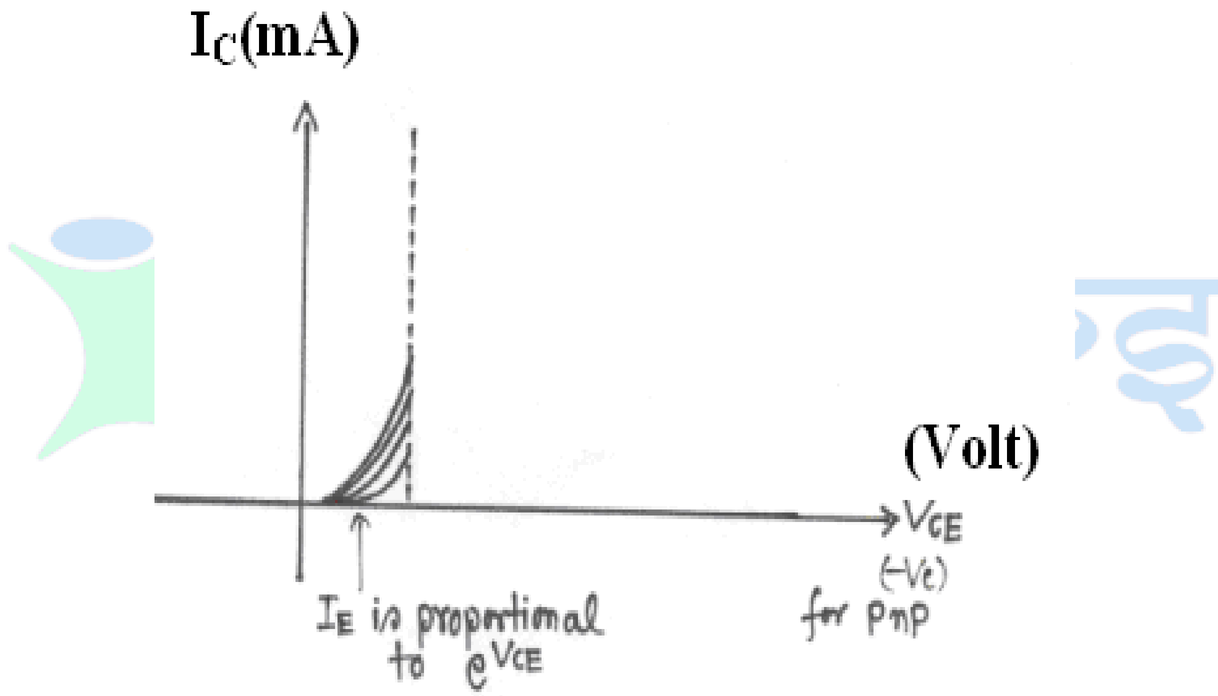

Figure-2(Saturation region)

Therefore we can say that in saturation region of output characteristics of common emitter configuration I_C, is saturated with respect to input current I_B and also I_E.

Cut off Region:

In cut off region emitter junction is reverse biased and collector junction is also reverse biased. So V_{BE} and V_{CB} both should be applied in such a manner that can reverse bias the emitter junction and collector junction respectively. For pnp, V_{BE} should be positive and V_{CB} should be negative.

So in current equation

$I_B = 0$, and $e^{(V_{CE} - V_{BE})/\eta V_T}$ will be neglected with respect ot 1.

So current equation for cut off region will be

$I_C = I_{CEO}$

So we can say I_C is cut off from I_B & I_E, so this biasing condition will be called cut off region and graph will be as shown in figure-3.

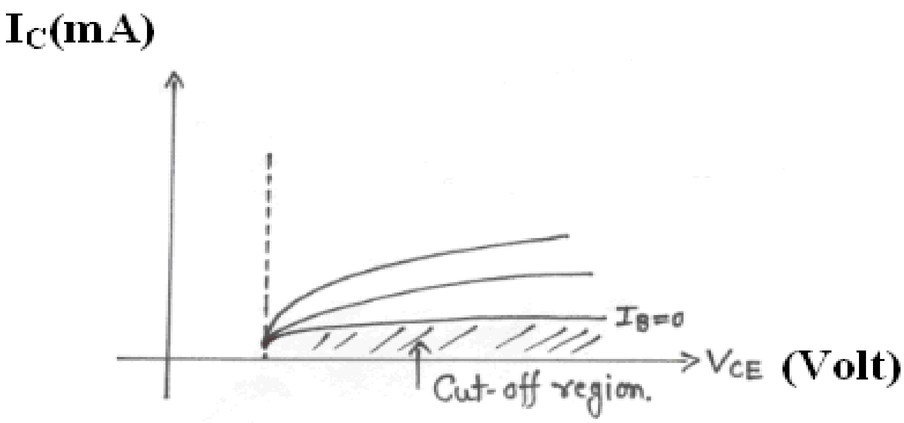

Figure-3(Cut off region)

From above discussion it is conform that output characteristics graph will be always for negative V_{CE} (for pnp). Active, saturation and cut off region will be on right side of vertical, I_C, axis. The slope of the graph will be greater than slope of graph in common base case. Means variation in I_C with respect V_{CE} will be greater than variation in I_C with respect V_{CB} (in common base) as shown in fig.

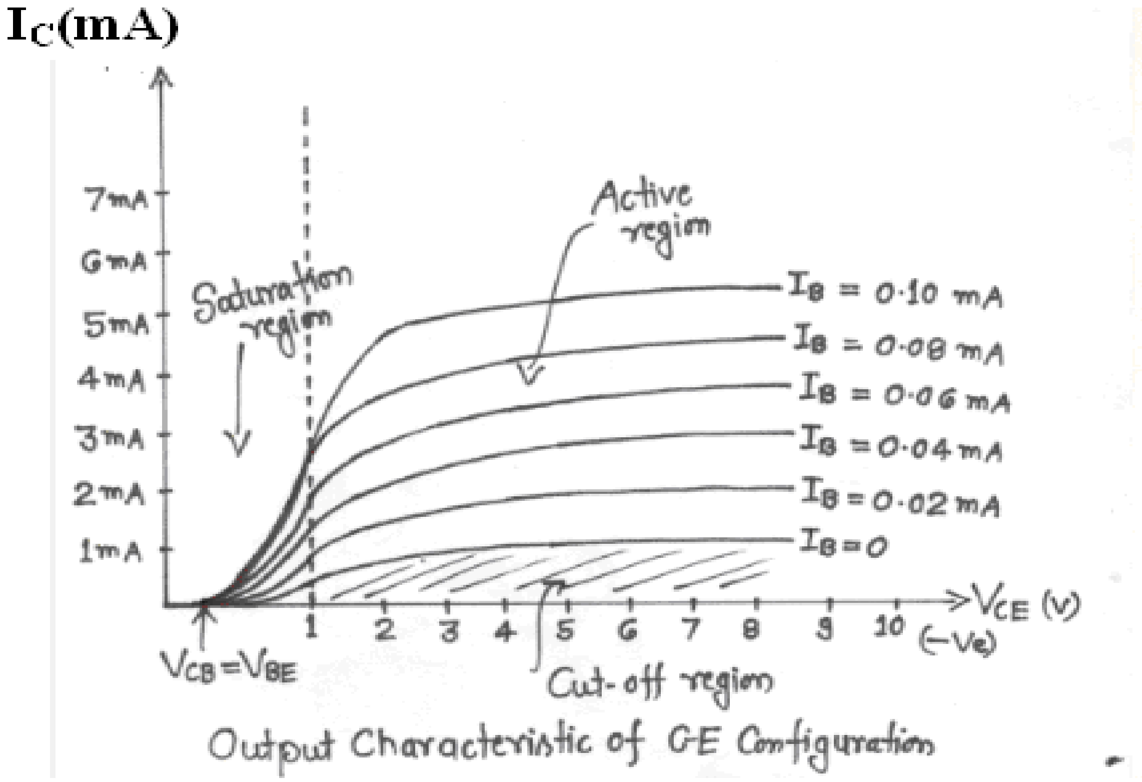

Figure-4 (Output characteristics of common emitter pnp transistor)