BIPOLAR JUNCTION TRANSISTOR III

Transistor Characteristics

Common Emitter

Common Base

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CHARACTERISTIC CURVE OF TRANSISTOR AND h-PARAMETERS

For a transistor in common –emitter connection the base current I_B and the collector voltage with respect to emitter V_{CE}, are taken as independent variable.

The functional equations can be written as

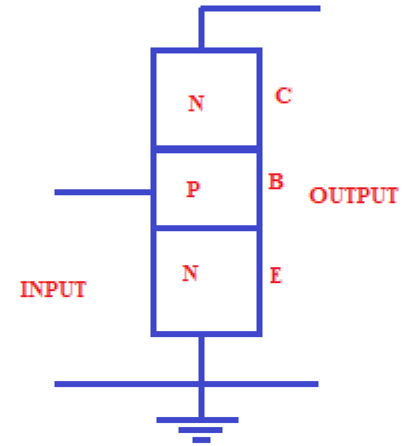
$$V_{BE} = f_1(I_B, V_{CE})$$
$$I_C = f_2(I_B, V_{CE})$$

(I) $(V_{BE} - I_B)$ at constant V_{CE} , input characteristic

(ii) $(V_{BE} - V_{CE})$ at I_B constant, feedback characteristic

(iii) $(I_C - I_B)$ at V_{CE} constant, transfer characteristic

(iv) $(I_C - V_{CE})$ at I_B constant, output characteristic



$$dV_{BE} = \left(\frac{\partial V_{BE}}{\partial I_B}\right)_{V_{CE}} dI_B + \left(\frac{\partial V_{BE}}{\partial V_{CE}}\right)_{I_B} dV_{CE}$$
$$= h_{ie} dI_B + h_{re} dV_{CE}$$
$$dI_C = \left(\frac{\partial I_C}{\partial I_B}\right)_{V_{CE}} dI_B + \left(\frac{\partial I_C}{\partial V_{CE}}\right)_{I_B} dV_{CE}$$
$$= h_{fe} dI_B + h_{oe} dV_{CE}$$

Where $h_{ie} = \left(\frac{\partial V_{BE}}{\partial I_B}\right)_{V_{CE}} = input\ impedaance$

$$h_{re} = \left(\frac{\partial V_{BE}}{\partial V_{CE}}\right)_{I_B} = reverse\ voltage\ ratio$$

$$h_{fe} = \left(\frac{\partial I_C}{\partial I_B}\right)_{V_{CE}} = forward\ current\ transfer\ ratio$$

$$h_{oe} = \left(\frac{\partial I_C}{\partial V_{CE}}\right)_{I_B} = output\ admittance$$

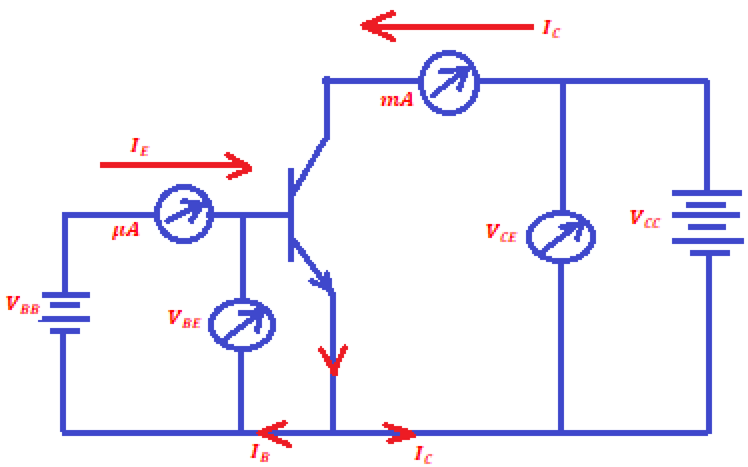
These parameters are of different dimensions and referred as hybrid parameters

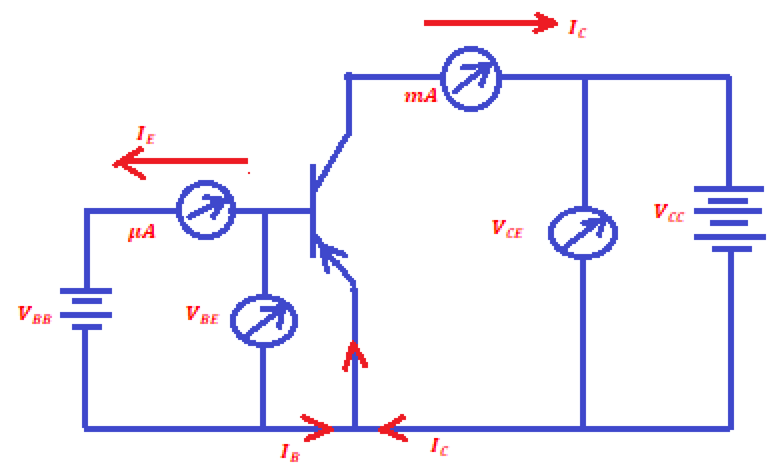
$h_{ie} = \left.\frac{v_{be}}{i_b}\right|_{v_{ce}=0}$ => input impedance with output short circuited to ac

$h_{re} = \left.\frac{v_{be}}{v_{ce}}\right|_{i_b=0}$ => reverse voltage ratio with input open circuited to ac

$h_{fe} = \left.\frac{i_c}{i_b}\right|_{v_{ce}=0}$ => forward current transfer ratio with output short circuited to ac

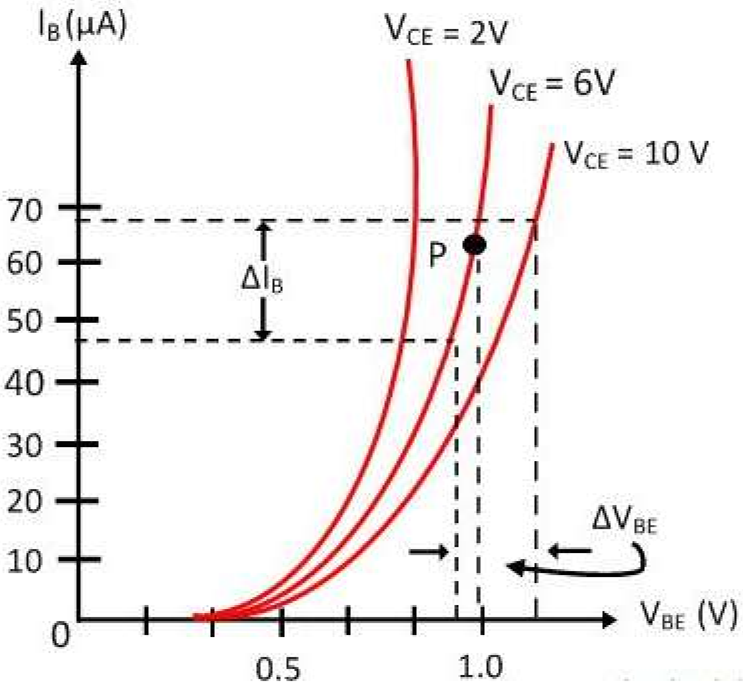
$h_{oe} = \left.\frac{i_c}{v_{ce}}\right|_{i_b=0}$ => output admittance with input open circuited to ac





INPUT CHARACTERISTIC

In CE connection input characteristics are similar to that of a forward biased pn junction



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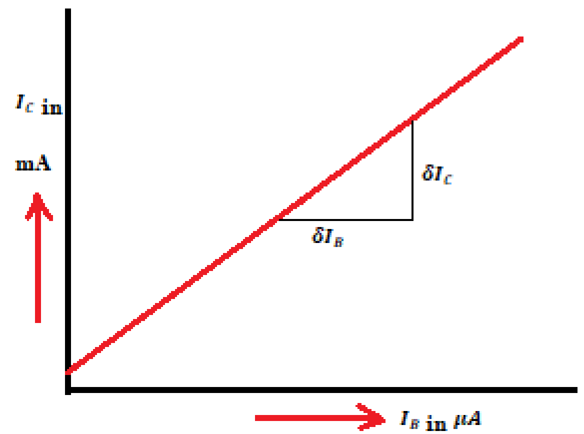
TRANSFER CHARACTERISTIC



$$h_{fe} = \frac{\delta I_C}{\delta I_B}\bigg|_{V_{CE}} = \beta_{ac}$$

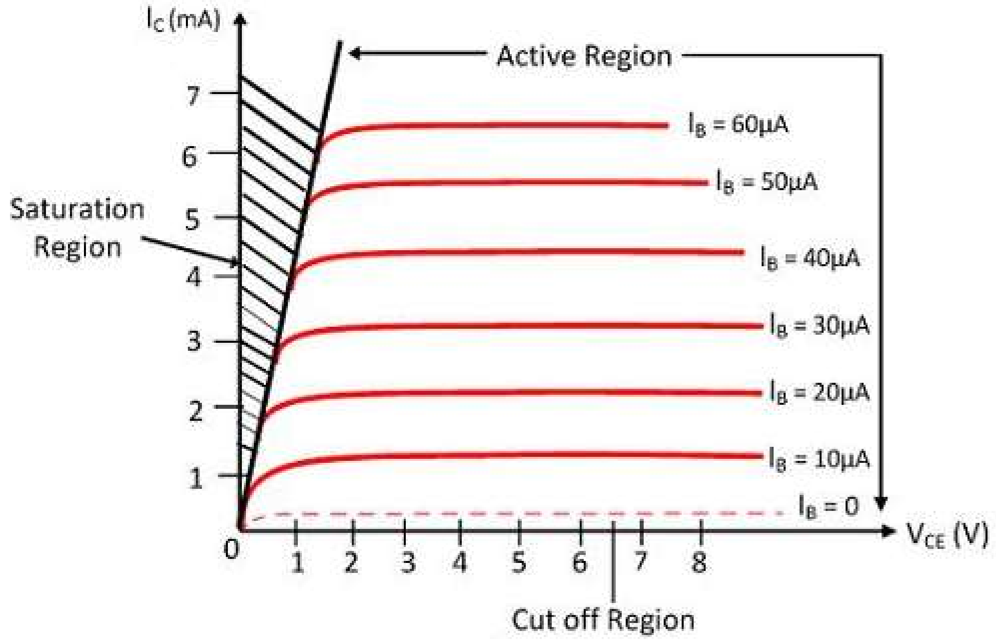
$$h_{FE} = \frac{I_C}{I_B} = \beta_{dc}$$

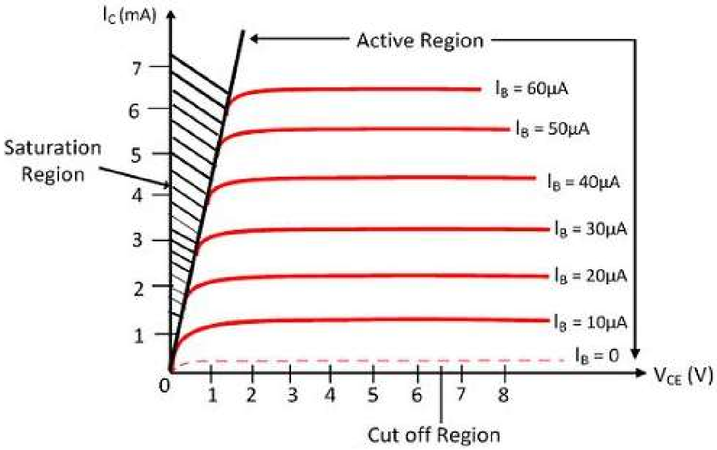
The base current is kept constant at a suitable value by adjusting the base emitter voltage V_{BE}. The magnitude of the collector-emitter voltage $|V_{CE}|$ is increased in suitable equal steps from zero and the collector current I_C is noted for each setting of V_{CE}.

At a suitable operating point, the slope of the characteristic gives the output admittance

$$h_{oe} = \frac{\delta I_C}{\delta V_{CE}}\bigg|_{I_B}$$

The output resistance is of moderate value and depends on the type of transistor and the operating point.





ACTIVE REGION

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

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

I_C would be independent of V_{CE}, if α is really constant.

When $|V_{BE}|$ is increased, the effective width of the base will decrease. Hence the number of majority carriers from the emitter, recombining with the majority carriers in the base will decrease. This will slightly increase the value of I_C.

The value of α will increase by a small amount

The value if β will also increase by a large amount as $|V_{CE}|$ is increased

For large increase in V_{CE} , there may cause breakdown in the collector region

CUT OFF REGION

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

For $I_B = 0$

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

At reverse bias $I_E = 0$

$$I_B = -I_C = -I_{CBO}$$

SATURATION REGION

For a forward bias of the Collector-Emitter junction, I_C increases exponentially

The electrons flows from n side across the collector junction p side (npn transistor)

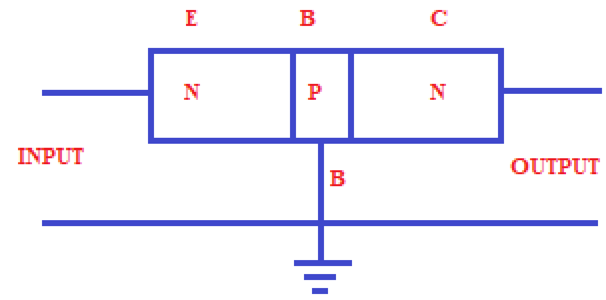
This causes a positive changes in collector current

The knowledge of the behavior of the transistor in the saturation and cut off regions is necessary if the transistor is used in switching circuits.
In switching circuits, the transistor is required to be in "ON" and "OFF" position alternatively

COMMON BASE CONFIGURATION

In this configuration V_{CB} and I_E are taken as independent variable and I_C and V_{CB} are dependent variable

$$V_{EB} = f_1(I_E, V_{CB})$$
$$I_C = f_2(I_E, V_{CB})$$



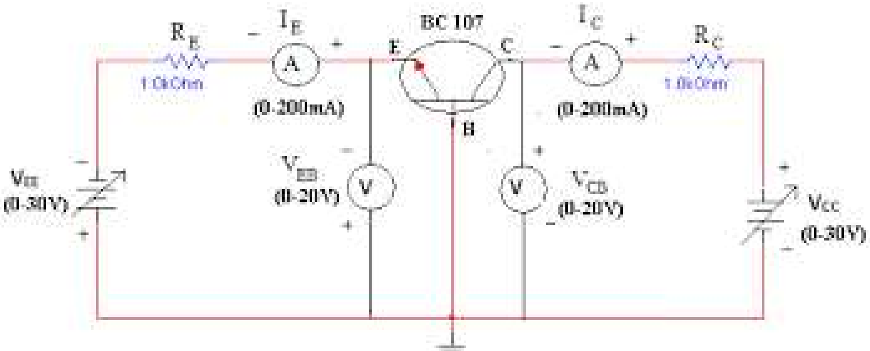
1. $(V_{EB} - I_E)_{V_{CB}} \Rightarrow$ *Input characteristics*
2. $(V_{EB} - V_{CB})_{I_E} \Rightarrow$ *Feedback characteristics*
3. $(I_C - I_E)_{V_{CB}} \Rightarrow$ *Transfer characteristics*
4. $(I_C - V_{CB})_{I_E} \Rightarrow$ *Output characteristics*

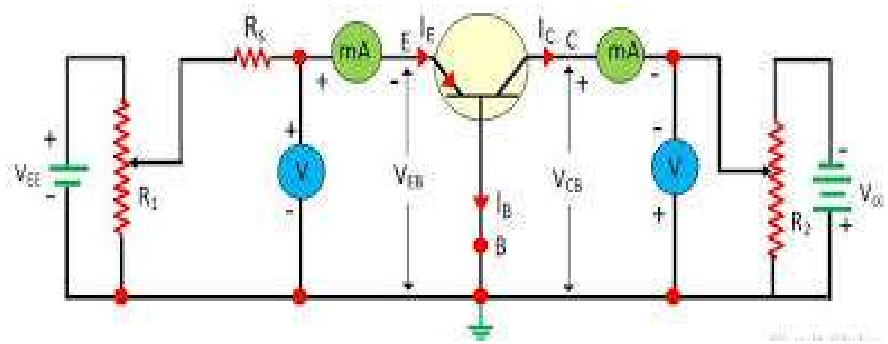
$$dV_{EB} = \left(\frac{\partial V_{EB}}{\partial I_E}\right)_{V_{CB}} dI_E + \left(\frac{\partial V_{EB}}{\partial V_{CB}}\right)_{I_E} dV_{CB}$$

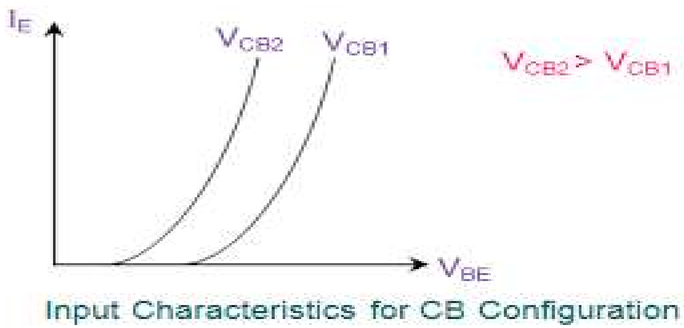
$$= h_{ib} dI_E + h_{rb} dV_{CB}$$

$$dI_C = \left(\frac{\partial I_C}{\partial I_E}\right)_{V_{CB}} dI_E + \left(\frac{\partial I_C}{\partial V_{CB}}\right)_{I_E} dV_{CB}$$

$$= h_{fb} dI_E + h_{ob} dV_{CB}$$

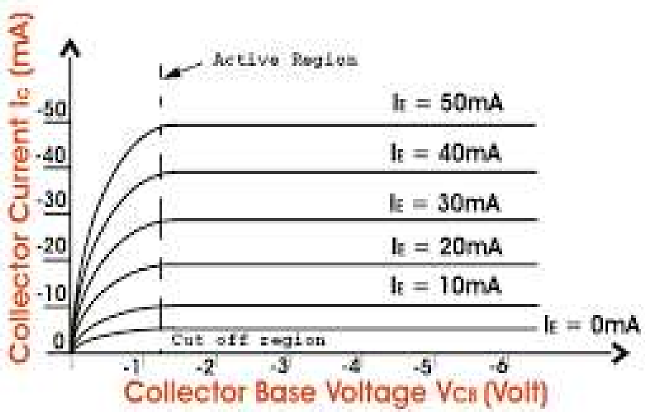

R E
I E
BC 107
E
C
I C
R C
1.0kOhm
(0-200mA)
B
V EE
(0-30V)
V EB
(0-20V)
V
A
V CB
(0-20V)
V CC
(0-30V)


R S
mA
E
I E
I C
C
V EE
R 1
V
V EB
I B
B
V CB
R 2



In normal operating region the Emitter-Base junction is forward biased and the input curves are similar to that of a forward biased pn junction

If the reverse bias voltage V_{CB} is increased the width of the depletion region of the collector – base junction increases and decreases the width of the base region



In CB mode the variation of I_C with V_{CB} with I_E as parameter gives the static output characteristics

ACTIVE REGION

$$I_C = \alpha I_E + I_{CBO} \approx \alpha I_E$$

- At lower end $I_E = 0$, the collector current $I_C \approx I_{CBO}$

- I_E is increased, α decreases and I_C changes and differs from I_E
- I_C is almost independent of V_{CB}
- If V_{CB} is increased very much there may be collector junction breakdown causing a sharp rise in I_C

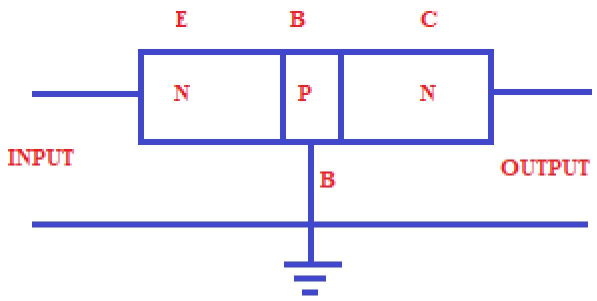
- For $|V_{CB}| > 0$, I_C is independent of V_{CB}
- Output admittance $h_{ob} = (\frac{\Delta I_C}{\Delta V_{CB}})_{I_E}$ is negligible and output resistance will be very large

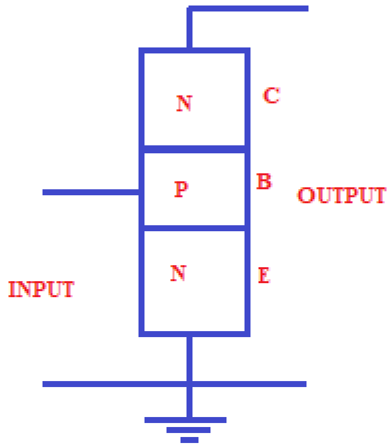
SATURATION REGION

In this region both the Emitter-Base and Collector-Base junctions are forward biased
The region of the curves to the left of the ordinate $V_{CB} = 0$ and above $I_E = 0$ is called the saturation region

CUT OFF REGION

In this region both the junctions are reverse biased and the region below the curve for $I_E = 0$ is called the cut-off region


E
B
C
N
P
N
INPUT
B
OUTPUT


N
C
P
B
OUTPUT
N
E
INPUT