EE210: Microelectronics-I

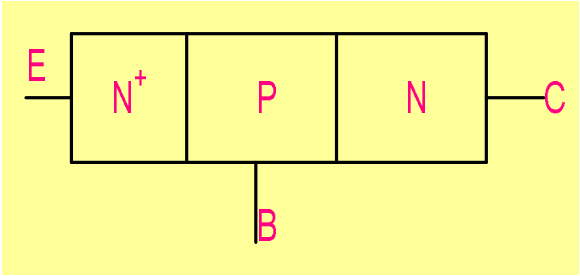
Lecture-9 : Bipolar Junction Transistor-2

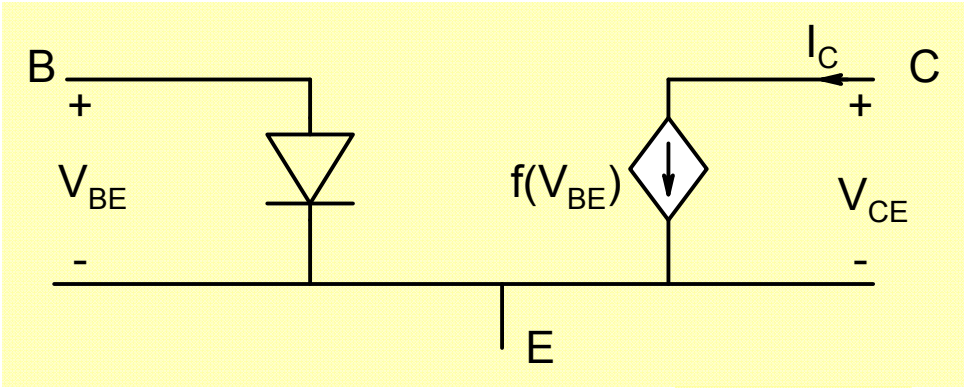
Instructor: Y. S. Chauhan

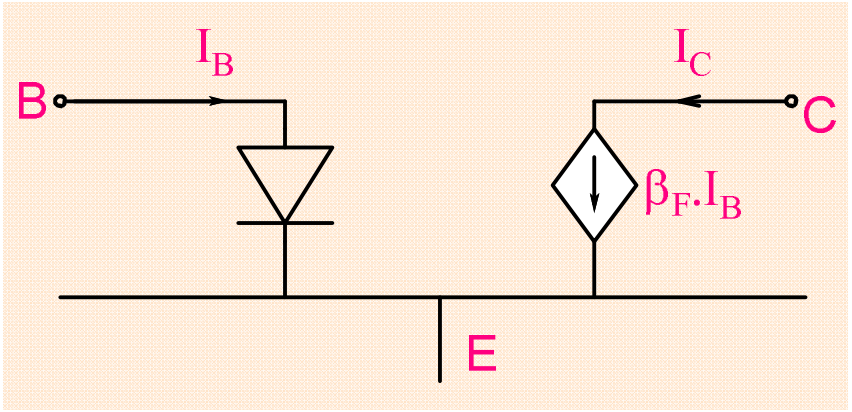
Slides from:

B. Mazhari
Dept. of EE, IIT Kanpur

BJT : equivalent circuit





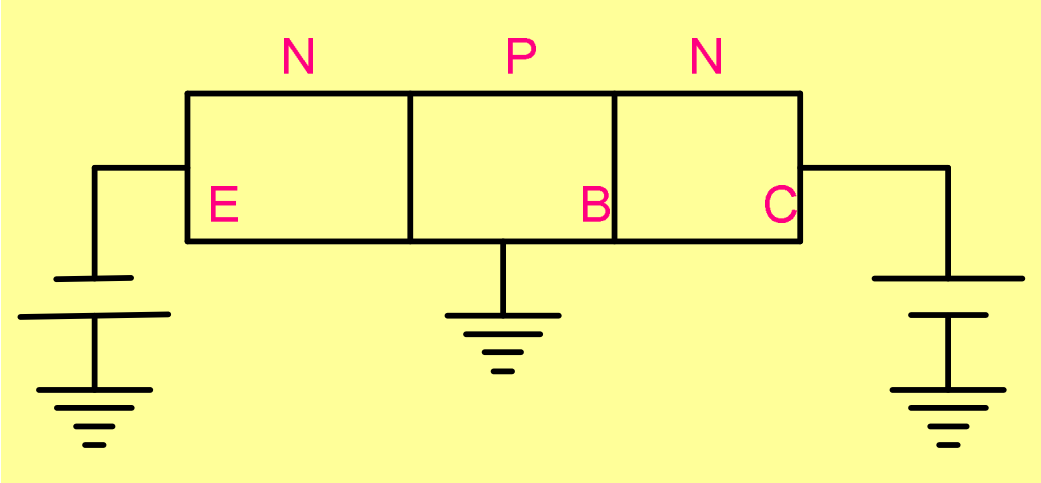


$$\beta = \frac{I_C}{I_B}$$

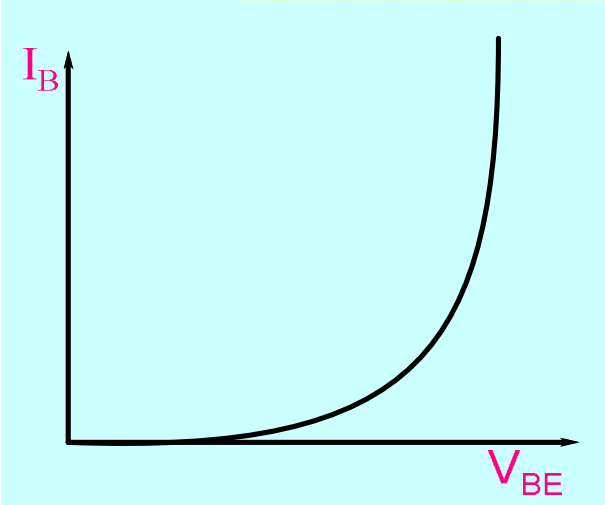
$$I_C = I_S \left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1 \right)$$

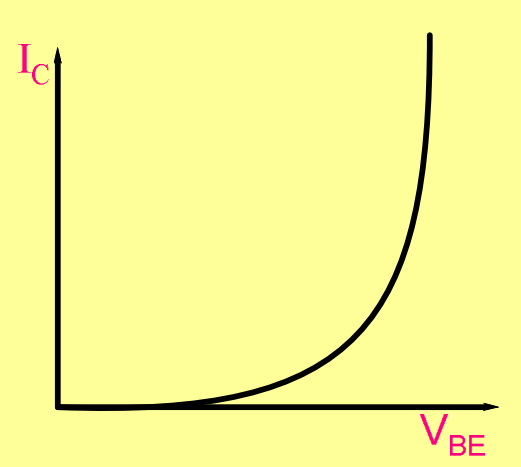
$$I_B = \frac{I_C}{\beta}$$

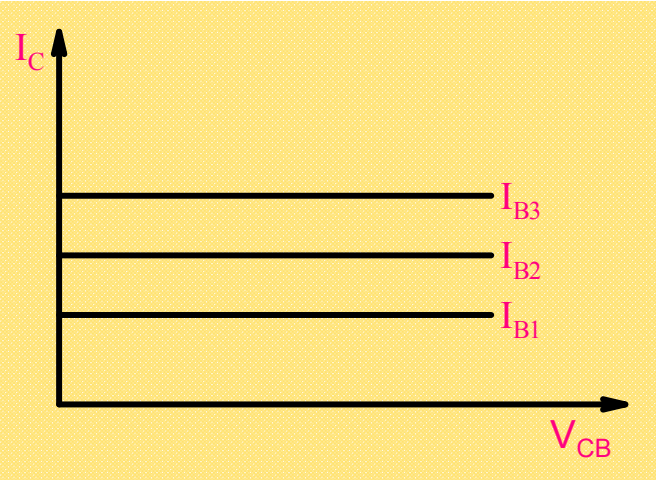
Forward Active Mode



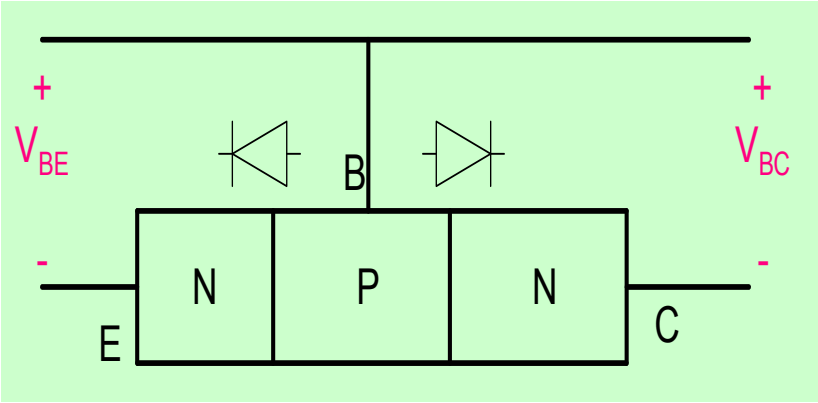
$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right) \quad ; \quad I_B = \frac{I_C}{\beta}$$

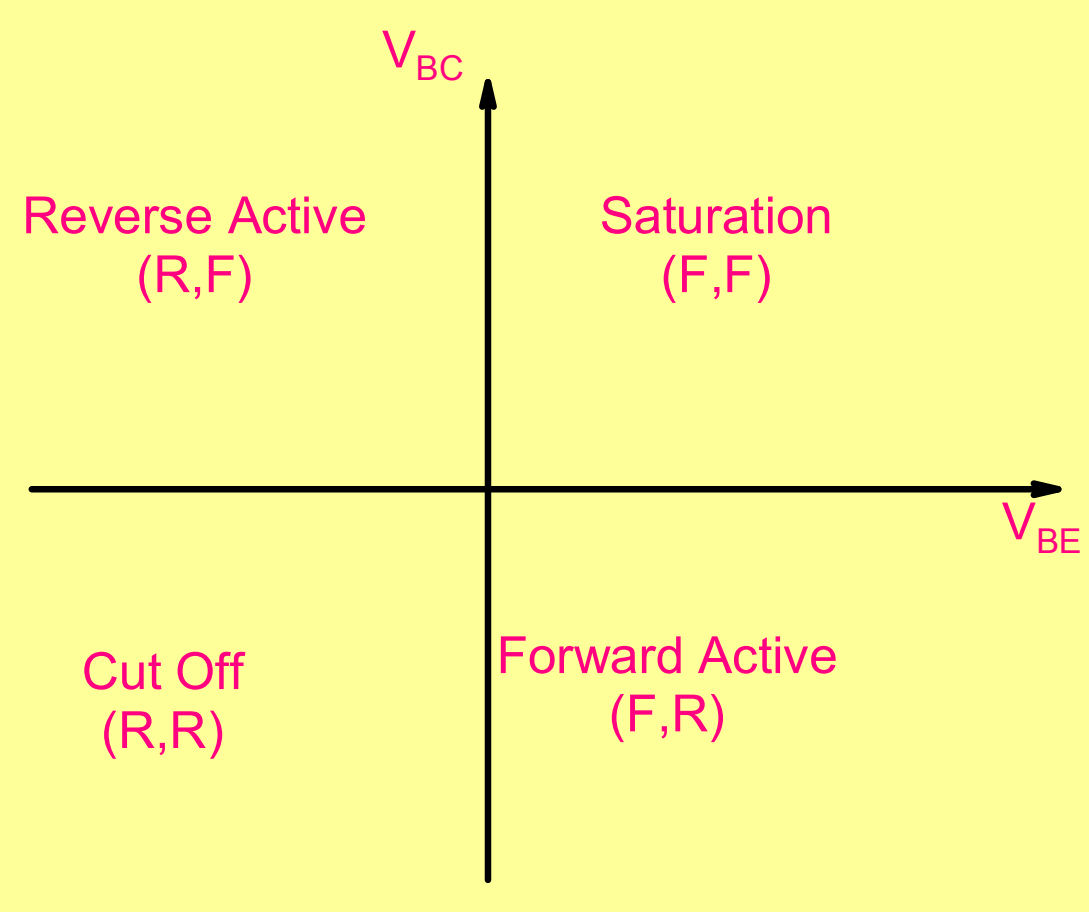




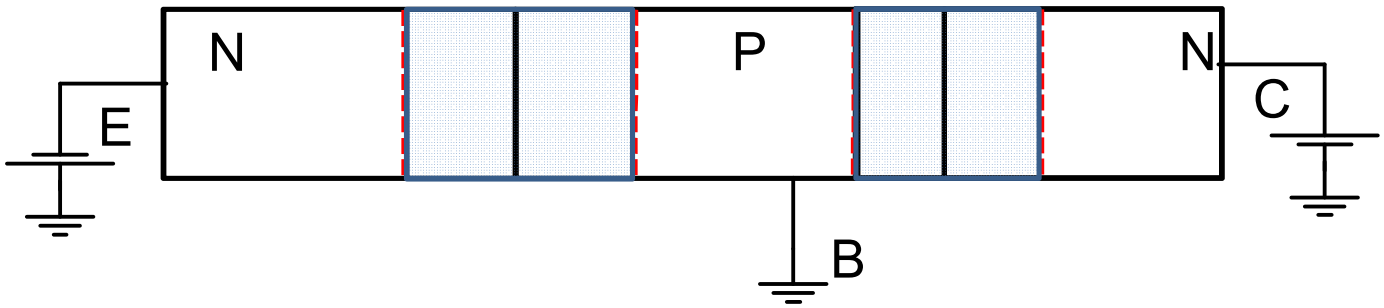


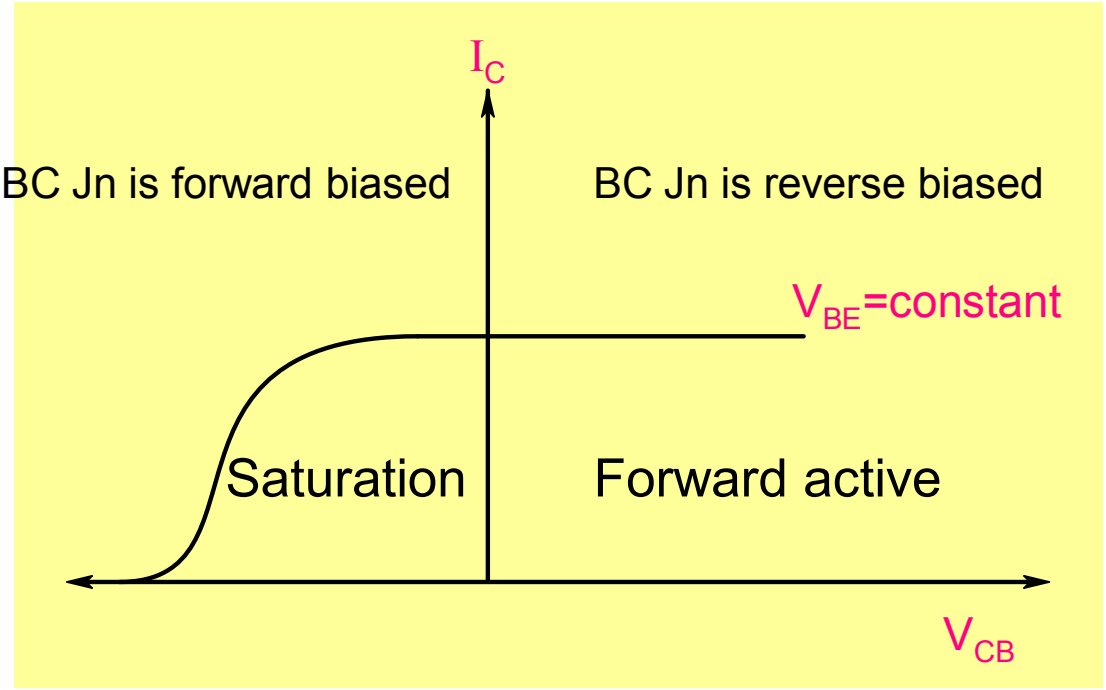
Modes of operation





Saturation

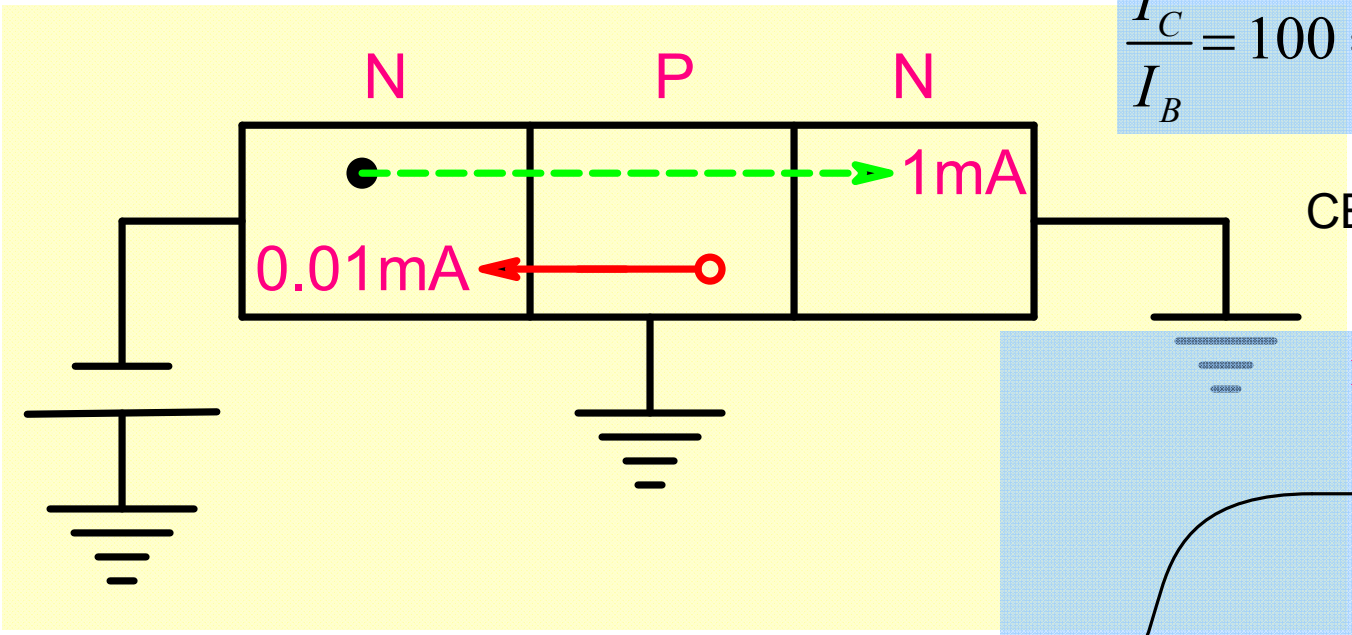

N
P
N
E
C
B


I_C
BC Jn is forward biased
BC Jn is reverse biased
V_{BE}=constant
Saturation
Forward active
V_{CB}

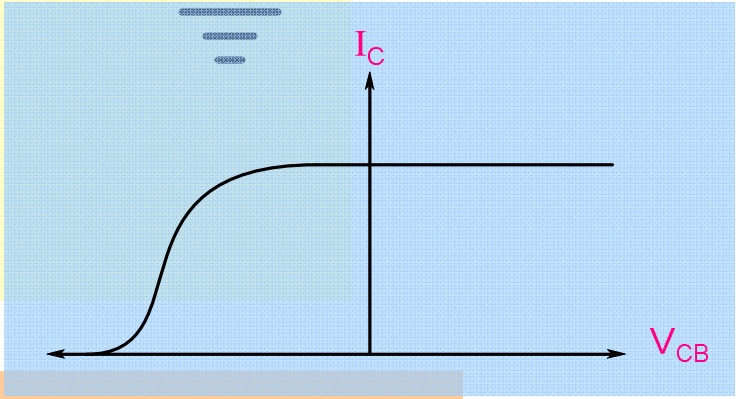
Why does I_C drop in saturation?

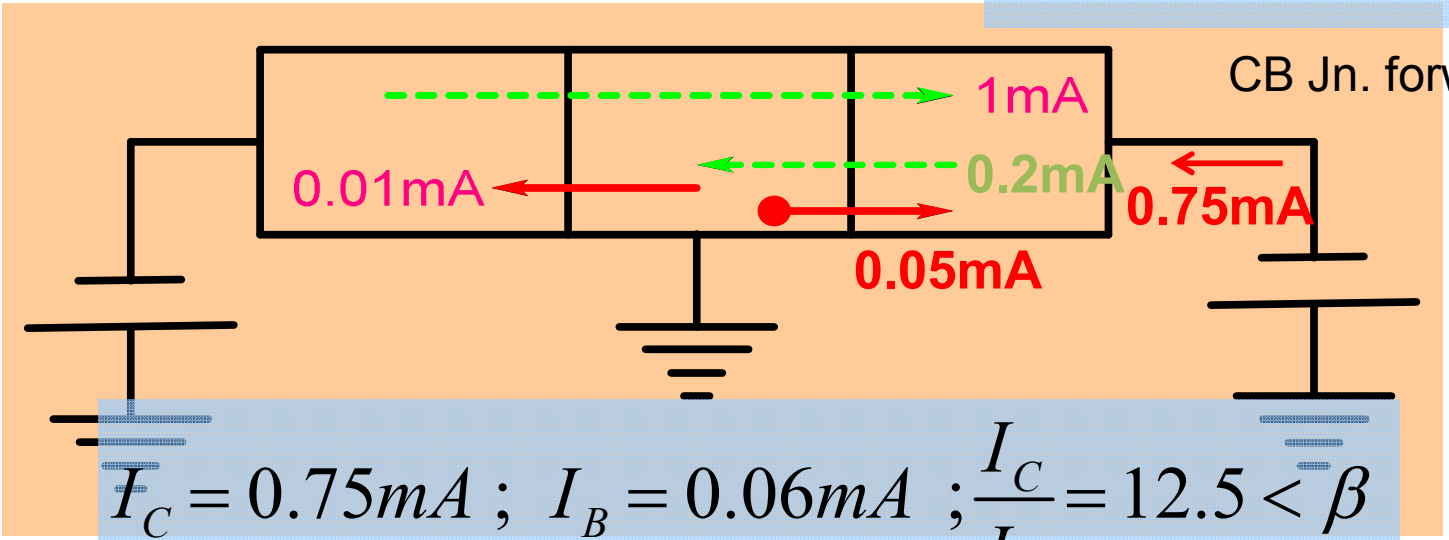
$$I_C = 1mA\ ;\ I_B = 0.01mA$$

$$\frac{I_C}{I_B} = 100 = \beta$$



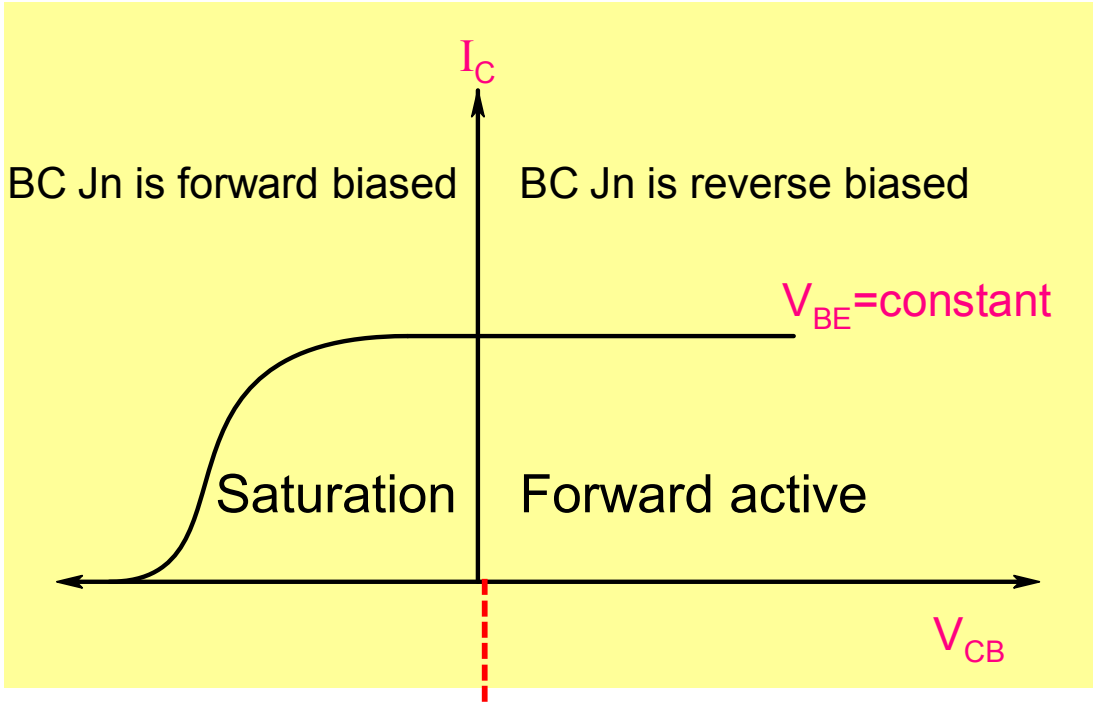
CB Jn. zero biased

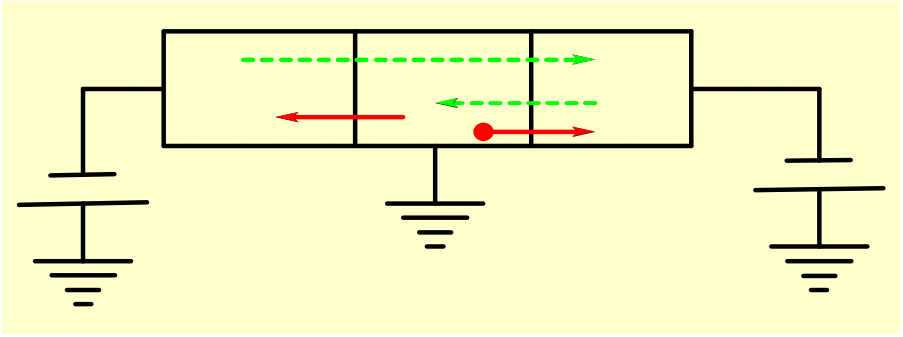


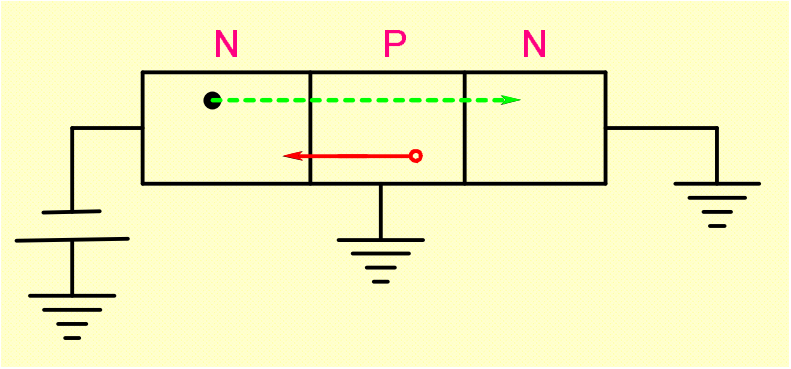


CB Jn. forward biased

$$I_C = 0.75mA\ ;\ I_B = 0.06mA\ ;\ \frac{I_C}{I_B} = 12.5 < \beta$$





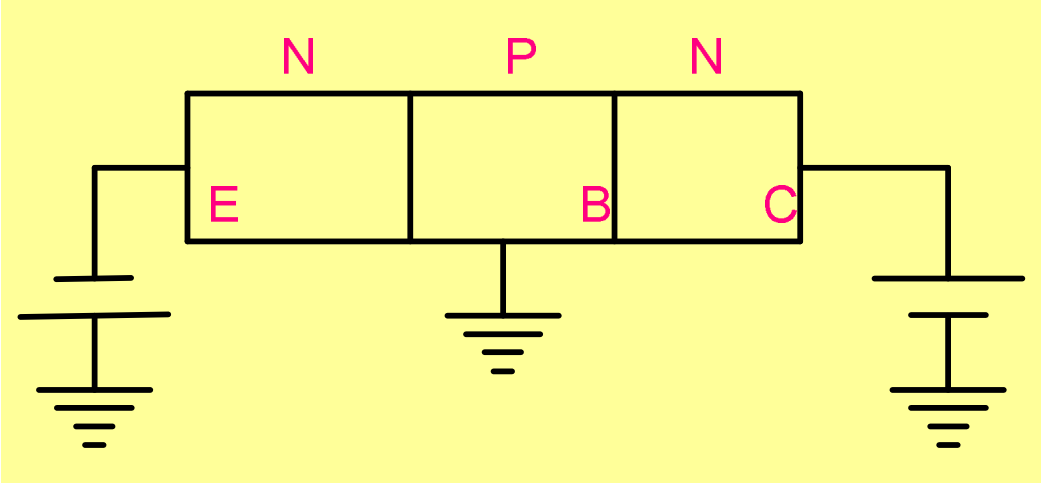


$$\frac{I_C}{\beta \times I_B} < 1$$

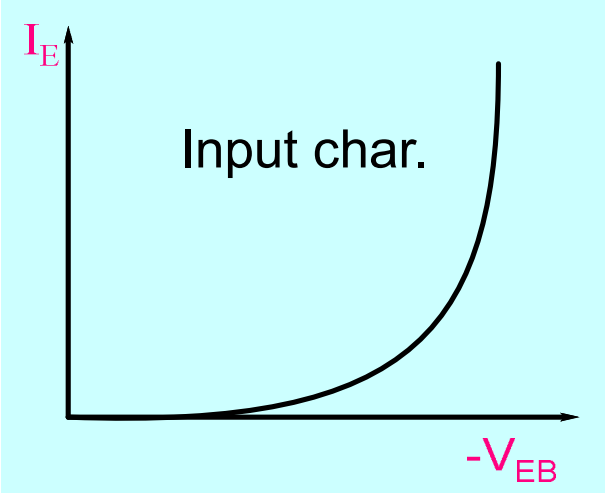
$$\frac{I_C}{\beta \times I_B} = 1$$

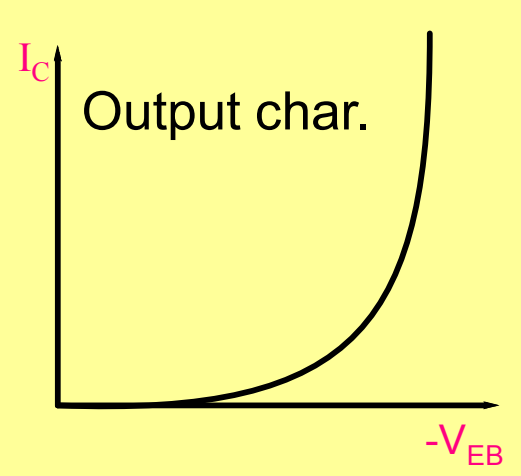
Forward Active Mode

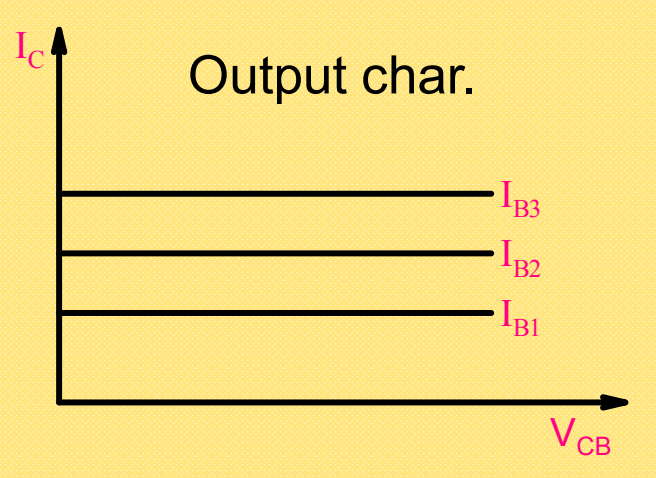
Common-Base



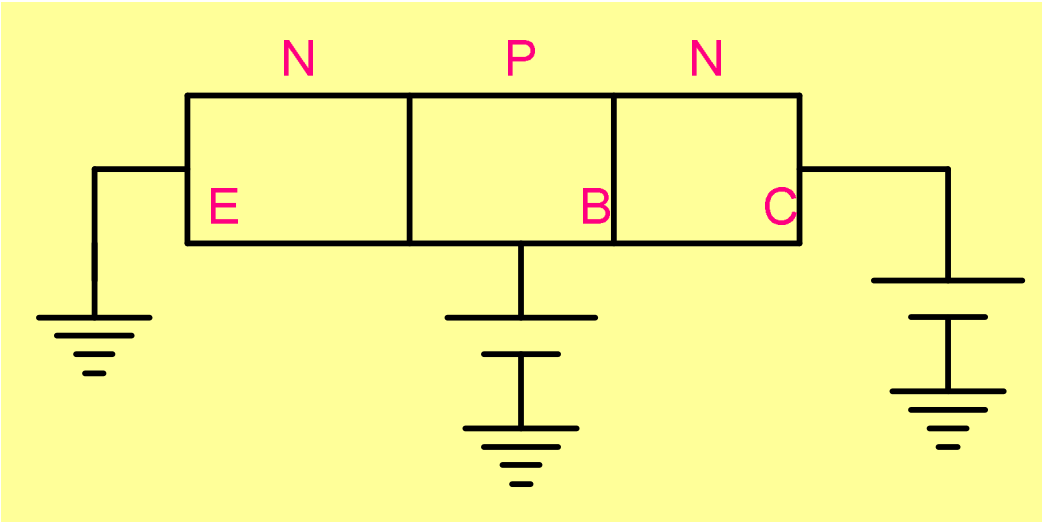
$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right) \quad ; \quad I_B = \frac{I_C}{\beta_F}$$

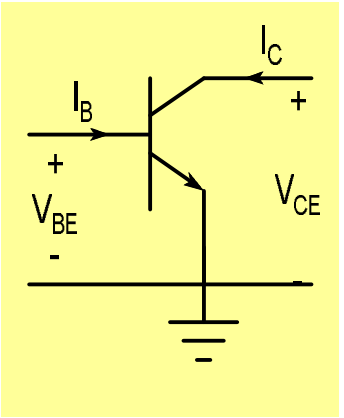




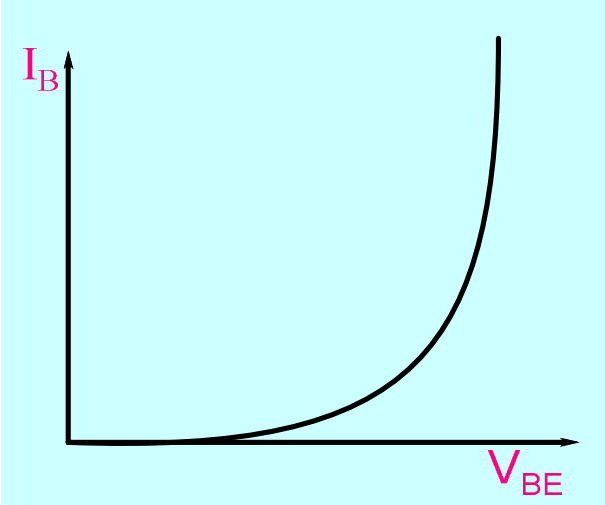


Common-Emitter

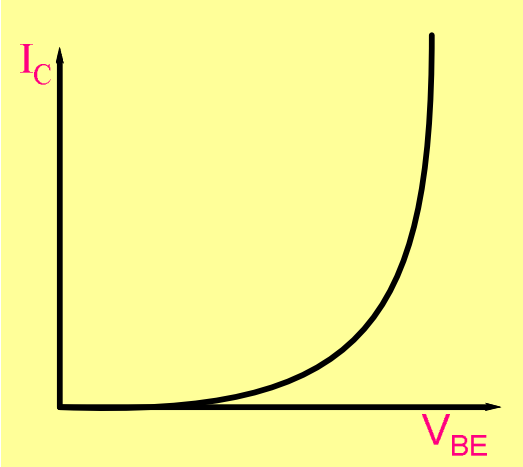




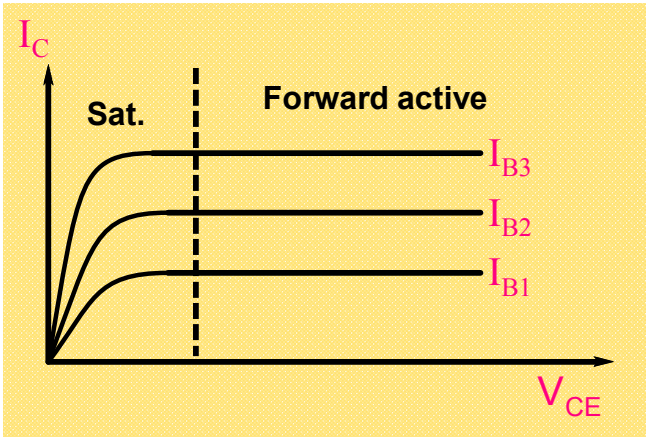
Input char.

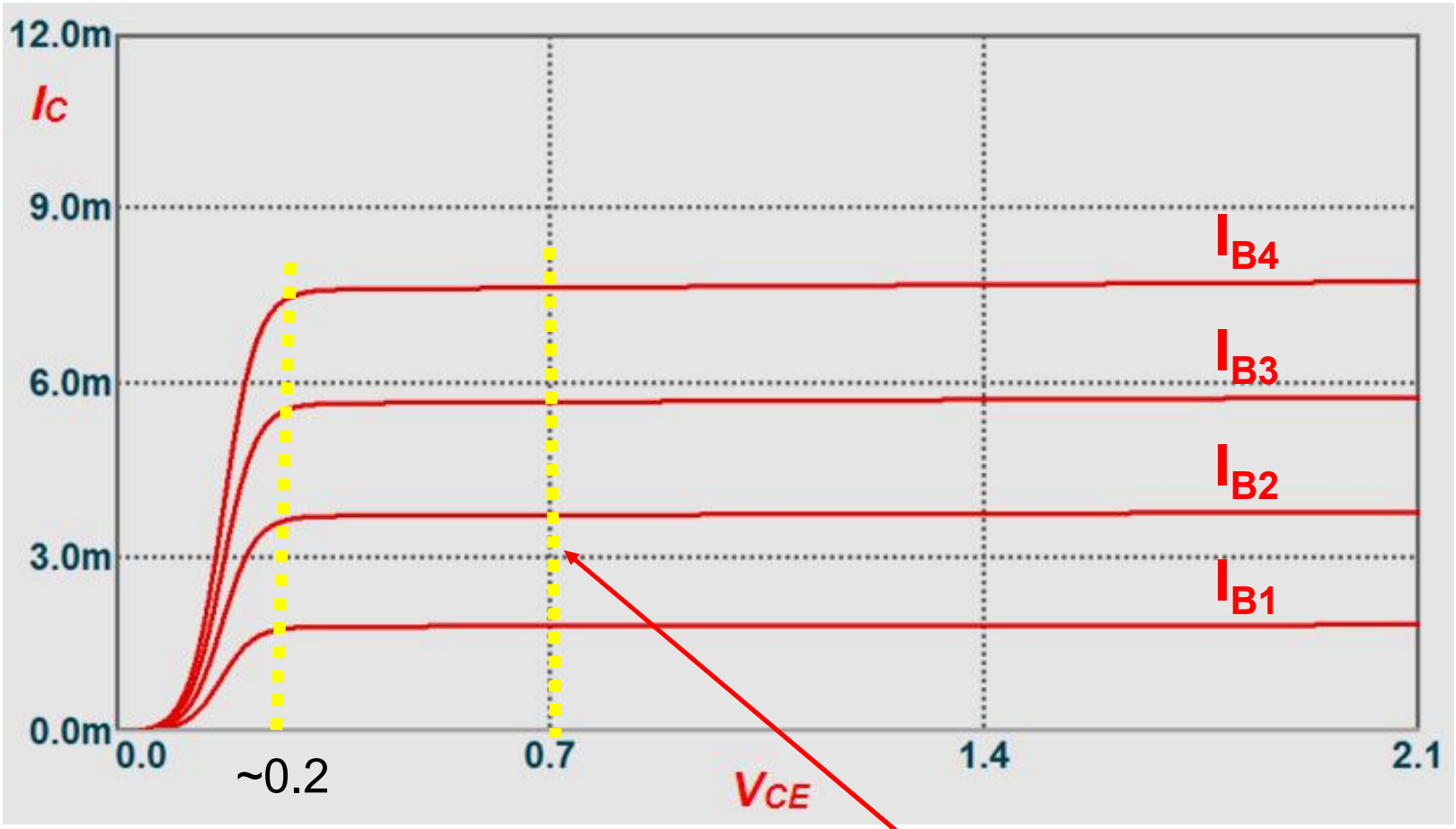


Output char.



Output char.





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

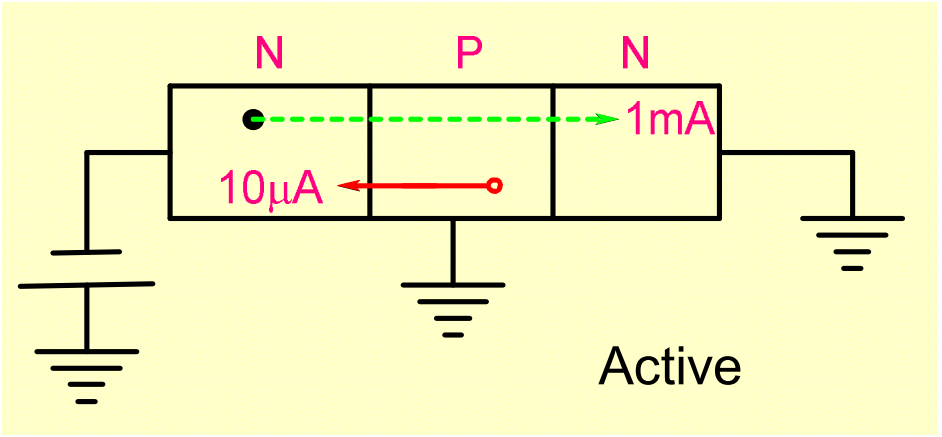
$= V_{BE} - V_{BC}$

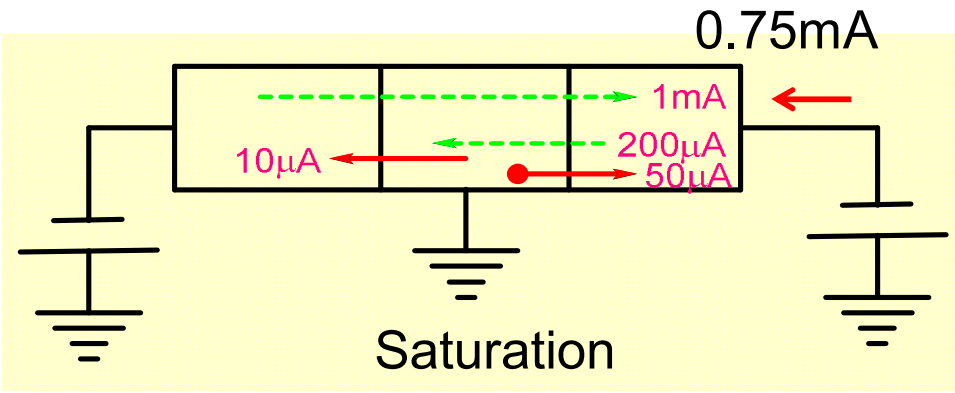
$$V_{BC} = 0.7 - V_{CE}$$

CbB jn. Starts to get forward biased

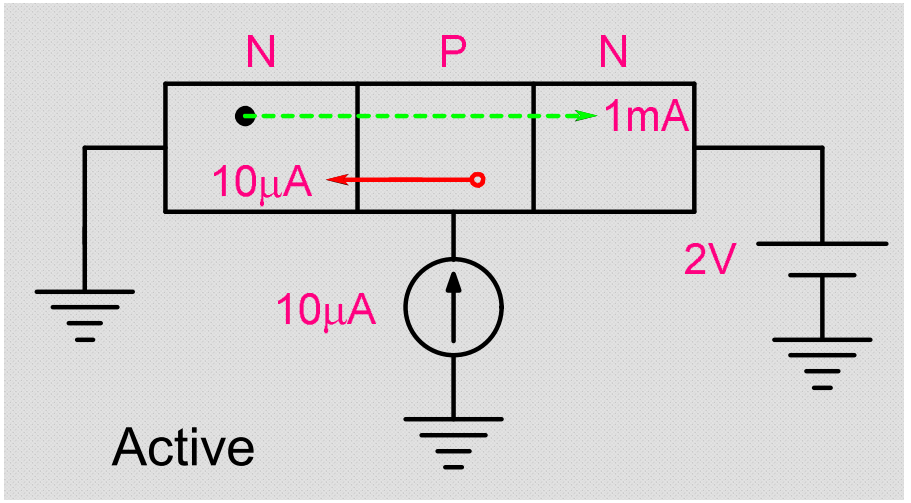
Note that in saturation: $\frac{I_C}{\beta I_B} < 1$

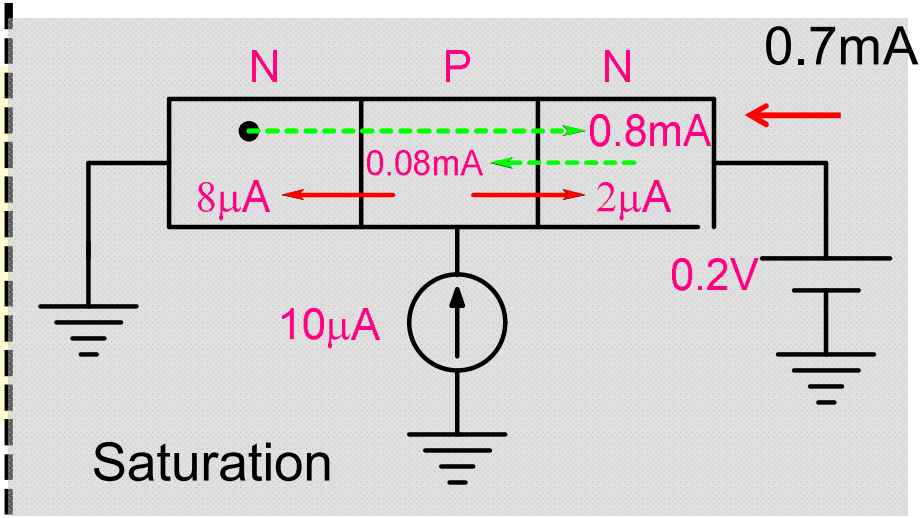
CB


N
P
N
1mA
10μA
Active

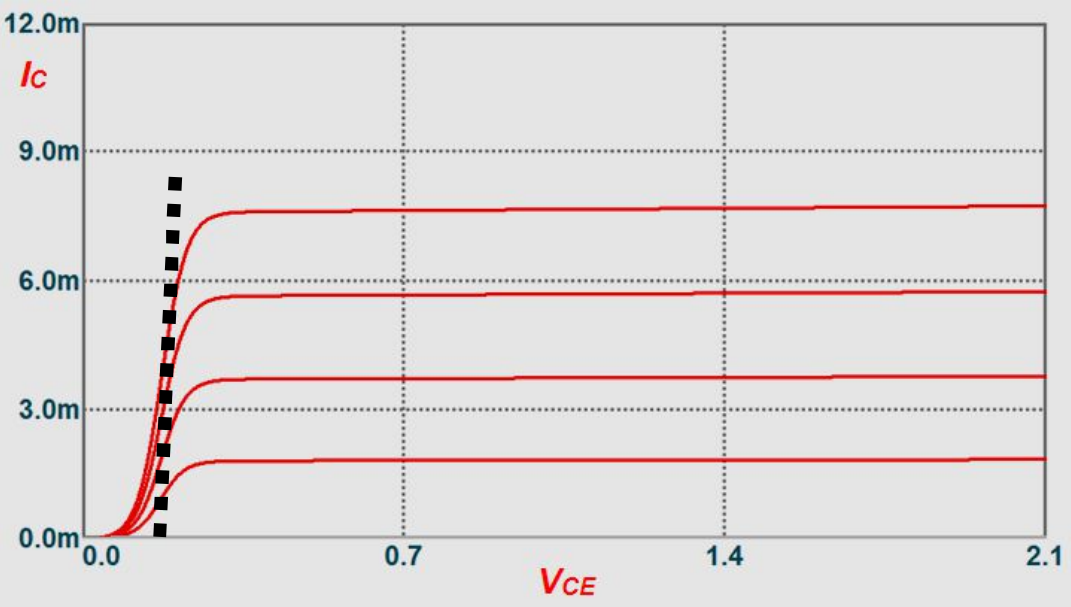

0.75mA
1mA
10μA
200μA
50μA
Saturation

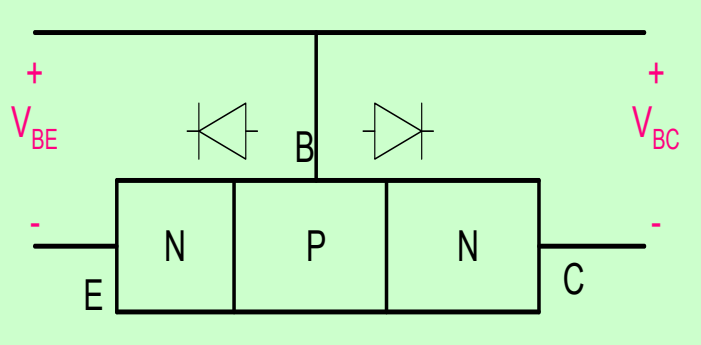
CE

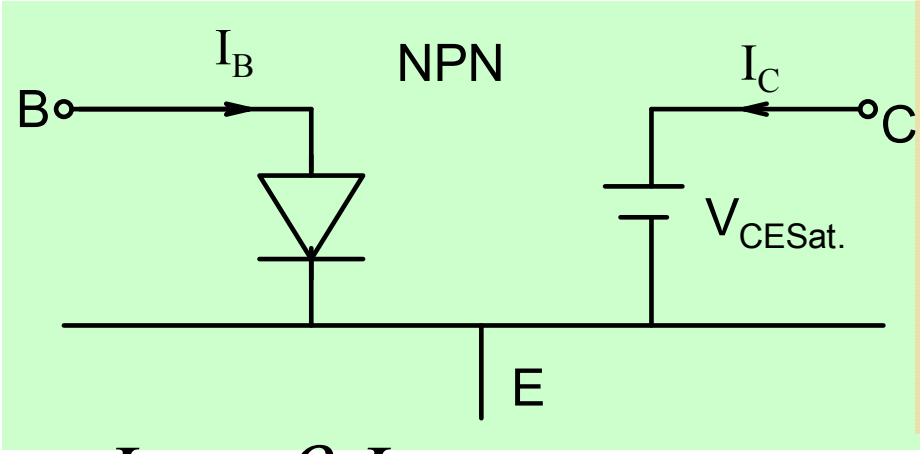

N
P
N
1mA
10μA
2V
10μA
Active

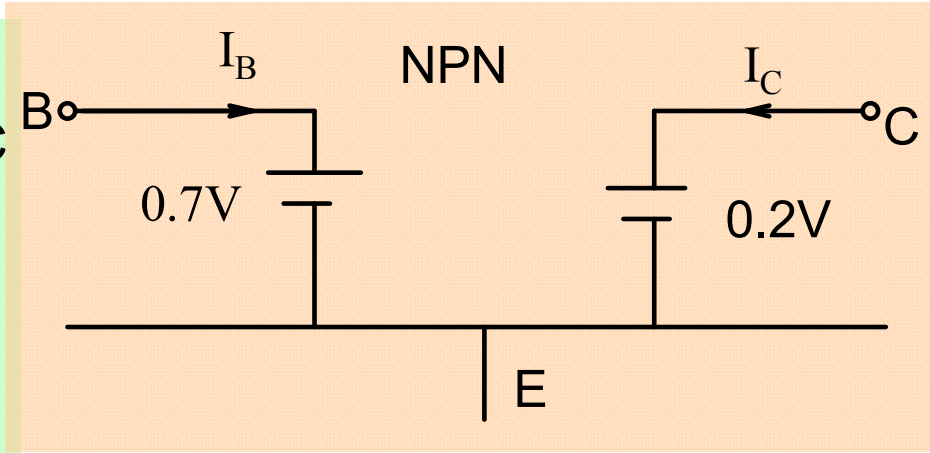

0.7mA
N
P
N
0.8mA
0.08mA
8μA
2μA
0.2V
10μA
Saturation

Model of a BJT in Saturation mode



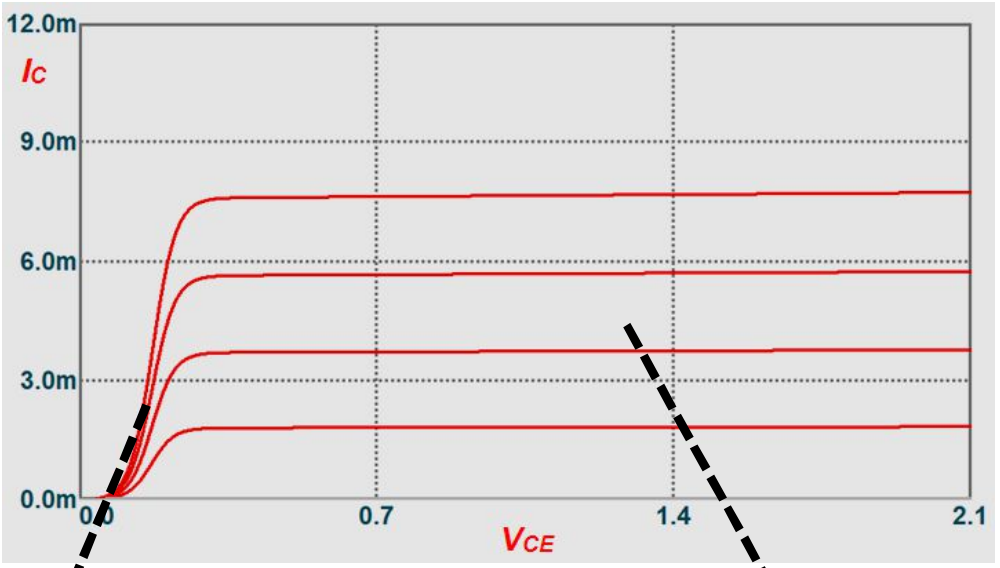


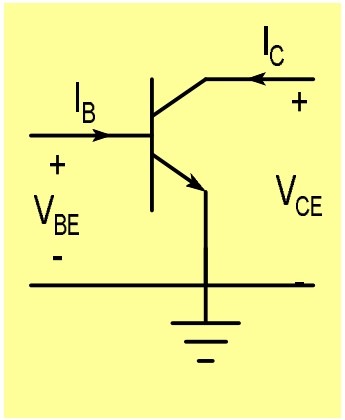


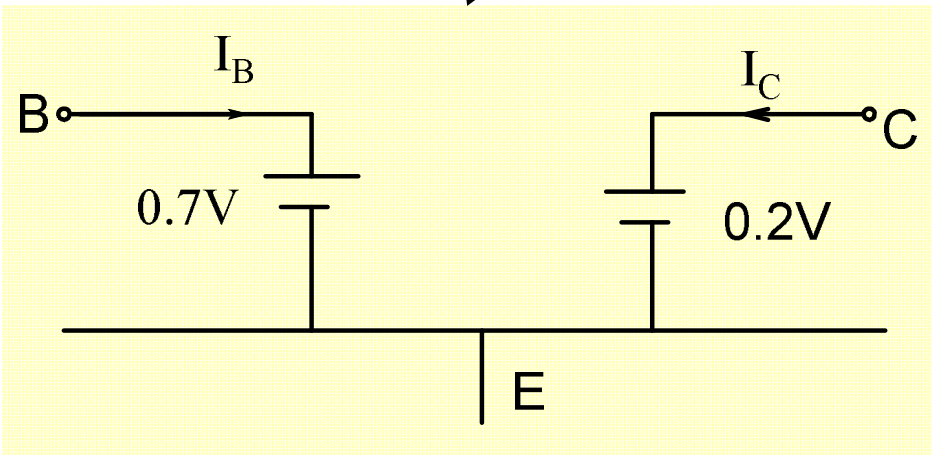


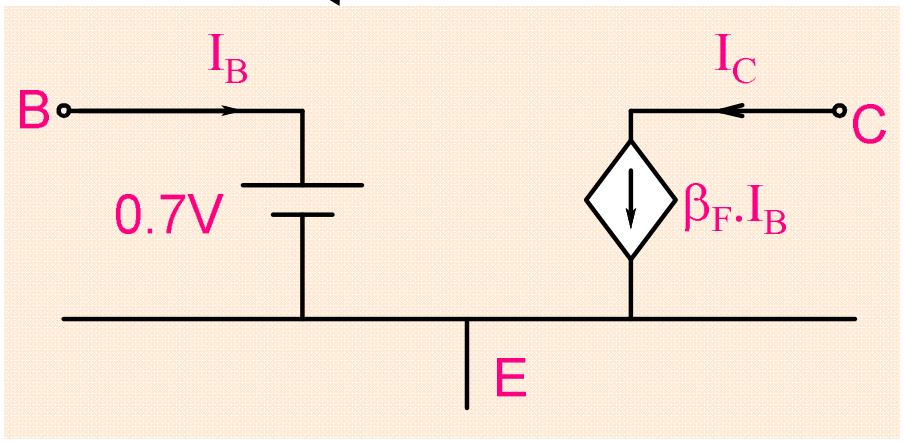
$$I_C \neq \beta I_B \qquad V_{CESat.} \cong 0.2V$$

Simplified Model



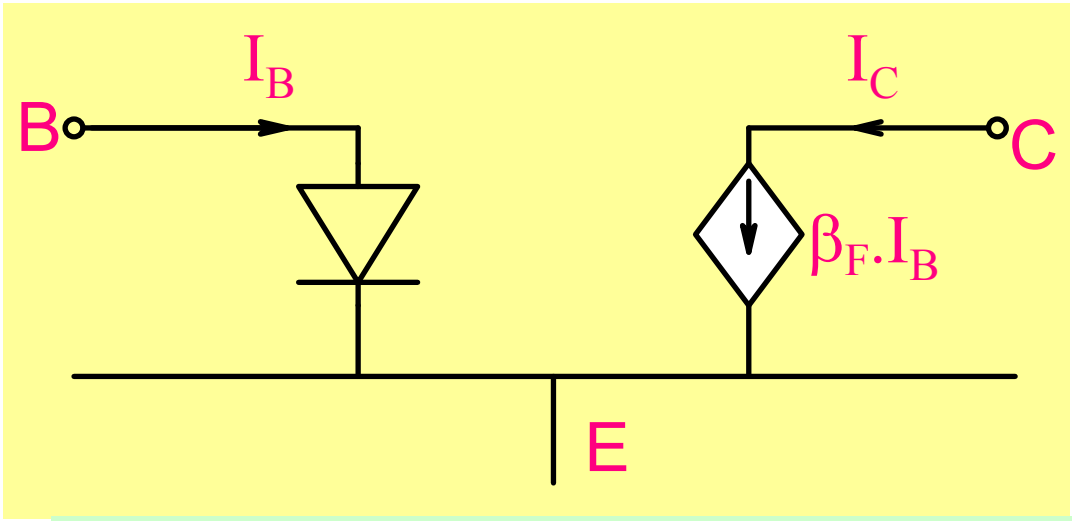






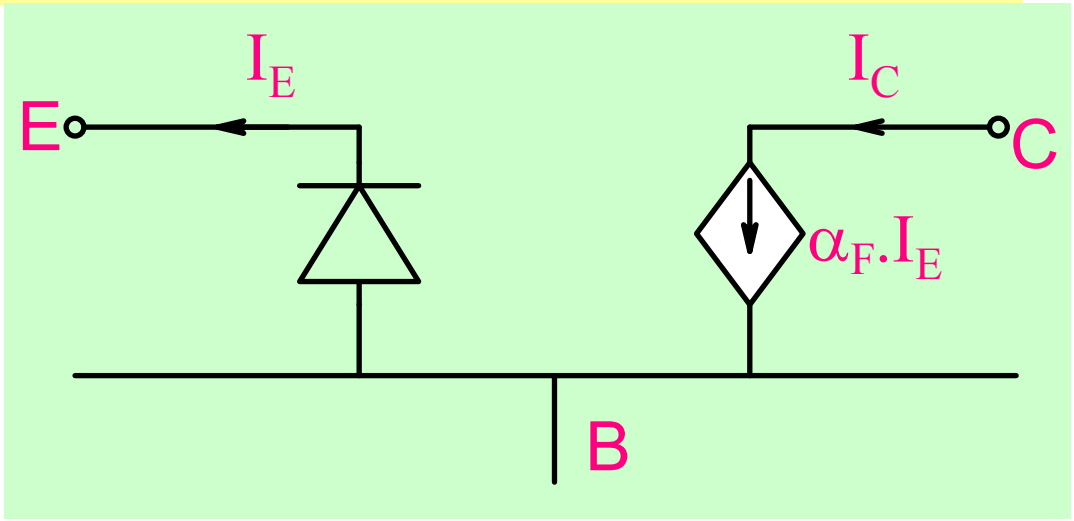
Generalized Transistor Model

Forward Active Mode



$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)$$

$$I_B = \frac{I_C}{\beta_F}$$



$$I_C = \beta_F \times I_B$$

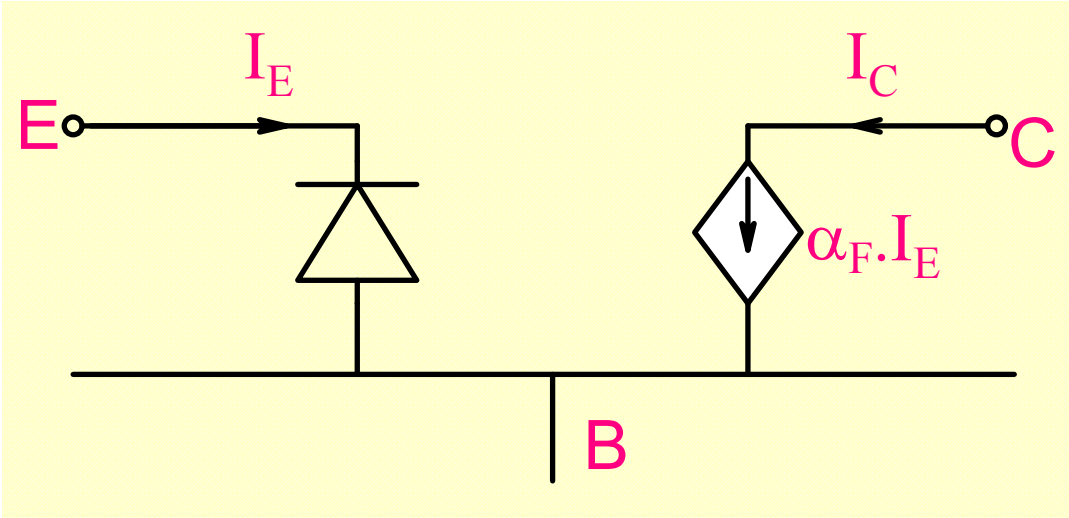
$$I_E = I_C + I_B$$

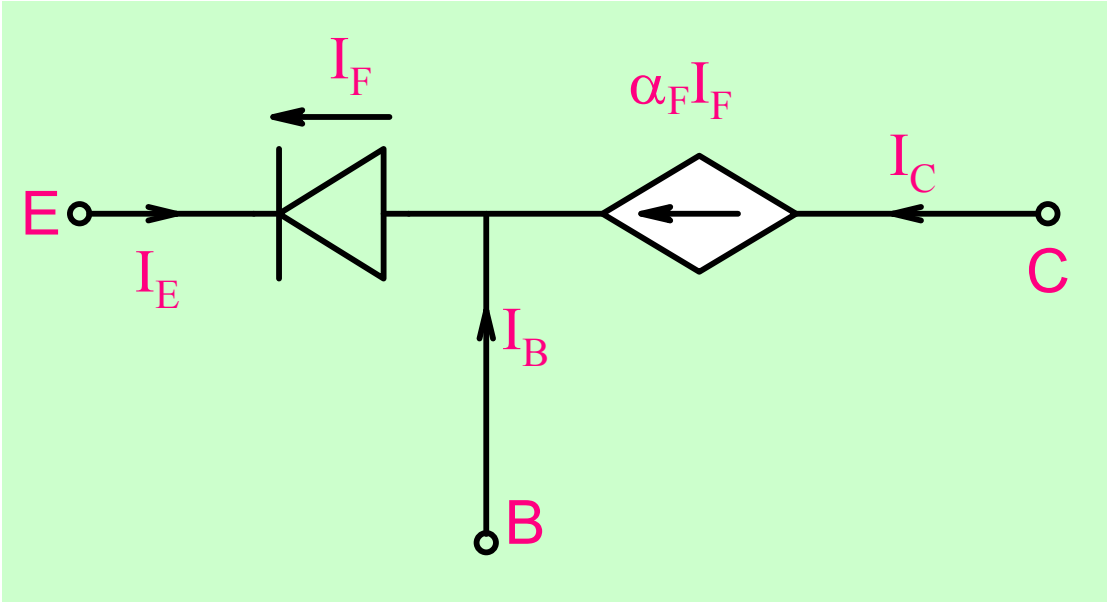
$$I_C = \alpha_F \times I_E$$

$$\alpha_F = \frac{\beta_F}{1+\beta_F}$$

β_F : Common Emitter Current Gain

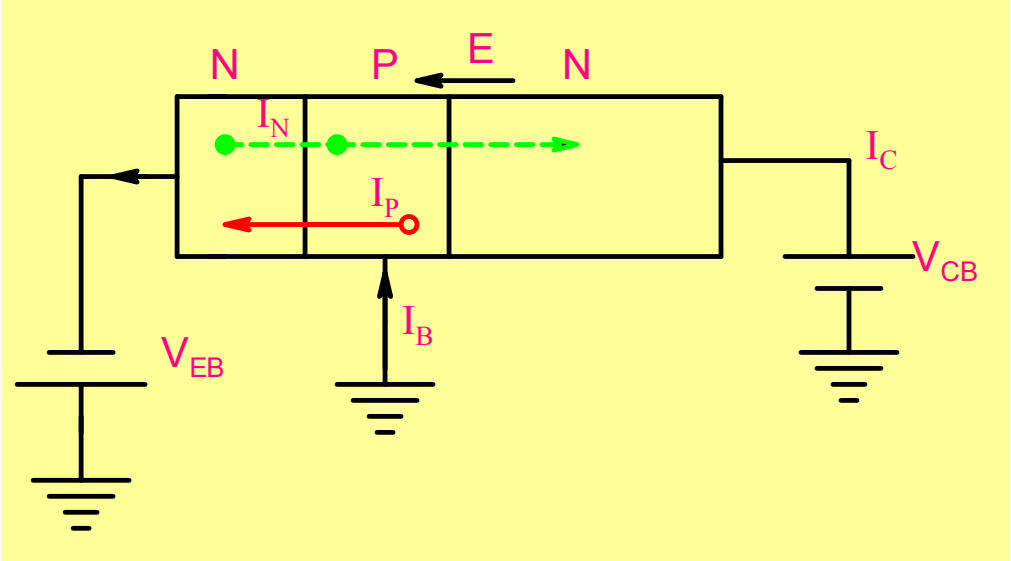
α_F : Common Base Current Gain

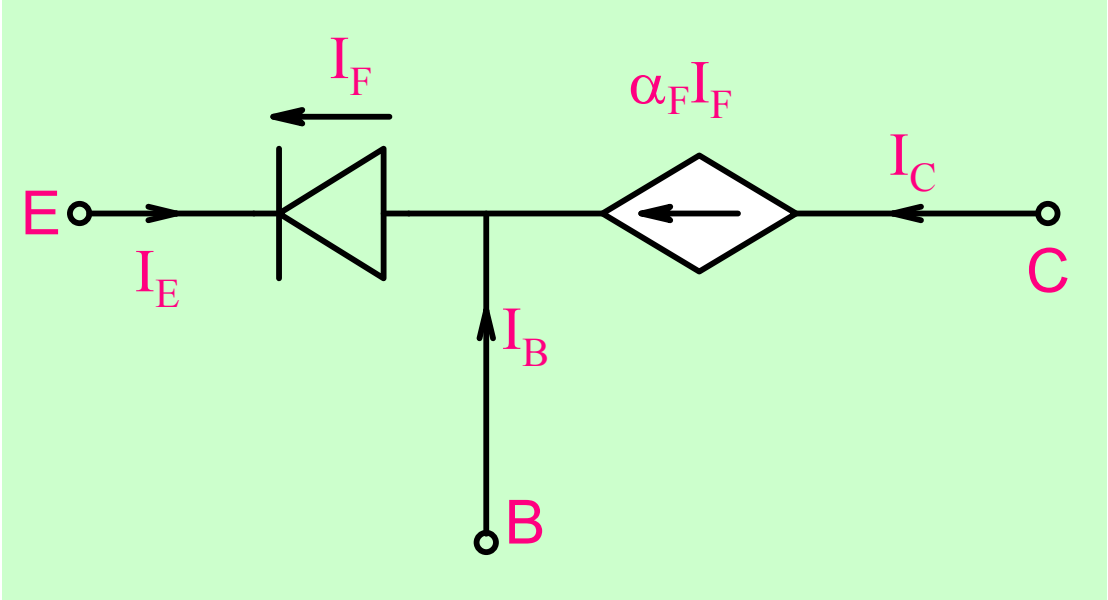




Forward Active Mode

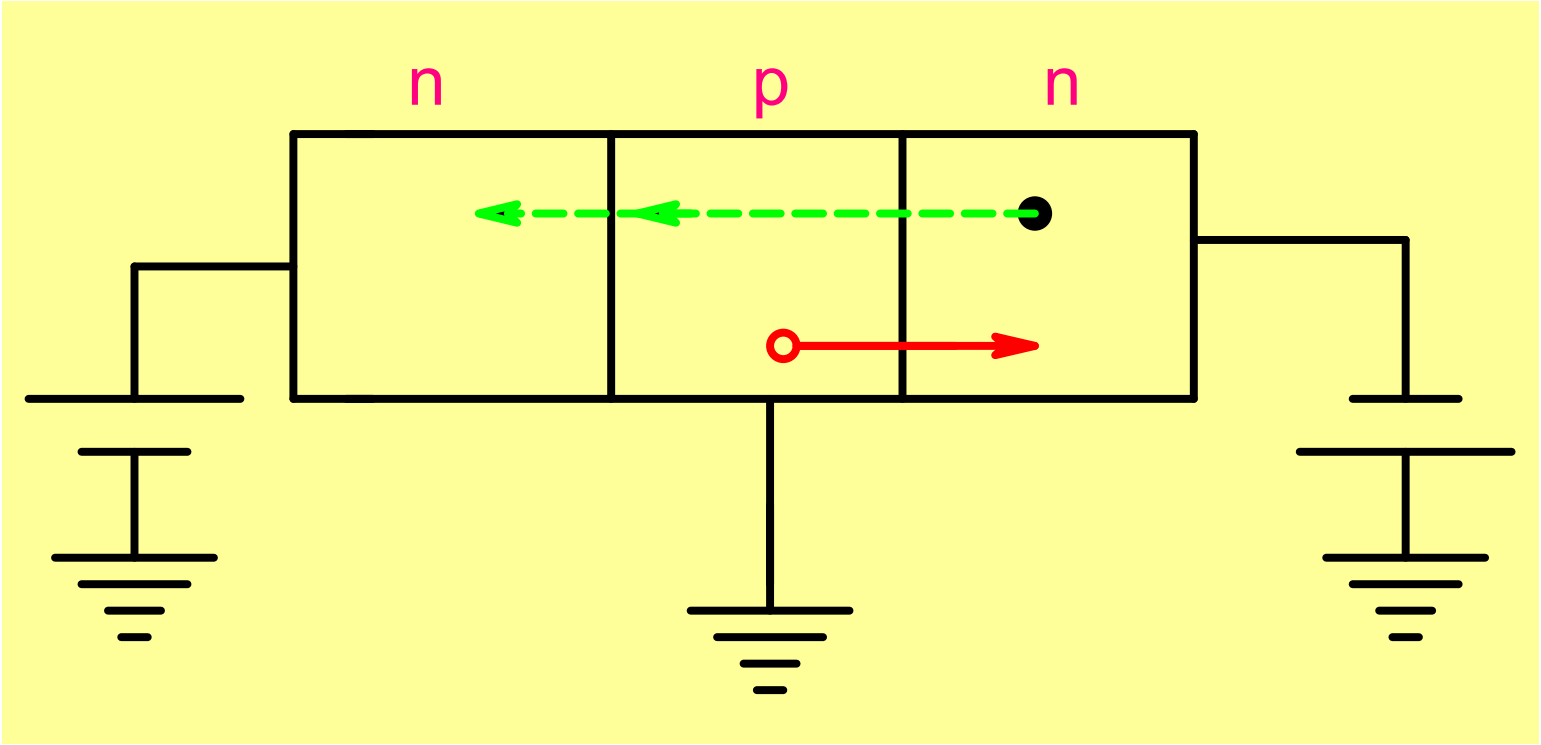
Forward Active Mode

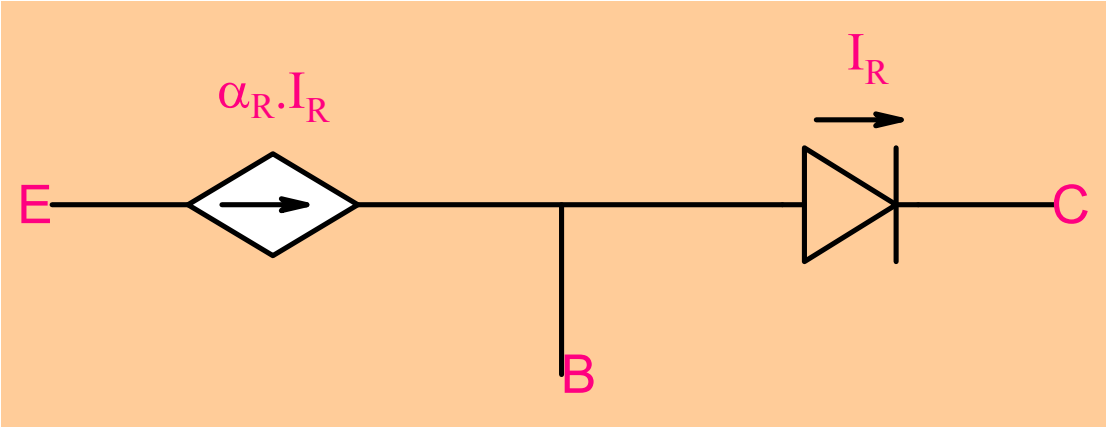




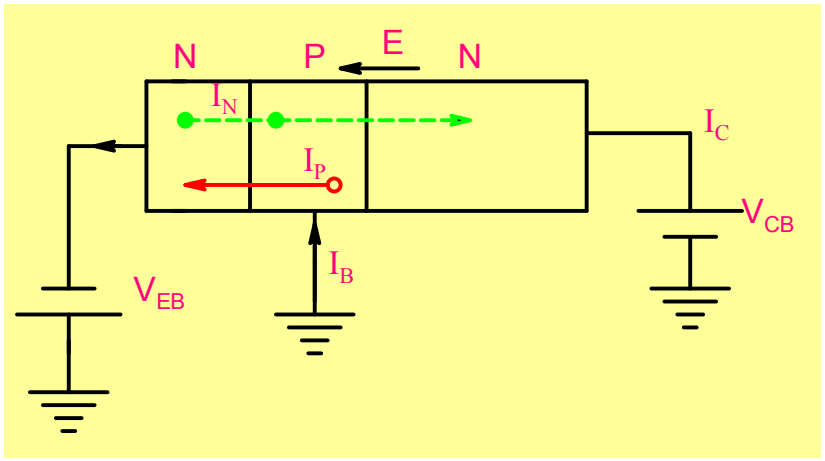
$$\beta_F = \frac{\alpha_F}{1-\alpha_F}$$

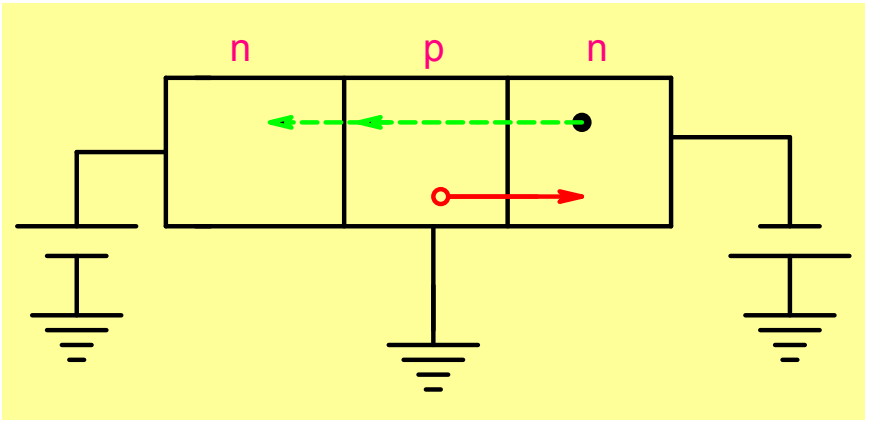
Reverse Active Mode

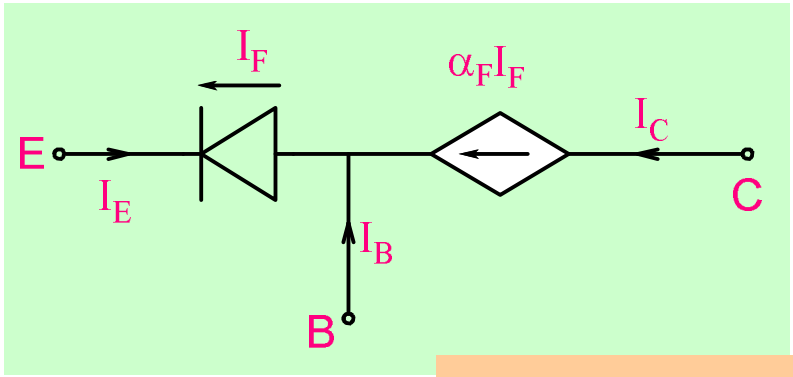


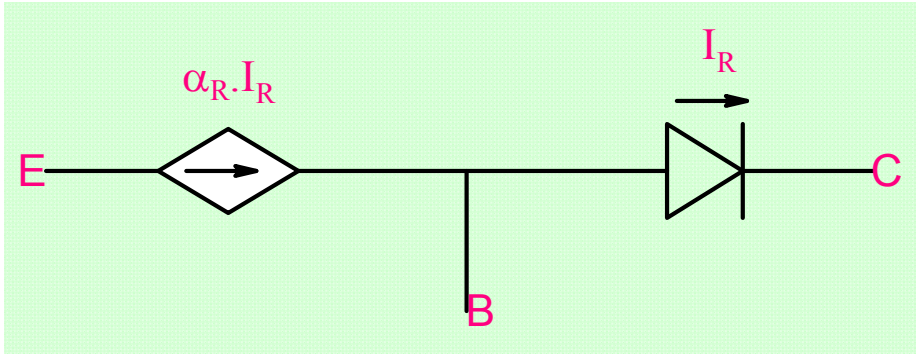


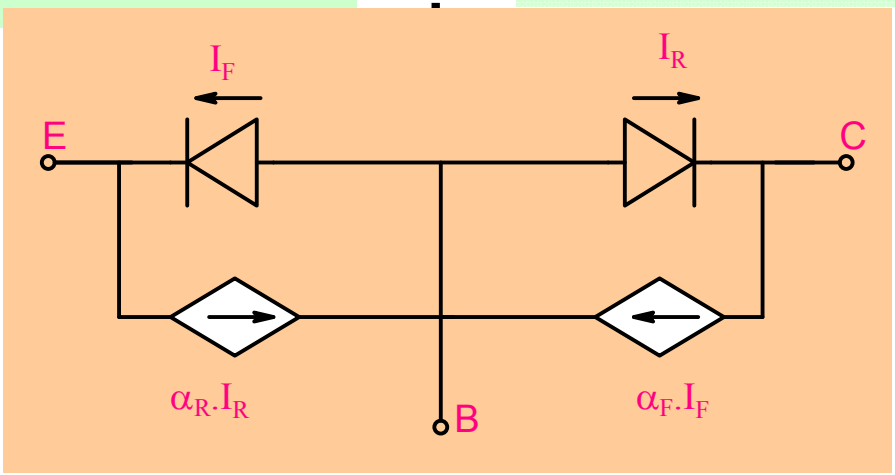
$$\beta_R = \frac{\alpha_R}{1-\alpha_R}$$


N
P
E
N
I_N
I_P
I_B
I_C
V_{CB}
V_{EB}


n
p
n


I_F
$\alpha_F I_F$
I_C
E
I_E
C
I_B
B


$\alpha_R.I_R$
I_R
E
C
B


I_F
I_R
E
C
$\alpha_R.I_R$
B
$\alpha_F.I_F$

Ebers Moll Model