IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Microelectronics: Devices to Circuits

BJT as a Switch and Ebers Moll Model

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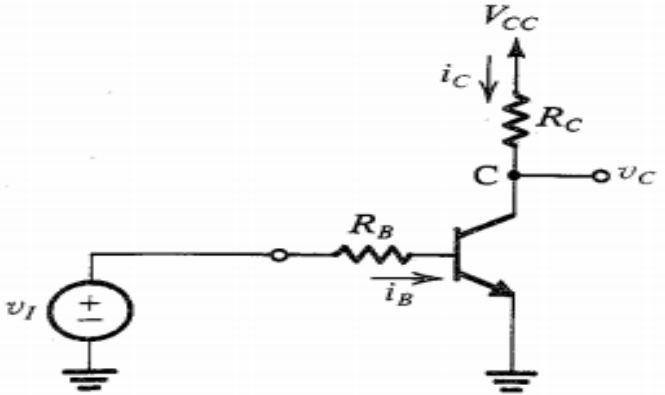


Outline

- BJT as a switch
- Ebers-moll model
- Ebers-moll model equations
- Transistor operating in Normal Mode or Forward active mode
- Transistor operating in Inverse Mode or Reverse active mode
- Ebers Moll Model of PNP and NPN Transistor
- Recapitulation

BJT as a Switch

- Logic gate can turn loads ON (BJT in Saturation) or OFF (BJT in Cut-off).
- Consider the common emitter circuit.



Vi< 0.5 V transistor off

Vi> 0.7 V transistor on

Assume Vbe= 0.7 V

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

$$I_B = \frac{v_I - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

$$v_C = V_{CC} - R_C i_C$$

$$I_{C(EOS)} = \frac{V_{CC} - 0.3}{R_C}$$

$$I_{B(EOS)} = \frac{I_{C(EOS)}}{\beta}$$

$$V_{I(EOS)} = I_{B(EOS)} R_B + V_{BE}$$

$$I_{Csat} = \frac{V_{CC} - V_{CEsat}}{R_C}$$

$$\beta_{forced} = \frac{I_{Csat}}{I_B}$$

$$V_{CEsat} = 0.2V$$

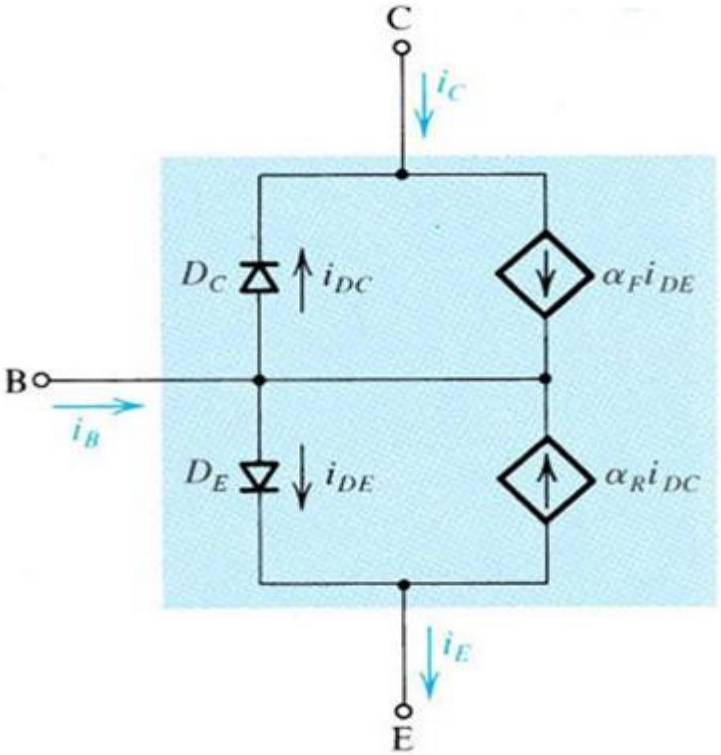
EOS- Edge of saturation

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Ebers Moll Model (EM)

- The Ebers Moll Model (EM) is a large-signal Model for BJT, It relates the transistor d.c. terminals currents to voltage.
- EM Model is low frequency (static) model based on the fact that BJT is composed of two pn junctions –EB and CB junction.
- Therefore terminal currents of BJT can be expressed as a superposition of the currents due to the two pn junction.
- Ebers- Moll equations is that I_E and I_C are described by resembling diode relations(I_{CI} and I_{EN}), plus terms which provide coupling between the properties of the emitter and collector.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



$$i_E = i_{DE} - \alpha_R i_{DC}$$

$$i_C = -i_{DC} + \alpha_F i_{DE}$$

$$i_B = (1-\alpha_F) i_{DE} + (1-\alpha_R) i_{DC}$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Equations of Ebers Moll Model (EM)

$$i_{DE} = I_{SE}\left(e^{\frac{v_{BE}}{v_T}} - 1\right)$$

$$i_{DC} = I_{SC}\left(e^{\frac{v_{BC}}{v_T}} - 1\right)$$

$$i_E = \left(\frac{I_S}{\alpha_F}\right)\left(e^{\frac{v_{BE}}{v_T}} - 1\right) - I_S\left(e^{\frac{v_{BC}}{v_T}} - 1\right)$$

$$i_C = -\left(\frac{I_S}{\alpha_F}\right)\left(e^{\frac{v_{BC}}{v_T}} - 1\right) + I_S\left(e^{\frac{v_{BE}}{v_T}} - 1\right)$$

$$i_B = \left(\frac{I_S}{\beta_F}\right)\left(e^{\frac{v_{BE}}{v_T}} - 1\right) + \frac{I_S}{\beta_R}\left(e^{\frac{v_{BC}}{v_T}} - 1\right)$$

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

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

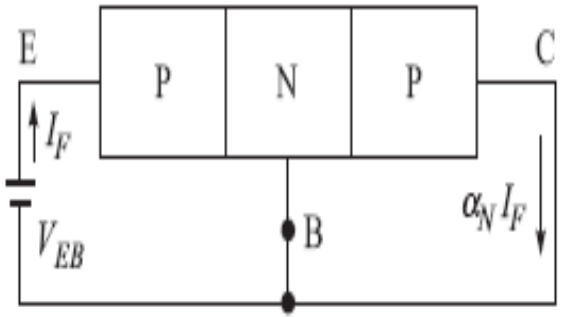
$$i_E = \left(\frac{I_S}{\alpha_F}\right)e^{\frac{v_{BE}}{v_T}} + I_S\left(1 - \frac{1}{\alpha_F}\right)$$

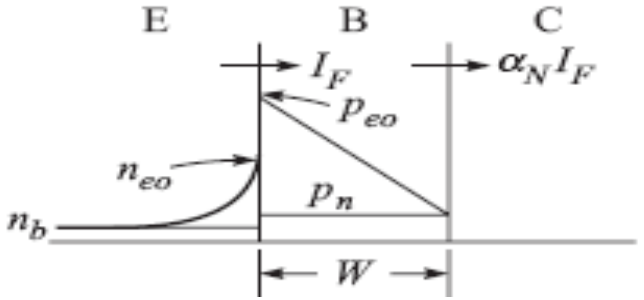
$$i_C = I_S e^{\frac{v_{BE}}{v_T}} + I_S\left(\frac{1}{\alpha_R} - 1\right)$$

$$i_B = \left(\frac{I_S}{\alpha_F}\right)e^{\frac{v_{BE}}{v_T}} + I_S\left(\frac{1}{\beta_F} + \frac{1}{\beta_R}\right)$$

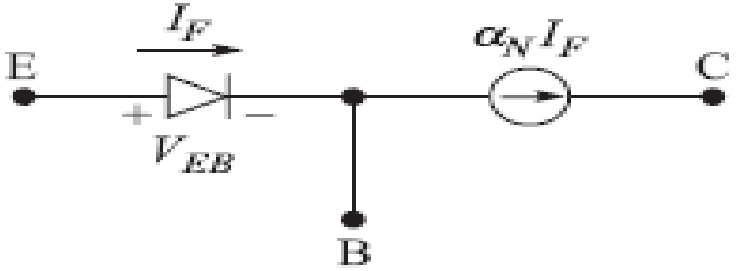
Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Transistor operating in Normal Mode or Forward active mode



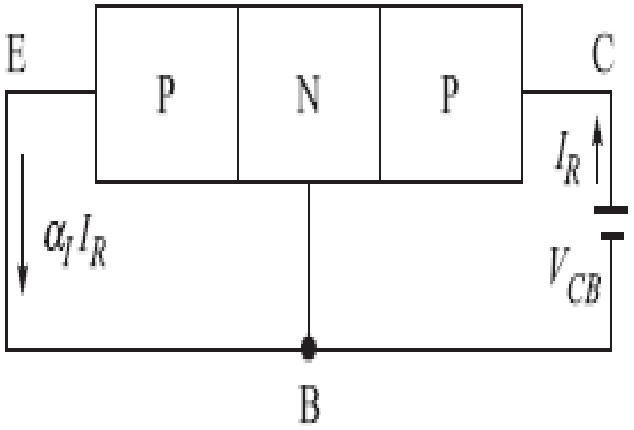


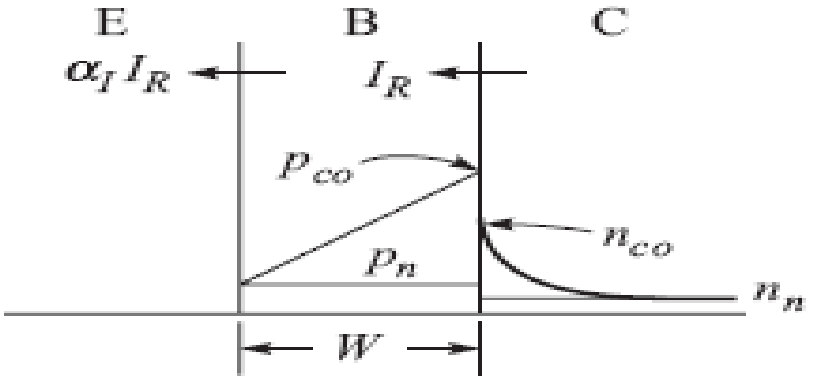
$$I_F = I_{ES}\left(e^{\frac{v_{EB}}{v_T}} - 1\right)$$

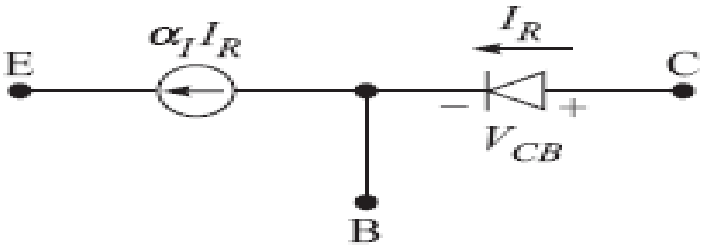


Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

Transistor operating in Inverse Mode or Reverse active mode



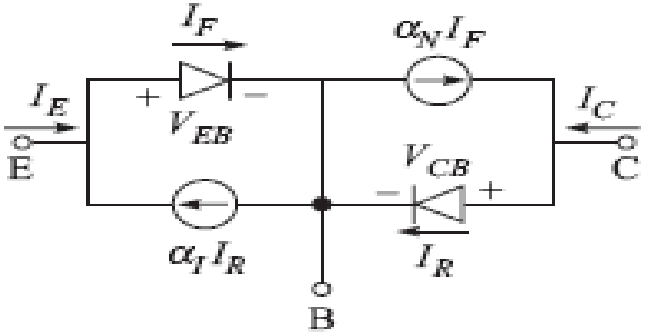


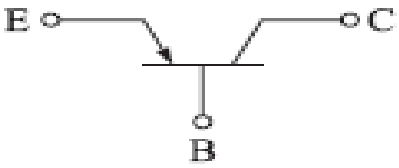


$$I_R = I_{CS}\left(e^{\frac{v_{CB}}{v_T}} - 1\right)$$

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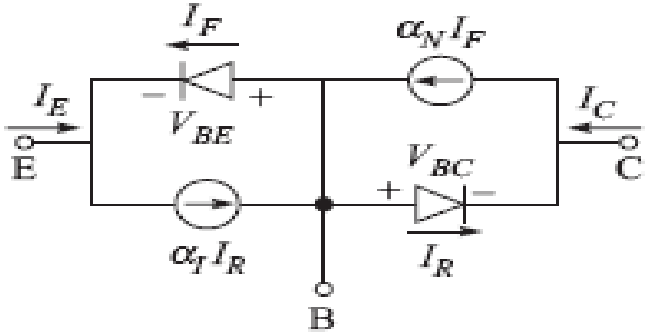
Ebers Moll Model of PNP and NPN Transistor

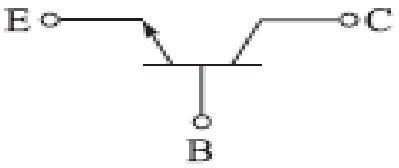




pnp

$$I_E = I_F - \alpha_I I_R$$
$$I_C = -\alpha_N I_F + I_R$$





npn

$$I_E = I_F + \alpha_I I_R$$
$$I_C = \alpha_N I_F - I_R$$

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

Recapitulation

- Ebers Moll model enables us to estimate the currents for all modes of BJT operation.
- BJT used as a switch in saturation mode.
- Ebers Moll model is a simple and elegant way of representing the transistor as a circuit model.
- Ebers moll model is based on assumption that base spreading resistance can be neglected.
- The Ebers-moll model runs into problems if a high degree of accuracy is required for very small BJTs, or where second order effects are important.

Thank You