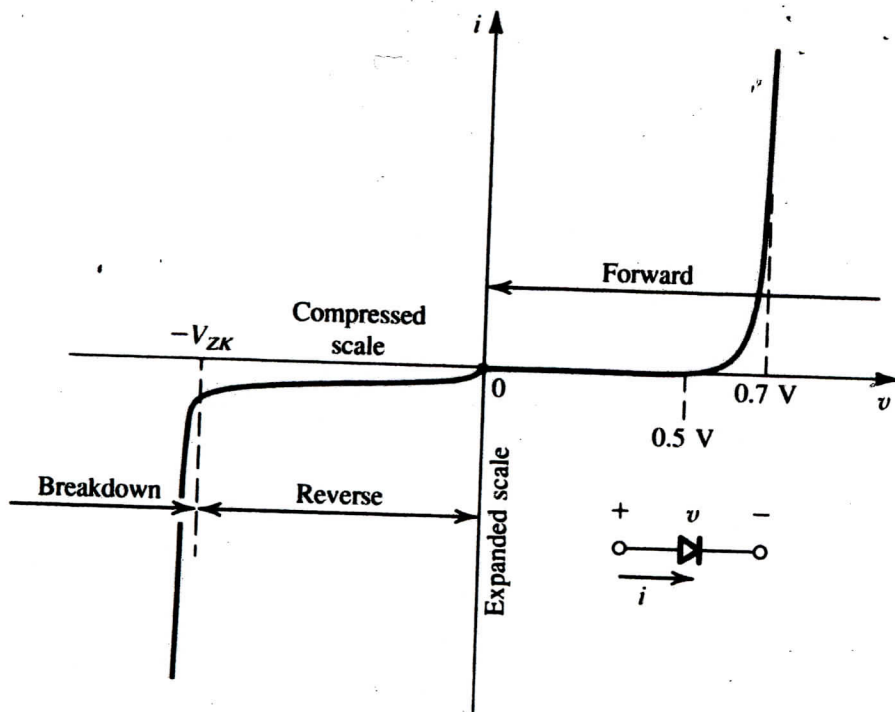


TYPICAL DIODE CHARACTERISTIC



$$i_D = I_S \left[e^{v_D/v_T} - 1 \right]$$

$$v_T = \frac{kT}{q}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$T = C^\circ + 273$$

Table 6.2 Summary of the **BJT** Current-Voltage Relationships in the Active Mode

$$i_C = I_S e^{v_{BE}/V_T}$$

$$i_B = \frac{i_C}{\beta} = \left(\frac{I_S}{\beta} \right) e^{v_{BE}/V_T}$$

$$i_E = \frac{i_C}{\alpha} = \left(\frac{I_S}{\alpha} \right) e^{v_{BE}/V_T}$$

Note: For the *pnp* transistor, replace v_{BE} with v_{EB} .

$$i_C = \alpha i_E$$

$$i_B = (1 - \alpha) i_E = \frac{i_E}{\beta + 1}$$

$$i_C = \beta i_B$$

$$i_E = (\beta + 1) i_B$$

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

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

$$V_T = \text{thermal voltage} = \frac{kT}{q} \approx 25 \text{ mV at room temperature}$$

Table 6.1 **BJT** Modes of Operation

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

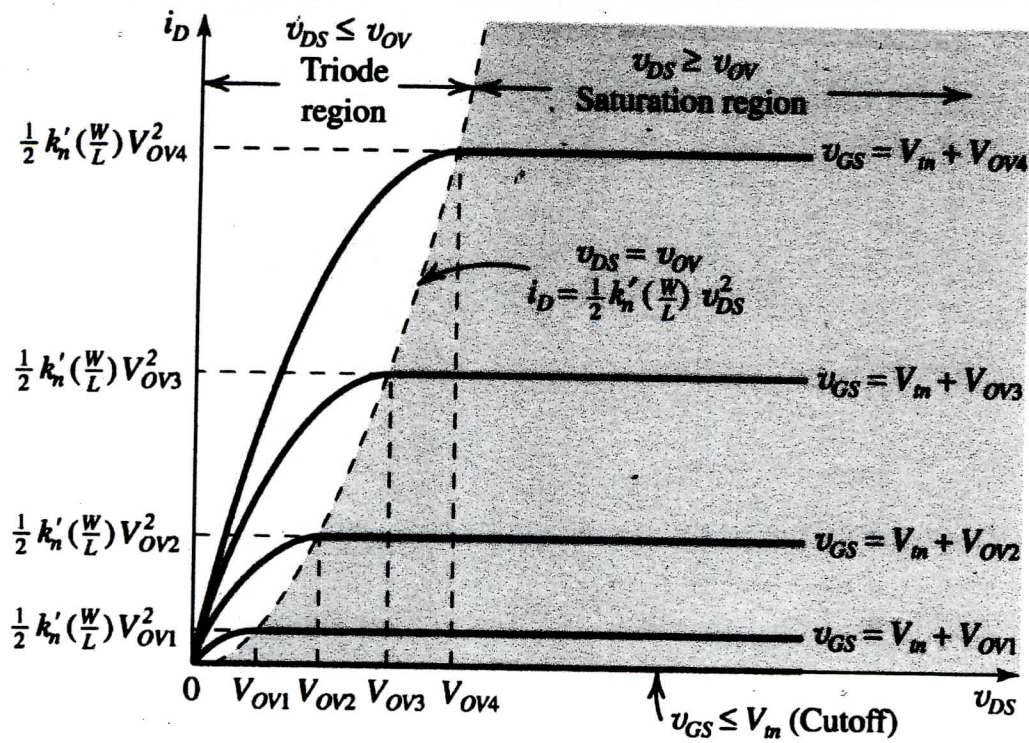
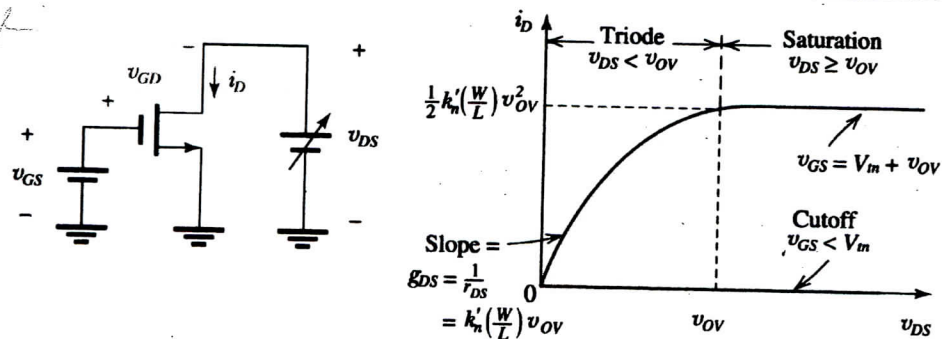


Table 5.1 Regions of Operation of the Enhancement NMOS Transistor



- $v_{GS} < V_{in}$: no channel; transistor in cutoff; $i_D = 0$
- $v_{GS} = V_{in} + v_{OV}$: a channel is induced; transistor operates in the triode region or the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{GD} > V_{in}$$

or equivalently:

$$v_{DS} < v_{OV}$$

Then,

$$i_D = k'_n \left(\frac{W}{L} \right) \left[(v_{GS} - V_{in}) v_{DS} - \frac{1}{2} v_{DS}^2 \right]$$

or equivalently,

$$i_D = k'_n \left(\frac{W}{L} \right) \left(v_{OV} - \frac{1}{2} v_{DS} \right) v_{DS}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{GD} \leq V_{in}$$

or equivalently:

$$v_{DS} \geq v_{OV}$$

Then

$$i_D = \frac{1}{2} k'_n \left(\frac{W}{L} \right) (v_{GS} - V_{in})^2$$

or equivalently,

$$i_D = \frac{1}{2} k'_n \left(\frac{W}{L} \right) v_{OV}^2$$