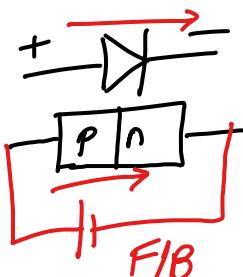


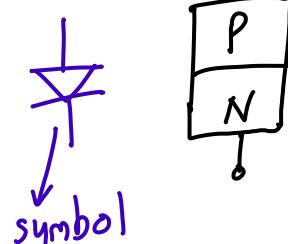
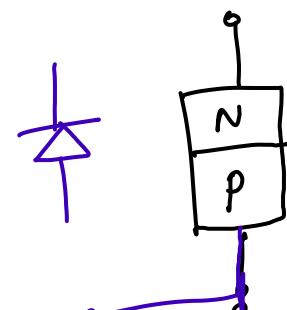
Module 1.1:

Bipolar Junction transistor (BJT)

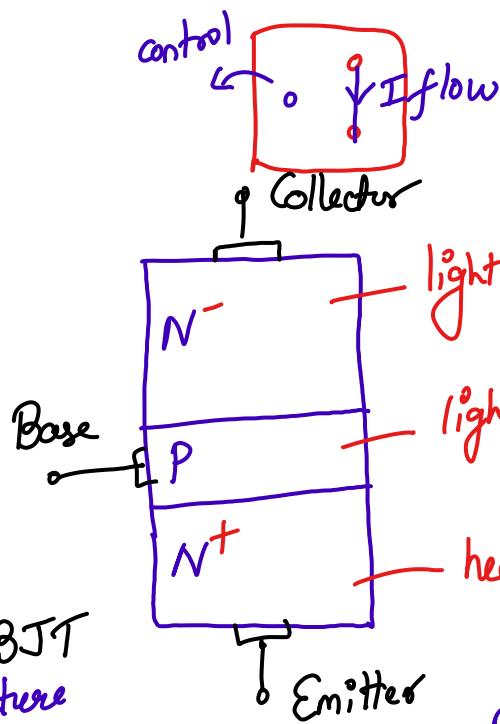
- Three Terminal device



2 terminal
device



$I_C = I_B e^{\frac{V_B}{V_T}}$ NPN BJT structure

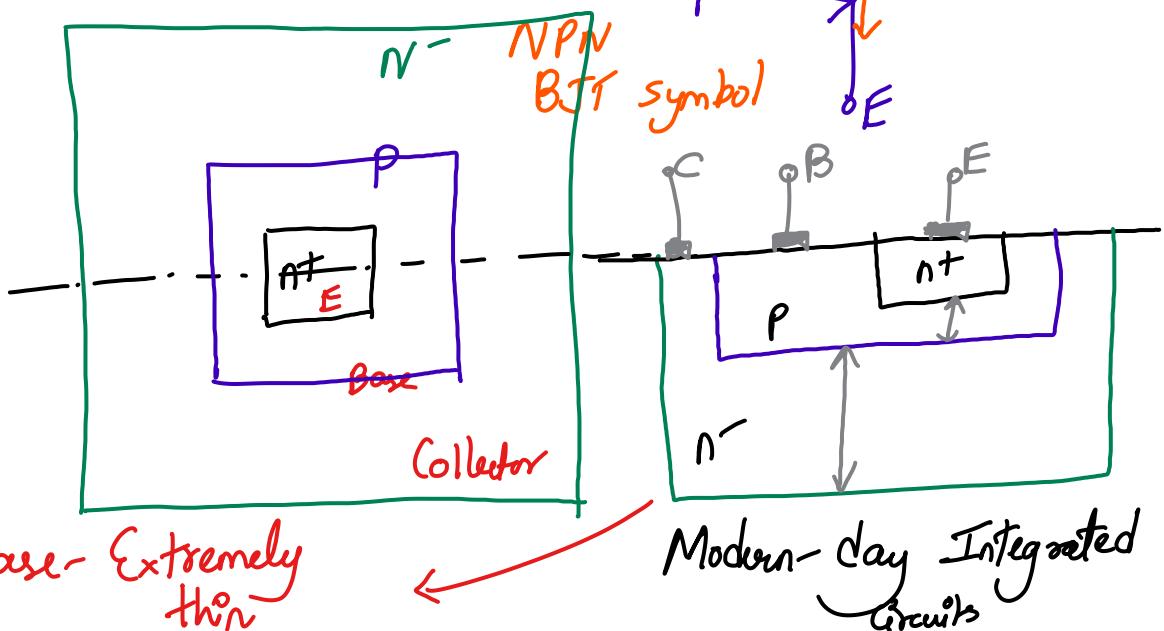
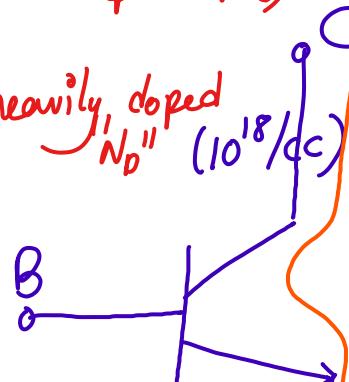


$V_I \uparrow \rightarrow D.L \uparrow$

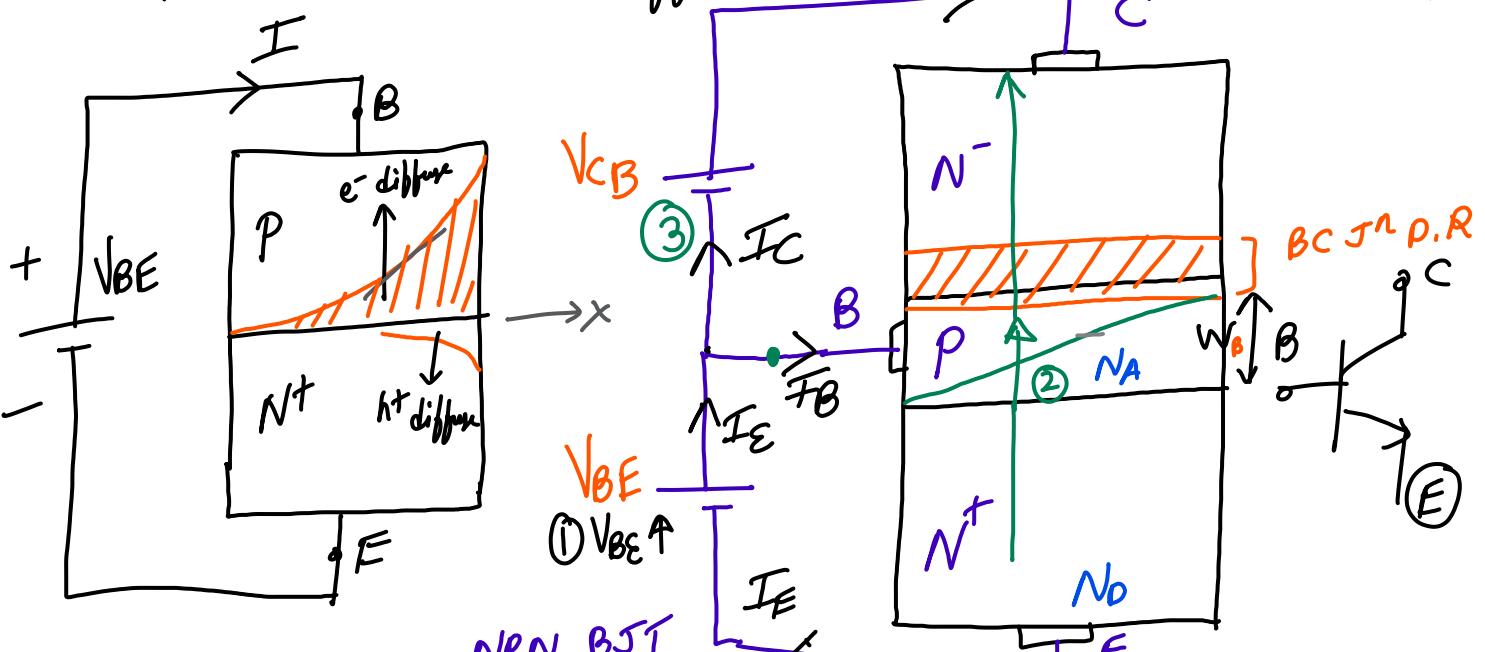
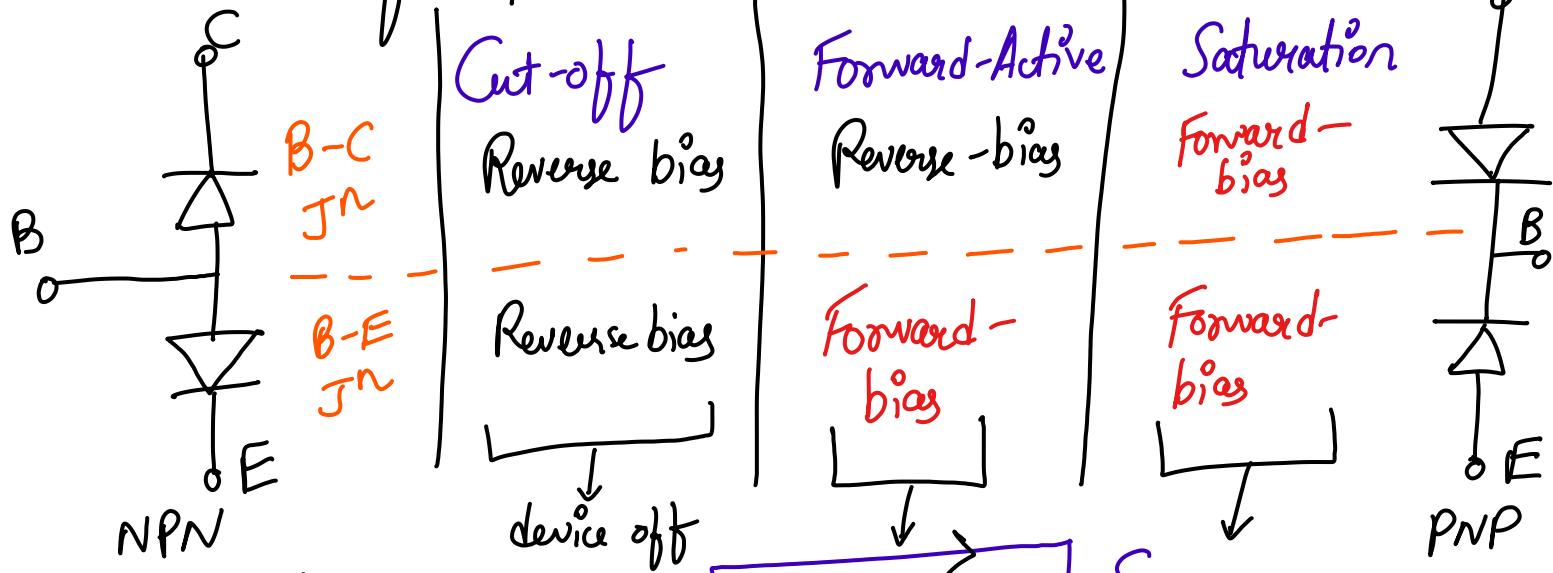
lightest doped ($10^{15}/cc$)

lighter doped (Acceptor doping) ($10^{16}/cc$)

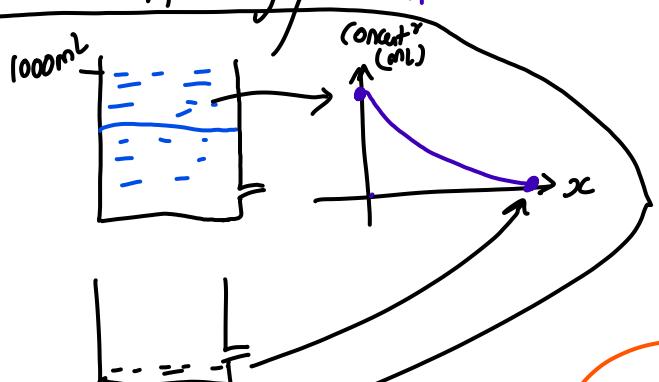
heavily doped N_D ($10^{18}/cc$)



* Modes of operations (BJT):



Analogy in Active mode



To \uparrow base current

① W_B (reduce Base width)

② $\frac{N_D}{N_A}$

$$I_C \approx I_S \exp\left(\frac{V_{BE}}{V_T}\right)$$

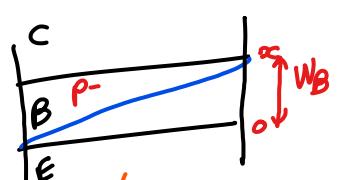
$$I_C = f(V_{BE})$$

$W_B \rightarrow$ \bar{c}^S concⁿ in P Si

$$n_p = \frac{n_i^2}{N_A}$$

Saturation current

$$I_S = A_E q \frac{dn_p}{dx} = A_E q \left(\frac{n_i^2}{N_A} \right) \frac{1}{W_B}$$



3, 18, 14, 22, 17
 41, 25, 24, 44,
 96, 93, 101, 67,
 7, 83, 95, 82, 69,
 61, 75, 4, 38, 45,
 16, 30, 11,
 89, 76, 97, 78,
 6, 58, 26, 64

Attendance: 19/7/23 (AEC lec.)

$$I_S = A_E q \frac{h_i^2}{W_B N_A}$$

Temperature
NA - doping in Base

- ① $A_E \uparrow$
- ② Reduce W_B
- ③ Reduce N_A

Base current:

I_{B1}
holes diffusing
in emitter
 $\propto e^{V_B \epsilon / kT}$

I_{B2}
hole recombining in
base region with
electrons
 $\propto e^{V_B \epsilon / kT}$

Summary: Base current: $I_B = \frac{I_C}{\beta} \rightarrow$ current gain (>1)

$\beta \uparrow \rightarrow W_B \downarrow$

$\beta \uparrow \rightarrow \frac{N_{DE}}{N_{A_B}} \uparrow$

Emitter current:

$$I_E = I_C + I_B$$

$$I_E = I_C + \frac{I_C}{\beta}$$

$$I_E = I_C \left(1 + \frac{1}{\beta} \right) = I_C \left(\frac{\beta+1}{\beta} \right)$$

$$I_E = \left(\frac{\beta+1}{\beta} \right) I_C = \frac{I_C}{\alpha} \quad \beta > 1$$

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

$$\beta = 100$$

$$\alpha \rightarrow 1$$

$$I_E = \frac{I_C}{\alpha}$$

$$I_E = \frac{I_S}{\alpha} \exp\left(\frac{V_{BE}}{V_T}\right)$$

"forward-active region"

Small changes in
Base current



large changes in
Collector current

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

I_B



$$\beta I_C$$

$2mA - 5mA$

current gain

Current-Controlled device



