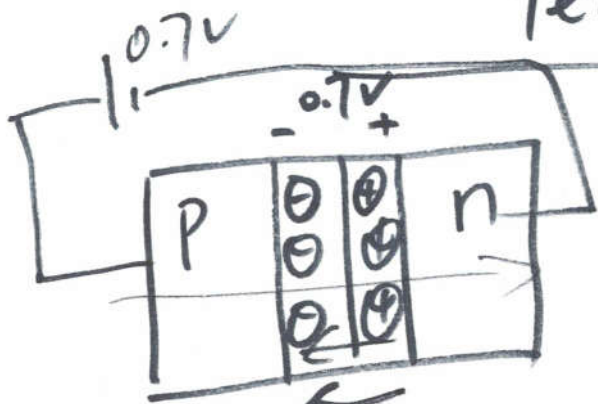
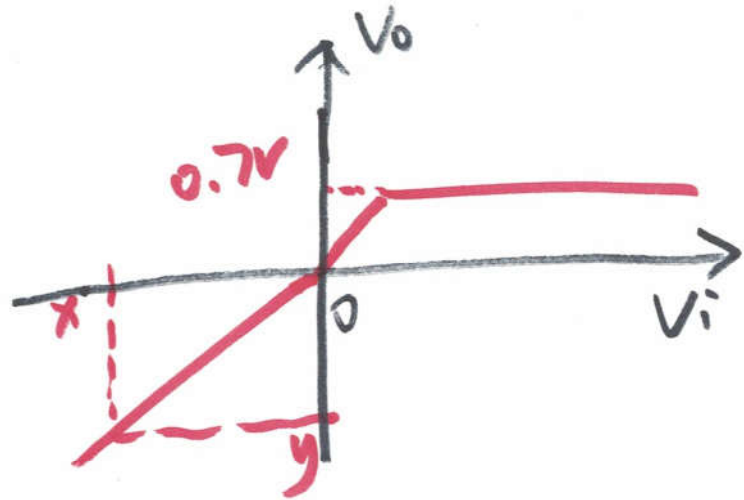
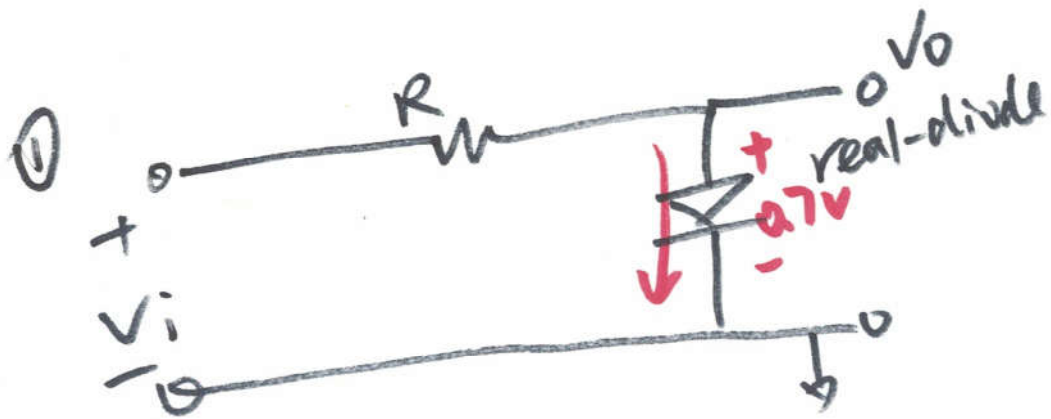
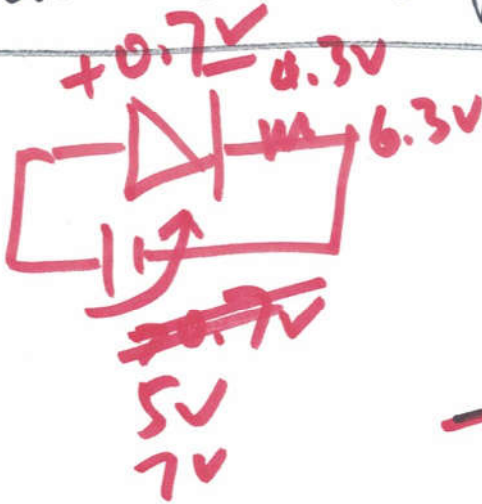


Terminal characteristics of Diodes



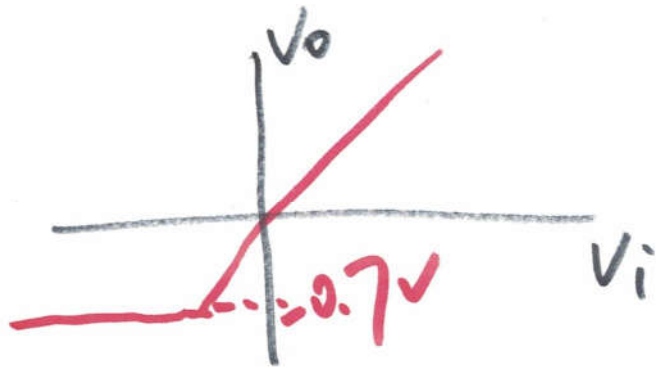
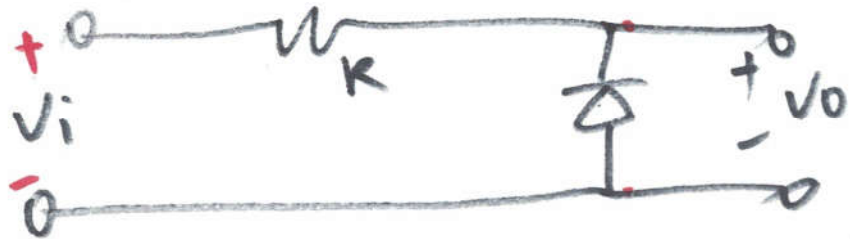
V_b : built in voltage
 barrier voltage
 Si: $V_b \approx 0.6 \sim 0.9V$
 $0.7V$



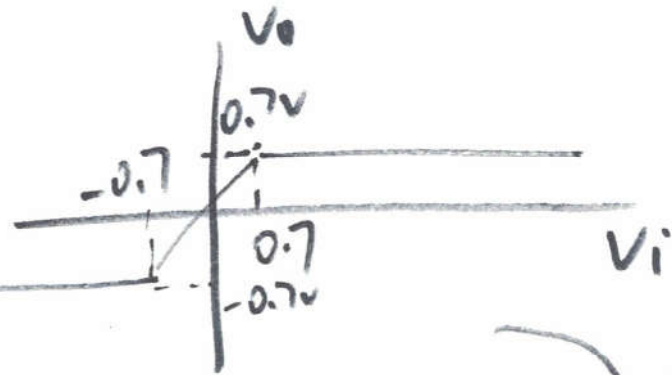
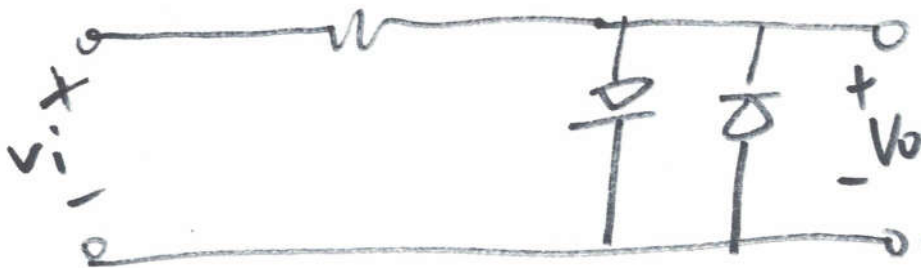
$y = x$

①

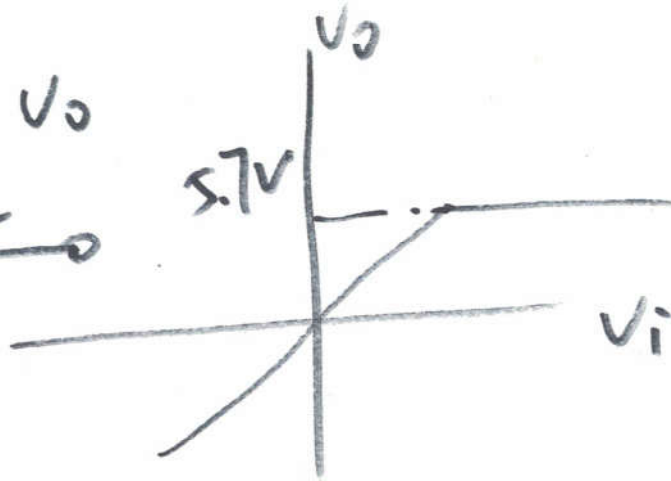
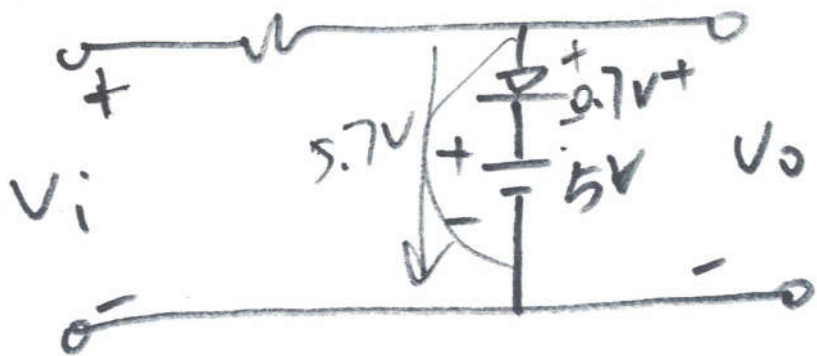
②



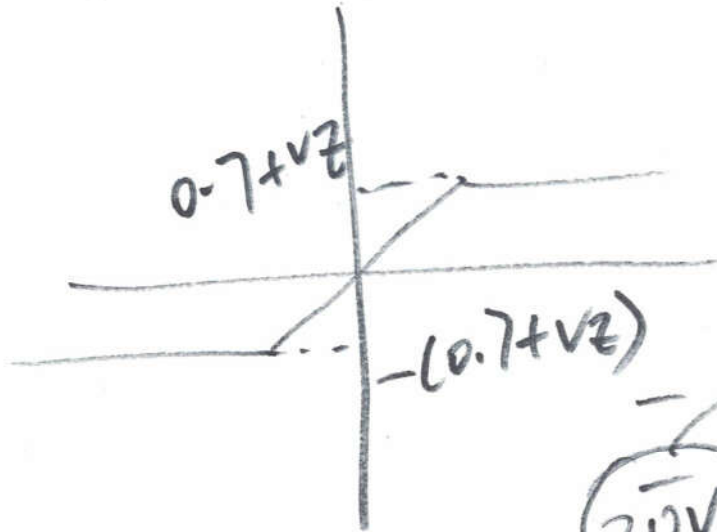
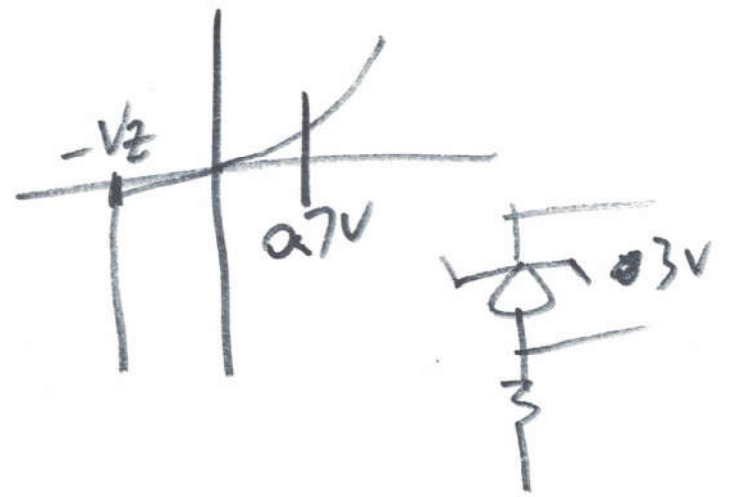
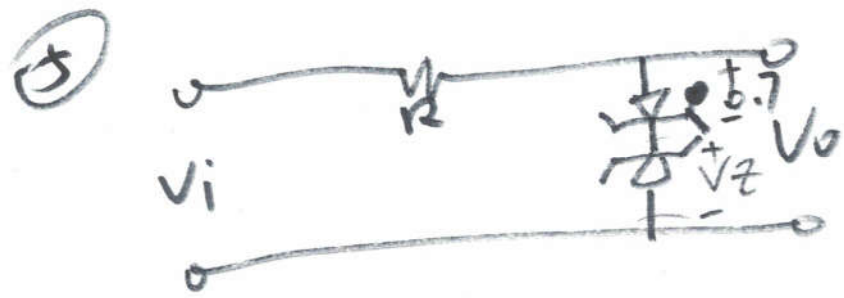
③



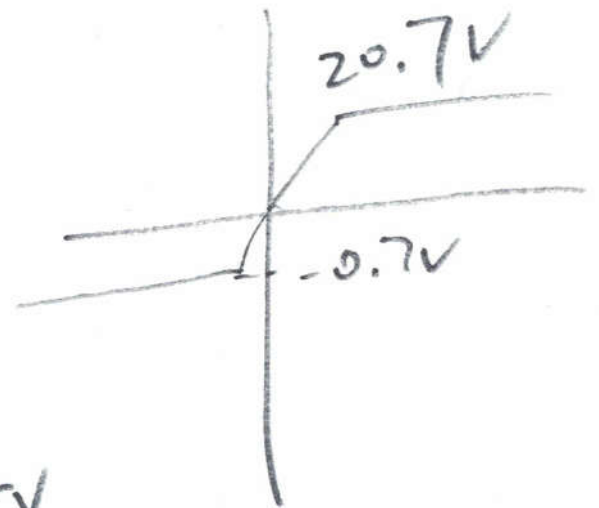
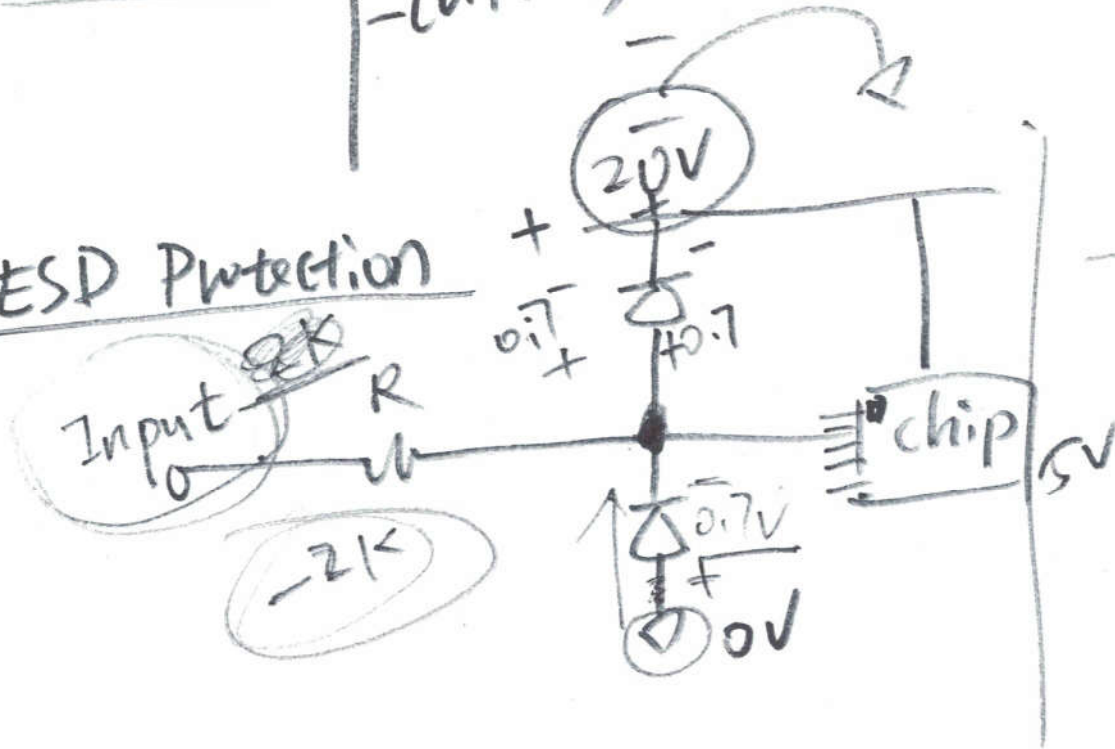
④



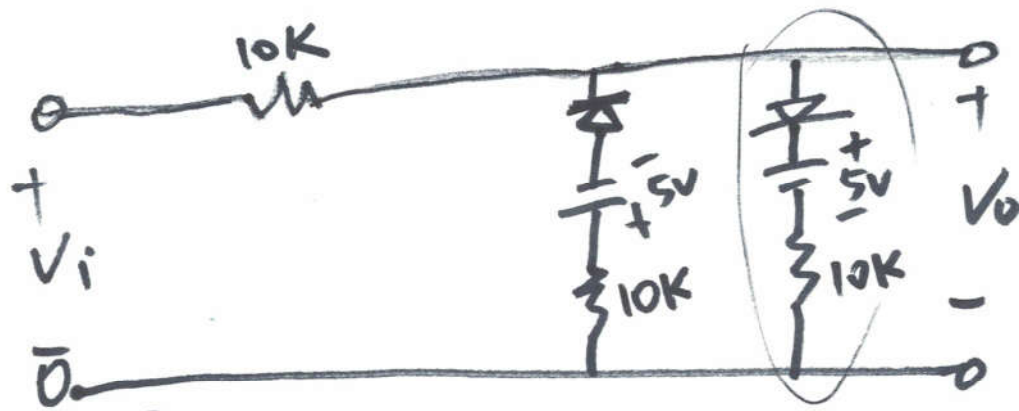
②



⑥ ESD Protection

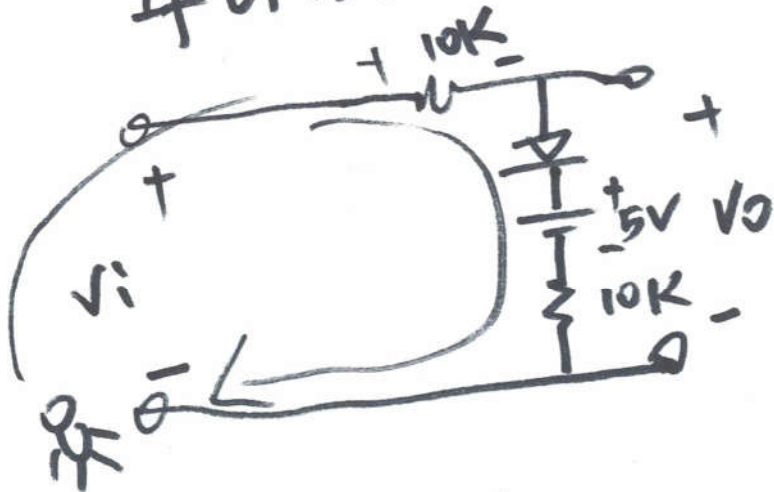


①



(Ideal diodes,
No reverse breakdown)

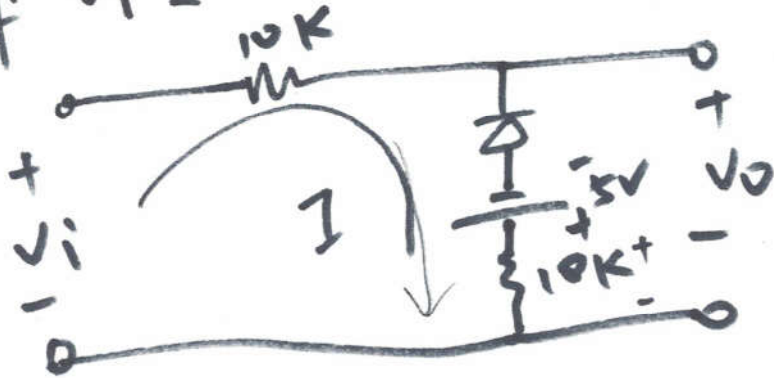
If $V_i > 5V$



$$\begin{cases} -V_i + 10K \cdot I + 5V + 10K \cdot I = 0 \\ V_o = 5V + 10K \cdot I \\ I = \frac{V_i - 5}{20K} \end{cases}$$

$$V_o = 5V + 10K \cdot \frac{V_i - 5}{20K} = 2.5V + \frac{V_i}{2}$$

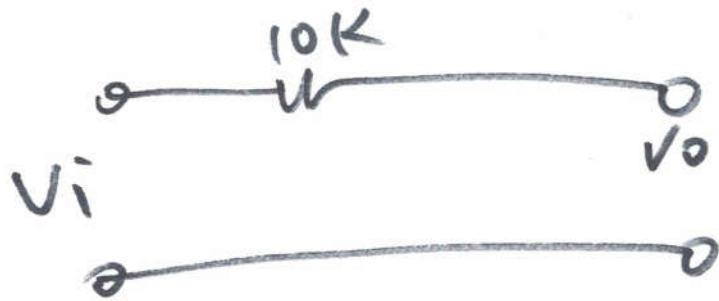
If $V_i \leq -5V$



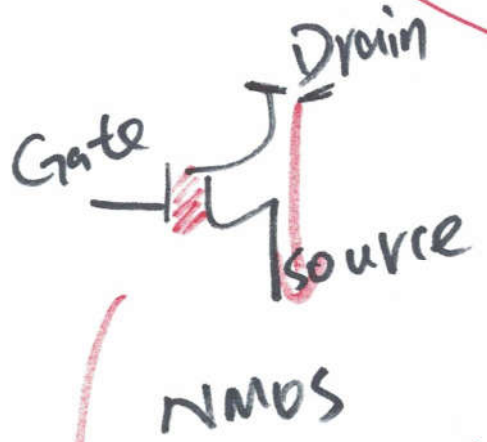
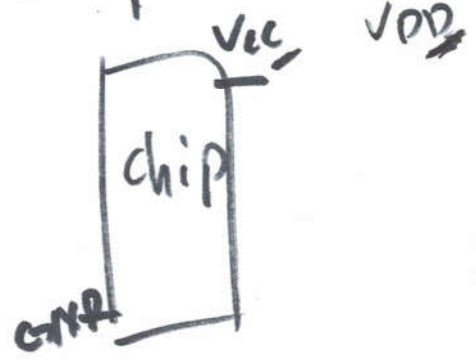
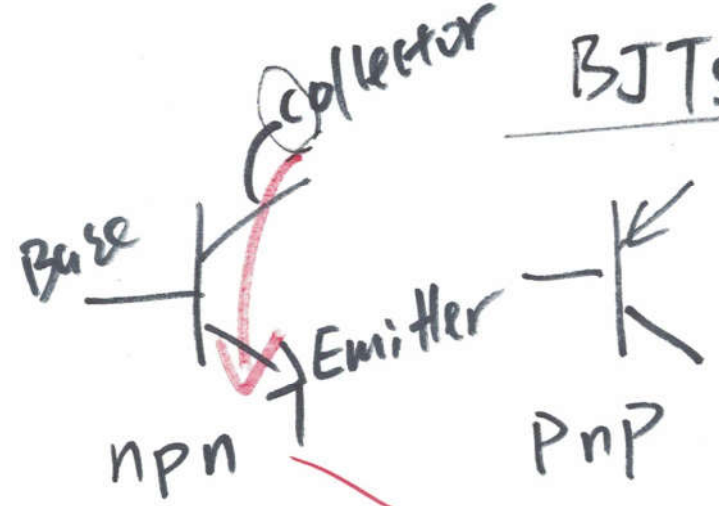
$$\begin{cases} -V_i + 10K \cdot I - 5V + 10K \cdot I = 0 \\ V_o = -5 + 10K \cdot I \\ I = \frac{V_i + 5}{20K} \\ V_o = -5 + \frac{V_i + 5}{2} = \frac{V_i}{2} - 2.5 \end{cases}$$

④

$$\text{If } -5 \leq V_i \leq 5, \quad V_i = V_o$$

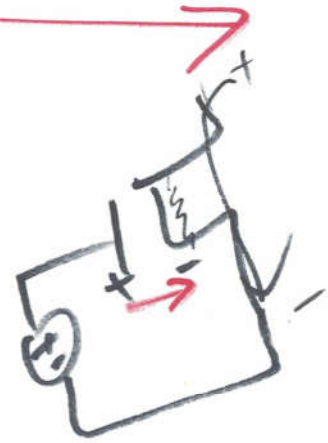
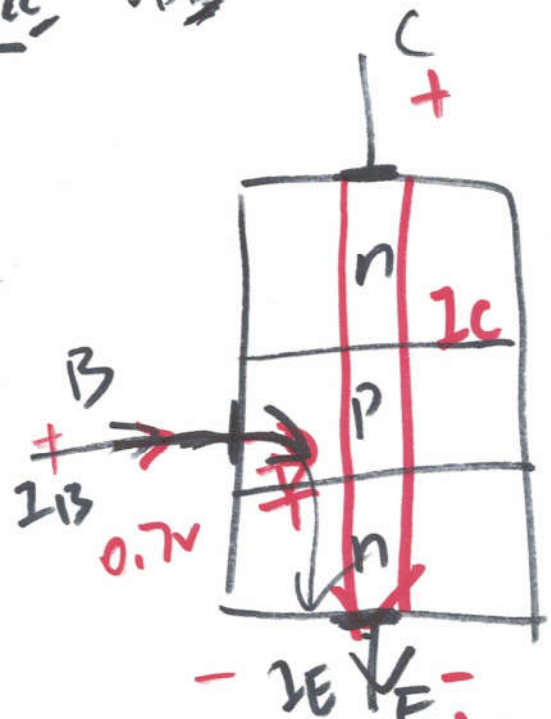
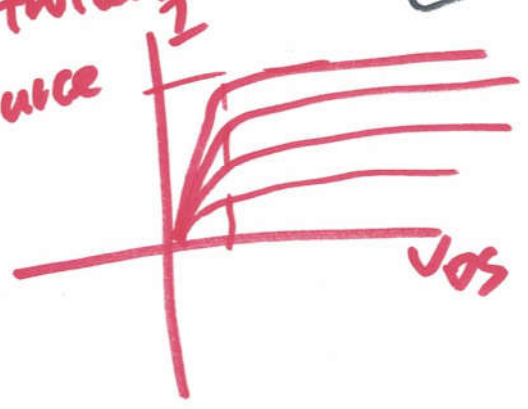


BJTs (Bipolar Junction Transistors)



NMOS

Voltage controlled current source



$$I_c = I_s \cdot e^{\frac{V_{be}}{V_T}} \rightarrow \sim 100, 50, 200$$

$$I_c = \beta \cdot I_b \rightarrow \sim 0.9$$

$$I_e = \alpha I_c$$

$$I_e = I_c + I_b$$

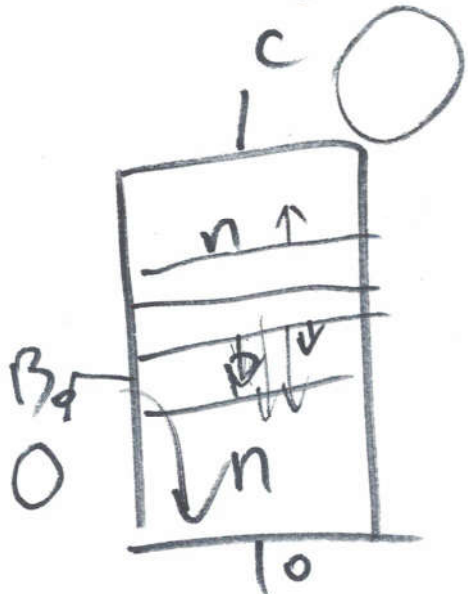
$$I_E = \frac{1}{\alpha} I_C$$

$$\frac{1}{\alpha} I_C = I_C + \frac{I_{C0}}{\beta}$$

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

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

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



$$V_C > V_B > V_E$$

$$I_C = \beta I_B$$

$$I_E = I_B + I_C$$

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

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

V_A
Early effect.

