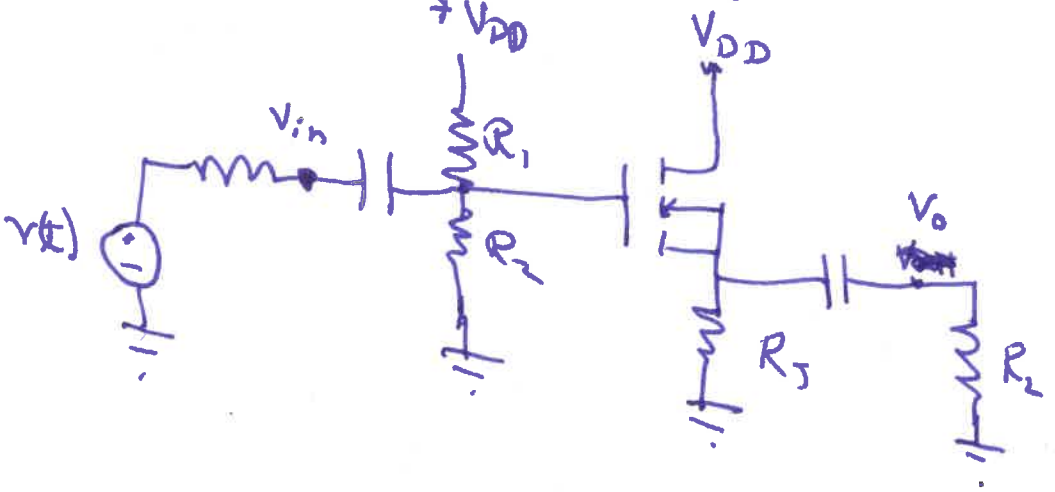
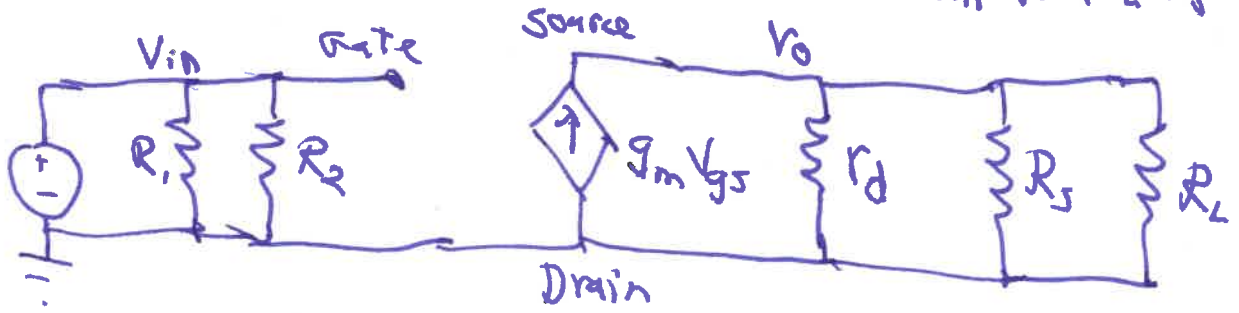
Common Drain Amp (Source Follower)



$$V_{in} = V_{GS} + V_o$$

$$V_o = g_m V_{GS} (R_L \| R_S \| r_d)$$



$$V_{in} = V_{GS} + g_m V_{GS} (R_L \| R_S \| r_d)$$

$$V_{in} = V_{in} - V_o + (V_{in} - V_o) g_m (R_L \| R_S \| r_d)$$

$$A_r = \frac{V_o}{V_{in}} = \frac{g_m (R_L \| R_S \| r_d)}{1 + g_m (R_L \| R_S \| r_d)}$$

$g_m = 9 \frac{mA}{V}$ $\quad R_L = 300\,\Omega \ll r_d$

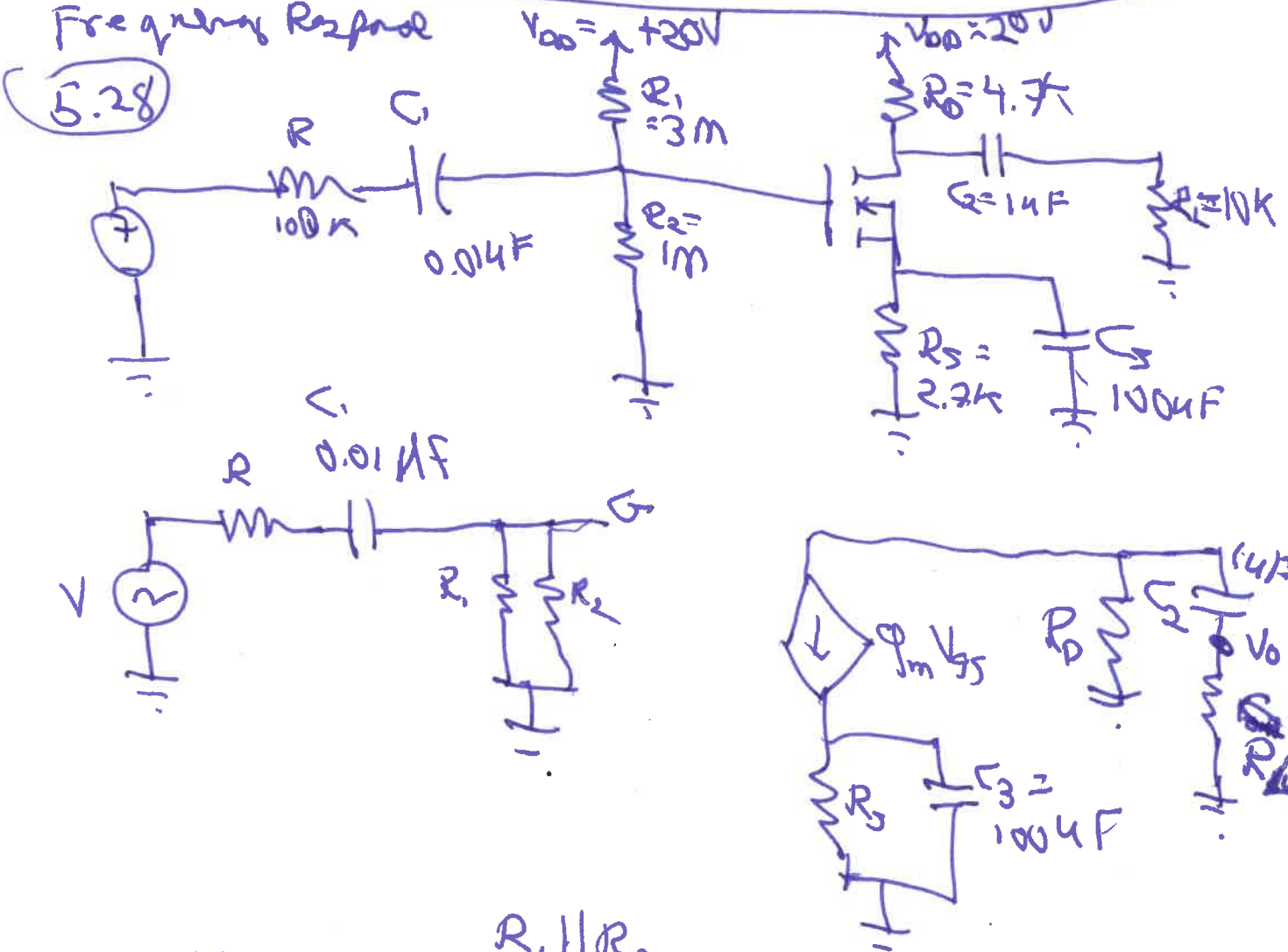
$$A_r = \frac{2.7}{3.7} = 0.73$$

$$R_{in} = R_1 \| R_2$$

without proof $$R_o = \frac{1}{g_m} \| R_s \| r_d$$

Frequency Response

5.28



$$V_g = V \frac{R_1 \| R_2}{R + \frac{1}{j\omega C_1} + R_1 \| R_2}$$

$$V_s = i_d \left(R_S \| \frac{1}{j\omega C_3} \right) \qquad i_d = g_m V_{gs} = g_m (V_g - V_s)$$

$$i_d = g_m V \frac{R_1 \| R_2}{R - \frac{1}{j\omega C_1} + R_1 \| R_2} - g_m i_J R_S \| \frac{1}{j\omega C_S}$$

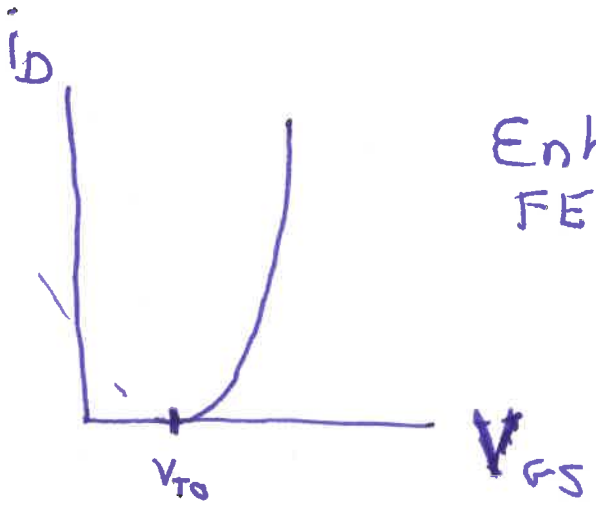
$$i_J = \left(1 + g_m R_S \| \frac{1}{j\omega C_S}\right) = g_m V \frac{R_1 \| R_2}{R - \frac{1}{j\omega C} + R_1 \| R_2}$$

$$V_d = - i_J R_D \| \left(\frac{1}{j\omega C_2} + R_L \right)$$

$$V_{out} = V_J \frac{R_L}{\frac{1}{j\omega C_2} + R_L} = - \frac{g_m R_D R_L}{R_D + \frac{1}{j\omega C_2} + R_L}$$

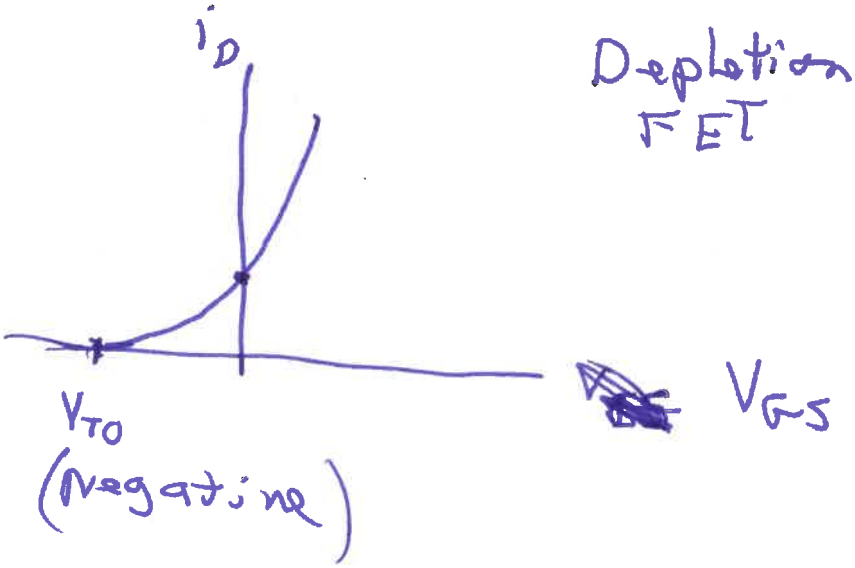
$$V_{in} = V \frac{\frac{1}{j\omega C_1} + (R_1 \| R_2)}{R + \frac{1}{j\omega C_1} + (R_1 \| R_2)}$$

$$A_V = \frac{V_{out}}{V_{in}}$$



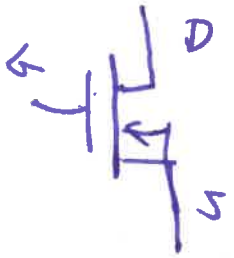
Enhancement FET

$$i_d = K(V_{GS} - V_{TO})^2$$

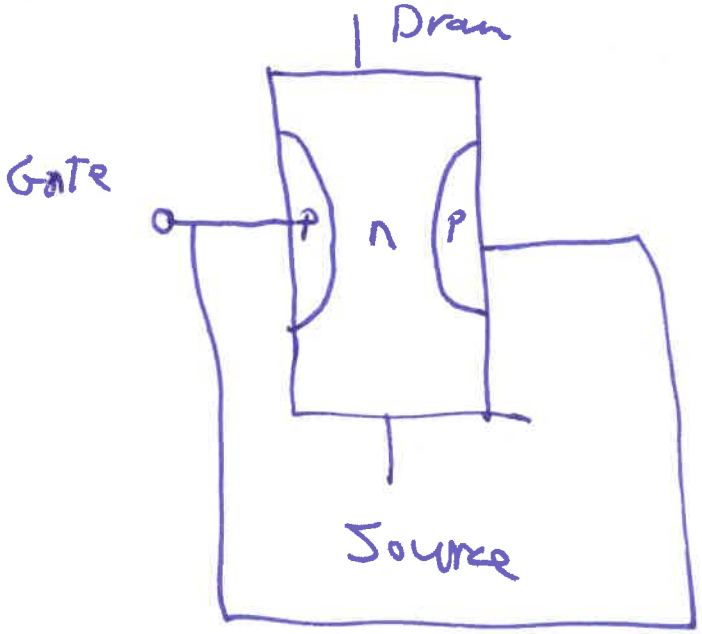


Depletion FET

Circuit Symbol



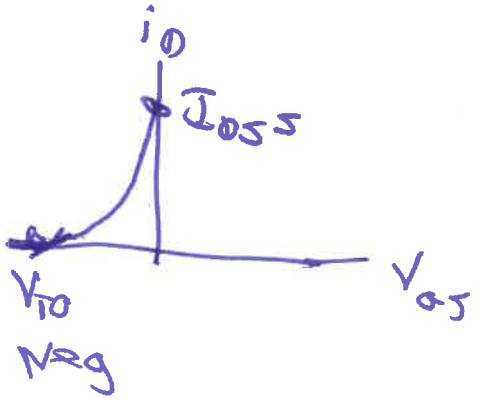
Junction FET J-FET



$V_{GS} = 0$
Channel exists
Current flows

$V_{GS} < 0$
Channel is pinched
Less current flows

$V_{GS} = V_{TO}$ $i_D = 0$



V_{GS} must be < 0

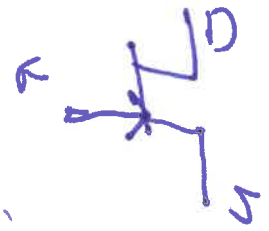
$$K = \frac{I_{DSS}}{V_{TO}^2}$$

PFET

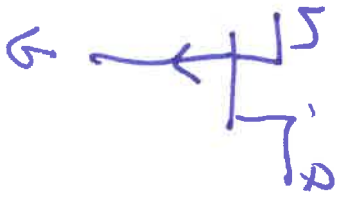
NFET

	mosFET	JFET
Enh	Y	N
Depl	Y	Y

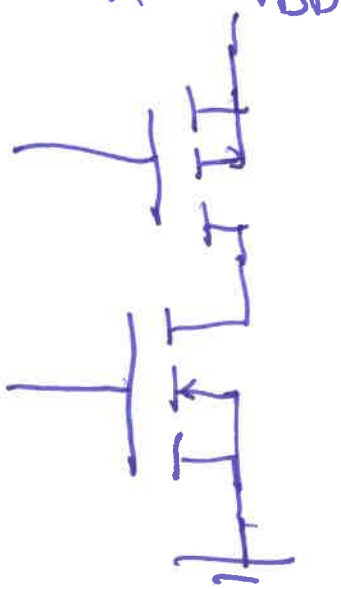
N-JFET symbol

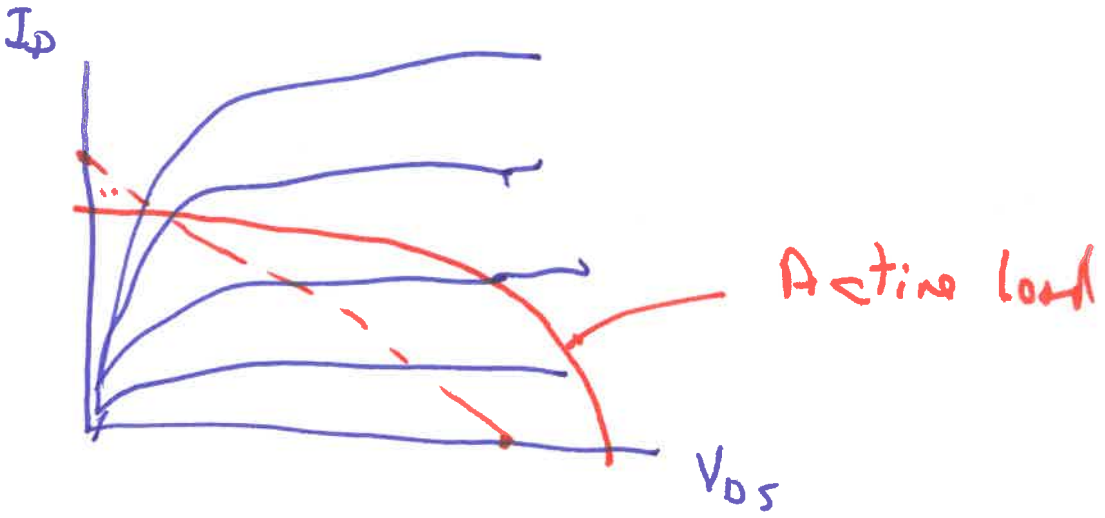


P-JFET

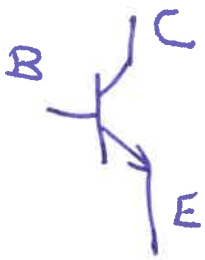


Active Load

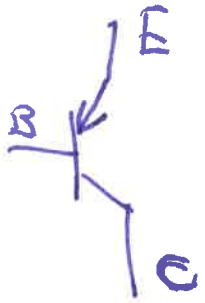



I_D
Active load
V_{DS}

BJT symbols



NPN



PNP

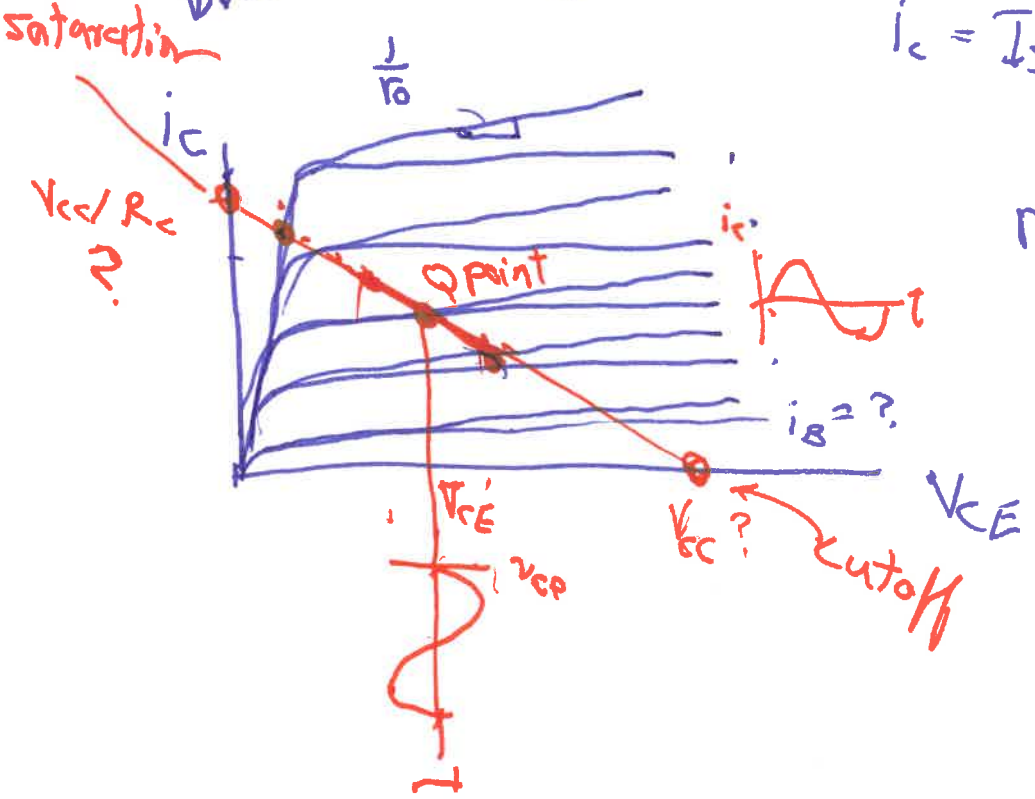
$i_C = \beta i_B$

$i_E = i_C + i_B$

$i_E = (\beta + 1) i_B$

$i_C = \alpha i_E \qquad \alpha = \frac{\beta}{\beta+1}$

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

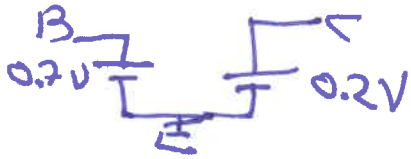


$r_o = \frac{V_A}{I_C}$ ← Early voltage ← DC "current Q point"

Active $\quad V_{BE} = 0.7\,V \qquad I_C = \beta I_B$

$V_{CE} > 0.2\,V$

Saturation $\quad V_{BE} = 0.7\,V \qquad V_{CE} = 0.2\,V$



cutoff

$I_? = 0$ (2) $V_{CE} = V_{cc}$

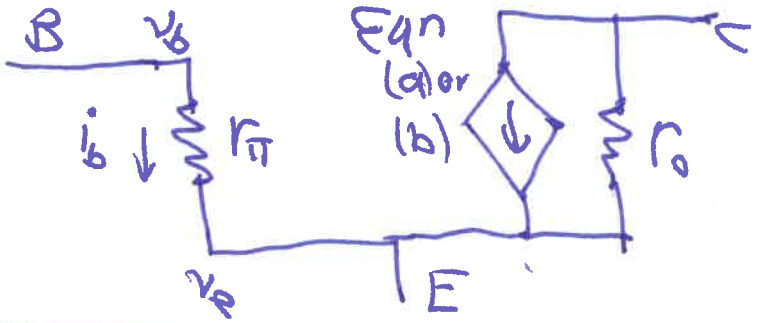
Small Signal Model

$V_T = 25\,mV$

(a) $i_c = \beta\, i_b$ or $g_m = \frac{I_C}{V_T}$ (b) $i_c = g_m V_{be}$

$r_\pi = \frac{\beta V_T}{I_C}$

$r_o = \frac{V_A}{I_C}$ or $\left(\frac{d i_c}{d V_{CE}}\right)^{-1}$



AC circuit

Small v_{in} or i_{in} → v_{out} or i_{out}

R_{in} R_{out}

$A_v = \frac{v_{out}}{v_{in}}$

$A_i = \frac{i_{out}}{i_{in}}$

$R_{out} = \frac{V_{out}(R_L \to \infty)}{i_{out}(R_L \to 0)}$

$R_{in} = \frac{v_{in}}{i_{in}}$

Typical circuits

Common Emitter $|A_v| > 1$ $|A_i| > 1$

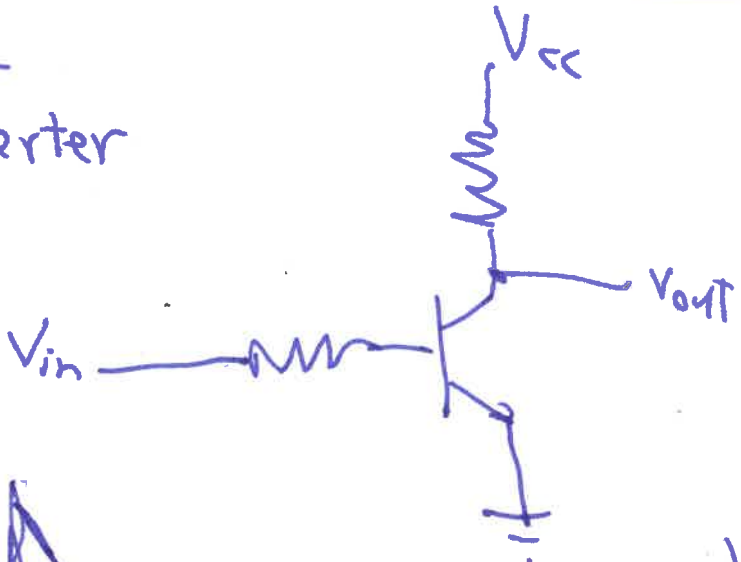
Common Base $A_i \approx 1$

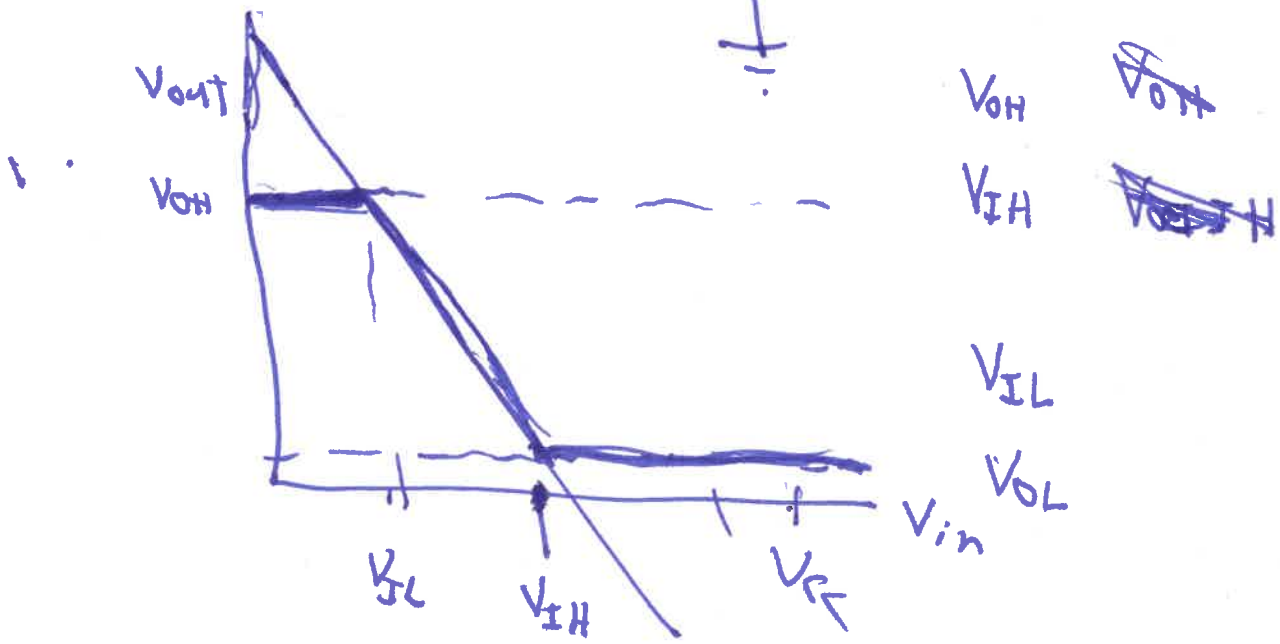
Common Collector $A_v \approx 1$

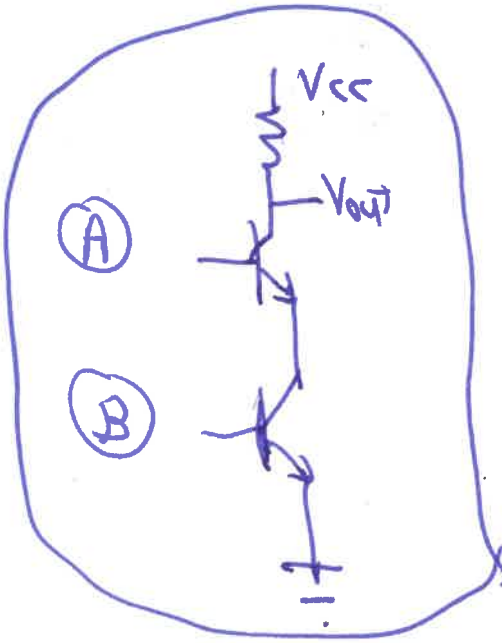
4 - Resistor model.

Logic

Inverter







IN A	IN B	OUT	
L	L	H	H
L	H	H	L
H	L	H	L
H	H	L	L

NAND NOR