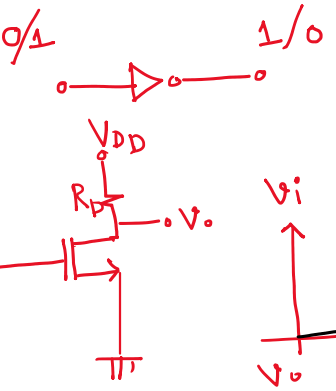
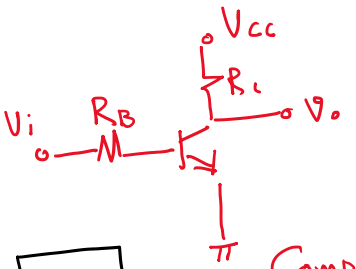
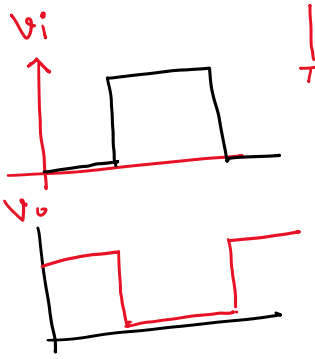
CMOS Inverter Lecture

Monday, December 29, 2025 12:36 PM



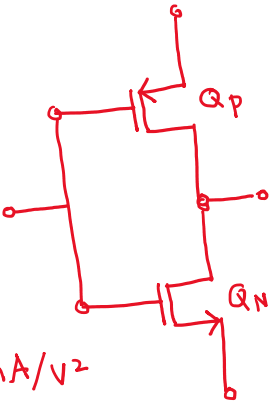




CMOS

Complementary Metal Oxide Semiconductor

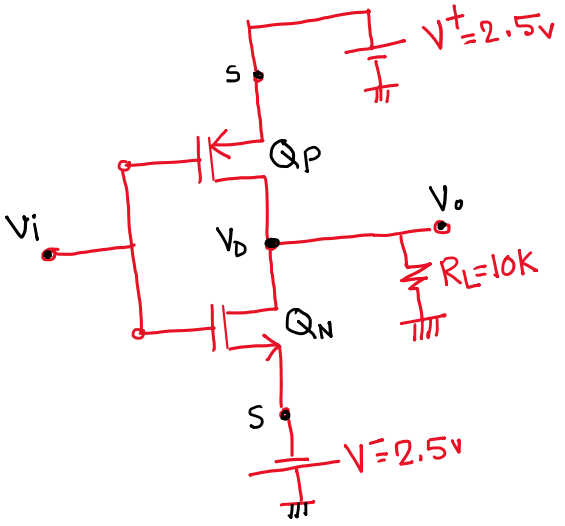
VLSI. EEE 411



$K_n = K_p = 1 mA/V^2$

$V_{TN} = -V_{TP} = 1V$

$V_I = 0V, +2.5V, -2.5V$



Case I. $V_I = 0V$

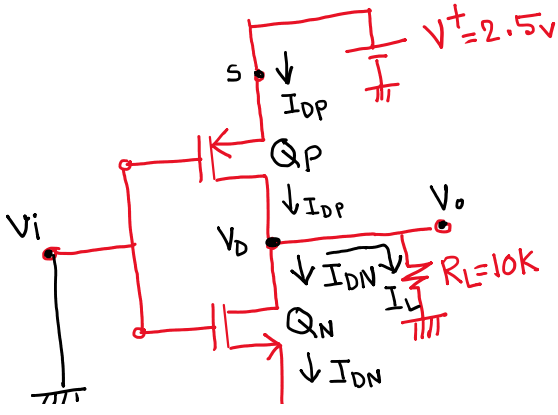
Check if ch. is induced or not.

Q_P: $V_{GS} = V_G - V_S = 0 - 2.5 < V_{TP}$ [ch. Ind]

Q_N: $V_{GS} = V_G - V_S = 0 - (-2.5) = 2.5V > V_{TN}$ [ch. Ind]

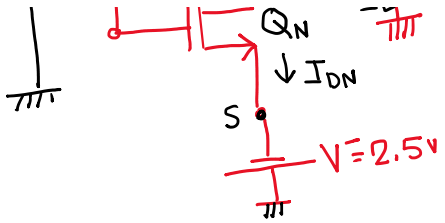
Do $V_{GD} = V_G - V_D = 0 - V_D$ (?)

Assume saturation for both Mosfets



Q_N: $I_{DN} = K_n (V_{GS} - V_{TN})^2 = 1 (2.5 - 1)^2 = 2.25 mA$

Q_P: $I_{DP} = K_p (V_{GS} - V_{TP})^2 = 1 (-2.5 + 1)^2 = 2.25 mA$



Q_P: $I_{DP} = K_P(V_{GS} - V_{TP})^2 = 1(-2.5+1)^2 = 2.25\,mA$

$I_{DN} = I_{DP} = 2.25\,mA$

$V_D = V_o = I_L R_L = 0V \rightarrow V_{GD} = 0-0 = 0V$

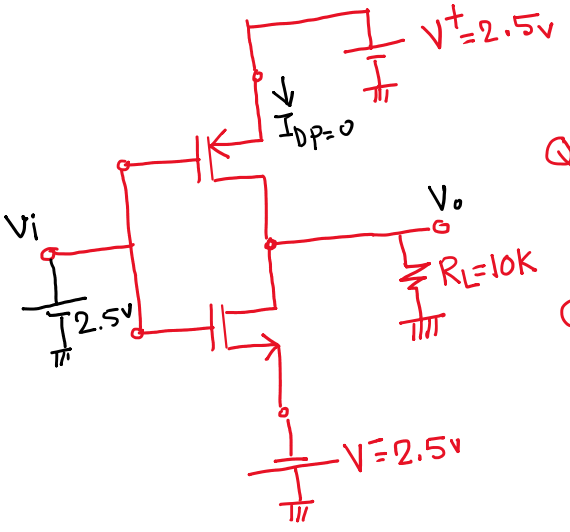
KCL @ D, $I_{DP} = I_{DN} + I_L \Rightarrow I_L = 0$

For Q_N: $V_{GD} = 0 < V_{TN}$ [No ch. exists at drain end]

For Q_P: $V_{GD} = 0 > V_{TP}$ [No ch. exists at drain end]

$V_I = 0V \longrightarrow V_o = 0V$

Case II. $V_I = 2.5V$

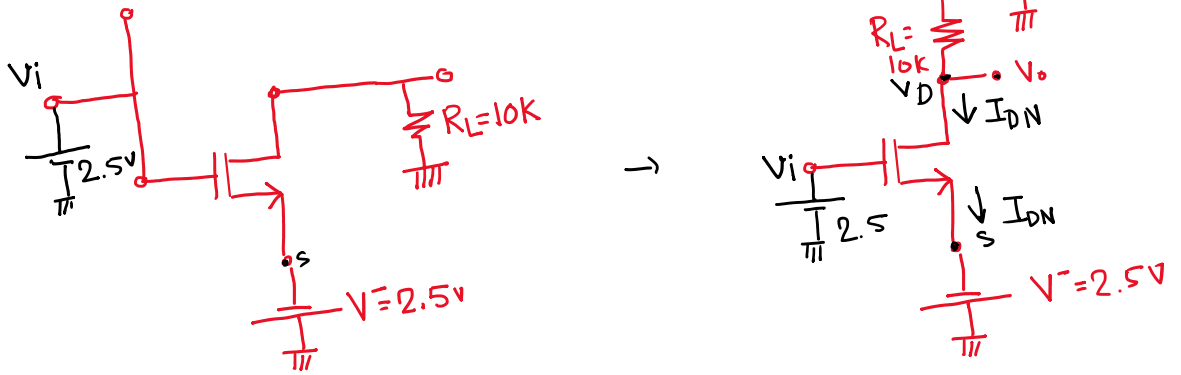


Q_P: $V_{GS} = V_G - V_S = 2.5-2.5 = 0 > V_{TP}\ (-1V)$

No ch Ind. → cut-off. $I_{DP} = 0$

Q_N: $V_{GS} = V_G - V_S = 2.5-(-2.5)$

$= 5 > V_{TN}$ [ch. Ind.]



Triode Region

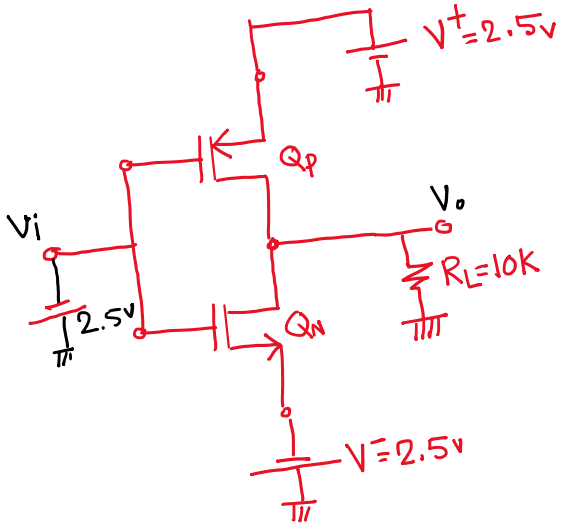
$$I_{DN} = K_n\left[2(V_{GS}-V_{TN})V_{DS} - V_{DS}^2\right] = \frac{0-V_D}{R_L}$$

$$\Rightarrow 1\left[2(5-1)(V_D-V_S) - (V_D-V_S)^2\right] = -\frac{V_D}{R_L}$$

$$\Rightarrow 8(V_D+2.5) - (V_D+2.5)^2 = -\frac{V_D}{10}$$

$$V_o = V_D = -2.44\,V$$

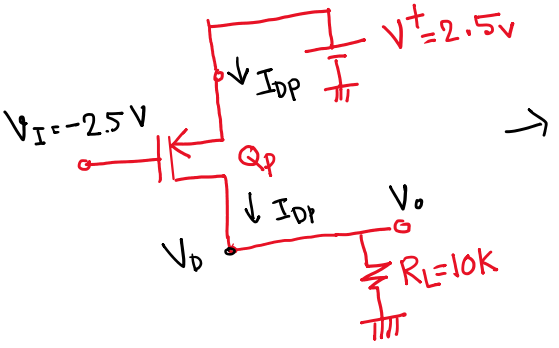
$V_I = 2.5V$, $V_o = -2.44V$

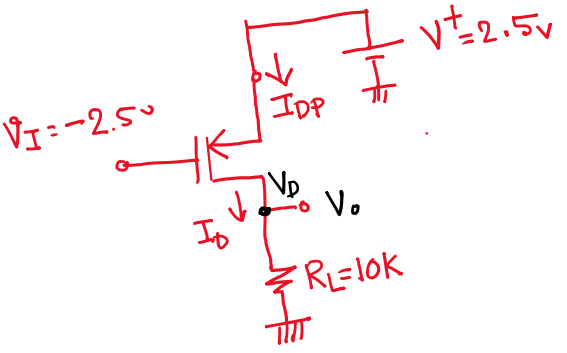


Case III, $V_I = -2.5V$

Q_p: Ch. Ind

Q_N: NA Ind.

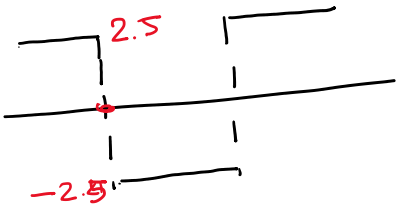




$$I_{DP} = K_P\left[2(V_{GS}-V_{TP})V_{DS} - V_{DS}^2\right] = \frac{V_D-0}{R_L}$$

$$= 1\left[2(-5+1)(V_D-V_S) - (V_D-V_S)^2\right] = \frac{V_D}{10}$$

$$V_D = 2.44V$$



V_I	V_o
2.5V	-2.44V
0V	0V
-2.5V	2.44