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LECTURE - 37

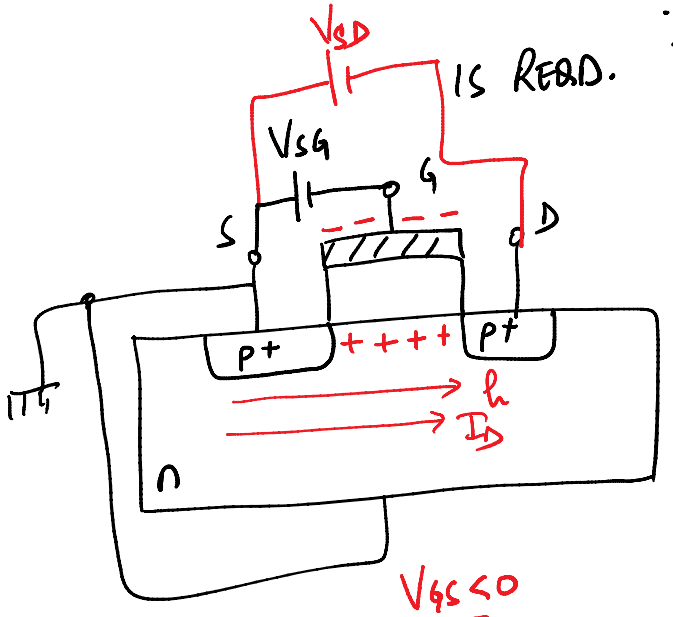
P-CHANNEL → PMOS

SAME OPERATION!

ENHANCEMENT MODE

$V_{TP} < 0$

∴ NEGATIVE VOLTAGE TO CREATE AN INVERSION LAYER



$V_{GS} < 0$

$V_{TP} < 0$

$V_{SG} > 0$ GATE IS NEGATIVE

$V_{SD} > 0$ DRAIN IS NEGATIVE W.R.T SOURCE

EQUATIONS

$V_{TP} < 0$

$V_{SD(SAT)} = V_{SG} + V_{TP}$ $\quad I_D = I_{SD}$

TRIODE $\quad I_D = K_P \left[2 (V_{SG} + V_{TP}) V_{SD} - V_{SD}^2 \right]$

SAT. $\quad I_D = K_P \left[V_{SG} + V_{TP} \right]^2$

$V_{SD} > V_{SD(SAT)} = V_{SG} + V_{TP}$

$K_p \rightarrow$ CONDUCTION PARAMETER

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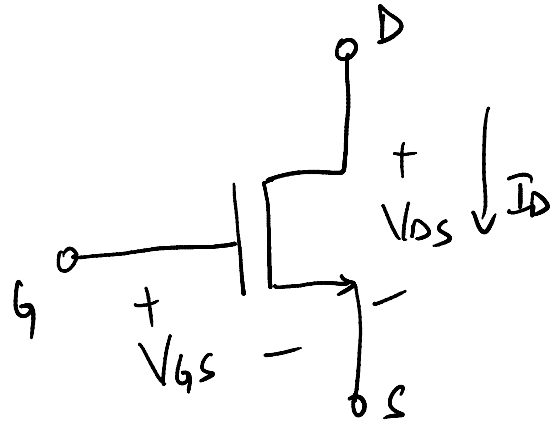
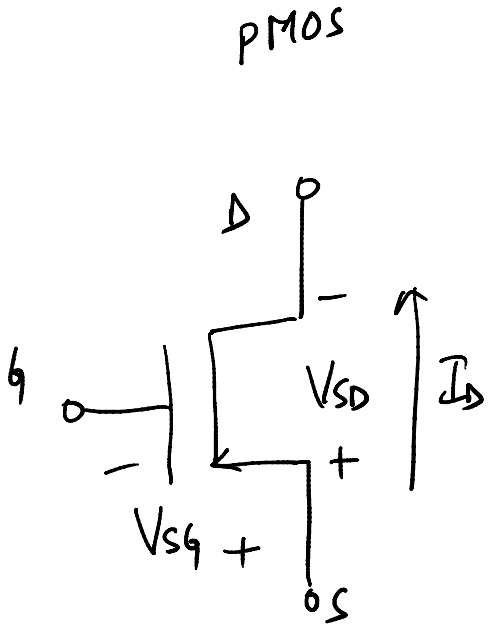
CIRCUIT SYMBOLS → ENHANCEMENT MODE

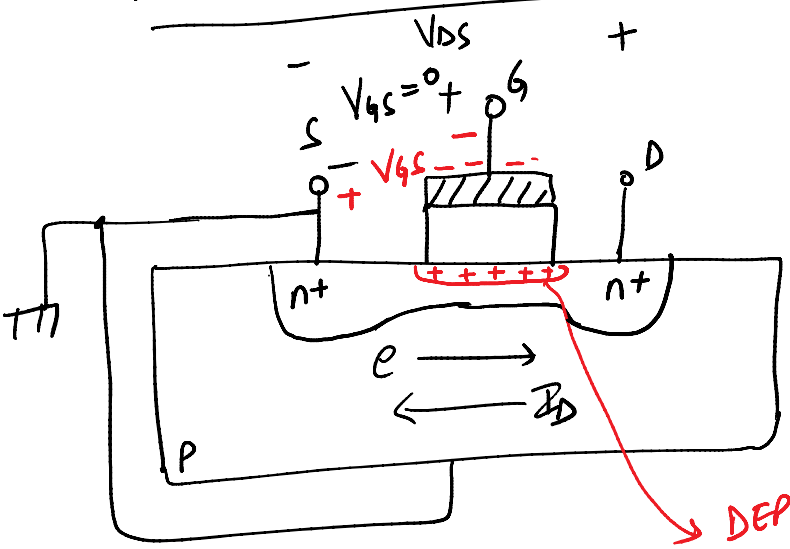
nMOS



pMOS



n-CHANNEL DEPLETION MODE MOSFET



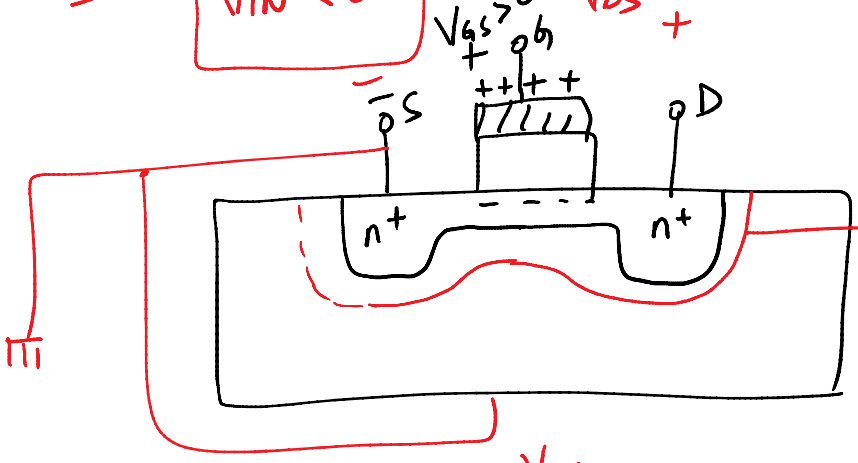
$V_{GS}=0$
CHANNEL EXISTS
$\therefore I_D > 0$ IF $V_{DS} > 0$

NORMALLY ON DEVICE

DEPLETION REGION NARROWS THE CHANNEL CONDUCTANCE

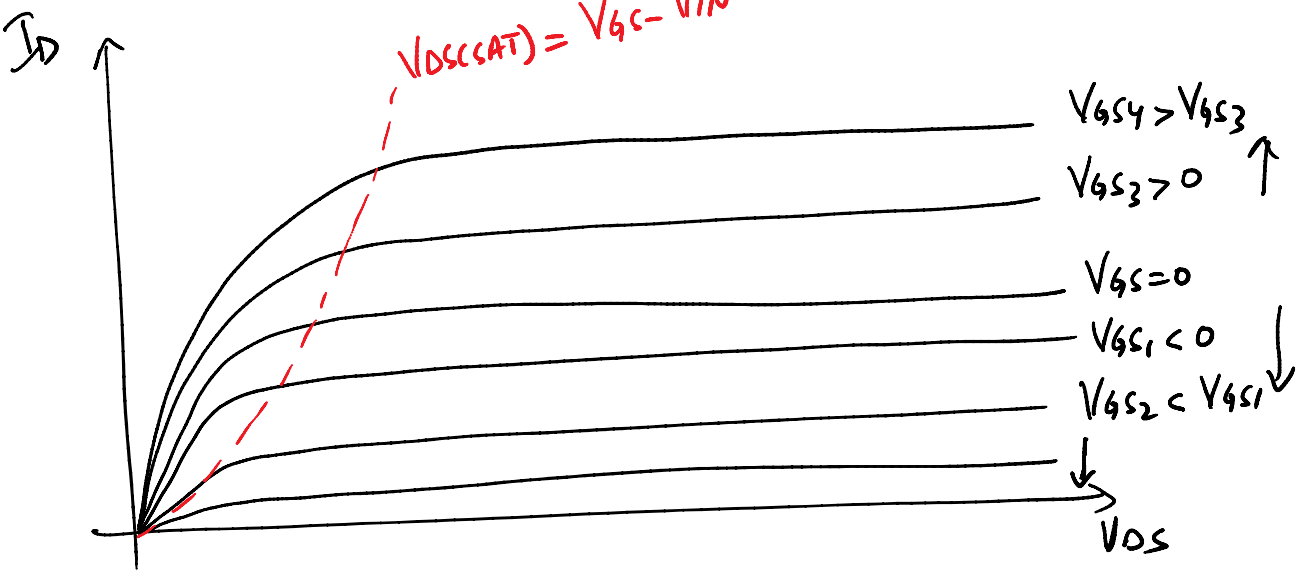
SPECIFICATION

$V_{TN} < 0$



CHANNEL EXPANDS FURTHER

$I_D \uparrow$



* V_{TN} IS POSITIVE FOR ENHANCEMENT MODE
* V_{TN} IS NEGATIVE FOR DEPLETION MODE

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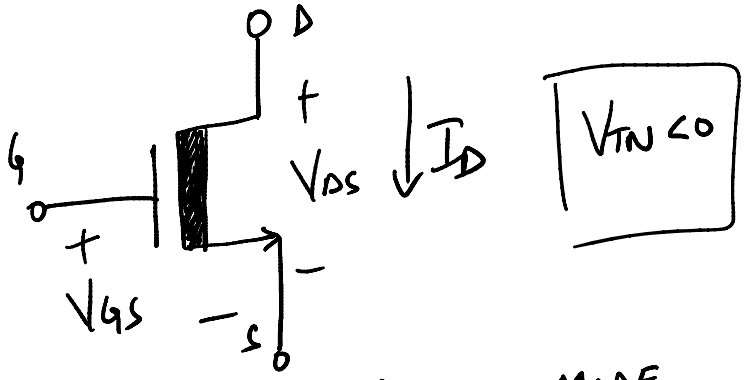
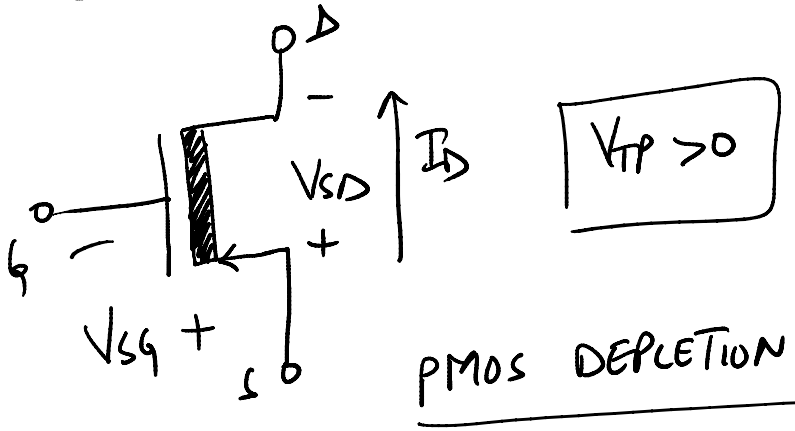
CIRCUIT SYMBOLS

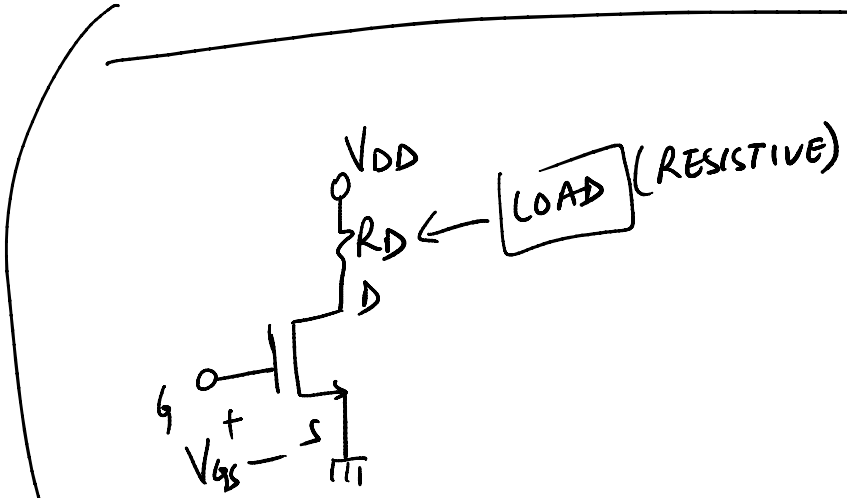


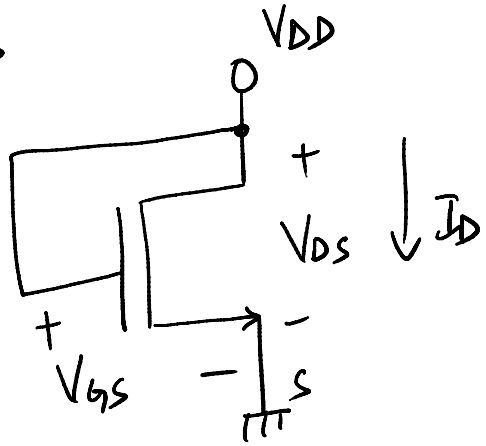
nMOS DEPLETION MODE



pMOS DEPLETION MODE

n- CHANNEL ENHANCEMENT LOAD DEVICE





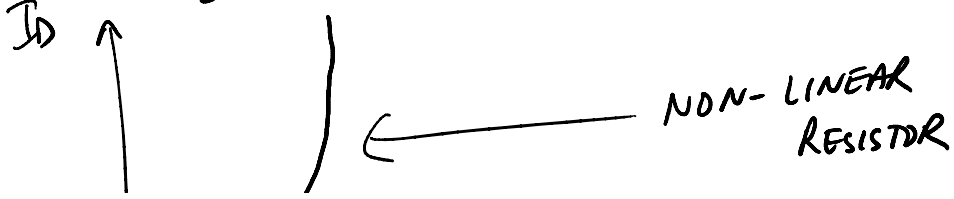
$V_{TN} > 0$

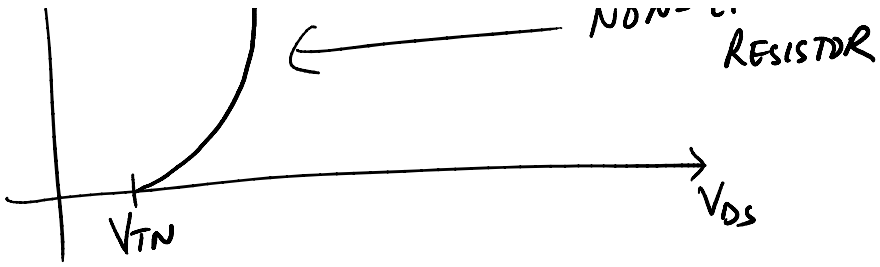
$V_{GS} = V_{DS} > V_{DS(SAT)}$

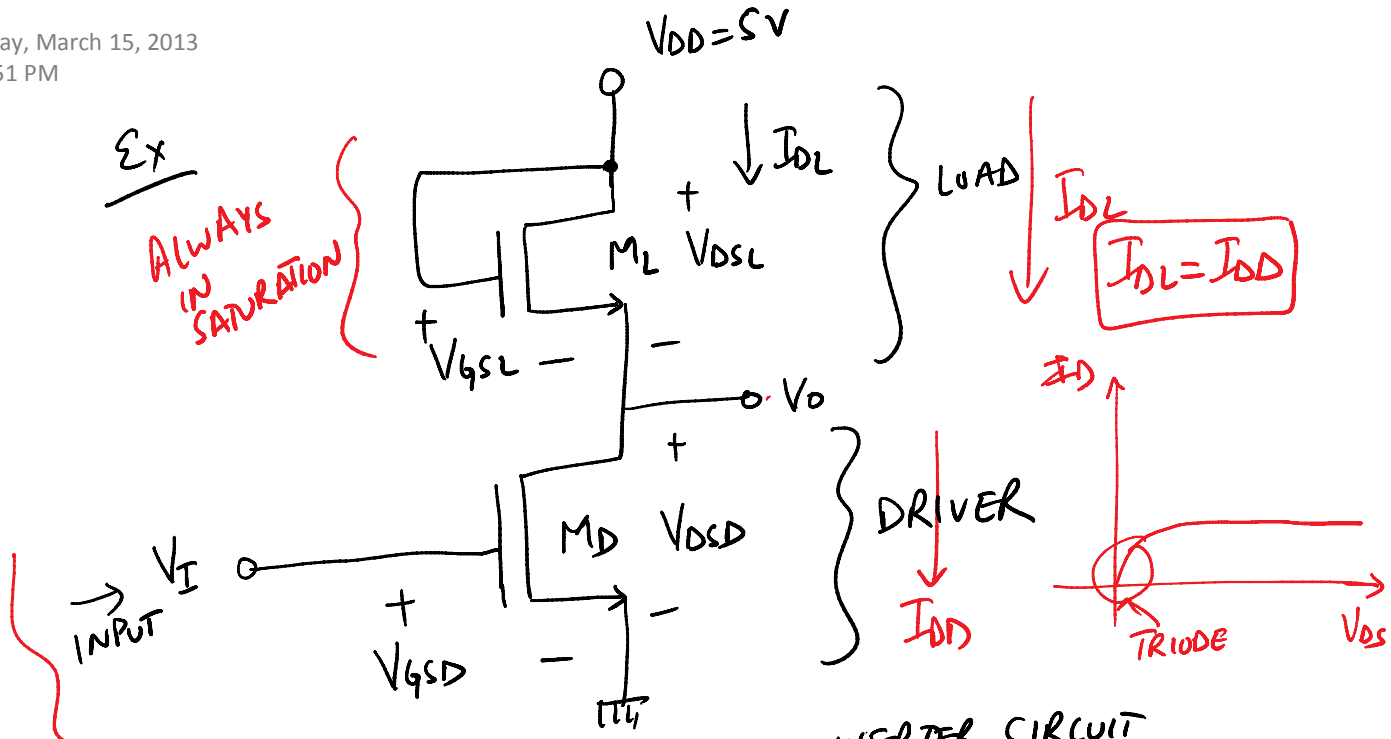
$V_{DS(SAT)} = V_{GS} - V_{TN}$

$\therefore$ ALWAYS IN SATURATION

$I_D = K_n (V_{GS} - V_{TN})^2$




RESISTOR
V_{TN}
V_{DS}



INVERTER CIRCUIT

$V_{TND} = V_{TNL} = 1V$

$K_{nD} = 50\,\mu A/V^2 \qquad K_{nL} = 10\,\mu A/V^2$

$V_I = 5V \;,\; 1.5V \qquad V_o?$

INVERTER IF INPUT IS HIGH, OUTPUT SHOULD BE LOW!

WOULD PREFER THE DRIVER TO BE IN TRIODE REGION

$$I_{DL} = I_{DD}$$

$$K_{nD}\left[2(V_{GSD} - V_{TND})V_{DSD} - V_{DSD}^2\right] = K_{nL}\left[V_{GSL} - V_{TNL}\right]^2$$

$V_{GSD} = V_I$ $\quad V_{DSD} = V_o$ $\quad V_{GSL} = V_{DSL} = V_{DD} - V_o$

$$K_{nD}\left[2(V_I - V_{tnD})V_o - V_o^2\right] = K_{nL}\left[V_{DD} - V_o - V_{tnL}\right]^2$$

$$\text{so} \quad \left[2(5-1)V_o - V_o^2\right] = (10)(5 - V_o - 1)^2$$

$$\therefore \quad 3V_o^2 - 24V_o + 8 = 0$$

$V_o = 7.65$ ~~,~~ 0.349 ✓ o/p is low!

$V_{DSD} = V_o = 0.349\ V \quad < \quad V_{GSD} - V_{tnD} \Big/ (5-1) = 4V$

$\therefore$ DRIVER IS IN TRIODE REGION!

$I_D = 133\mu A$

$V_I = 1.5V$

$V_{TND} = 1V$ $\quad V_{GSD} = V_I = 1.5V$

$V_{GSD} - V_{TND} = 0.5V = V_{DSD(SAT)}$

ASSUME THAT MD IS IN SAT. REGION → O/P IS HIGH

$I_{DD} = I_{DL}$

$K_{nD}\left[V_{GSD} - V_{TND}\right]^2 = K_{nL}\left[V_{GSL} - V_{TNL}\right]^2$

$V_{GSD} = V_I$ $\quad V_{GSL} = V_{DSL} = V_{DD} - V_o$

$K_{nD}\left[V_I - V_{TND}\right]^2 = K_{nL}\left[V_{DD} - V_o - V_{TNL}\right]^2$

$\sqrt{50}\left[1.5 - 1\right] = \sqrt{10}\left(5 - V_o - 1\right)$

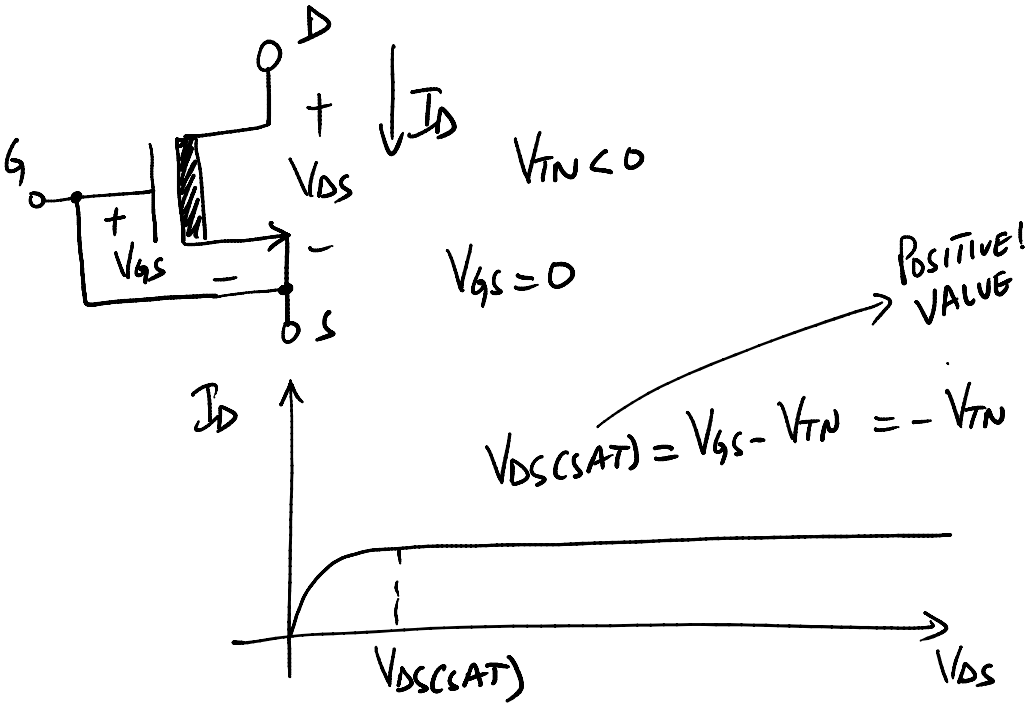
$V_o = 2.88V$

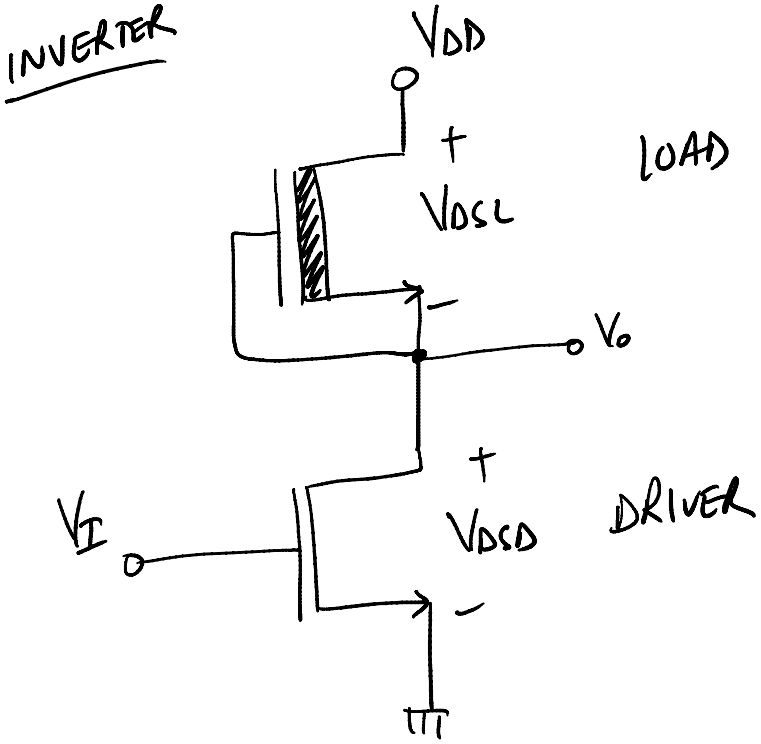
$V_{DSD} = V_o = 2.88V > V_{GSD} - V_{TND} = 1.5 - 1 = 0.5V$

$\therefore$ DRIVER IS IN SAT.

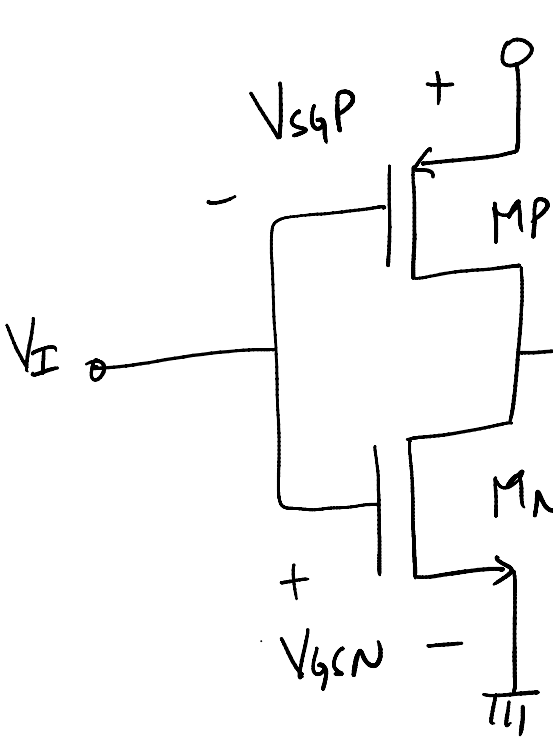
$I_D = 12.5\mu A$

n- CHANNEL DEPLETION LOAD DEVICE





CMOS → COMPLIMENTARY MOS



K_P $V_{TP}<0$

K_n $V_{TN}>0$

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

$V_I =$ $\underbrace{0V \leftrightarrow 1V}_{\text{Low}}$

NMOS IS OFF
PMOS IS ON
$\therefore V_O = V_{DD}$ (HIGH)

$V_I =$ $\underbrace{V_{DD}}_{\text{HIGH}}$

nMOS IS ON
PMOS IS OFF $\therefore V_O = 0$ (LOW)