Name PID

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Electrical and Computer Engineering Department

ECE 65 – Fall 2020

Components and Circuits lab

Midterm Exam2

You should submit your handwritten solutions in a PDF format to Gradescope by Monday, 11/9, at 11:50 am (Pacific Time).

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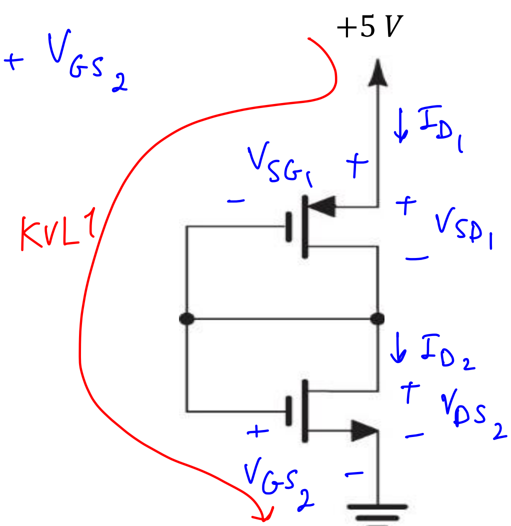
Problem 1.

Find the node voltages at the drain, source, and gate terminals of both MOSFETs in the below circuit. Make sure to check if the MOSFETs are in cut-off or not.

Assume the MOS transistors in the following circuit have $\mu_n C_{ox} = 2\,\mu_p C_{ox} = 320\,\mu A/V^2$, $|V_t| = 1\,V, \lambda = 0\; L = 1\,\mu m$, and $W = 3\,\mu m$.

Show your work.

KVL 1 : $5\,V = V_{SG_1} + V_{GS_2}$



Assume Q_1 and Q_2 are in cut-off : $I_{D_1} = 0$, $I_{D_2} = 0$, $V_{SG_1} < |V_{tp}|$,
$V_{GS_2} < V_{tn}$

$$
\begin{array}{rl}
 & V_{SG_1} < |V_{tp}| \\
+ & V_{GS_2} < V_{tn} \\
\hline
 & V_{SG_1} + V_{GS_2} < V_{tn} + |V_{tp}|
\end{array}
$$

$\rightarrow V_{SG_1} + V_{GS_2} < 2$

according to KVL 1 : $V_{SG_1} + V_{GS_2} = 5V$. This contradics the assumption, so MOSFETs are not in cut-off.

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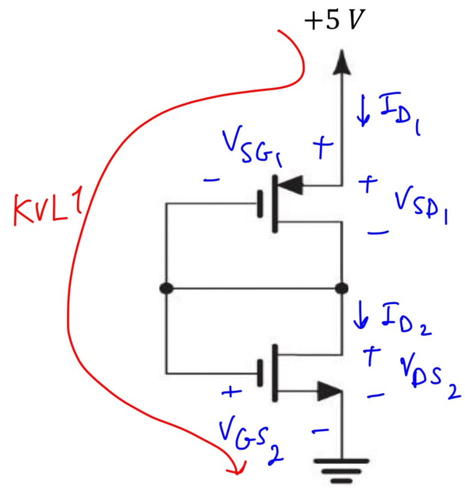

$V_{G_1} = V_{D_1} \rightarrow V_{SG_1} = V_{SD_1} \rightarrow V_{SD_1} > V_{SG_1} - |V_{tp}|$

$V_{G_2} = V_{D_2} \rightarrow V_{GS_2} = V_{DS_2} \rightarrow V_{DS_2} > V_{GS_2} - V_{tn}$

$\boxed{\text{So, both transistors are in saturation.}}$

The gate current is zero.

KCL at the drain node: $I_{D_1} = I_{D_2}$

$$I_{D_1} = \frac{1}{2} \mu_p C_{ox} \frac{W}{L} V_{ov_p}^2$$

$$I_{D_2} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} V_{ov_n}^2$$

$$I_{D_1} = I_{D_2} \rightarrow \cancel{\frac{1}{2}} \mu_p C_{ox} \cancel{\frac{W}{L}} V_{ov_p}^2 = \cancel{\frac{1}{2}} \mu_n C_{ox} \cancel{\frac{W}{L}} V_{ov_n}^2$$

$$\rightarrow V_{ov_p}^2 = 2 V_{ov_n}^2 \rightarrow \boxed{V_{ov_p} = \sqrt{2}\, V_{ov_n}} \quad , V_{ov_p} > 0,\ V_{ov_n} > 0$$

From KVL 1: $V_{SG_1} + V_{GS_2} = 5V \rightarrow V_{ov_p} + |V_{tp}| + V_{ov_n} + |V_{tn}| = 5\ V$

$$\rightarrow \boxed{V_{ov_p} + V_{ov_n} = 3\ V}$$

$$\begin{cases} V_{ov_p} = \sqrt{2}\, V_{ov_n} \\ V_{ov_p} + V_{ov_n} = 3\ V \end{cases} \rightarrow (1+\sqrt{2})\, V_{ov_n} = 3\ V \rightarrow \begin{matrix} V_{ov_n} = 1.24\ V \\ V_{ov_p} = 1.76\ V \end{matrix}$$

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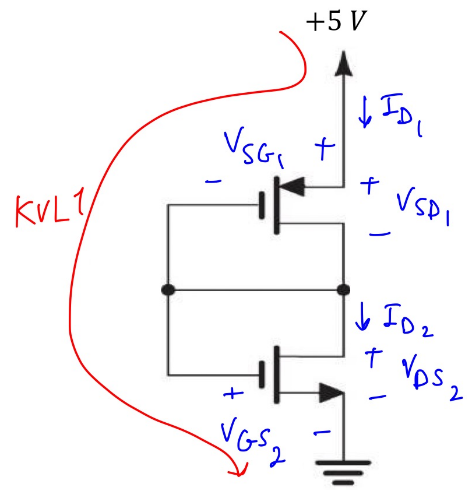
$\boxed{\text{both transistors are in saturation}}$



$$I_{D_1} = I_{D_2} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} V_{ov_n}^2 \simeq 0.74 \text{ mA}$$

$$V_{ov_n} = 1.24 \text{ V} \longrightarrow V_{GS_2} = V_{ov_n} + V_{t_n} = 2.24 \text{V}$$

$$V_{G_2} - V_{S_2} = V_{G_2} - 0 = 2.24\text{V} \longrightarrow V_{G_2} = 2.24\text{V}$$

$$\boxed{V_{G_2} = V_{D_2} = V_{G_1} = V_{D_1} = 2.24\text{V}}$$

$$\boxed{V_{S_2} = 0 \text{ V} \quad , \quad V_{S_1} = 5 \text{ V}}$$