Design & Simulate 16

ECE2204 CRN:82929

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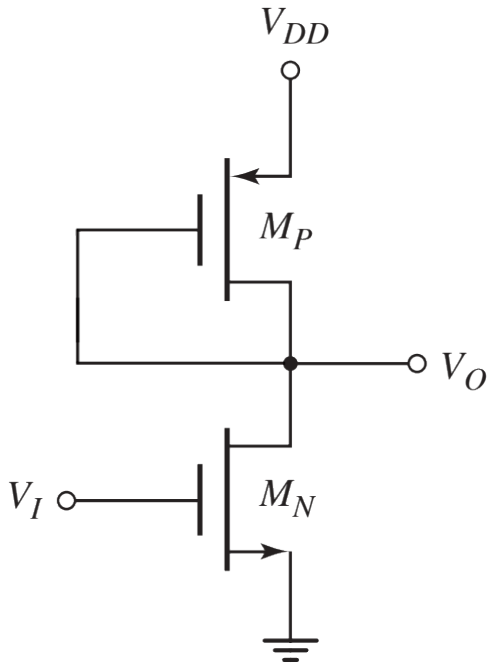
Problem 16.3-9.a.1:

Design

For the circuit below, find V_{It}, the modes of operation of the MOSFETs, V_O, I_D, and the static power. Assume $V_{TP} = -1V$, $V_{TN} = 1V$, $K_p = 10\mu A/V^2$, $K_n = 50\mu A/V^2$, $\lambda = 0$, $V_{DD} = 5V$, and $V_I = 5V$.



$$
\begin{aligned}
V_{SGp} &= V_{SDp} = V_{DD} - V_O = 5V - V_O \\
V_{GSn} &= V_I \\
V_{DSn} &= V_O \\
I_{DD} &= I_{DL} \\
&= K_p[V_{SGp} + V_{TP}]^2 \\
&= K_n[2(V_{DSn})(V_{GSn} - V_{TN}) - V_{DSn}^2]
\end{aligned}
$$

$$
\begin{aligned}
V_I &= V_{DD} - V_{SGp} - |V_T| = 5V - 5V + V_O - 1V = V_O - 1V \\
V_O &= V_I + 1V \\
K_P(V_{SGp} + V_{TP})^2 &= K_N(V_I - V_{TN})^2 \\
V_{It} &= \frac{\sqrt{\frac{K_P}{K_N}}(V_{DD}) - V_TP}{\sqrt{\frac{K_P}{K_N}} + V_{TN}} = \frac{\sqrt{\frac{1}{5}}(5V) + 1V}{\sqrt{\frac{1}{5}} + 1V} = 2.236V
\end{aligned}
$$

$$
\begin{aligned}
K_p[V_{SGp} + V_{TP}]^2 &= K_n[2(V_{DSn})(V_{GSn} - V_{TN}) - V_{DSn}^2] \\
(10\mu A/V^2)[5V - V_O - 1V]^2 &= (50\mu A/V^2)[2(V_O)(5V - 1V) - V_O^2] \\
V_O &= 7.65V \text{ OR } 0.349V = 0.349V \\
I_D &= K_p(V_{DD} - V_O + V_{TP})^2 \\
&= (10\mu A/V^2)(5V - 0.349V - 1V)^2 = 133.3\mu A \\
P &= V_O \times I_D = 0.349V \times 133.3\mu A = 46.52\mu W
\end{aligned}
$$

$0.349V < 4V$ and therefore M_N is biased in the non-saturation region.

$0 \leq V_I \leq 1V$: M_N is off.

$1V \leq V_I \leq 2.236V$: M_N is in saturation mode.

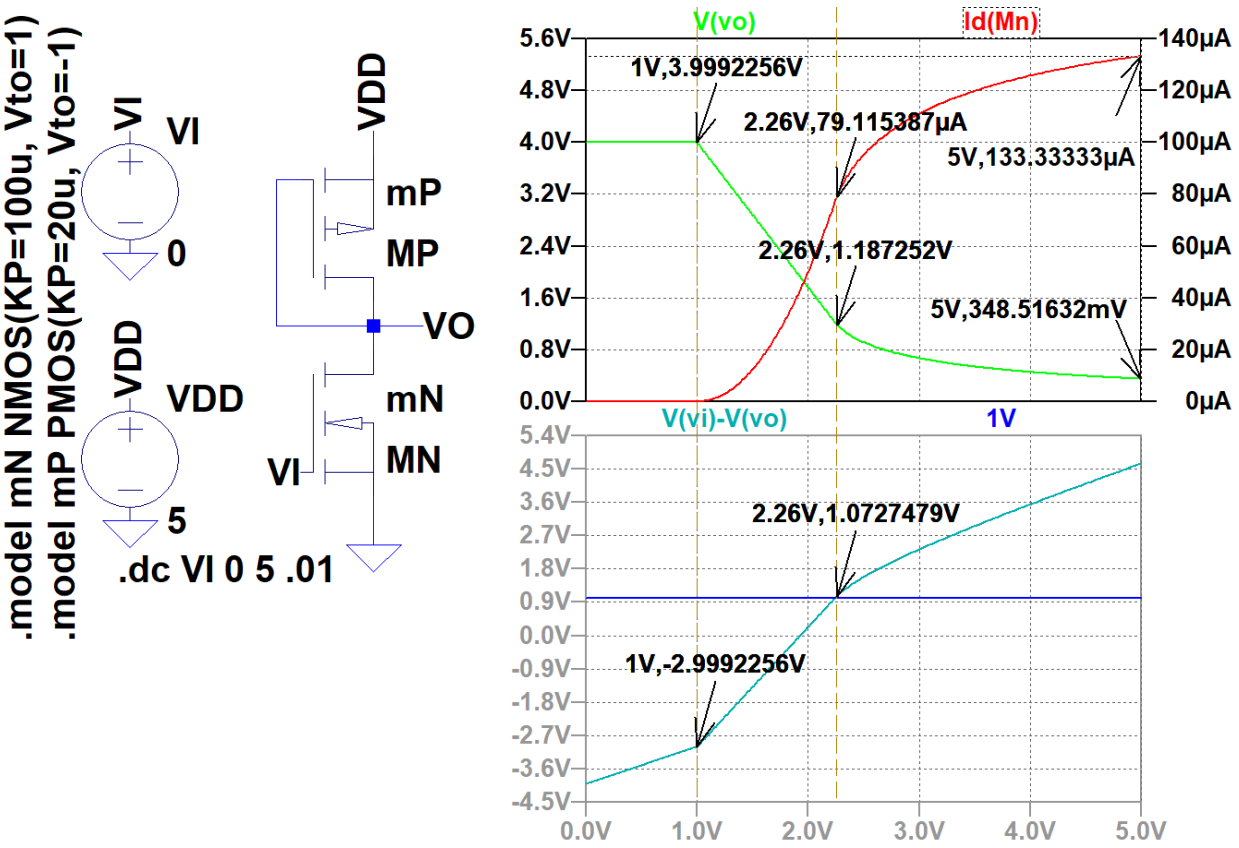
$V_I > 2.236V$: M_N is in ohmic mode.

M_P is always in saturation mode as $V_{DD} - V_O > V_T$ in all cases.

$V_O = 0.349V$, $I_D = 133.3\mu A$, and $P = 46.52\mu W$.

Validation

LTSpice Implementation (values within $< 1\%$)



$$Err_{V_O} = \frac{|349 - 348|}{349} = 0.28\%$$

$$Err_{I_D} = \frac{|133.3 - 133.3|}{133.3} = 0.00\%$$

$$Err_{V_{It}} = \frac{|2.236 - 2.26|}{2.236} = 1.07\%$$

This assignment should demonstrate a basic ability to manipulate, design, and analyse enhancement load MOSFET circuits.

I have neither given nor received unauthorized assistance on this assignment.