Name Last:_____First:_____ID: SOLUTIONS **Oct 11, 2013**

Pop Quiz 1
Section 1 - Time: 50 min
Show your work for full credit. Please read the questions carefully!

n-channel MOSFET

$i_D = K_n(v_{GS} - V_{Tn})^2$ SAT

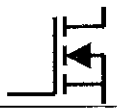
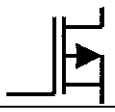
$i_D = K_n\left[2(v_{GS} - V_{Tn})v_{DS} - v_{DS}^2\right]$ NON-SAT

p-channel MOSFET

$i_D = K_p(v_{SG} + V_{Tp})^2$ SAT

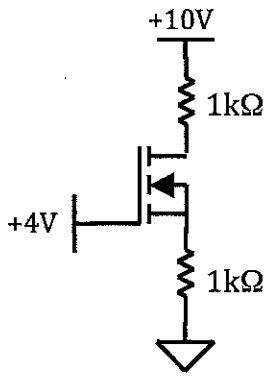
$i_D = K_p\left[2(v_{SG} + V_{Tp})v_{SD} - v_{SD}^2\right]$ NON-SAT

1. (20 points) Express the type of the transistors shown below. What is the sign of the threshold voltage? What are the conditions for the following operating states?

		
TYPE	n-channel Enhancement	p-channel Depletion
V_{TH}	$V_{Th} > 0$	$V_{Th} > 0$
OFF	$V_{GS} \leq V_{Th}$	$V_{SG} \leq -V_{Th}$
SAT	$V_{DS} \geq V_{GS} - V_{Th}$	$V_{SD} \geq V_{SG} + V_{Th}$
NON-SAT	$V_{DS} \leq V_{GS} - V_{Th}$	$V_{SD} \leq V_{SG} + V_{Th}$

(2 points each)

2. (40 points) Find the Q-point (operating point) values of I_{DS} and V_{DS} of the transistor shown below. V_{TH}=2V, K_n=1mA/V².



$V_G = 4^V$
$V_S = I_D \cdot 1k$
$V_D = 10^V - I_D \cdot 1k$

(10 points) $V_{GS} = 4^V - I_D \cdot 1k$

if $V_{GS} \geq V_{Th} \Rightarrow$ NOT OFF

Assume SAT check $V_{DS} \geq V_{GS} - V_{Th}$

$I_D = 1\frac{mA}{V^2}\left(4^V - 1k \cdot I_D - 2\right)^2$

if I_D in mA units:

$I_D = 1 \cdot (2 - I_D)^2 \Rightarrow I_D = \begin{cases} 1mA \\ 4mA \end{cases}$ (10 points)

if $I_D = 1mA$

$V_S = 1^V$, $V_D = 9^V$ $\Rightarrow V_{DS} = 8^V$

$V_{DS} \geq V_{GS} - V_{Th}$

$8^V \geq 3^V - 2^V$ — (10 points) SAT OK

$V_{GS} = 3^V \geq V_{Th} = 2^V$ — (10 points) NOT OFF

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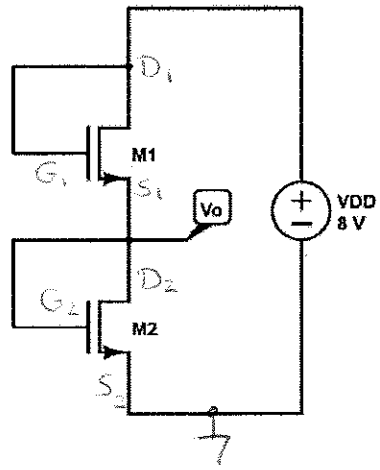
3. (40 points) In the circuit shown below, the field effect transistors have threshold voltages, $V_{TH} = 1V$. The transistors' conductance parameters are $K_{n1} = 4K_{n2} = 4mA/V^2$. Determine V_{GS1}, V_{GS2}, V_0, I_D. Show your work!



(5 points)

$V_{GS_1} = V_{DS_1}$, $I_{D_1} = I_{D_2}$

$V_{GS_2} = V_{DS_2}$

$V_{DS_1} + V_{DS_2} = 8^V$ (*) (5 points)

if T/R conducting they must be in SAT state because $V_{DS} \geq V_{GS} - V_{TH}$

assume M_1 and M_2 in SAT

$I_{D_1} = I_{D_2}$ (KCL) (5 points)

$K_{n_1}(V_{GS_1} - V_{TH})^2 = K_{n_2}(V_{GS_2} - V_{TH})^2$ (5 points)

$4K_{n_2}(V_{DS_1} - 1^V)^2 = K_{n_2}(V_{DS_2} - 1)^2$

$2(V_{DS_1} - 1) = (V_{DS_2} - 1)$

$2V_{DS_1} - 1 = V_{DS_2}$ (5 points)

from (*) $V_{DS_1} + V_{DS_2} = 8^V$ (10 points)

$3V_{DS_1} = 9^V \Rightarrow V_{DS_1} = 3^V \Rightarrow V_{DS_2} = 5^V$

$V_{GS_1} = 3^V$ $V_{GS_2} = 5^V$

$\Rightarrow V_o = 5^V$

$I_{D_1} = I_{D_2} = 4\frac{mA}{V^2}(3^V - 1^V)^2 = 16mA$ (5 points)