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

Pop Quiz 1

Section 2 - 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

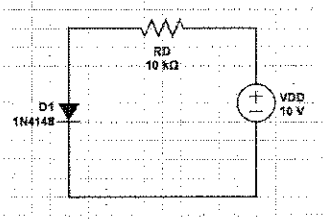
$i_D = K_n\left[2(v_{GS} - V_{Tn})v_{DS} - v_{DS}^2\right]$ NON-SAT

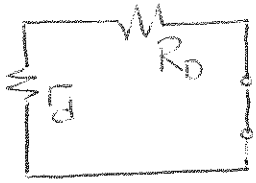
p-channel MOSFET

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

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

1. (20 points) Draw the small signal ac equivalent of the following circuit.





$r_d = \frac{V_T}{I_{DQ}}$

2. (40 points) What are the operating states of the transistors below? Justify your answer. For each, express the value of I_{DS} and V_{DS}.

$V_G = 10^V$

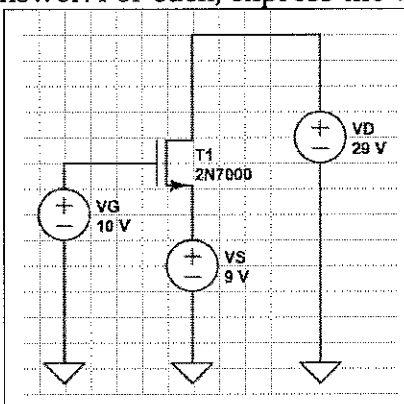
$V_S = 9^V$

$V_{GS} = 1^V < V_{Th}$

$\Rightarrow$ OFF

$I_D = 0$

$V_{DS} = 20^V$



V_{TH}=2V, K_n=1mA/V².	V_{TH}=2V, K_n=1mA/V².
State: OFF	*State:* SAT
I_{DS} = 0 mA	I_{DS} = 1mA
V_{DS} = 20V	V_{DS} = 17V

$V_G = 6^V$

$V_D = 30^V - 10k \cdot 1mA$

$= 20^V$

$I_D = 1mA$

assume SAT

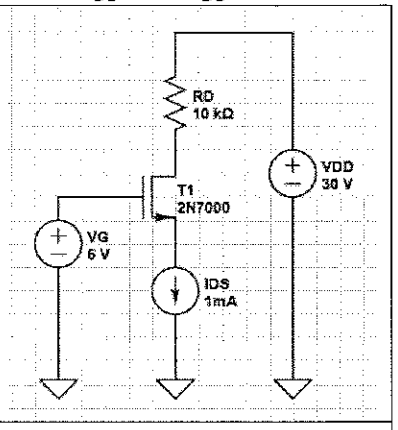
$1mA = \frac{1mA}{V^2}(6^V - V_S - 2^V)^2$

$\Rightarrow V_S = 3^V$

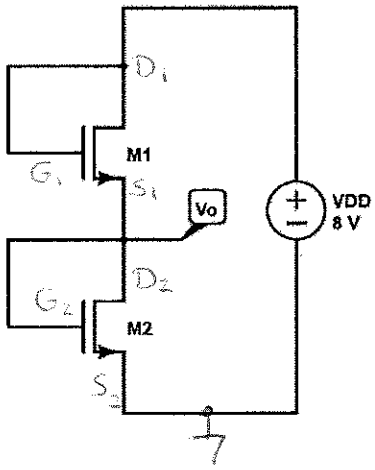
$V_{DS} = 17^V \geq V_{GS} - V_{Th}$

$17^V \geq 3^V - 2^V$

SAT OK.



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)

$V_{GS_1} = V_{DS_1}$ $\quad I_{D_1} = I_{D_2}$

$V_{GS_2} = V_{DS_2}$

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

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

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

$\Rightarrow V_o = 5^V$

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