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ECE 2280

Homework #7

1.

V_S	V_G	V_D	$\lvert V_{GS}\rvert$	$\lvert V_{OV}\rvert$	$\lvert V_{DS}\rvert$	Region of operation
+1	+1	+2	0V	-1V	1V	cutoff
+1	+2.5	+1.5	1.5V	.5V	.5V	triode
0	+2.5	+1	2.5V	1.5V	1V	triode
-1	0	+1	-1V	0V	2V	saturation

$V_t = 1V$

2.

V_S	V_G	V_D	$\lvert V_{GS}\rvert$	$\lvert V_{OV}\rvert$	$\lvert V_{DS}\rvert$	Region of operation
2	2	0	0V	1V	2V	cutoff
2	0	0	2V	1V	2V	cutoff
2	0	1.5	2V	1V	.5V	cutoff

$V_t = -1V$

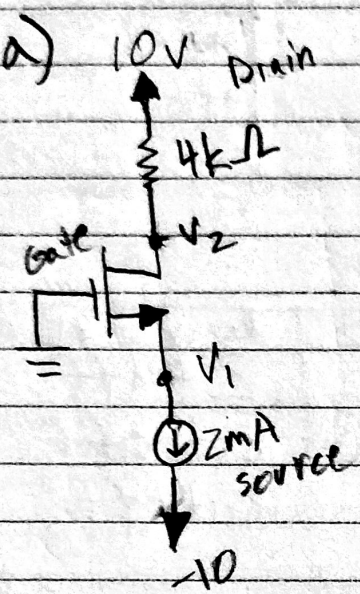
3.

- Assume saturation
- Put $I_G = 0$ and $I_D = I_S$
- Use $I_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS} - V_t)^2$
- Calculate voltages and current
- Check saturation conditions $\Rightarrow \lvert V_{DS}\rvert > \lvert V_{GS}\rvert - \lvert V_t\rvert$

4. NMOS is built with n-type source and drain and a p-type substrate, while PMOS is built with p-type source and drain and n-type substrate. NMOS carriers are electrons, PMOS carriers are holes, when high voltage is applied to gate, NMOS conducts, while PMOS will not. When low, PMOS conducts and NMOS does not.

5. $|V_t| = 2v$ $kn\left(\frac{W}{L}\right) = 1mA/V_1^2$ $\lambda = 0$

a)



$V_2 = 10v - (2mA)(4k\Omega)$

$= 2v$

$2mA = \frac{1}{2}(1mA)(V_{GS} - 2)^2$

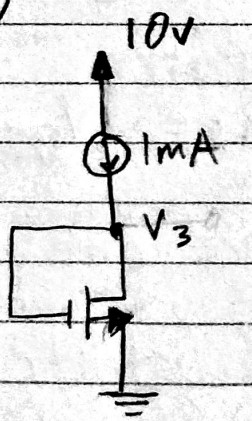
$V_{GS} = 4$

$V_G = 0$

$4 = 0 - V_S$

$V_1 = V_S = -4v$

b)



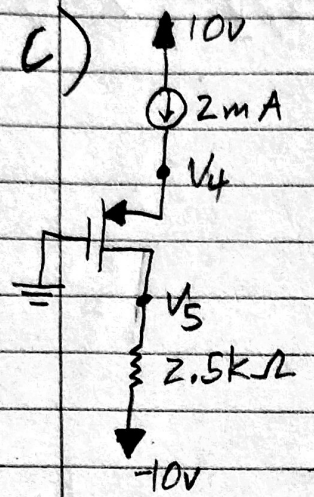
$1mA = \frac{1}{2}(1mA)(V_{GS} - 2)^2$

$V_{GS} = 3.41$

$V_S = 0$

$V_G = V_3 = 3.41v$

c)



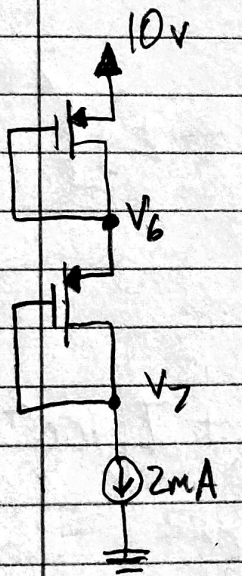
$V_5 = -2mA(2.5k\Omega) = -5V$

$V_G = 0$

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

$V_4 = V_5 = 4$

d)



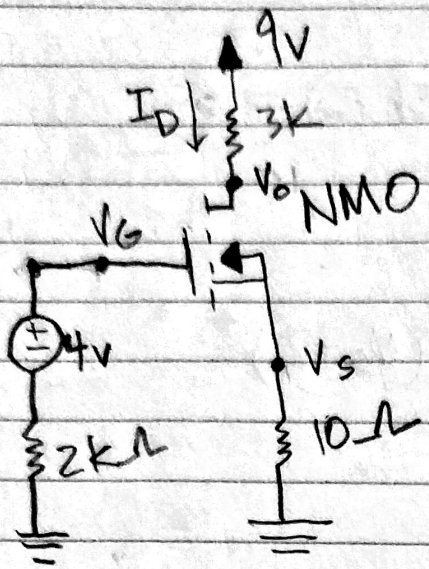
$2mA = \frac{1}{2}(1mA)(-V_G + 10 - 2)^2$

$V_G = V_6 = 6V$

$2mA = \frac{1}{2}(1mA)(-V_G + 6 - 2)^2$

$V_G = V_7 = 2V$

6. $V_t = 2V \quad k_n\left(\frac{W}{L}\right) = 4mA/V^2 \quad \lambda = 0$



a)

$$I_D = \frac{1}{2}(4mA)\left[\left(4_V - I_D(10\Omega)\right) - 2\right]^2$$

$$500 I_D = \left[2 - I_D(10)\right]^2$$

$I_1 = 0$

$V_G = 4V$

$$500 I_D = 4 - 20 I_D - 20 I_D + I_D 100^2$$

$$0 = 4 - 540 I_D + I_D 100^2$$

$$I_S = I_D = \frac{540 \pm \sqrt{540^2 - (4)(100)(4)}}{2(100)}$$

~~538.5164807~~

For 7.4mA: 7.4mA, 5.39A

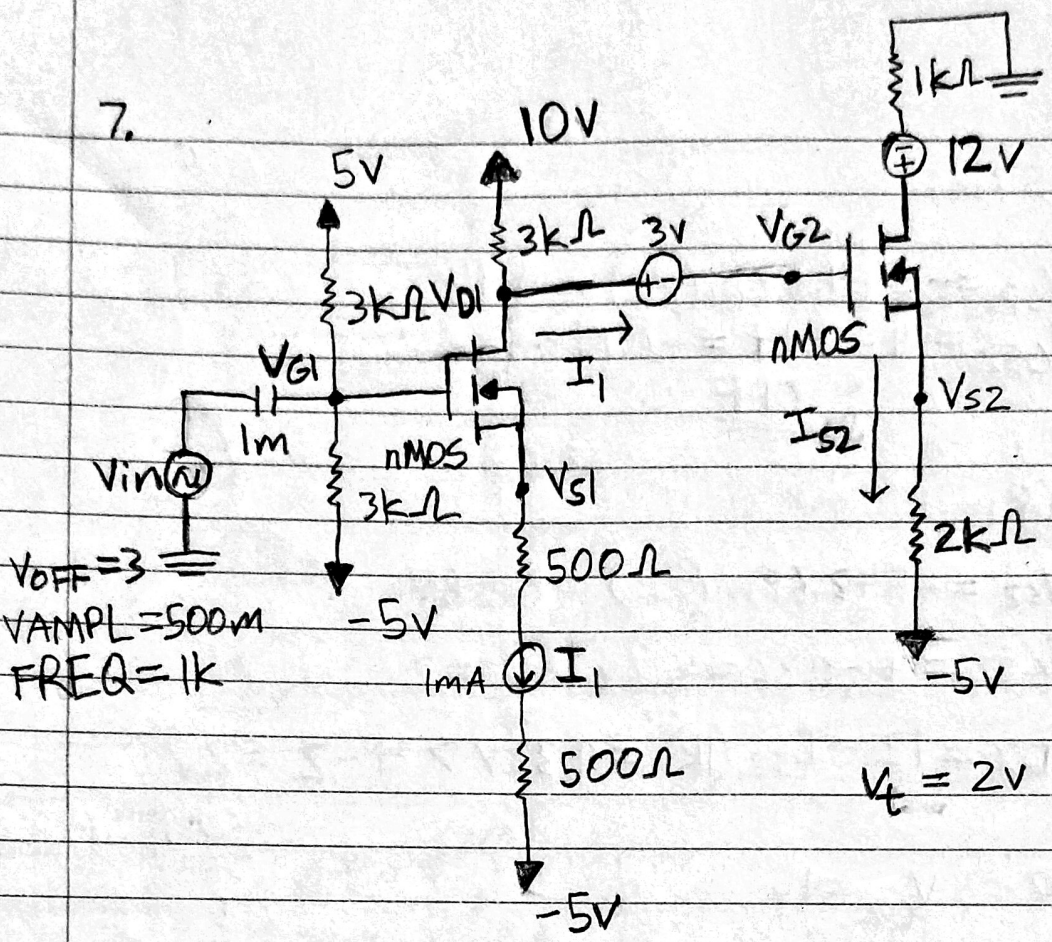
$V_S = (7.4mA)(10) = .074V$

$V_{GS} = 4V - .074 = 3.26V > V_t$

$V_{DS} = 9V - 0.74V = 8.26V > 3.26 - 2 = 1.26$

Saturation!! ✓

7.



$V_t = 2V \quad k'_n\left(\frac{W}{L}\right) = 2mA/V^2$

$\lambda = 0$

$V_{G1} = 0V$

$1mA = \frac{1}{2}(2m)(V_{GS1} - 2)^2$

$V_{GS1} = 3$

$3 = 0 - V_{S1}$

$V_{S1} = -3V$

$V_{G2} = 7V - 3V = 4V$

$V_{S2} = I_{D2}(2k)$

$V_{D1} = 10 - 3k(1mA) = 10 - 3 = 7V$

$I_{D2} = \frac{1}{2}(2m)(4 - I_D(2k)) + 5 - 2)^2$

$|V_{DS}| > |V_{GS}| - |V_t|$

$I_{S2}(1k) = (7 - I_{S2}(2k))^2$

$7 + 3 > 1 \quad \checkmark$

$0 = 4MI_{S2}^2 - 29kI_{S2} + 49$

$3 > 2 \quad \checkmark$ SAT

$2.68m, 4.57m$

For 4.57m:

$V_{S2} = -5 + 4.57m(2k) = 4.14$

$V_{GS2} = 4 - 4.14 = -0.14 < V_t = 2$

OFF

For 2.68m:

$V_{S2} = -5 + 2.68m(2k) = 0.36V$

$V_{GS2} = 4 - 0.36 = 3.64 > V_t = 2$

$V_{D2} = 12 - I_{S2}(1k) = 9.32V > 4 - 2 = 2V$

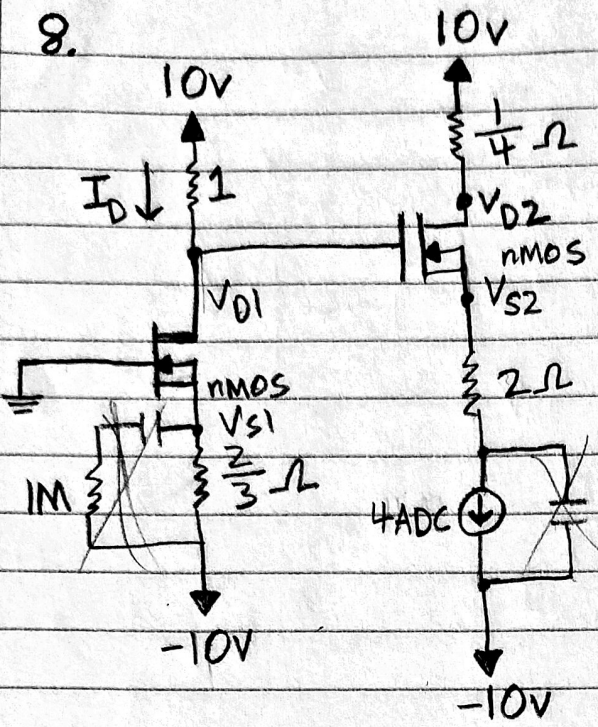
SAT

$I_1 = 0 \quad V_{G2} = 4v$

$I_{S2} = 2.68m \quad V_{G2} = 4V$

$V_{S2} = 0.36V$

8.



$V_t = 1V$

$K'n\left(\frac{W}{L}\right) = 2A/V^2$

$\lambda = 0$

$V_{DS_2} = 9 - 4 = 5$

$V_{GS_2} = 1 - 4 = -3$

$4 = \frac{1}{2}(2)(1 - V_S - 1)^2$

$\boxed{4 = V_{S_2}}$ $5 > 3 - 1$ ✓ SAT

$\boxed{V_{D2} = 10 - 1 = 9V}$

$V_{G1} = 0$

$V_{S1} = -10 + I_D(2/3)$

$I_{D1} = \frac{1}{2}(2A)\left(10 + I_D(2/3) - 1\right)^2$

$I_{D1} = 81 - I_D 6 - I_D 6 + I_D^2 \frac{4}{9}$

$0 = 81 - I_D 13 + I_D^2 \frac{4}{9}$

$\frac{13 \pm \sqrt{13^2 - 4\left(\frac{4}{9}\right)(81)}}{2\left(\frac{4}{9}\right)}$ $\frac{5}{}$

$\boxed{9}, 20.25$

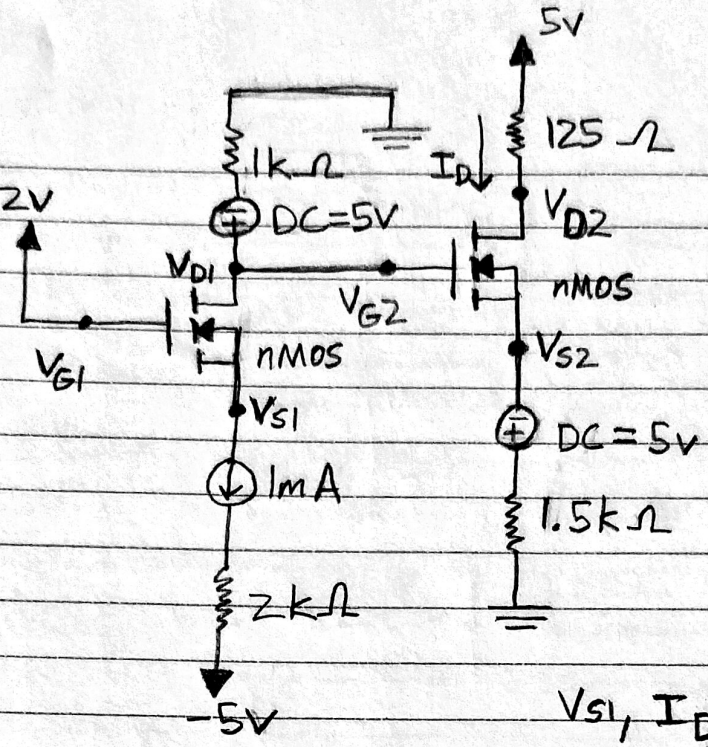
$V_{D1} = 10 - 9 = 1V$ $\quad V_{D1} = 10 - 20.25 = 10.25V$

$V_{S1} = +10 + 6 = -4$ $\quad V_{S1} = -10 + 13.5 = 3.5$

$V_{DS_1} = 5V$ SAT $\quad V_{DS_1} = 6.75$

$V_{GS_1} = 4V$ $\quad V_{GS_1} = -3.5$

9.



$V_t = 1v$

$kn\left(\frac{W}{L}\right) = 2mA$

$\lambda = 0$

V_{S1}, I_D, V_{D2}?

$$1mA = \frac{1}{2}(2mA)(2 - V_{S1} - 1)^2$$

$$\boxed{V_{S1} = 0}$$

$$V_{D1} = 5v$$

$$I_D = \frac{1}{2}(2mA)(5 - I_D(1.5k) + 5 - 1)^2$$

$$1kI_D = (9 - I_D 1.5k)^2$$

$$81 - 13.5kI_D - 13.5kI_D + I_D^2 2.25M$$

$$0 = I_D^2 2.25M - 28kI_D + 81$$

$$\frac{28k \pm \sqrt{-28k^2 - 4(2.25M)(81)}}{2(2.25M)}$$

$\boxed{.0045}$ $.0078$

$$\boxed{V_{D2} = 5 - 4mA(125) = 4.5V}$$

$V_{S2} = 1.5k(4mA) - 5 = 1v$ ✓

$V_{GS} = 5 - 1 = 4V$ $3.5 > 4 - 1$ SAT

$V_{DS} = 4.5 - 1 = 3.5$

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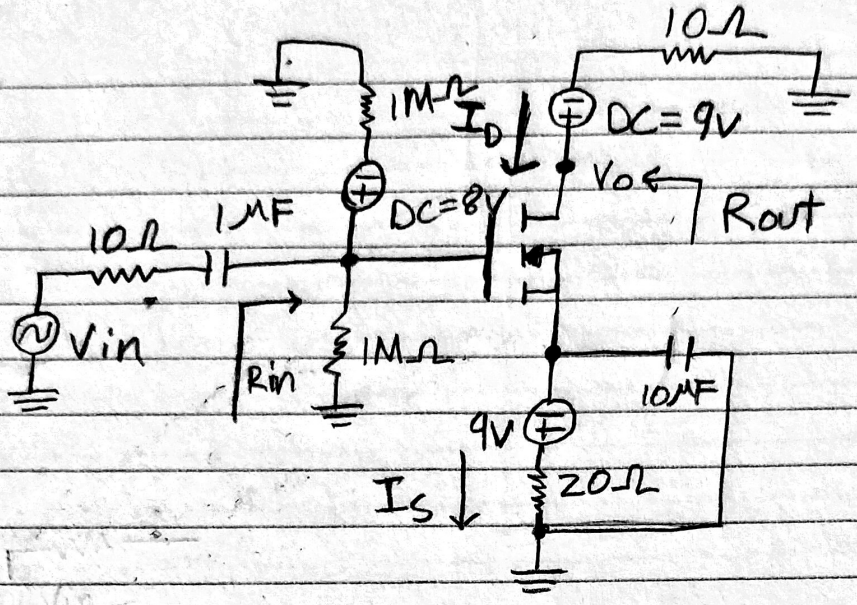
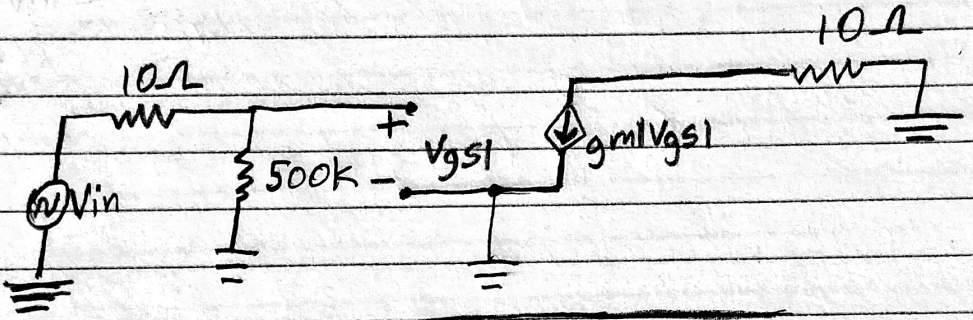
10.



$V_t = 2V$

$k_n\left(\frac{W}{L}\right) = 180\mu A/V^2$



$$g_m = \sqrt{(180\mu A)(2)(10mA)} = 1.9mA$$