

Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Fall 2011

Exam #3

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are 4 pages in your exam
- You may use one double-sided page of notes and equations for the exam
- Good Luck!

Problem	Score	Max Score
1		30
2		35
3		35
Total		100

Name: SAM PALERMO

UIN: _____

Problem 1 (30 points)

For all the circuits below, use the following NMOS parameters

$$K_{PN} = \mu_n C_{ox} = 100 \mu A/V^2, V_{TN} = 1V, \lambda_n = 0V^{-1}$$

and the following PMOS parameters

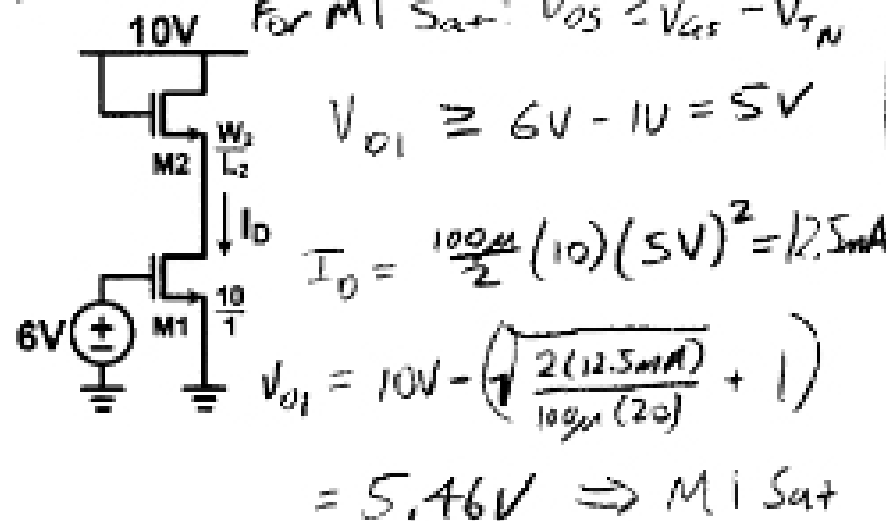
$$K_{PP} = \mu_p C_{ox} = 30 \mu A/V^2, V_{TP} = -1V, \lambda_p = 0V^{-1}$$

For the following two circuits calculate

i. I_D with $W_2/L_2 = 20/1$. (10 points)

ii. The minimum W_2/L_2 such that the M1 transistor remains in saturation (10 points)

a)



For $V_{D1} = 5V \Rightarrow \left(\frac{W}{L}\right)_2 = \frac{2(12.5mA)}{100 \mu (4V)^2} = 15.625$

$I_D (W_2/L_2 = 20/1) = 12.5mA$

M1 Sat. Min $W_2/L_2 = 15.625$

For M1 Sat:

$$V_{SD1} \geq V_{SD1} - |V_{TP}|$$

$$V_{SD1} \geq 6V - 1V = 5V$$

or $V_{D1} \leq 10V - 5V = 5V$

$$I_D = \frac{30 \mu}{2} (10)(5V)^2 = 3.75mA$$

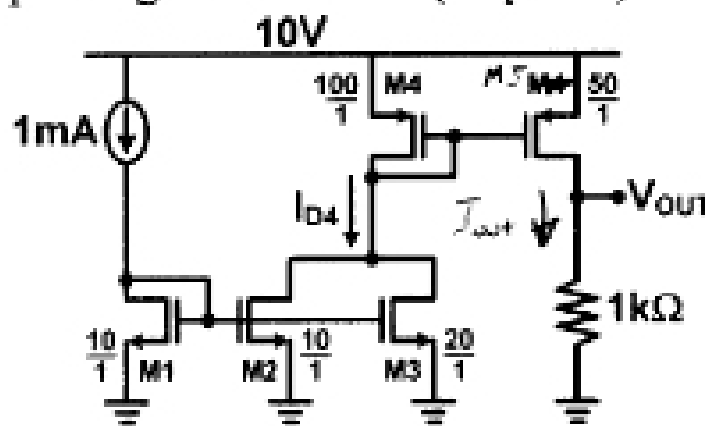
$$V_{D1} = \sqrt{\frac{2(3.75mA)}{100 \mu (20)}} + 1 = 2.94V \Rightarrow M1 \text{ Sat}$$

For $V_{D1} = 5V \Rightarrow \left(\frac{W}{L}\right)_2 = \frac{2(3.75mA)}{100 \mu (4V)^2} = 4.69$

$I_D (W_2/L_2 = 20/1) = 3.75mA$

M1 Sat. Min $W_2/L_2 = 4.69$

c) For the following circuit find the values for I_{D4} and V_{OUT} . Assume all transistors are operating in saturation. (10 points)



From Current Mirrors (M1/M2/M3)

$$I_{D4} = 1mA \left[\frac{(10/1)}{(10/1)} + \frac{(20/1)}{(10/1)} \right] = 3mA$$

From Current Mirror (M4/M5)

$$I_{OUT} = 3mA \left(\frac{(50/1)}{(100/1)} \right) = 1.5mA$$

$$V_{OUT} = 1.5mA(1k\Omega) = 1.5V$$

$I_{D4} = 3mA$

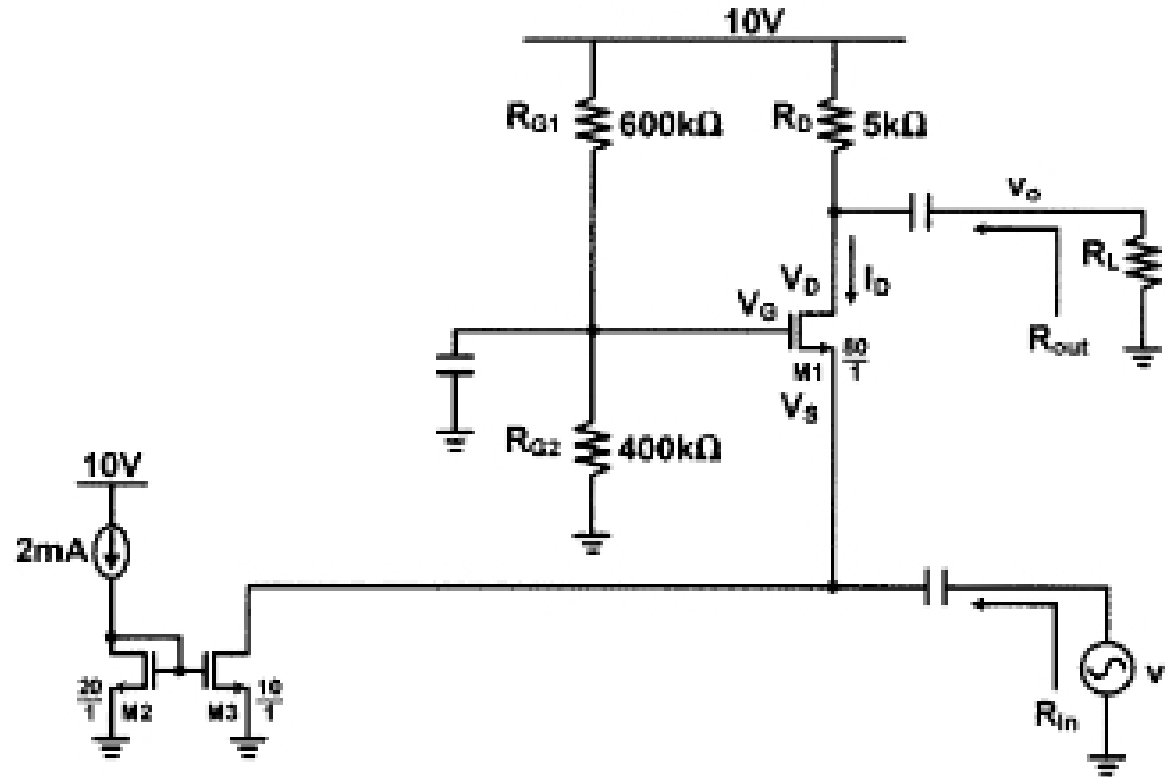
$V_{OUT} = 1.5V$

Problem 2 (35 points)

Assume for problem 2 that the NMOS transistors are all operating in saturation and have

$$K_{PN} = \mu_n C_{ox} = 100 \mu A/V^2, V_{TN} = 1V, \lambda_n = 0V^{-1}$$

a) Calculate the DC values for I_D , V_D , V_G , V_S and the AC small-signal g_{m1} . (10 points)



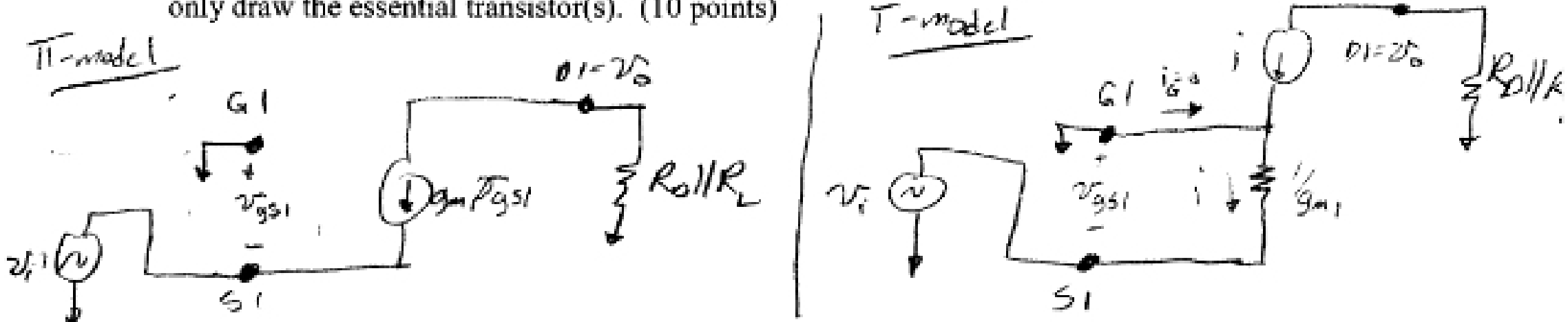
From current mirror
 $I_D = 2mA \cdot \frac{(10/1)}{(20/1)} = 1mA$
 $V_G = 10V \cdot \left(\frac{400k}{400k + 600k} \right) = 4V$
 $V_D = 10V - 5k(1mA) = 5V$

$$V_S = V_G - (V_{DD} + V_{TN}) = 4V - \left(\sqrt{\frac{2(1mA)}{100\mu(80)}} + 1 \right) = 2.5V$$

$$g_{m1} = \sqrt{2K_{PN} \left(\frac{W}{L} \right) I_D} = \sqrt{2(100\mu)(80)(1mA)} = 4 mA/V$$

$I_D = 1mA$
 $V_D = 5V$
 $V_G = 4V$
 $V_S = 2.5V$
 $g_{m1} = 4 mA/V$

b) Sketch the small-signal model of the circuit. Assume that the capacitors act as AC shorts and only draw the essential transistor(s). (10 points)



c) Calculate small signal gain $A_v = v_o/v_i$, input resistance R_{in} , output resistance R_{out} . (15 points)

$$v_o = g_{m1} v_i (R_D || R_L) \Rightarrow A_v = g_{m1} (R_D || R_L) = 4mA(5k || 5k) = 10 V/V$$

$$R_{in} = \frac{1}{g_{m1}} = 250 \Omega$$

For R_{out} :

$$R_{out} = R_D = 5k \Omega$$

$A_v = 10 V/V$
 $R_{in} = 250 \Omega$
 $R_{out} = 5k \Omega$