Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Fall 2025

Exam #3

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are **6** 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		20
2		10
3		35
4		35
Total		**100**

Name: SAM PALERMO

UIN:

Problem 1 (20 points)

For all the circuits below, use the following NMOS parameters

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

and the following PMOS parameters

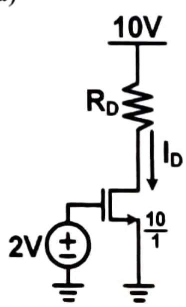
$KP_P=\mu_p C_{ox}=30\mu A/V^2$, $V_{TP}=-1V$, $\lambda_P=0V^{-1}$

For the following two circuits calculate

i. I_D with $R_D=10k\Omega$. (10 points)

ii. The maximum R_D such that the transistor remains in saturation. (10 points)

a)



i. Assume Saturation

$$I_D = \frac{1}{2} KP_N \frac{W}{L}(V_{GS}-V_{TN})^2 = \frac{1}{2}(100\mu A/V^2)\left(\frac{10}{1}\right)(2V-1V)^2 = 500\mu A$$

For Sat $V_{DS} \geq V_{GS}-V_{TN}$

$V_{DS} = VDD - I_D R_D = 10V - 0.5mA(10k\Omega) = 5V \geq 2V-1V = 1V$ ✓

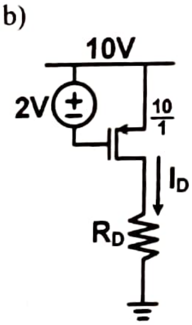
ii. For Sat $V_{DS} \geq 1V = VDD - I_D R_D$

$$\text{Max } R_D = \frac{VDD - V_{DS}}{I_D} = \frac{10V-1V}{0.5mA} = 18k\Omega$$

I_D ($R_D=10k\Omega$) = $500\mu A$

Sat. Max R_D = $18k\Omega$

b)



i. Assume Saturation

$$I_D = \frac{1}{2} KP_P \frac{W}{L}(V_{SG}-|V_{TP}|)^2 = \frac{1}{2}(30\mu A/V^2)\left(\frac{10}{1}\right)(2V-|-1V|)^2 = 150\mu A$$

For Sat $V_{SD} \geq V_{SG}-|V_{TP}|$

$V_{SD} = VDD - I_D R_D = 10V - 150\mu A(10k\Omega) = 8.5V \geq 2V-|-1V| = 1V$ ✓

ii. For Sat $V_{SD} \geq 1V = VDD - I_D R_D$

$$\text{Max } R_D = \frac{VDD - V_{DS}}{I_D} = \frac{10V-1V}{150\mu A} = 60k\Omega$$

I_D ($R_D=10k\Omega$) = $150\mu A$

Sat. Max R_D = $60k\Omega$

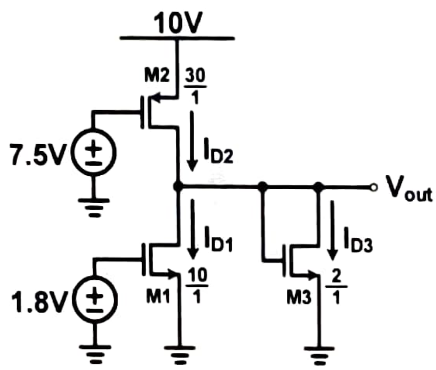
Problem 2 (10 points)

For the circuit shown below, all transistors are operating in the saturation region. Use the following transistor parameters

$KP_N = \mu_n C_{ox} = 100\mu A/V^2$, $V_{TH,N} = 1V$

$KP_P = \mu_p C_{ox} = 30\mu A/V^2$, $V_{TH,P} = -1V$

$\lambda_N = \lambda_P = 0V^{-1}$



Calculate the DC operating points of the circuit, including I_{D1-3} and V_{out}.

$$I_{D1} = \frac{1}{2} KP_N \frac{W}{L} (V_{GT} - V_{TN})^2 = \frac{1}{2}\left(100 \frac{\mu A}{V^2}\right)\left(\frac{10}{1}\right)(1.8V - 1V)^2 = 320\mu A$$

$$I_{D2} = \frac{1}{2} KP_P \frac{W}{L} (V_{SG} - |V_{TP}|)^2 = \frac{1}{2}\left(30 \frac{\mu A}{V^2}\right)\left(\frac{30}{1}\right)(2.5V - |-1V|)^2 = 1.01mA$$

$$I_{D3} = I_{D2} - I_{D1} = 1.01mA - 320\mu A = 693\mu A$$

$$V_{OUT} = V_{GS3} = \sqrt{\frac{2I_D}{KP_N \frac{W}{L}}} + V_{TN} = \sqrt{\frac{2(693\mu A)}{\left(100 \frac{\mu A}{V^2}\right)\left(\frac{2}{1}\right)}} + 1V = 3.63V$$

$I_{D1} = 320\mu A$

$I_{D2} = 1.01 mA$

$I_{D3} = 693\mu A$

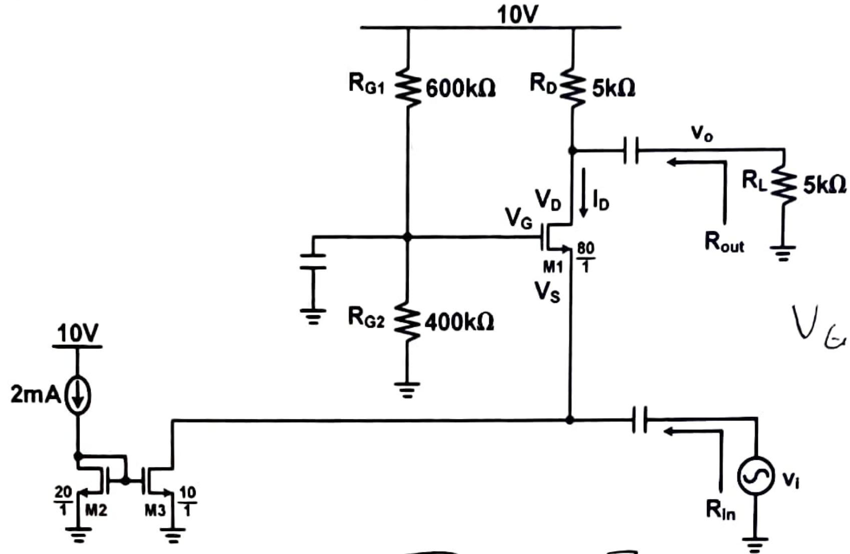
$V_{out} = 3.63V$

Problem 3 (35 points)

Assume for problem ~~2~~ 3 that the NMOS transistors are all operating in saturation and have

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

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



From M2/3 Current Mirror

$I_o = 2mA\left(\frac{(10/1)}{(20/1)}\right) = 1mA$

$V_G = 10V\left(\frac{400K}{600K+400K}\right) = 4V$

$V_S = V_G - V_{GS} = V_G - \left[\sqrt{\frac{2I_o}{KP_N(\frac{W}{L})_1}} + V_{TN}\right] = 4V - \left[\sqrt{\frac{2(1mA)}{100\mu(\frac{80}{1})}} + 1V\right]$

$= 2.5V$

$V_D = VDD - I_D R_D = 10V - 1mA(5k\Omega) = 5V$

$g_{m1} = \sqrt{KP_N(\frac{W}{L})_1 2I_o} = \sqrt{(100\mu A/V^2)(80/1)(2)(1mA)} = 4 mA/V$

$I_D =$ 1mA

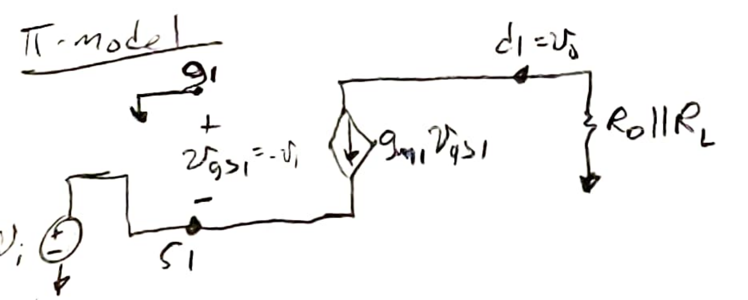
$V_D =$ 5V

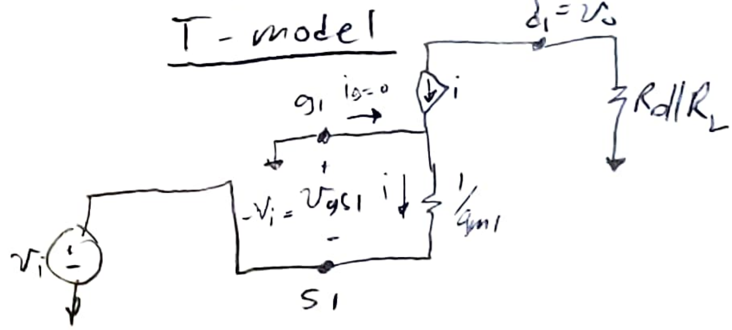
$V_G =$ 4V

$V_S =$ 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)

$v_o = -g_{m1} v_{gs1}(R_o \| R_L) = g_{m1} v_i (R_o \| R_L)$

$A_V = g_m(R_o \| R_L) = 4mA/V(5k\Omega \| 5k\Omega) = 10 V/V$

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

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

$A_v =$ 10 V/V

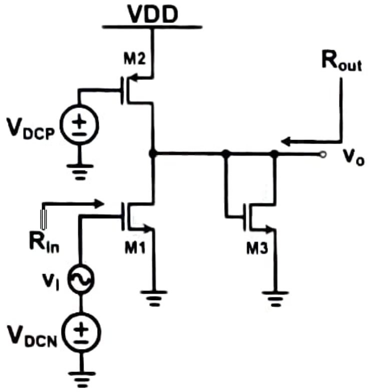
$R_{in} =$ 250Ω

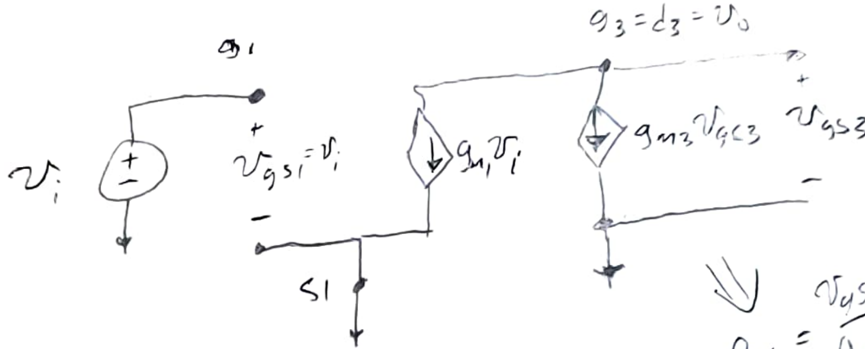
$R_{out} =$ 5kΩ

Problem 4 (35 points)

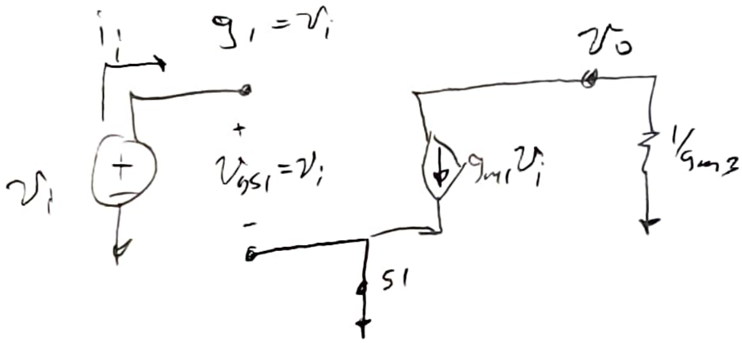
This problem involves the small signal analysis of the circuit below. Assume that the transistors are all operating in saturation and have $r_o=\infty$.

a) Sketch the circuit's small-signal model. Assume the capacitors act as AC shorts. (15 points)





$$R_{eq} = \frac{v_{gs3}}{g_{m3} v_{gs3}} = \frac{1}{g_{m3}}$$

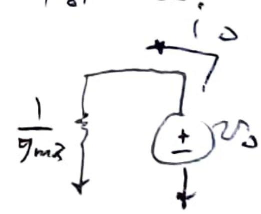


b) Derive expressions for the small signal gain $A_v=v_o/v_i$, input resistance R_{in}, and output resistance R_{out}. (20 points)

$$v_o = -g_{m1} v_i \left(\frac{1}{g_{m3}}\right) \Rightarrow A_v = -\frac{g_{m1}}{g_{m3}}$$

$$R_{in} = \frac{v_i}{i_i} = \frac{v_i}{0} = \infty$$

For R_{out}:



$$R_{out} = \frac{1}{g_{m3}}$$

$A_v = -\frac{g_{m1}}{g_{m3}}$

$R_{in} = \infty$

$R_{out} = \frac{1}{g_{m3}}$