EECS40
Summer 2006

University of California Berkeley
Midterm Exam # 2
August 8th, 2006
Instructor: Octavian Florescu

Name: ______Hung_____________________________, ________Bill____________________
Last **First**

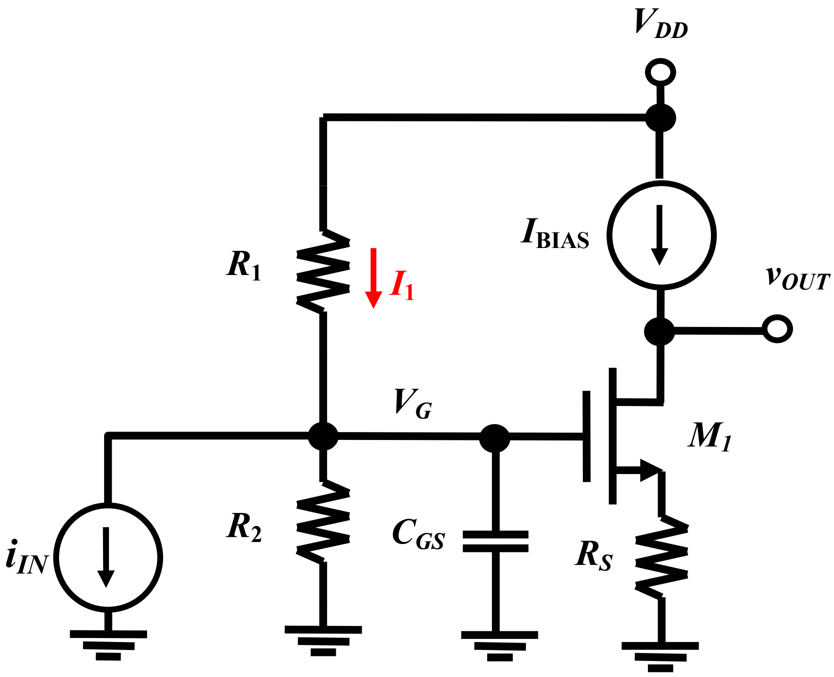
Student ID: ___________________________, Signature_____________________________

1. **This is a closed book exam. However you may use one page of handwritten double sided notes.**
2. **Non programmable calculators are allowed only.**
3. **Make sure to write down your name on every page.**

Problem	Mark
1	/25
2	/25
3	/20
4	30/30
Total	/100

Name__ _Good Student_ _

Problem 4. **MOSFET [30 points]**



Parameters:

$V_{DD} = 9V$
$I_{BIAS} = 2mA$

$R_1 = 3k\Omega$
$R_2 = 6k\Omega$
$R_S = 500\Omega$

$V_T(M_1) = 0.5V$
$\lambda(M_1) = 0.5V^{-1}$
$\mu_n C_{ox}(M_1) = 100\ uA/V^2$
$W/L(M_1) = 2$

a. The voltage V_G considering I_{IN} = 1mA. Note that $i_{IN} = i_{in} + I_{IN}$ [5pts]

$$V_G = V_{DD} - I_1 \cdot R_1$$

$$I_1 = i_{IN} + \frac{V_G}{R_2}$$

$$V_G = 9V - (i_{IN} + \frac{V_G}{6k}) \cdot 3\text{k}$$

$$\frac{3}{2}V_G = 9V - i_{IN} \cdot 3\text{k}\Omega$$

$$\frac{3}{2}V_G = 9V - (i_{in} + 1mA) \cdot 3\text{k}\Omega$$

$$V_G = 4V - 2\text{k} \cdot i_{in}$$

V_G = 4V if i_{in} is 0 for DC analysis

Mistake 1: Ignoring I_{IN} = 1mA, and just do a voltage divide. (-0.5 point)

Mistake 2: Plug in the wrong values for unknown reasons. (-0.5 point)

Mistake 3: Wrong sign when setting up the equation(+ or -) (-0.5 point)

b. Find the source voltage of M_1. [5pts]

$$V_S = I_{BIAS} \cdot R_S = 1V$$

c. Find V_{DS} using the values from **a.** and **b.** What region is M1 operating in? [5pts]

Assume M1 is in saturation region.

$$\text{I}_{\text{DS}} = \mu Cox\frac{W}{2L}(V_{GS} - Vt)^2(1 + \lambda V_{DS})$$

$$2mA = (100\mu A / V^2)\frac{2}{2}(3V - 0.5V)^2(1 + 0.5V^{-1} \cdot V_{DS})$$

Mistake 1:Wrong Vds (-0.5) Mistake 2:No Vds but otherwise correct (-1)

$$V_{DS} = 4.4V, V_{GS} = 3V, Vt = 0.5V$$

$$V_{DS} > V_{GS} - Vt \quad \text{and} \quad V_{GS} > Vt$$

Assumption was correct, and M1 is in Saturation Region.

d. Find the transfer function v_g / i_{in}. Note that i_{in} is a small signal without a DC component. [5pts]

$V_g = -i_{in} (R_1 // R_2 // Z(C_{GS}))$

$$\frac{V_g}{i_{in}} = -\frac{1}{(\frac{1}{R_1} + \frac{1}{R_2} + jwC_{GS})}$$

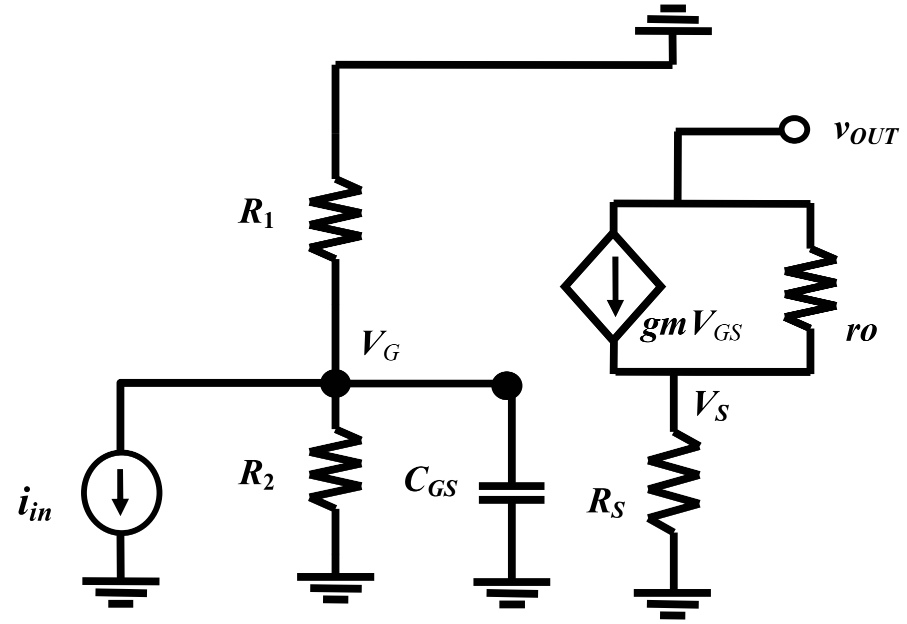
Common Mistake 1:Forgetting the negative sign (-0.5 point)

Common Mistake 2: Inverting the answer Vg/iin because the student forgot how to calculate impedance in parallel (-0.5 point)

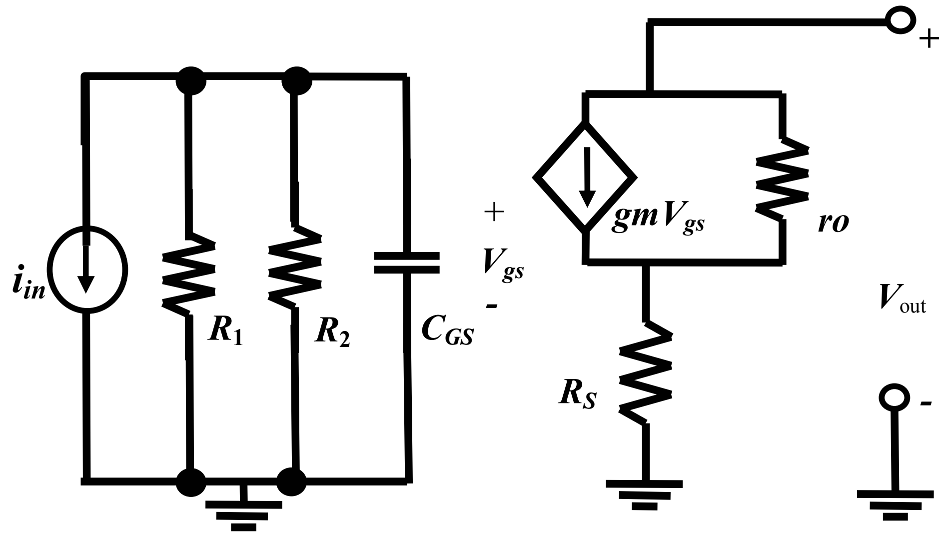
Common Mistake 3: Both Mistake 1 and Mistake 2. (-1 point)

e. Sketch the small signal model of this configuration and find the transfer function v_{out}/i_{in}. [10 pts: 5pts for the small signal model, 5 pts for the calculations]

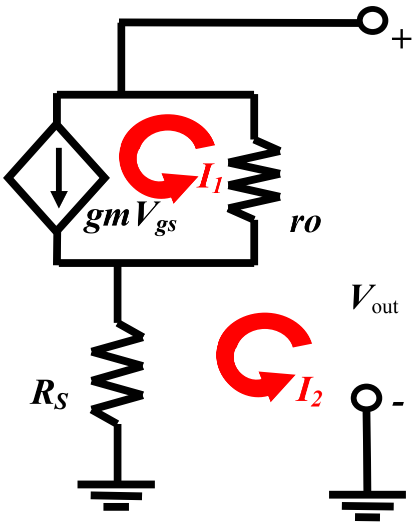
Step 1. Replace the circuit with all small circuit elements. That is eliminate all the DC (constant voltage or constant current) elements.



Step 2. which gives a small signal model of:



- Notice, the small signal circuit is a new circuit, the "big" signal V_G, V_S, and V_{OUT} are not here. Only small signal elements exist in a small signal model.
- C_{GS} is a misnomer. It is not the capacitor between the gate and source of M1.



$$\begin{cases} I_1 = gmVgs \\ I_1 = \frac{Vs - Vout}{ro} \\ Vout = (I_2 - I_1)ro + I_2 \cdot R_S \\ I_2 = \frac{Vs}{Rs} \end{cases}$$

$$gm = \mu_n C_{ox} (\frac{W}{L})(V_{GSQ} - V_t) = 0.5m$$

$$ro = \frac{1}{\lambda I_{DS}} = 1k$$

$$\begin{cases} I_1 = 0.5m\,(Vg - Vs) \\ I_1 = \frac{Vs - Vout}{1k} \\ vout = (I_2 - I_1) \cdot 1k + I_2 \cdot 500 \\ I_2 = \frac{Vs}{500} \end{cases}$$

Vout = - 1.375 Vg

$$\frac{Vout}{i_{in}} = 1.375\ (R_1 // R_2 // Z(C_{GS}))$$

Common Mistake 1: The circuit said v_{OUT}, but this question asked for vout/vin. So the vout is supposed to be small signal output only, without the DC bias.

Common Mistake 2: Wrong small signal circuit. Some assumed C_{GS} is infinite and shorted C_{GS} in the small signal circuit.

BONUS [2 points]: Find the output impedance of this configuration.

$$Rout = \frac{1}{gm} // ro + Rs$$

$$Rout = ro + Rs + gm \cdot Rs \cdot ro$$