February 14th 2013

NAME: Solution Set

MAXIMUM POINTS: 100

EECE 322: Electronics-II (Spring 2013, University of New Mexico)
MID TERM EXAMINATION-I

RULES:

- Write your name on the top left corner
- Time Allotted = 75 Minutes
- Closed Book and Closed Notes
- You are allowed one single sided 8.5 x 11 page of formulae
- You may use a scientific calculator
- Write your answers on the question paper. You may use additional sheets if needed.

HINTS:

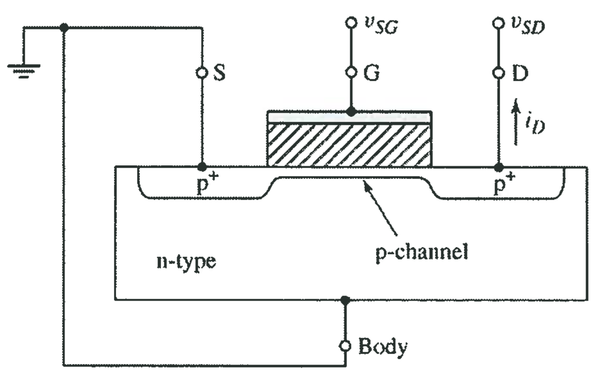
- Please read the questions carefully and only provide only the information that is requested. This will save you time.
- If you are stuck in a particular question, move on to the next and come back to the question later. Solving the easy problems will give you confidence to solve the more challenging questions.

Section A: Conceptual Questions

Multiple Choice: Circle the correct answer. (60 Points)

1. Consider the transistor shown below.

5 Points



Which of these statements about this transistor is true?

a. This is a normally off PMOS with no body effect
b. This is a normally on PMOS with no body effect
c. This is a normally off PMOS with body effect
d. This is a normally on NMOS with body effect

MOSFET

2 Consider an NMOS enhancement mode ~~MOST~~ with the following parameters. V_{TN}=0.4V, W=20μm, L=0.8μm, μ_n= 650cm^2/Vs, t_{ox}=20nm, and ε_{ox}= (3.9) ε_0, where ε_0= 8.85x10^{-14} F/cm. Determine the current when the transistor is biased in saturation with V_{GS}= 1.6V.

5 Points

$$K_n = \frac{W}{2L} \frac{\mu_n \varepsilon_{ox}}{t_{ox}} = 1.40 mA/V^2$$

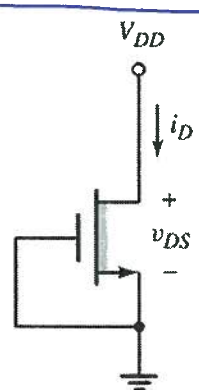
v_{GS} = 1.6V. In saturation

$$I_{DQ} = K_n (V_{GSQ} - V_{TN})^2$$
$$= 2.02mA$$

3 Consider the transistor below. Which of these statements is true?

5 Points

a. This transistor is always in saturation
b. This transistor is always in non-saturation
c. This transistor is always in cut-off
d. The state of this transistor depends on the biasing conditions.



Depletion mode load

4 A transistor has a threshold voltage of V_{TN}=1V, K_n=0.1 mA/V^2 and V_{GS}=2.35V. Calculate the transition point of the transistor (i.e. determine the value of V_{DS} that makes the transistor go from saturation to non-saturation).

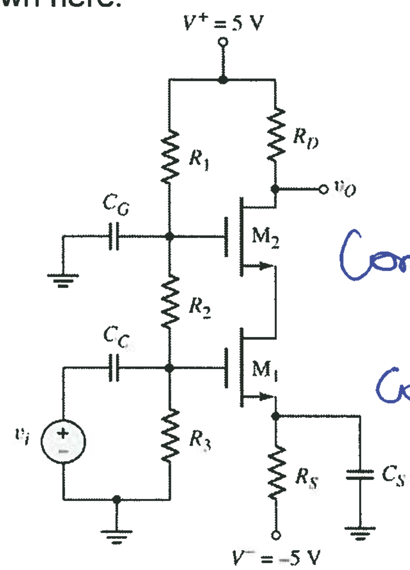
5 Points

Transition point is the same as $V_{DS}(sat)$ since V_{GS} is fixed

$$V_{DS}(sat) = (V_{GS} - V_{TN}) = \underline{\underline{1.35\,V}}$$

5. Consider the circuit shown here.

5 Points



Common Gate

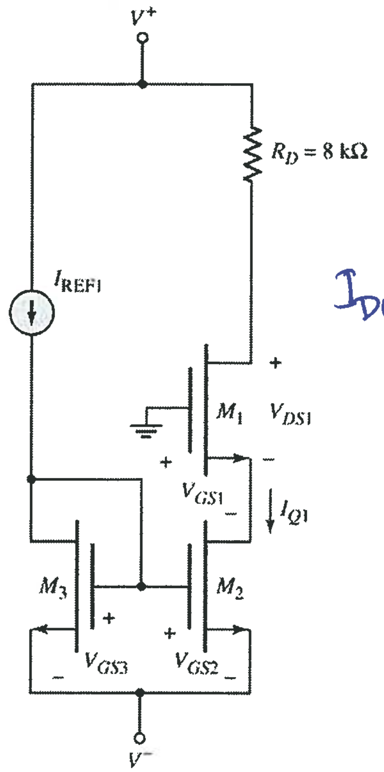
Common source

In this circuit,

a. The first stage is a common gate amplifier and the second stage is common source amplifier
b. The first stage is a common source amplifier and the second stage is common gate amplifier
c. The first stage is a common gate amplifier and the second stage is common drain amplifier
d. The first stage is a common drain amplifier and the second stage is common gate amplifier

6. For the circuit shown below, assume that I_{REF1}=120μA, V^+=3V, V^-=-3V and the transistor parameters are V_{TN}=0.4V, λ=0, K_{n1}=50μA/V^2, K_{n2}=30μA/V^2 and K_{n3}=60μA/V^2. Determine I_{Q1}.

6 Points



$I_{Ref1} = I_{DQ3}$

$I_{DQ3} = k_{n3}\,(V_{GSQ3} - V_{TN})^2$

$I_{DQ1} = I_{DQ2} = k_{n2}\,(V_{GSQ2} - V_{TN})^2$

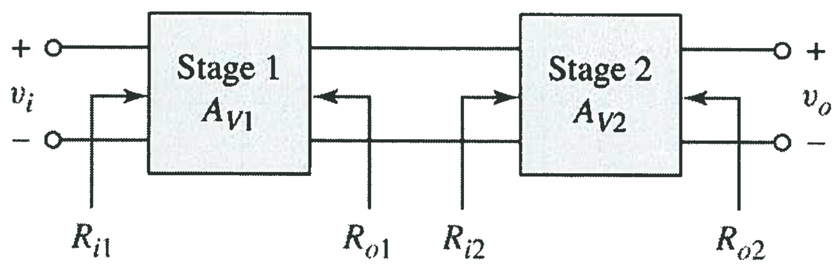
Since $V_{GSQ2} = V_{GSQ3}$, and

$k_{n3} = 2k_{n2}$

$I_{DQ1} = I_{Q1} = \underline{60\,\mu A}$

7. Consider this two stage amplifier. Write an expression for the overall gain of this amplifier (i.e. A_v=v_o/v_i)

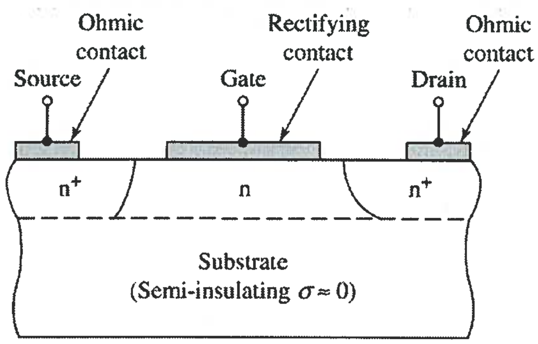
8 Points



$$A_v = \left[\frac{R_{i2}}{R_{i2} + R_{o1}}\right] A_{v1} \times A_{v2}$$

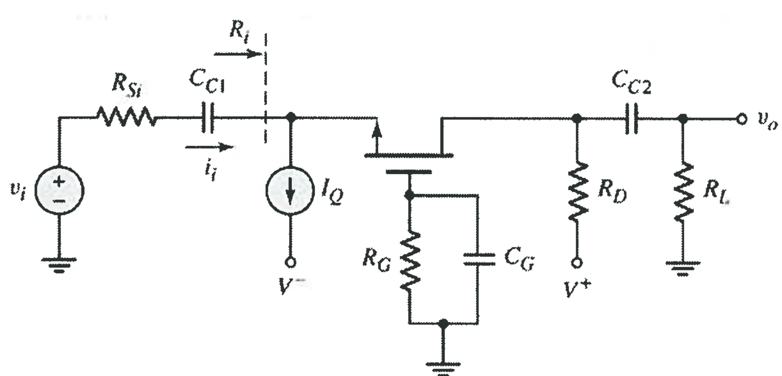
8. The schematic below is that of a *5 Points*

a. Enhancement mode MESFET
b. ~~Enhancement mode MOSFET~~
c. Depletion mode JFET
d. Depletion mode MESFET



9. In the circuit below, what is the value of R_i (input resistance to an <u>AC</u> source). Given that g_m=2mA/V, λ=0, R_{si}=1KΩ, R_G=100MΩ, R_D=R_L=10KΩ.

6 Points

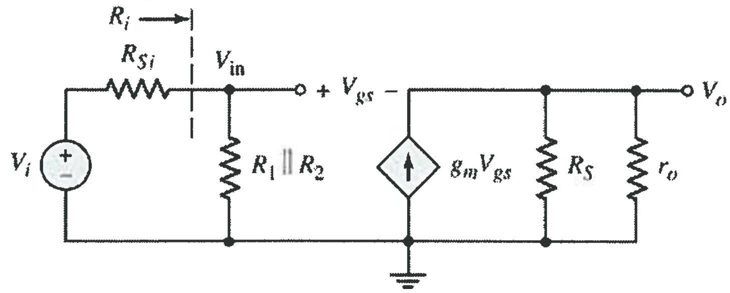


R_i for common gate amplifier $= \frac{1}{g_m}$

$$R_i = \frac{1}{2mA/V} = \underline{\underline{500\,\Omega}}$$

10. What is the overall gain ($A_v = V_o/V_i$) for the circuit shown below.

10 Points



Common Drain Amplifier

$$V_o = g_m V_{gs} (R_s \| r_o)$$

$$V_i = V_{gs} + V_o \Rightarrow V_{gs} = (V_i - V_o)$$

$$V_o = g_m (R_s \| r_o) (V_i - V_o)$$

$$V_o (1 + g_m (R_s \| r_o)) = g_m (R_s \| r_o) V_i$$

$$A_v = \frac{V_o}{V_i} = \frac{g_m (R_s \| r_o)}{1 + g_m (R_s \| r_o)}$$

Section B: Problems (40 Points)

B.1 The transistor in the common-gate circuit in the figure below has transistor parameters of $V_{TN} = 0.4$ V, $k_n' = 100\,\mu$A/V^2, and $\lambda = 0$. The output resistance R_o is to be 500 Ω and the drain-to-source quiescent voltage is to be $V_{DSQ} = V_{DS}(sat) + 0.3$ V.

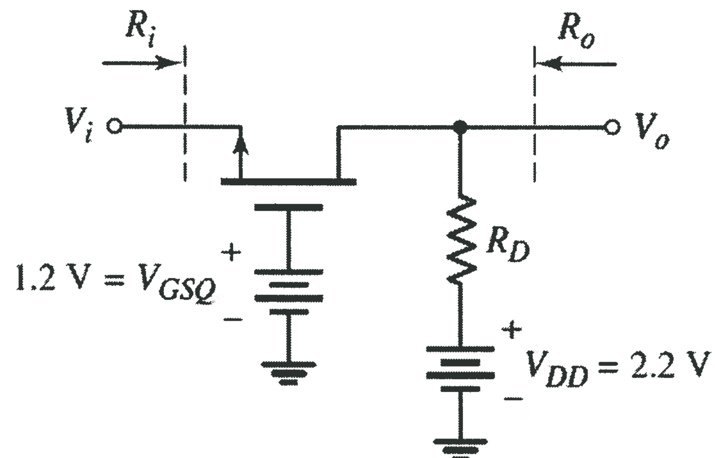
(a) What is the value of R_D?

(b) What is the quiescent drain current I_{DQ}?

20 Points

(c) Find the input resistance R_i.

(d) Determine the small-signal voltage gain $A_\upsilon = V_o / V_i$.



(a) Common gate amplifier

$$R_o = R_D = 500\,\Omega$$

(b) $V_{GSQ} = 1.2$ V

Doing KVL on DS loop

$$I_{DQ} = \frac{V_{DD} - V_{DS}}{R_D} = \frac{2.2 - (V_{DS}(sat) + 0.3)}{0.5}$$

$$= \frac{2.2 - (1.2 - 0.4 + 0.3)}{0.5} = \underline{\underline{2.2\,mA}}$$

(c) $g_m = 2\sqrt{k_n I_{DQ}}$

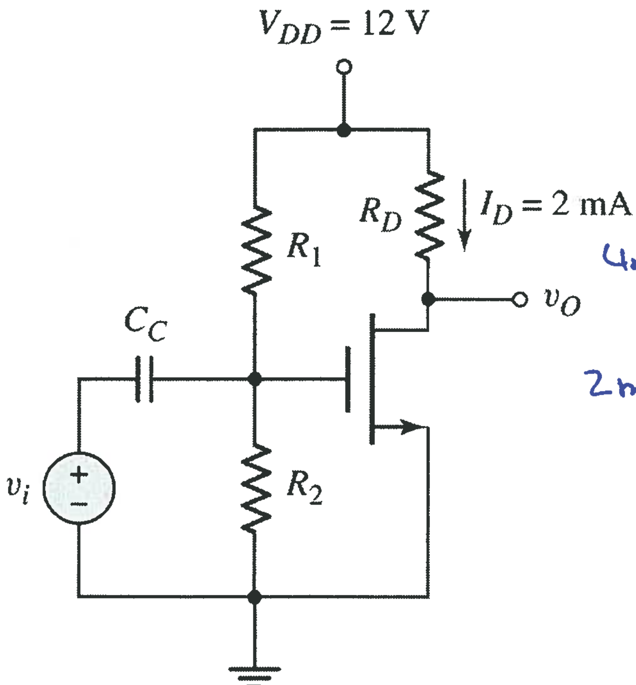
$I_{DQ} = K_n (V_{GSQ} - V_{TN})^2 = K_n = 3.44\,mA/V^2$

$g_m = 5.5\,mA/V$ and $R_i = \frac{1}{g_m} = \underline{\underline{182\,\Omega}}$

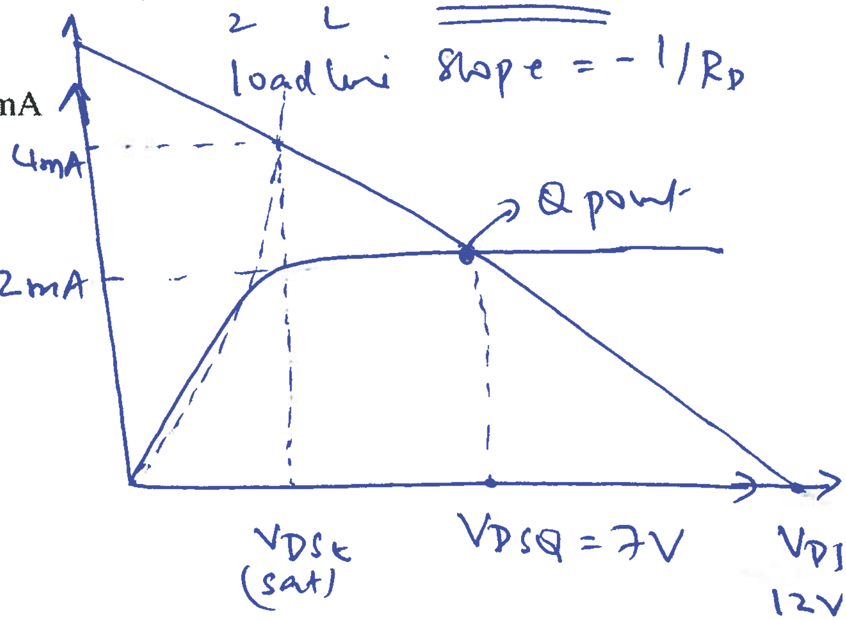
(d) $A_V = g_m R_D = \underline{\underline{+2.75}}$

B.2 The circuit below has a Q-point with I_{DQ}=2mA. $R_1||R_2$ is equal to 100KΩ. Design the circuit (calculate the values of all the resistors) such that the Q-point is in the middle of the saturation region. The transistor parameters are V_{TN}=1V, $k_n' = 80\,\mu$A/V^2, $W/L = 25$, and $\lambda = 0.015$ V^{-1}. Hint: In the saturation region, V_{DS} is bounded by V_{DD} on one side and V_{DS} (sat) on the other. The values of the drain current at these two points will help you determine the range of the drain current along the load line.

20 Points



$$K_n = \frac{k_n'}{2}\frac{W}{L} = \underline{1mA/V^2}$$



Since the transistor is biased in the center of saturation region I_{Dt} (I_D at transition point) = $\underline{4mA}$

$$I_{Dt} = 4 = K_n(V_{GSt} - V_{TN})^2 \Rightarrow \underline{V_{GSt} = 3V}$$

$$V_{DSt} = V_{GSt} - V_{TN} = \underline{2V}$$

Since transistor Q-point is midway between V_{DSt} & V_{DD}, $\underline{V_{DSQ} = 7V}$

$$R_D = \frac{V_{DD} - V_{DSQ}}{I_{DQ}} = \frac{12-7}{2} = \underline{2.5k\Omega}$$

So We need to find V_{GSQ}

$$I_{DQ} = 2 = K_n(V_{GSQ} - V_{TN})^2$$

$$V_{GSQ} = 2.41V$$

$$V_{GSQ} = 2.41 = \frac{R_2}{R_1+R_2} V_{DD} = \frac{1}{R_1} R_{in} V_{DD}$$

$$\Rightarrow \underline{R_1 = 498\,k\Omega \text{ \& } R_2 = 125\,k\Omega}$$