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Signature: SOLUTIONS EEE 313 Fall 2013

Bilkent University
Department of Electrical and Electronics Engineering
EEE 313 Electronic Circuit Design
Midterm 1
1 November 2013, 18:00
(4 questions, 120 minutes)

- This is a **closed book**, closed notes exam. No cheat sheet allowed.
- All cell-phones should be completely **turned off.**
- Use a calculator for numerical computations. Carry at least **4 significant digits** during calculations. Your final answer should be at least **3 significant digits**.
- Be sure to write the **units** of all numerical results.
- **Show** all work clearly.
- Please put your **final answer** for each part inside a box for easy identification. Do not give multiple answers, they will not be graded.
- Do not remove the **staple** from the exam sheets or separate pages of the exam. All extra pages must be stamped to your exam.
- You may leave the exam room when you are done. However, please do not leave during the **last five minutes** of the exam.
- At the end of the exam, please stay seated unitl **all** exam papers are collected.

FET equations:

n-channel MOSFET

$i_D = K_n(v_{GS} - V_{Tn})^2$ SAT

$i_D = K_n\left[2(v_{GS} - V_{Tn})v_{DS} - v_{DS}^2\right]$ NON-SAT

p-channel MOSFET

$i_D = K_p(v_{SG} + V_{Tp})^2$ SAT

$i_D = K_p\left[2(v_{SG} + V_{Tp})v_{SD} - v_{SD}^2\right]$ NON-SAT

n-channel JFET

$i_D = \frac{I_{DSS}}{V_P^2}(v_{GS} - V_P)^2$ SAT

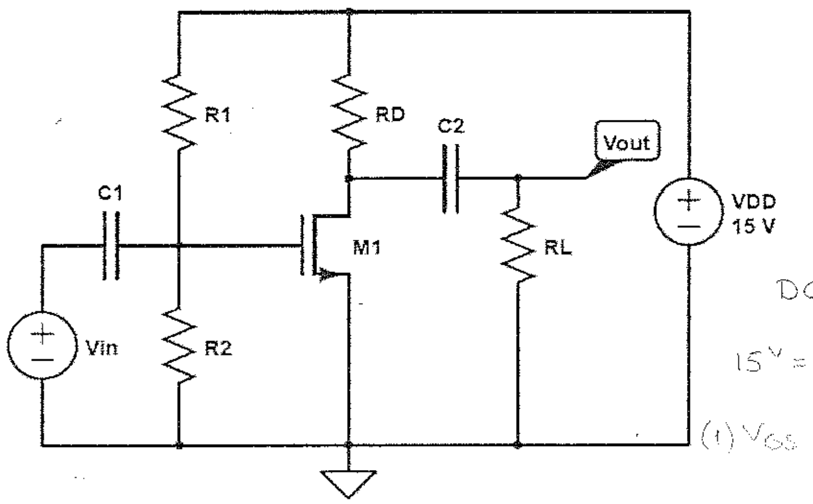
$i_D = \frac{I_{DSS}}{V_P^2}\left[2(v_{GS} - V_P)v_{DS} - v_{DS}^2\right]$ NON-SAT

Please do not write below this line

1. 25 pts.	
2. 20 pts.	
3. 25 pts.	
4. 30 pts.	
Total 100 pts.	

3. (25 points) Design the common source circuit below using an n-channel enhancement-mode MOSFET. The quiescent values are to be I_{DQ}= 25 mA and V_{GSQ}= 7 V. The transconductance is g_m= 10 mA/V. Let R_L= 1 kΩ, $A_v = v_{out}/v_{in} = -5$, R_{in}= 56 kΩ. Find:

a) (6 points) R_1 and R_2
b) (6 points) R_D
c) (7 points) K_n
d) (6 points) V_{tn}



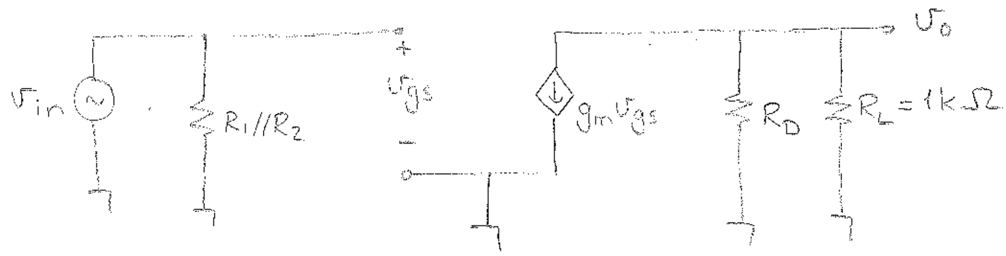
DC load line

$15^V = 25mA \cdot I_{DQ} + V_{DSQ}$

$(1)\ V_{GS} = 7^V = 15^V \frac{R_2}{R_1+R_2}$

$(1)\ 7R_1 = 8R_2$

a) ac equiv.



$R_{in} = 56\ k\Omega = R_1 // R_2 \quad (2)$

$A_v = -g_m (R_D // R_L) = -5$

$25mA = I_{DQ} = K_n (V_{GS} - V_{Th})^2$

(1) & (2) $\frac{R_1 R_2}{R_1+R_2} = 56k$ & $7R_1 = 8R_2$.

$\frac{R_1 \cdot \frac{7}{8} R_1}{R_1 \cdot \frac{15}{8}} = 56\ k\Omega$

$R_1 = 120k\Omega$
$R_2 = 105k\Omega$

b) $-5 = A_v = -10mA/V\ (R_D // 1k)$

$500\Omega = R_D // 1k$

$\boxed{R_D = 1k\Omega}$

c) $10 \frac{mA}{V} = 2\sqrt{K_n I_D}$

$100 = 4 \cdot K_n I_D$

$\boxed{K_n = 1 \frac{mA}{V^2}}$

d) $25mA = 1 \frac{mA}{V^2} (7 - V_{Th})^2$

$\boxed{V_{Th} = 2^V}$

$i_D = 2.5 mA$

a) $R_1 = 120k$

$R_2 = 105k$

b) $R_D = 1k$

c) $10 \frac{mA}{V} = 2\sqrt{K_n (2.5 mA)} \Rightarrow K_n = 10 \frac{mA}{V}$

d) $2.5 mA = 10 \frac{mA}{V} (V_{GS} - V_{Th})^2$

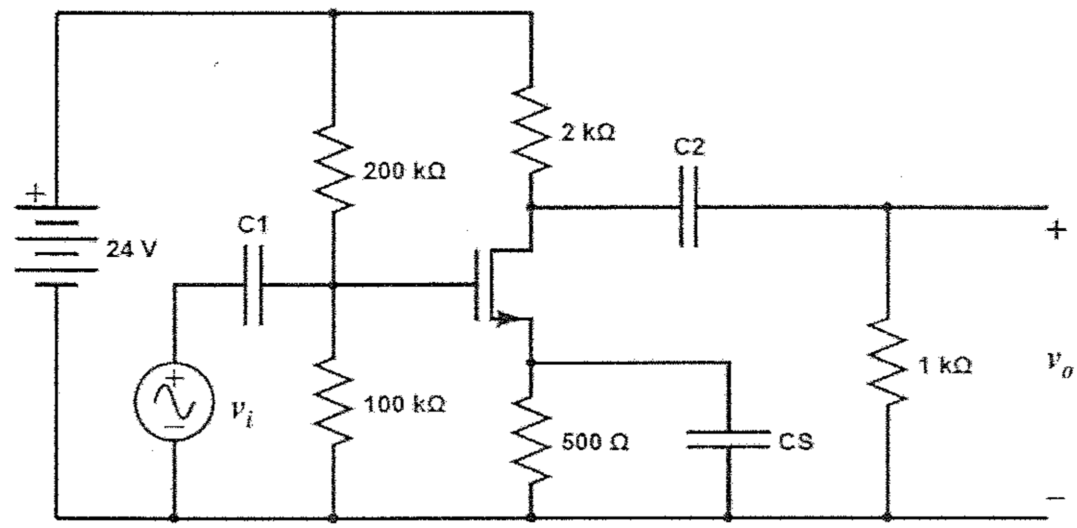
$0.25 = (7 - V_{Th})^2$

$0.5 = 7 - V_{Th}$

$V_{Th} = 6.5^V$

4. (30 points) Consider the single stage FET amplifier shown in the figure. The transistor parameters are $K_n = 1mA/V$ and $V_{TN} = 3V$.

a. (6 points) Find the DC quiescent-point drain current
b. (8 points) Find the small signal voltage gain $A_v = v_o/v_{in}$
c. (8 points) Determine the input and output impedance of the amplifier
d. (8 points) Determine the maximum peak-to-peak undistorted and symmetric output voltage swing, V_{pp}



a) $V_G = \frac{1}{3} \cdot 24^V = 8^V$

DC load line (1) $24^V = 2.5\, I_{DQ} + V_{DSQ}$ (2) $I_{DQ} = \frac{1mA}{V^2}\left(8^V - V_S - 3^V\right)^2$

(3) $V_S = I_{DQ} \cdot 0.5k$

(2) & (3) $2V_S = \frac{1mA}{V}\left(5 - V_S\right)^2$

$2V_S = 25 - 10V_S + V_S^2$

$V_{DSQ} =$

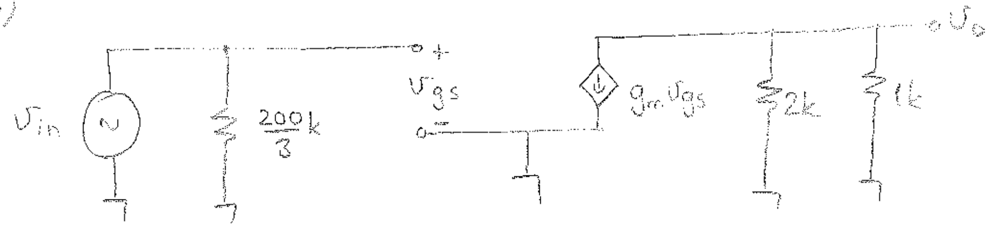
$V_S^2 - 12V_S + 25 = 0$

$V_S = 2.6834^V$

$V_S = 9.3166^V$?

$V_{GS} = 5.3166^V \Rightarrow \boxed{I_{DQ} = 5.3666mA}$

b)



$A_v = -g_m \frac{2k}{3}$

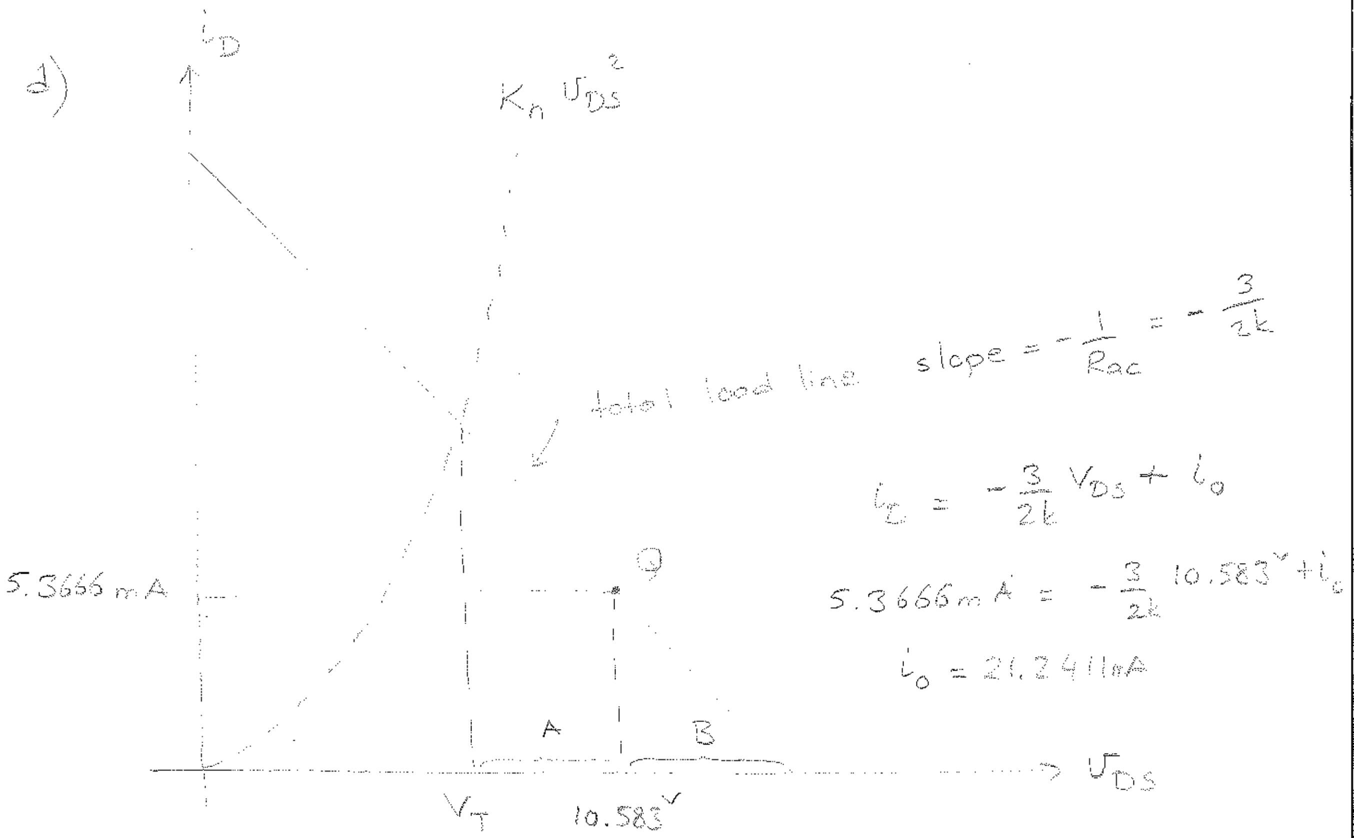
$g_m = 2\sqrt{K_D I_{DQ}}$

$g_m = 4.63\, mS$

$\boxed{A_v = -3.0886}$

c) $\boxed{R_{in} = \frac{200k}{3}\Omega = 66.66}$ $R_{out} = 2k\Omega$

d)



$R_{ac} = R_D \parallel R_L = \frac{2}{3}k$ $\qquad B = 5.3666mA \cdot \frac{2}{3}k = 3.5777^V$

$1mA/V^2$
↓
$$K_n V_T^2 = -\frac{3}{2k} V_T + 21.2411mA$$

$$V_T^2 = -1.5 V_T + 21.2411$$

$$V_T^2 + 1.5V_T - 21.2411 = 0 \Rightarrow V_T = 3.919^V \Rightarrow A = 6.619^V$$

$$B < A$$

$$\Rightarrow \boxed{V_{pp} = 2 \cdot B = 7.1554^V}$$