Name: Tarik Reyhan Section: ______

Signature: ______ EEE 313 Spring 2009

Bilkent University
Department of Electrical and Electronics Engineering
EEE 313 Electronic Circuit Design
Final Examination
21 May 2009, 15:40
(3 questions, ~~120~~ minutes) 150 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 **3 significant digits**. Double check your numerical calculations.
- 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

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

$i_D = K_n[2(v_{GS} - V_{Th})v_{DS} - v_{DS}^2]$ NON-SAT

p-channel MOSFET

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

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

n-channel JFET

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

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

Please do not write below this line

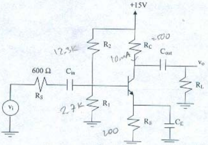
1. 40 pts.	
2. 30 pts.	
3. 30 pts.	
Total 100 pts.	

1. (40 points) For the circuit shown below, assume $B = 100$, $V_{BEON} = 0.7V$
~~$I_{CQ} = 10mA$~~, $R_C = 500\Omega$, $R_L = 1k\Omega$, $R_E = 200\Omega$, $R_1 = 2.7k\Omega$ and $R_2 = 12.3k\Omega$.

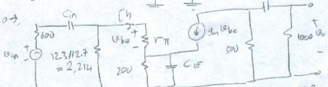
a) (15 points) Find the gain of the amplifier assuming C_{in}, C_{out} and C_E are infinite. as defined as v_o/v_{in} and assuming that $I_{CQ} = 10mA$

b) (10 points) Assuming C_{out} and C_E are very large, find C_{in} that makes the lower corner frequency 300Hz. and assuming that $I_{CQ} = 10mA$

c) (15 points) Find the output peak-to-peak undistorted swing. by finding out your own D.C. solution

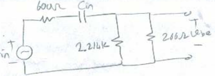


a)



$500 // 1000 = 500 \times \frac{2}{3} = 333.3\Omega$ $\quad r_\pi = \frac{26.6}{10mA} \cdot B = 266\Omega$

$g_m = \frac{10mA}{266mV} = 0.3759 \approx 0.376$ mhos b-)



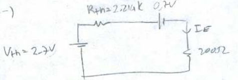
$$\frac{2214 \times 266}{2214+266} = R_{in} = 237.5\Omega$$

$$\frac{v_{be}}{v_{in}} = \frac{237.5\Omega}{237.5\Omega + 600\Omega + \frac{1}{j\omega C_{in}}}$$

$$= \frac{j\omega\, 237.5\, C_{in}}{1 + (237.5+600) j\omega C_{in}}$$

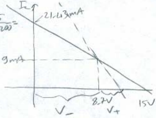
$$w_0 = 2\pi \times 300\,Hz = \frac{1}{837.5\, C_{in}} \Rightarrow C_{in} = \frac{1}{2\pi \times 300 \times 837.5} = 0.633\,\mu F$$

c-)



$$I_B = \frac{2.7V - 0.7V}{2214 + 101 \times 200} = 89.23\,\mu A$$

$$I_C = 8.923\,mA, \quad I_E = 9\,mA$$



$$I_{CQ} = 15 - 9 \times 10^{-3} \times (700\Omega$$

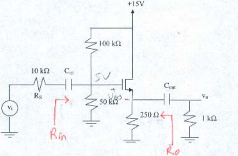
$$\frac{V_+}{I_{CQ}} = R_C // R_L = 333.3\Omega$$

$$V_+ = 333.3 \times 9\,mA = 3V$$

$$V_{p-p} = 2 \times 3V = 6V$$

2. (30 points) For the circuit shown below, $V_{TN} = 1V$ and $K_N = 2\ mA/V^2$

a) (15 points) Find the gain of the amplifier defined as $\frac{v_o}{v_i}$ assuming C_{out} and C_{in} are very large.
b) (5 points) Find the input impedance.
c) (10 points) Find the output impedance.



a-)

$$I_D = 2\times10^{-3}(V_{GS}-1)^2 = \frac{5-V_{GS}}{250} = \frac{5-V_{GS}}{0.25\times10^3}$$

$$5-V_{GS} = 0.5(V_{GS}^2 - 2V_{GS}+1)$$

$$\frac{5}{0.5} - \frac{V_{GS}}{0.5} = V_{GS}^2 - 2V_{GS}+1$$

$$10 - \cancel{2V_{GS}} = V_{GS}^2 - \cancel{2V_{GS}} + 1$$

$$V_{GS}^2 - 9 = 0 \quad V_{GS}^2 = 9 \Rightarrow V_{GS} = \pm 3V$$

$V_{GS} = -3V$ means cut-off $\Rightarrow V_{GS} = 3V$

$$I_D = 2\times10^{-3}(3-1)^2 = 2\times10^{-3}\times4 = 8mA \Rightarrow$$

$$V_S = 8mA \times 250\Omega = 2V$$

$$g_m = 2\sqrt{I_D K_n} = 2\sqrt{8\times10^{-3}\times2\times10^{-3}} = 2\times4\times10^{-3} = 8\times10^{-3}\text{mhos}$$

$$\frac{1}{g_m} = \frac{1}{8\times10^{-3}} = \frac{10^3}{8} = 125\Omega$$

2 continued

$$\frac{v_o}{v_{in}} = \frac{100K // 50K}{100K//50K + 10K} \cdot \frac{250 // 1000\Omega}{250//1000 + \frac{1}{9m}}$$

$$= \frac{33.33K}{43.33K} \cdot \frac{200\Omega}{200\Omega + 125\Omega}$$

$$= 0.473$$

b) $R_{in} = 100K // 50K = 33.33K$.

c) $R_o = \frac{1}{4m} // 250\Omega = 125\Omega // 250\Omega$

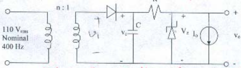
$R_o = 83.33\Omega$

3. (30 points) For the circuit shown below, the output voltage waveform is as shown in the figure. $V_\gamma = V_{ON} = 1.5\,V$ and $V_Z = 10V$ and $I_{Z\,min} = 20mA$

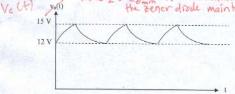
a) (10 points) Find the value of "n" if the input voltage is 118 Vrms.

b) (20 points) Design the output voltage regulator by choosing R and C values in order to sustain a DC output current equal to 200 mA. (Please find the maximum value of R and the minimum value of C, 10 points each).

Note: 1 Nominal means the designated value. The real value could be different.



Note 2: $I_{Z\,min}$ is the minimum current at which the zener diode maintains V_Z.



a-) $V_{c\,min} = 12V = V_{1peak} - V_\gamma = V_{1peak} - 1.5 = 15V$

$$\frac{118\sqrt{2}}{n} = V_{1p} = 16.5V \Rightarrow$$

$$n = \frac{118\sqrt{2}}{16.5} = 10.08$$

b-) Let us first find R_{max} and I_Z average

$$R_{max} = \frac{12V - V_Z}{I_o + I_{Zmin}} = \frac{12-10}{0.2+0.02} = \frac{2}{0.22} = 9.09\Omega \approx 9.1\Omega$$

$$I_{R\,max} = \frac{15V - 10V}{9.1\Omega} \qquad I_{R\,min} = \frac{12V - 10V}{9.1V}$$

$$I_{av} = \frac{5+2}{2} \cdot \frac{1}{9.1} = \frac{2.5}{9.1} = 0.274\,mA \longrightarrow$$

3. continued

$$I\Delta t = C\Delta V \Rightarrow C = \frac{I\Delta t}{\Delta V}$$

$$C = \frac{0.274 \times 2.5\times10^{-3}}{3V} = 2.289\times10^{-6}\ F = 230\,\mu F$$