EEL 3304C Midterm Exam

Name: _____________________________

UFID: _____________________________

Problem 1  25 pts.
Problem 2  25 pts.
Problem 3  25 pts.
Problem 4  25 pts.

Total :

Honor Code:
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Signature

Note: Please show work. Answers without analysis will not receive credit.
Problem 1 (25pts.): Consider the following circuit.

(a) Assuming an ideal opamp, \( R_2 = 99\,\text{k}\Omega \) and \( R_1 = 1\,\text{k}\Omega \), determine the closed loop gain.

\[
\frac{v_o}{v_i} = \left( 1 + \frac{R_2}{R_1} \right) = 100 \frac{V}{V}
\]

(b) Sketch the frequency response of the above amplifier if the closed loop gain can be described by a low-pass single-time-constant input network with a 3 dB corner frequency of 1 MHz. Label the magnitude in dB, the slope of the roll-off, and the corner frequency.

(c) If the gain is decreased by a factor of 10, what is the new 3 dB corner frequency?

\[
f_{3dB_{\text{new}}} = \frac{f_{3dB}}{A_v} \cdot A_{v_{\text{new}}}
\]

\[
f_{3dB_{\text{new}}} = \frac{100}{10} \frac{1\,\text{MHz}}{10\,\text{MHz}} = 10\,\text{MHz}
\]
Problem 2 (25pts.): For the circuit shown, using the constant-voltage-drop (VD=0.7V) diode model, find the voltage (V) and current (I) indicated. Hint: Be sure to check the validity of assumptions.

Assume D1 is ON and D2 is OFF. Then the current flowing across the first resistor (nearest to 9V supply) would be (9V-4V)/10k=0.5mA. The voltage drop across the middle resistor would be at least 5V, which is not possible as it would yield V<0. Therefore D1 cannot be ON.

Assume D1 is OFF and D2 is ON. Then V=2V and I=0.2mA. The current flowing through the first two resistors would be (9V-2V)/20k=0.35mA and the voltage drop across the first resistor would be 3.5V. The voltage at the cathode of D1 would be 5.5V which implies D1 is indeed OFF. In addition, note that 0.35mA>0.2mA so 0.15mA flows through D2. Our assumption is correct.
Problem 3 (25pts.): The parameters for the MOS transistor are: $V_T = 1\, \text{V}$, $k = 1\, \text{mA/V}^2$, and $\lambda = 0.05\, \text{V}^{-1}$.

The circuit diagram shows:
- $V_{G1} = 9\, \text{V}$
- $R_{G1} = 1\, \text{M\Omega}$
- $R_{G2} = 1.25\, \text{M\Omega}$
- $V_{G2} = 9\, \text{V}$
- $R_{D} = ?$
- $R_{L} = 10\, \text{k\Omega}$
- $R_{S} = ?$
- $C_{C1} = \infty$
- $C_{C2} = \infty$
- $V_{S} = \infty$
- $R_{S} = 100\, \text{\Omega}$

(a) Determine $R_D$ and $R_S$ such that 1/3 of the voltage drop is across $R_D$, 1/3 of the voltage drop is across $R_D$ and 1/3 of the voltage drop is across the transistor.

$$V_S = \frac{V_{DD}}{3} = \frac{9\, \text{V}}{3} = 3\, \text{V} \quad V_D = V_{DD} - \frac{V_{DD}}{3} = 6\, \text{V} \quad V_{DS} = V_D - V_S = 3\, \text{V}$$

$$V_G = \frac{R_{G2}}{R_{G2} + R_{G1}} V_{DD} = \frac{1\, \text{M}}{1\, \text{M} + 1.25\, \text{M}} \times 9\, \text{V} = 5\, \text{V}$$

$$V_{GS} = V_G - V_S = 5\, \text{V} - 3\, \text{V} = 2\, \text{V}$$

The current is given by

$$I_D = \frac{k}{2} (V_{GS} - V_t)^2 (1 + \lambda V_{DS}) = 0.5\, \text{mA/V}^2 (2\, \text{V} - 1\, \text{V})^2 (1 + 0.05 \times 3\, \text{V}) = 0.575\, \text{mA}$$

$$R_D = R_S = \frac{V_{DD}}{3I_D} = 5.217\, \text{k\Omega}$$

(b) Draw the small signal model and determine the voltage gain $A_v = V_o / V_i$ and overall voltage gain $G_v = V_o / V_{sig}$
The voltage gain $A_v$:

$$A_v = -gm \cdot r_o \parallel R_D \parallel R_L = -3.59V/V$$

and the overall voltage gain $G_v$:

$$G_v = \frac{R_G}{R_G + R_{\text{sig}}} A_v \sim A_v$$

(c) Determine the peak output voltage swing $V_o$ (peak-to-peak) if the largest allowable input amplitude is $v_{\text{gs max}} = 2V_{ov}/10$.

$$V_{pp} = 2v_{\text{gs max}} |A_v| = 2 \cdot 0.2V \cdot 3.59 = 1.436V$$
Problem 4 (25pts.): The parameters for the MOS transistor are: $V_T = 1V$, $k= 800\mu A/V^2$, and $V_A=40V$. Assume $R_G=10M\Omega$, $R_D=R_S=35k\Omega$ and $I_D=0.1mA$.

(a) Find the values for $g_m$ and $r_o$ at the bias point.

$$r_o = \frac{V_A}{I_D} = \frac{40V}{0.1mA} = 400k$$

$$g_m = \frac{2I_D}{V_{ov}} = 0.4mA/V^2$$

(b) If the terminal Y is grounded, find the voltage gain from X to Z with Z open-circuited. What is the output resistance of the source follower?

$$A_{vo} = \frac{v_o}{v_i} \bigg|_{R_z=\infty} = \frac{g_m \cdot (R_S \parallel r_o)}{1 + g_m \cdot (R_S \parallel r_o)} = \frac{0.4mA(35k \parallel 400k)}{1 + 0.4mA(35k \parallel 400k)} = 0.928V/V$$

$$R_O = R_S \parallel r_o \parallel \frac{1}{g_m} \sim 2.32k$$
(c) If the terminal X is grounded and terminal Z is connected to a current source delivering a signal current of 10µA and having a resistance of 100kΩ, find the voltage signal that can be measured at Y. For simplicity neglect the effect of $r_o$.

$$R_{in} = \left( R_s \parallel \frac{1}{gm} \right) = 2.33k$$

$$i_i = \frac{R_{sig}}{R_{sig} + R_{in}} i_{sig} = 9.77\mu A$$

$$v_o = \frac{R_s}{R_s + 1/gm} R_b i_i = 0.934 \cdot 35k \cdot 9.77\mu A = 0.319V$$