EEE 51 Assignment 6

2nd Semester SY 2018-2019
Due: 5pm Tuesday, March 19, 2019 (Rm. 220)

Instructions: Write legibly. Show all solutions and state all assumptions. Write your full name, student number, and section at the upper-right corner of each page. Start each problem on a new sheet of paper. Box or encircle your final answer.

Answer sheets should be color coded according to your lecture section. The color scheme is as follows:

THQ – yellow
THU – white
WFX – pink

1. **Single-Ended Operational Amplifier.**

   A single-ended operational amplifier was created with a topology slightly similar to the LF35 op amp which is shown in Figure 1. You are tasked to verify the approximate characteristics of the design at $T = 300\,\text{K}$. The MOSFETs have $k = \frac{\mu C_{ox}}{2}\frac{W}{L} = 250\,\mu\text{A/V}^2$ and $\lambda = 0.001\,\text{V}^{-1}$. The BJTs have the following: $\beta = 100$ and $V_A = 50\,\text{V}$. Assume that the current sources and diodes are ideal ($V_{min} = 0\,\text{V}$ and $\text{R} \to \infty$ for the current sources; and $V_f = 0.7\,\text{V}$, $\text{R}_{\text{ON}} = 0\,\Omega$, and $\text{R}_{\text{OFF}} \to \infty$ for the diodes) and that the transistors are in their necessary operating regions (saturation for MOSFETs and forward active for BJTs). **Show your complete solution and round off to the required value to merit a maximum of full points**.

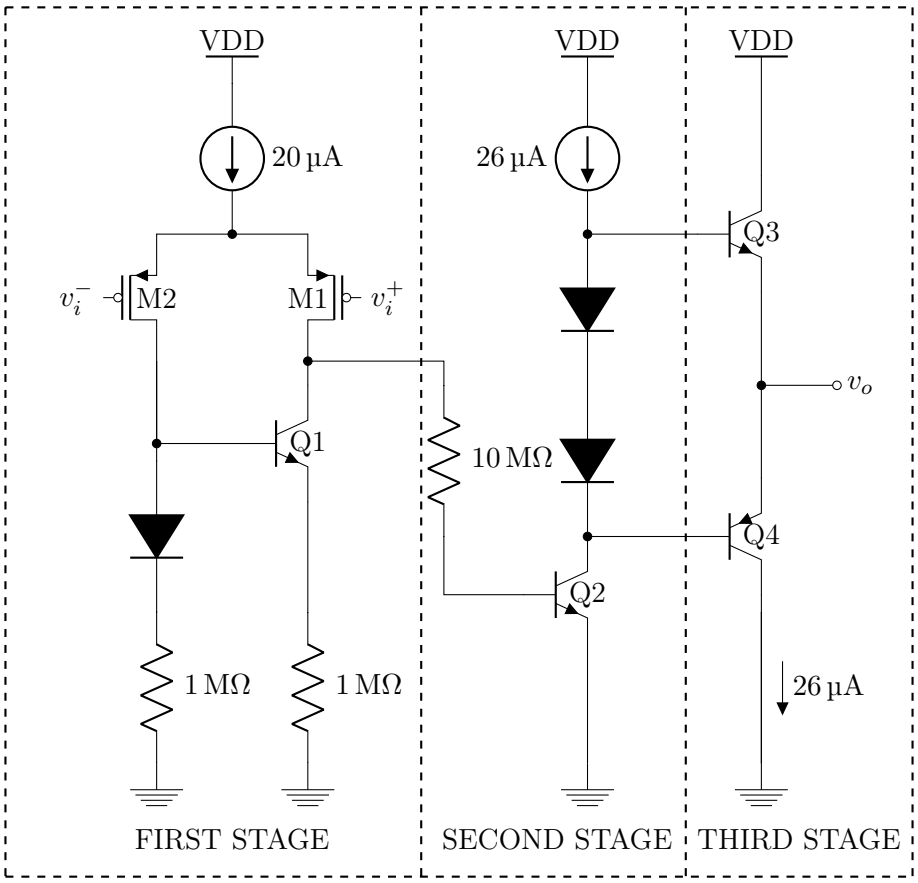

Figure 1: The Single-Ended Operational Amplifier

(a) What should be the value (rounded to the nearest ten thousands) of the load resistance to get maximum power? (2 pts)

(b) Find the value of the following rounded to the nearest whole number:

i. Gain of the first stage with respect to v_i^+ (ie: $A_{v1} = \frac{v_{o1}^-}{v_i^+}$) (2 pts)

ii. Gain of the second stage (2 pts)

iii. Gain of the third stage (2 pts)

(c) Give the value of the differential gain ($\frac{v_o}{v_{id}}$) approximate to the nearest ten thousands. (2 pts)

- Subscribe2PewDiePie

2. **Simple Two-stage Operational Amplifier.** Consider the circuit shown in Fig. 2. Given the following: $V_{DD} = 3V$, $I_{REF} = 1mA$, $k_p = 6.25mA/V^2$, $k_n = 19.75mA/V^2$, $V_{th,n} = 0.7V$, $|V_{th,p}| = 0.8V$.

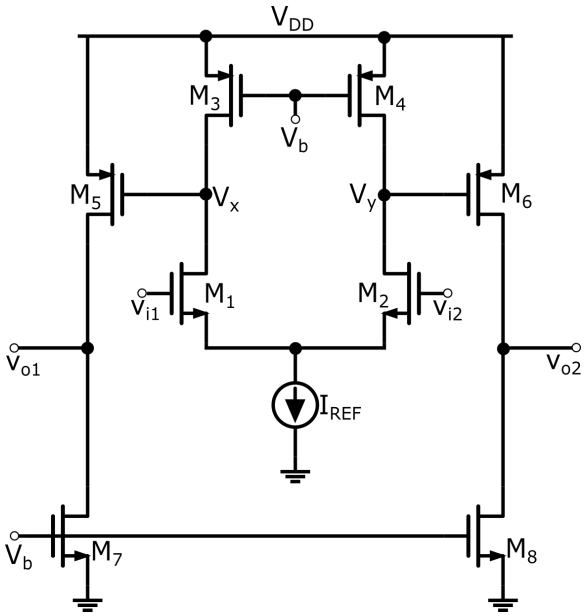

Figure 2: 2-stage Operational Amplifier Circuit

(a) What is the CM voltage level needed at the drains of M_3 and M_4 so that the current through the M_5-M_7 and M_6-M_8 is $1mA$? [2 pts]

(b) Keeping the values obtained in (a), what is the maximum input CM level? [2 pts]

(c) For all transistors, evaluate the following:

i. The drain-to-source currents, I_{DS}. [0.5 pts]

ii. The gate-to-source voltages, $|V_{GS}|$. [1 pt]

iii. g_m. [1 pts]

iv. r_o. Use $\lambda_n = 0.1V^{-1}$ and $\lambda_p = 0.2V^{-1}$. [0.5 pt]

For simplicity, compile your answers into a tabular format as shown below:

Parameter	M1	M2	M3	M4	M5	M6	M7	M8
I_{DS}								
$\|V_{GS}\|$								
g_m								
r_o								

(d) Calculate the overall voltage gain of the circuit. [2 pts]

(e) What is the maximum output swing? [1 pt]

TOTAL: 20 points.