EE115A Analog Circuits

Homework 6

Due date: 12/4/2025

Note:

- Please provide enough calculation process to get full marks.
- Please submit your homework to Gradescope (code **J62G3D**) in PDF version.
- It's highly recommended to write every exercise on a single sheet of page.
- Late submissions will have points deducted according to the penalty policy.
- Please use English only to complete the assignment, solutions in Chinese are not allowed.
- Plagiarizer will get zero points.
- The full score of this assignment is 100 points.

Exercise 1. (25pt)

For the PMOS differential amplifier shown in Fig. P1, let V_{tp} = -0.4 V and k'_pW/L = 5 mA/$\boldsymbol{V^2}$. Neglect channel-length modulation.

(a) For $V_{G1} = V_{G2}$ =0 V, find $|V_{ov}|$ and V_{SG} for each of Q1 and Q2. Also find V_s, V_{D1}, V_{D2}, and V_o.

(b) If the current source requires a minimum voltage of 0.2 V, find the input common-mode range.

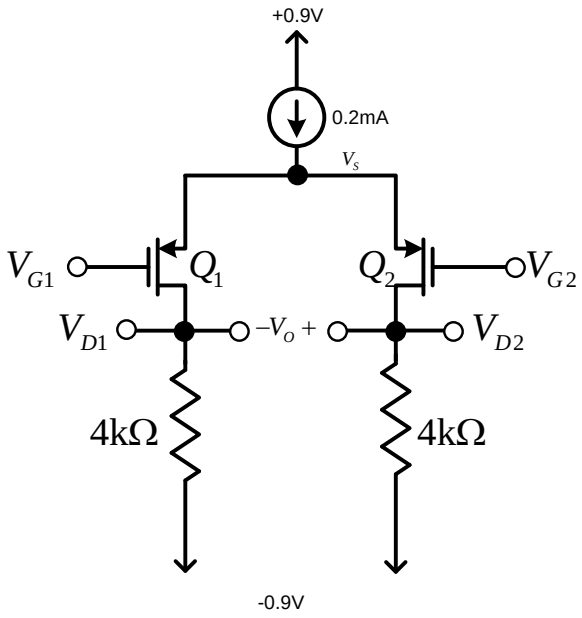

Fig. P1

Exercise 2. (25pt)

Consider the differential amplifier specified in Problem &2 with G_2 grounded and $V_{G1} = V_{id}$. Let V_{id} be adjusted to the value that causes i_{D1}=0.09mA and i_{D2}=0.07 mA. Find the corresponding values of V_{GS2}, V_S, V_{GS1} and hence V_{id}. What is the difference output voltage V_O? What is the voltage gain V_O / V_{id} ? What value of V_{id} results in i_{D1} =0.07 mA and i_{D2} =0.09 mA?

Problem &2：(This question does not require an answer)

For an NMOS differential pair with a common-mode voltage V_{CM} applied, as shown in Fig.P2, let $V_{DD} = V_{SS} = 1.0$ V, $k'_n = 0.4$ mA/$\boldsymbol{V^2}$, $(W/L)_{12} = 10$, $V_{tn} = 0.4$ V, I = 0.16 mA, RD = 5 kΩ, and neglect channel-length modulation.

(a) Find *Vov* and *VGS* for each transistor.

(b) For $V_{CM} = 0$, find Vs, I_{D1}, I_{D2}, V_{D1}, V_{D2}, and *Vo*.

(c) Repeat (b) for $V_{CM} = +0.4$ V.

(d) Repeat (b) for $V_{CM} = -0.1$ V.

(e) What is the highest value of V_{CM} for which $Q_1$and Q_2 remain in saturation?

(f) If current source *1* requires a minimum voltage of 0.2 V to operate properly, what is the lowest value allowed for *Vs* and hence for V_{CM}?

(g) What is the input common-mode range

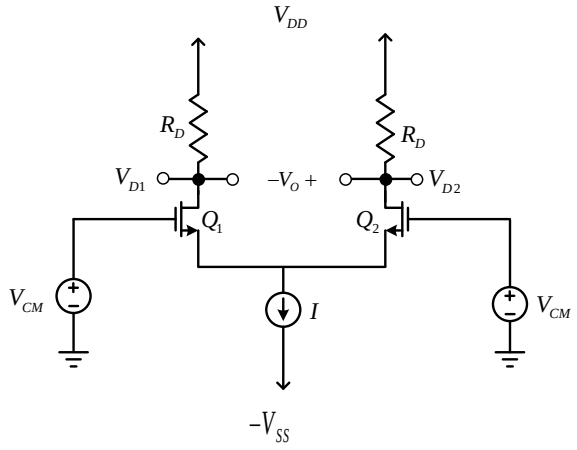

Fig. P2

Exercise 3. (25pt)

Note: This question requires simulation. Please note that you need to use Multisim for simulation and provide the simulation circuit and simulation results in your answer.

The differential amplifier in Fig. P3 utilizes a resistor Rss to establish a 0.02-mA dc bias current.

Note that this amplifier uses a single 2-V supply and thus the dc common-mode voltage cannot be zero. Transistors Q1 and Q2 have kn'W/L = 1 mA/$\boldsymbol{V^2}$, V, =0.4 V, and λ= 0.

(a) Find the required value of VCM.

(b) Find the value of RD that results in a differential gain Ad of 15 V/V.

(c) Determine the dc voltage at the drains.

(d) Determine the single-ended-output common-mode gain ΔVDI/ΔVCM. (Hint: You need to take 1/gm, into account.)

(e) Use the common-mode gain found in (d) to find the change in VCM that results in Q1 and Q2 entering the triode region.

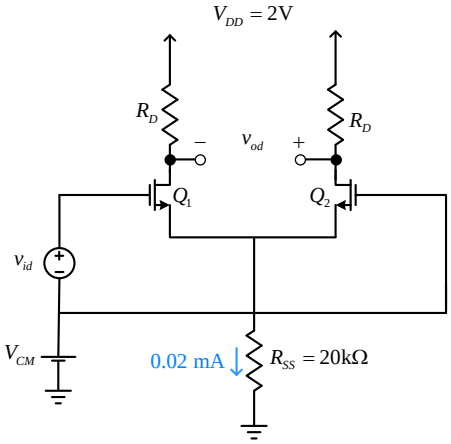

Fig. P3

Exercise 4. (25pt)

A current-mirror-loaded NMOS differential amplifier is fabricated in a technology for which $|V'_A| = 6V/\mu m$. All the transistors have $L = 0.5\ \mu m$. If the differential-pair transistors are operated at $V_{OV} = 0.2$ V, what open-circuit differential gain is realized?