EE115A Analog Circuits

Homework 5

Due date: 25/11/2025

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. (15pt)

The current-steering circuit of Fig. P1 is fabricated in a CMOS technology for which $\mu_n C_{ox}$ = 400 μA/V², $\mu_p C_{ox}$ = 100 μA/V², V_{tn} = 0.5 V, V_{tp} = -0.5 V, V'_{An} = 6 V/μm, and $|V'_{Ap}|$ = 6 V/μm. If all devices have L = 0.5 μm, design the circuit so that I_{REF} = 20 μA, I_2 = 80 μA, I_3 = I_4 = 50 μA, and I_5 = 100 μA. Use the minimum possible device widths needed to operate the current source Q_2 with voltages at its drain as high as +0.8 V and to operate the current sink Q_5 with voltages at its drain as low as -0.8 V. Specify the widths of all devices and the value of R. Find the output resistance of the current source Q_2 and the output resistance of the current sink Q_5.

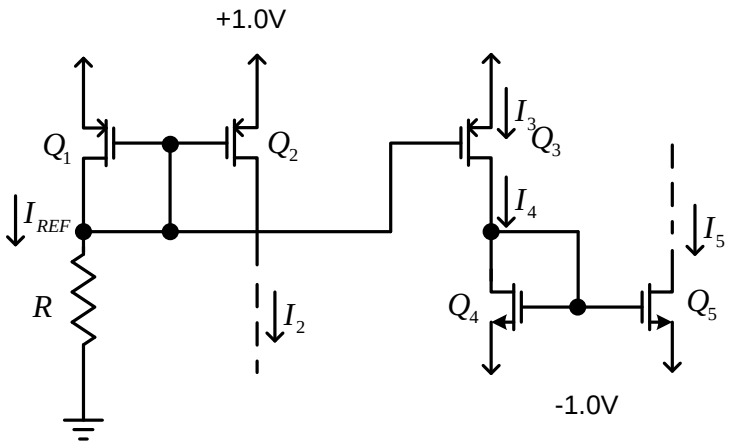

Fig. P1

Exercise 2. (15pt)

Consider an NMOS transistor fabricated in a 0.18-µm technology for which $k_n' = 400\ \mu A/V^2$ and $V'_A = 5\ V/\mu m$. It is required to obtain an intrinsic gain of 25 V/V and a g_m of 1 mA/V. Using $V_{OV} = 0.2\ V$, find the required values of L, W/L, and the bias current I.

Exercise 3. (20pt)

The purpose of this problem is to investigate the signal currents and voltages at various points throughout a cascode amplifier circuit. Knowledge of this signal distribution is very useful in designing the circuit so as to allow for the required signal swings. Figure P3 shows a CMOS cascode amplifier with all dc voltages replaced with signal grounds. As well, we have explicitly shown the resistance r_o of each of the four transistors. For simplicity, we are assuming that the four transistors have the same g_m and r_o. The amplifier is fed with a signal v_i.

(a) Determine R_1, R_2, and R_3. Assume $g_m r_o \gg 1$.

(b) Determine i_1, i_2, i_3, i_4, i_5, i_6, and i_7, all in terms of v_i. (Hint: Use the current-divider rule at the drain of Q_1.)

(c) Determine v_1, v_2, and v_3, all in terms of v_i.

(d) If v_i is a 5-mV peak sine wave and $g_m r_o = 20$, sketch and clearly label the waveforms of v_1, v_2, and v_3.

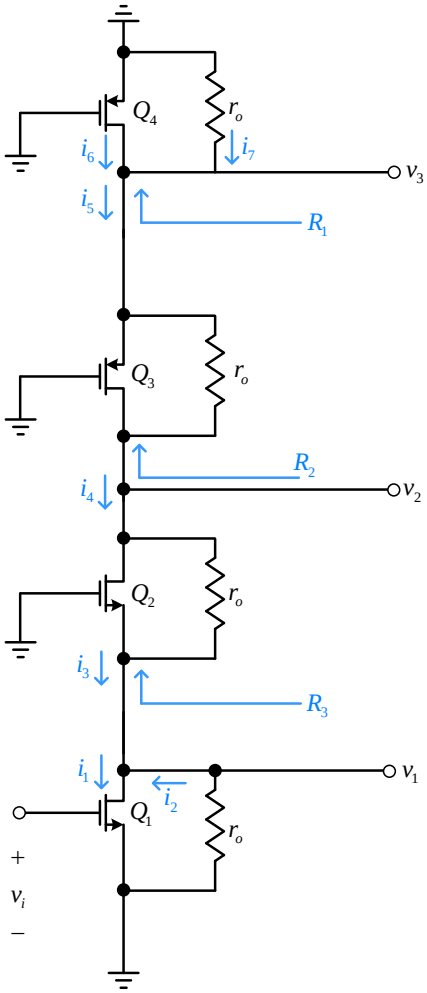

Figure P3

Exercise 4. (15pt)

A source follower for which $k_n' = 400\ \mu A/V^2$, $V_A' = 9\ V/\mu m$, $\chi = 0.2$, $L = 0.6\ \mu m$, $W = 12\ \mu m$, and $V_t = 0.5\ V$ is required to provide a dc level shift (between input and output) of 0.8 V.
(a) What must the bias current be?
(b) Find g_m, g_{mb}, r_o, A_{vo}, and R_o. Assume that the bias current source has an output resistance equal to r_o. Also find the voltage gain when a load resistance of 3 kΩ is connected to the output.

Exercise 5. (35pt)

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.

Ensure that you provide both theoretical calculation results and simulation results.

A particular cascoded NMOS current mirror, such as that shown in Fig. P5, is fabricated in the 0.18-μm CMOS process specified in Table 1. All transistors have equal channel lengths L = 0.54 μm. Width $W_1 = W_4 = 2.7$ μm, and $W_2 = W_3 = 27$ μm. The reference current I_{REF} is 20 μA.

(a) What output current results?
(b) What are the voltages at the gates of Q_2 and Q_3?
(c) What is the lowest voltage at the output for which proper current-source operation is possible?
(d) What are the values of g_m and r_o of Q_2 and Q_3?
(e) What is the output resistance of the mirror?

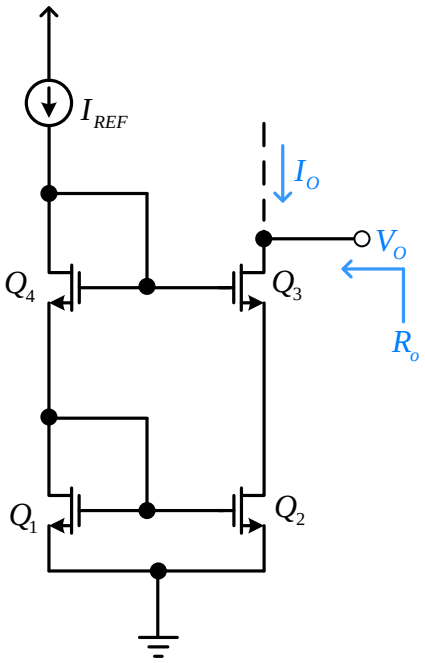

Fig. P5

Table 1:

Parameter (0.18μm)	NMOS	PMOS
t_{ox} (nm)	4	4
c_{ox} (fF/μm²)	8.6	8.6
μ (cm²/V·s)	450	100
μc_{ox} (μA/V²)	387	86
V_{t0} (V)	0.5	-0.5
V_{DD} (V)	1.8	1.8
$\lvert V_A' \rvert$ (V/μm)	5	6
C_{OV} (fF/μm)	0.37	0.33