

**NAME:** \_\_\_\_\_ **ID Number:** \_\_\_\_\_

**Problem 1 [35 points]**

a) Consider the current source shown in Figure 1.

Assume  $V_{DD} = 3 \text{ V}$  and  $I_{REF} = 50 \mu\text{A}$ .

Find  $R$  if the two MOSFETs are matched and have  $W = 4 \mu\text{m}$ ,  $L = 1.5 \mu\text{m}$ ,  $V_t = 0.6 \text{ V}$ , and  $k'_n = 250 \mu\text{A/V}^2$ . Assume that in this process,  $V'_A = 12 \text{ V}/\mu\text{m}$ .

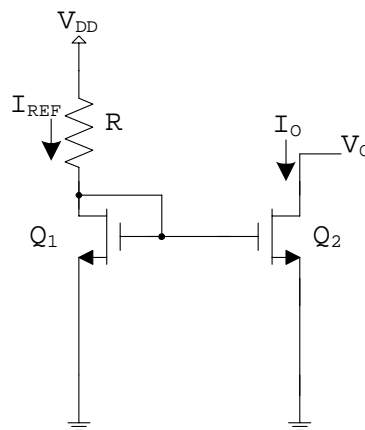


Figure 1

- b) What is the lowest possible value of  $V_O$ ?
- c) Find the change in the output current (in  $\mu\text{A}$ ) that corresponds to change in the output voltage from  $2 \text{ V}$  to  $2.5 \text{ V}$ .
- d) Repeat part (c) if  $Q_1$  has  $W/L = 4 \mu\text{m} / 1.5 \mu\text{m}$  and  $Q_2$  has  $W/L = 20 \mu\text{m} / 5 \mu\text{m}$ .

**Problem 2 [40 points]**

The CMOS common-source amplifier shown in Figure 2 is biased using  $I_{REF} = 80 \mu\text{A}$ , and has  $W/L = 10 \mu\text{m} / 0.36 \mu\text{m}$  for all transistors,  $k'_n = 400 \mu\text{A/V}^2$ ,  $k'_p = 100 \mu\text{A/V}^2$ ,  $V'_{An} = 10 \text{ V}/\mu\text{m}$ ,  $|V'_{Ap}| = 5 \text{ V}/\mu\text{m}$ ,  $V_{tn} = -V_{tp} = 0.6 \text{ V}$ .

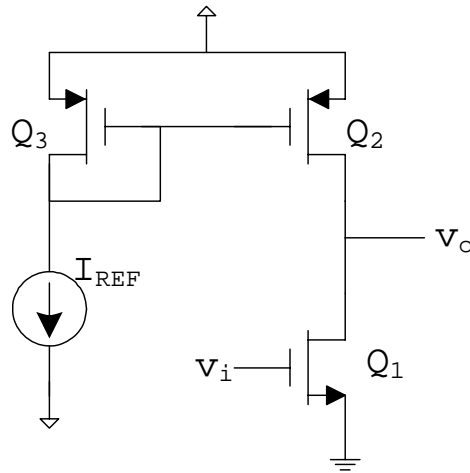


Figure 2

a) Neglecting channel-length modulation in the DC analysis, find:  $V_{OV1}$ ,  $g_{m1}$ ,  $r_{o1}$ ,  $r_{o2}$ , and the voltage gain  $v_o/v_i$ .

Assume now that for  $Q_1$ ,  $C_{gs} = 25$  fF,  $C_{gd} = 10$  fF, and  $C_L = 10$  fF. The signal source has a source resistance  $R_{SIG}$  of  $25$  K $\Omega$ .

b) Using Miller's theorem, and assuming that the input circuit determines the upper 3-dB frequency  $f_H$ , find the value of  $f_H$ .

c) Show and label the Bode plot for the magnitude of the voltage gain.

d) Using the open-circuit time constant methods, find the resistance seen by each capacitor, and estimate the value of  $f_H$ .

### Problem 3 [25 points]

a) Show the circuit for an emitter follower biased by a constant current source. The signal source has source resistance  $R_{SIG}$ , and the load resistance is  $R_L$ .

b) Show the small-signal equivalent circuit of the emitter follower. The BJT small-signal parameters are  $r_x$ ,  $r_\pi$ ,  $g_m$ ,  $\beta$ , and  $r_o$ . The current source has an output resistance equal to  $R_C$ .

c) Derive an expression for the voltage gain  $v_o/v_{sig}$ .