PROBLEM SET #7

Issued: Friday, Oct. 16, 2015

Due (at 8 a.m.): Monday, Oct. 26, 2015, in the EE 140/240A HW box near 125 Cory.

1. A design error has resulted in a mismatch in the circuit of Fig. PS7-1. Specifically, M_2 has twice the W/L ratiio of M_1. If V_{id} is a small sine-wave signal, find an expression for

(a) I_{D1} and I_{D2}.

(b) V_{OV} for each of M_1 and M_2.

(c) The differential gain A_{dm} in terms of R_D, I, and V_{OV}.

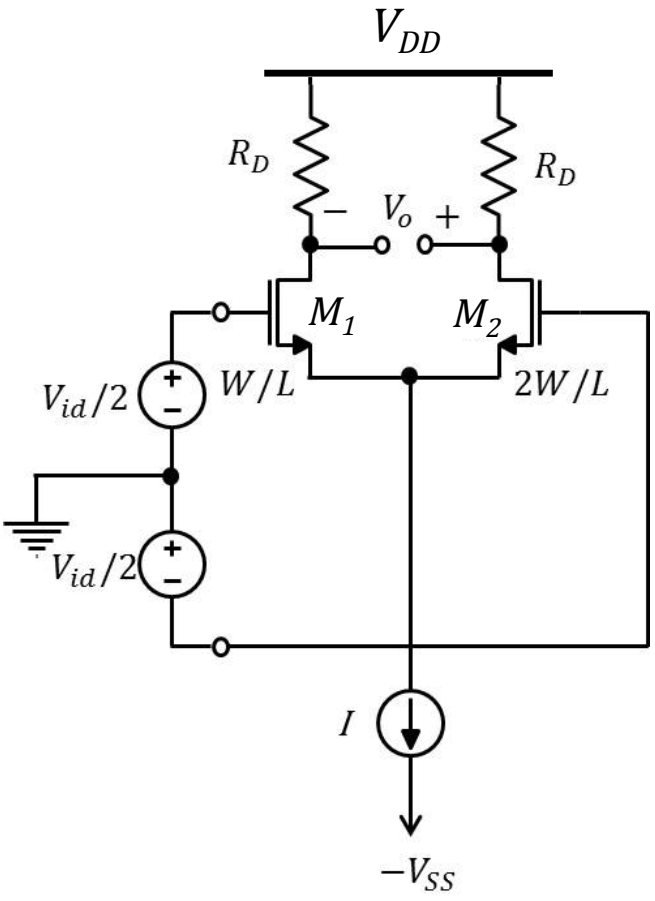

Fig. PS7-1

2. The differential amplifier in Fig. PS7-2 utilizes a resistor R_{SS} to esiablish a 1-mA dc bias current. Note that this amplifier uses a single 5-V supply and thus needs a dc common-mode voltage V_{CM}. Transistors M_1 and M_2 have $k'W/L$= 2.5mA/V^2, V_t=0.7V, and λ=0.

(a) Find the required value of V_{CM}.

(b) Find the value of R_D that results in a differential gain A_{dm} of 8 V/V.

(c) Determine the dc voltage at the drains

(d) Determine the common-mode gain v_D/v_{CM} and CMRR for this amplifier. (Hint: You need to take 1/g_m into account.)

(e) Use the common-mode gain found in (d) to determine the change in V_{CM} that results in M_1 and M_2 entering the triode region.

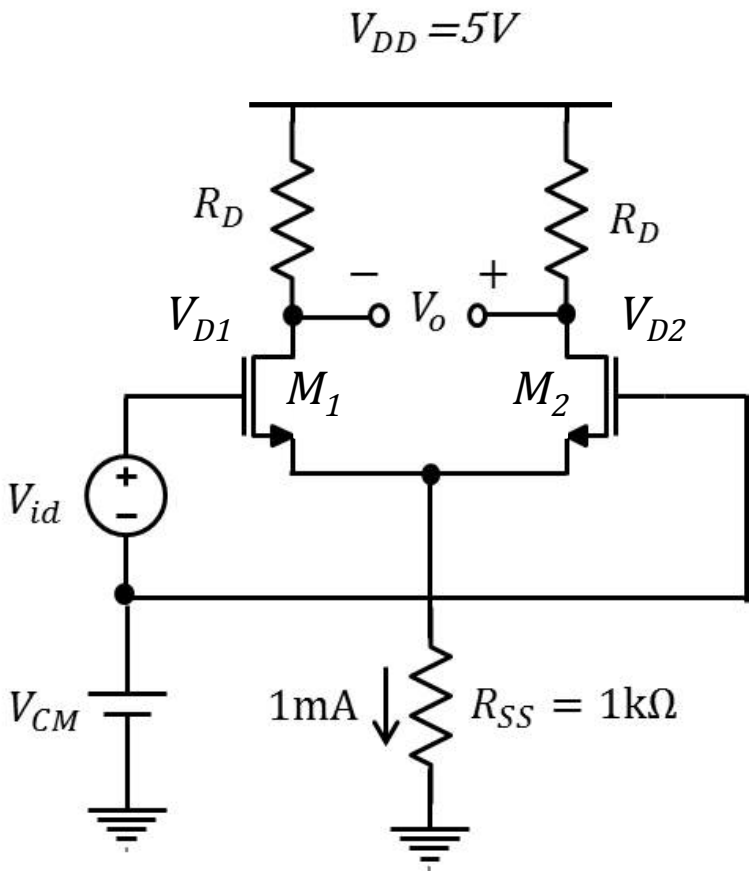

Fig. PS7-2

3. Fig. PS7-3 shows a high-gain op amp design with cascade devices. Let I_{SS} = 1mA, V_{DD} = 3V, V_{B1} = 1.7V and V_{B2} = 1.6V. Assuming $\gamma = 0$ and $V_{ov,Iss}$ =0.2V , find the mid-band gain v_{out}/v_{in}, input common-mode range, and the output swing.

MOS Parameters:

$$\mu_n C_{ox} = \frac{135\mu A}{V^2}, \mu_p C_{ox} = \frac{38\mu A}{V^2}\ V_{Tn} = 0.7\ V, V_{Tp} = -0.8\ V, \lambda_n = \lambda_p = 0.1,$$

$$\left(\frac{W}{L}\right)_{1,2,3,4} = \frac{100\mu m}{0.34\mu m}, \left(\frac{W}{L}\right)_{5,6,7,8} = \frac{100\mu m}{0.32\mu m}$$

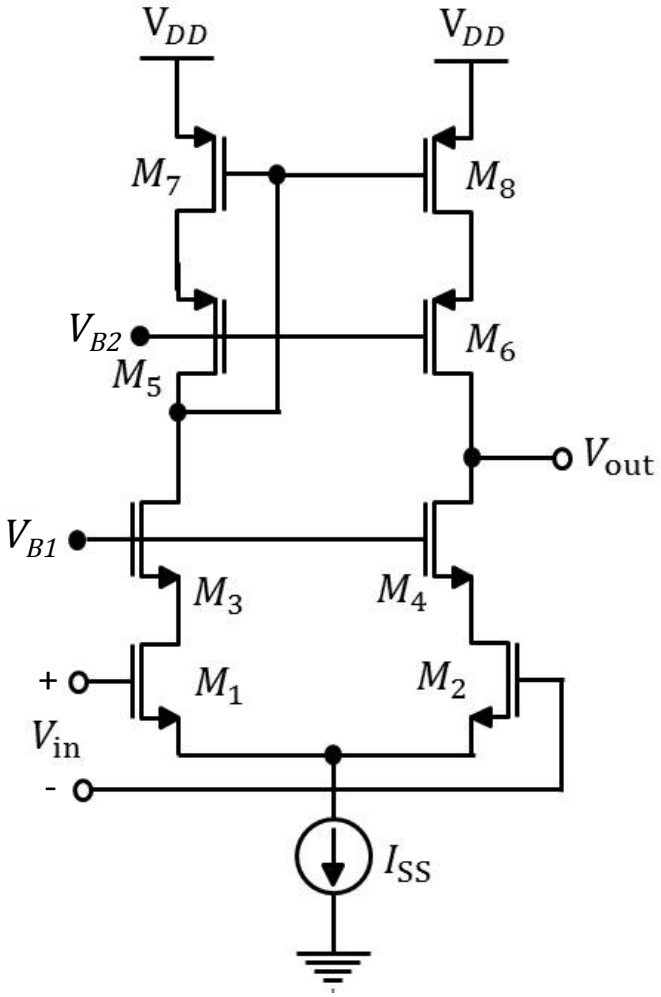

Fig. PS7-3

4. Fig. PS7-4 shows a two-stage CMOS op amp. Let $I_{REF} = 90\mu A$, $V_{DD} = V_{SS} = 2.5V$, and $C_C = 0$. Find the mid-band gain $v_O/(v_+ - v_-)$, input common-mode range, and the output swing.

MOS Parameters:

$$\mu_n C_{ox} = \frac{160\mu A}{V^2}, \mu_p C_{ox} = \frac{40\mu A}{V^2}, V_{Tn} = 0.7\ V, V_{Tp} = -0.8\ V, \lambda_n = \lambda_p = 0.1,$$

$$\left(\frac{W}{L}\right)_{1,2} = \frac{20\mu m}{0.8\mu m}, \left(\frac{W}{L}\right)_{3,4} = \frac{5\mu m}{0.8\mu m}, \left(\frac{W}{L}\right)_{5,7,8} = \frac{40\mu m}{0.8\mu m}, \left(\frac{W}{L}\right)_{6} = \frac{10\mu m}{0.8\mu m}$$

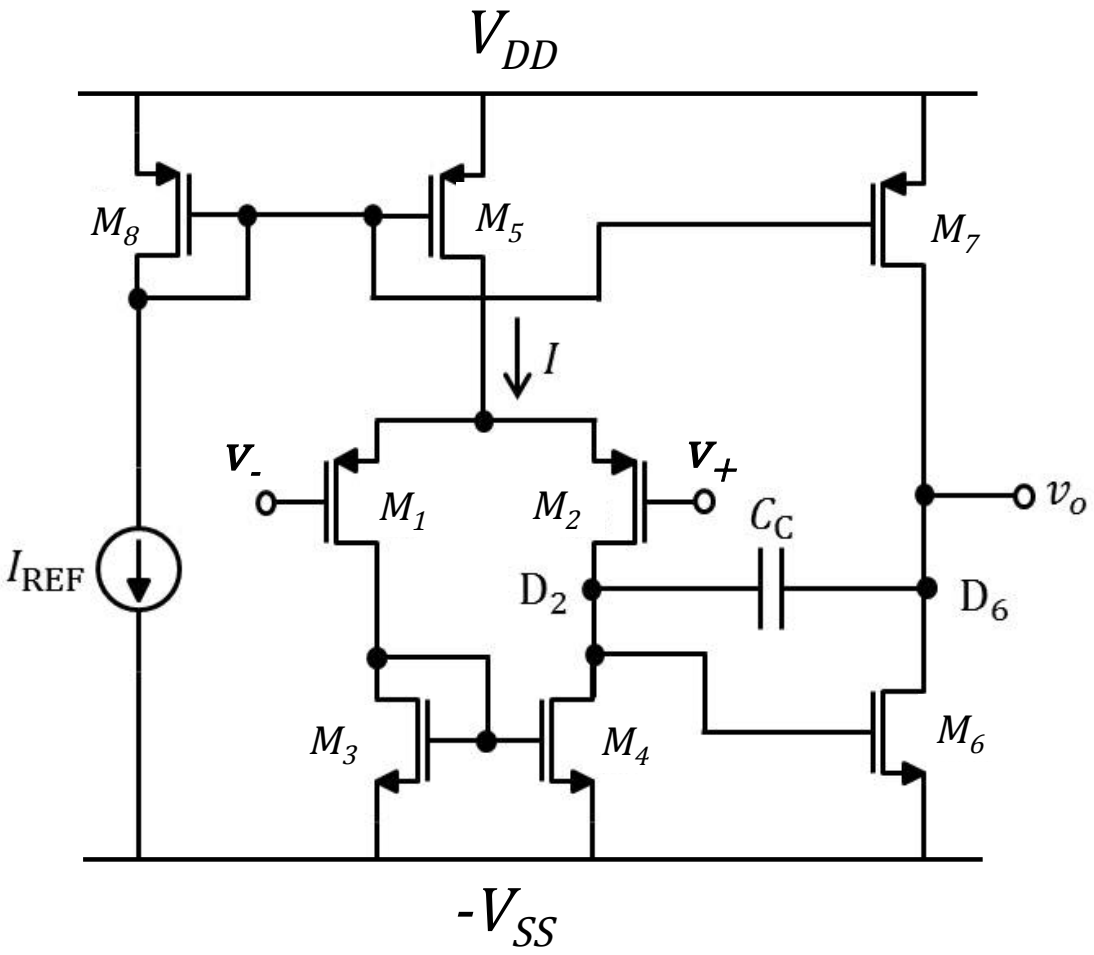

Fig. PS7-4

5. Fig. PS7-5 shows a multi-stage BJT OPAmp design. BJTs $Q_1 - Q_9$ have the same size except for Q_6, which is 4x larger than Q_9. Ignore Early effect.

(a) Assuming $\beta \gg 1$ and $|V_{BE}| = 0.7V$, calculate the DC currents flowing through $Q_1 - Q_9$.

(b) Calculate the static power dissipation of this op amp.

(c) If transistors Q_1 and Q_2 have $\beta = 100$, what is the input bias current of this op amp?

(d) If $V_{CE(sat)}$ = 0.4V, determine the input common-mode range of this op amp.

(e) Calculate the input resistance, mid-band gain v_o/v_{id}, and the output resistance of this op amp.

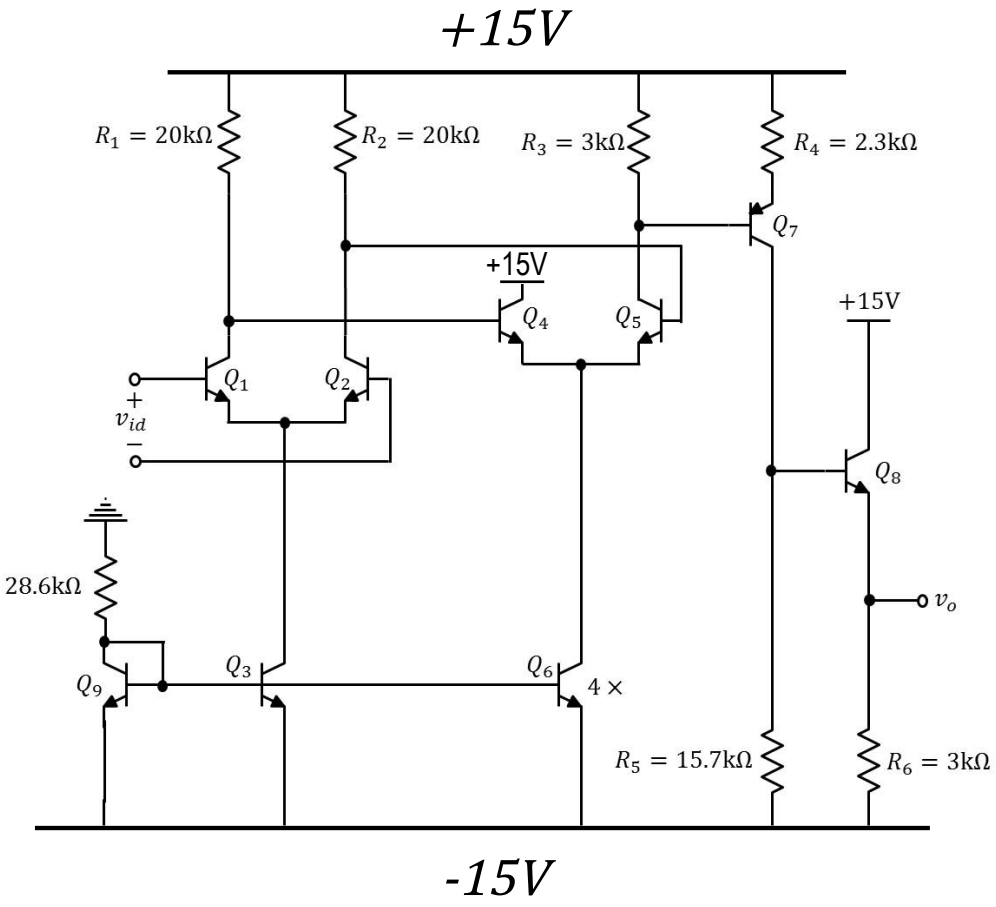

Fig. PS7-5