PROBLEM SET #7

Issued: Tuesday, Mar. 8th, 2011
Due: Tuesday, Mar. 15th, 2011, 5:00 p.m. in the EE 140 homework box in 240 Cory

1. The differential instrumentation amplifier shown in Fig. PS7.1 (the whole circuit, including resistors) must have a voltage gain of 1000 with an accuracy of 0.1 percent. What is the minimum required open-loop gain of the op amp? Assume the op amp open-loop gain may vary by +100% and -50% from its nominal value. Neglect the effects of the R_{in} and R_{out} of the op amp (i.e. $R_{in} = \infty$ and $R_{out} = 0$).

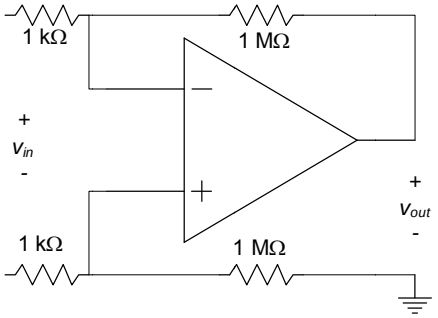

Fig. PS7.1

2. Calculate the common-mode input range of the op amp in Fig. PS7.2 in terms of V_{DD} and V_{SS}. Assume that the transistors have $|V_t| = 1$ V, and ignore the body effect. Also assume that the biasing is arranged so that $|V_{ov}| = 0.2$ V for each transistor except M_9. Finally, assume that M_1 and M_2 are biased at the edge of the saturation region by M_9 and I_C. What is the minimum supply difference required to satisfy this common-mode input range?

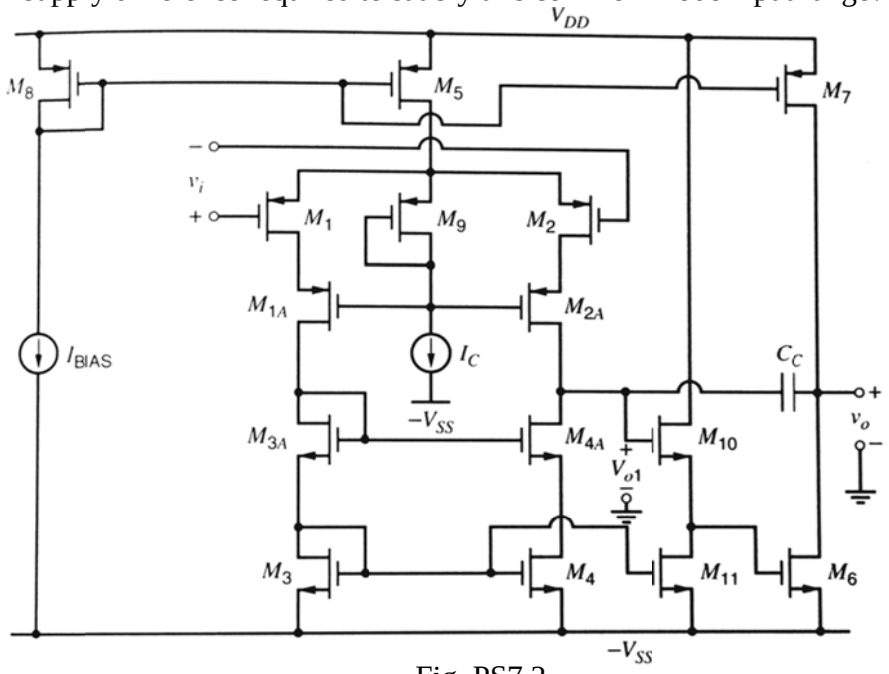

Fig. PS7.2

3. Write the expressions for the low frequency closed-loop gains and poles of Fig. PS7.3 (a) and (b). *A(s)* is the transfer function of a single pole amplifier (pole ω_{p1}) with a large low frequency gain of A_0

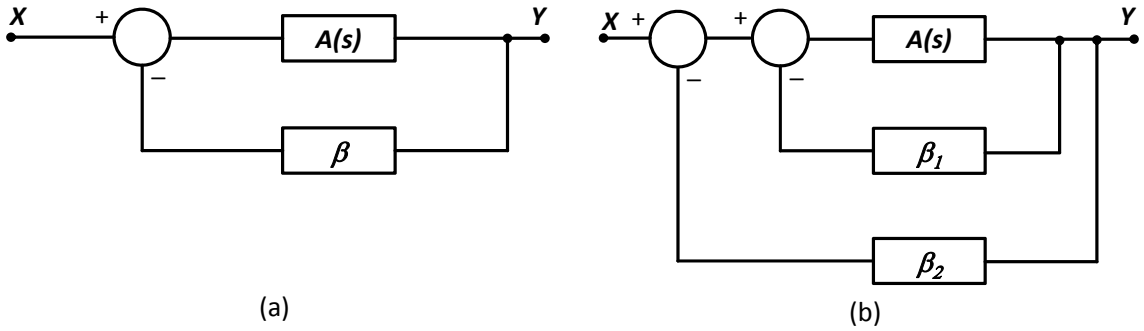

Fig. PS7.3

4. The circuit shown in Fig. PS7.4 is a two stage op amp employing cascoding. Assume I_{SS} = 1mA, I_{D9}-I_{D12} are all equal to 0.5mA, $(W/L)_{9\text{-}12}$ are all 100/0.5, and the two halves of the circuit are symmetric.
   a. Calculate the common mode voltage range at nodes X and Y over which all transistors remain in saturation.
   b. If at least 400mV is required across the I_{SS} current source, what are the minimum sizes, *(W/L)*, of M_1-M_8 in order to achieve a peak-to-peak swing of 200mV at X and Y? What are V_{b1}, V_{b2}, and V_{b3}?
   c. Calculate the overall voltage gain $(V_{out2}\text{-}V_{out1})/V_{in}$

μ_n = 350cm^2/Vs, μ_p = 100cm^2/Vs, t_{ox} = 9nm, λ_n = 0.1V^{-1}, λ_p = 0.2V^{-1}, γ = 0, V_{thp} =*-0.8V*, V_{thn} = *0.7V*

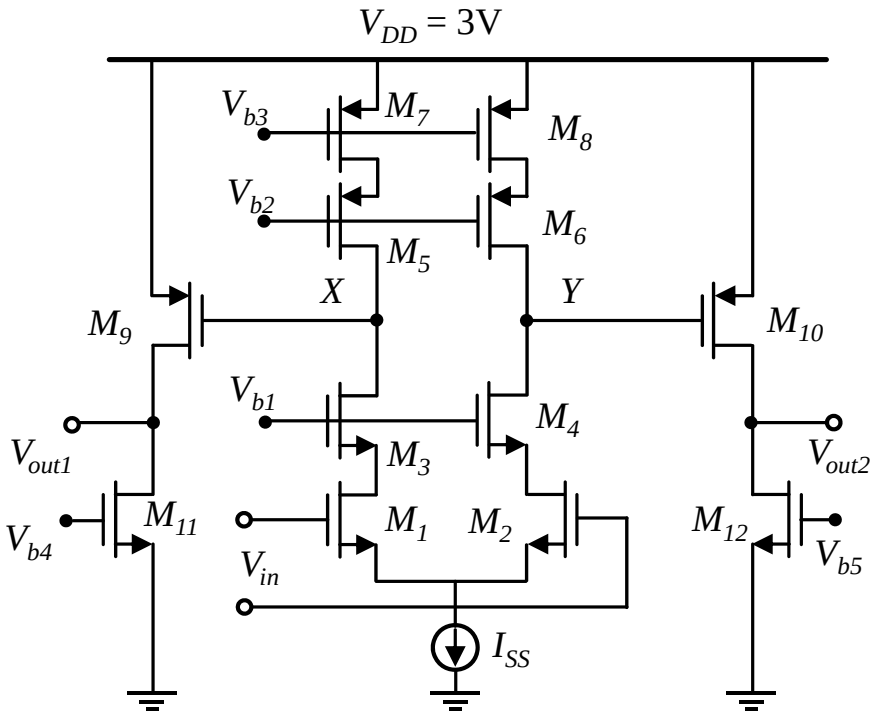

Fig. PS7.4

5. Derive the transfer function and sketch the Bode plot of the circuits shown in Fig. PS7.5. The op amp here is ideal. Specify the values of R_1, R_2 C_1 *and* C_2 to provide a gain of 60dB in the "midband frequency range", a low-frequency 3dB point at100Hz, a high-frequency 3dB point at 10 kHz, and an input resistance (at midband frequency) of 1kΩ.

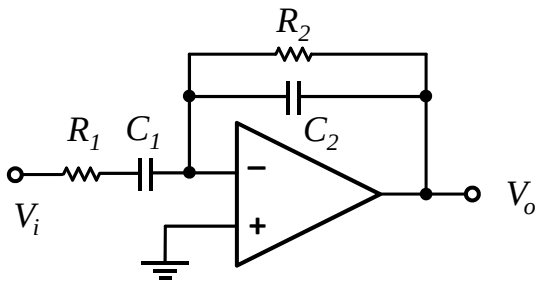

Fig. PS7.5

6. The circuits shown in Fig. 7.6 use an op amp having a ±4mV offset. What is the output offset voltage in (a)? What does the output offset become with the input ac coupled through a large capacitor C as shown in (b)? If instead, the 1kΩ resistor is capacitively coupled to ground as shown in (c), what does the output offset become? For each case, assume that the input is grounded.

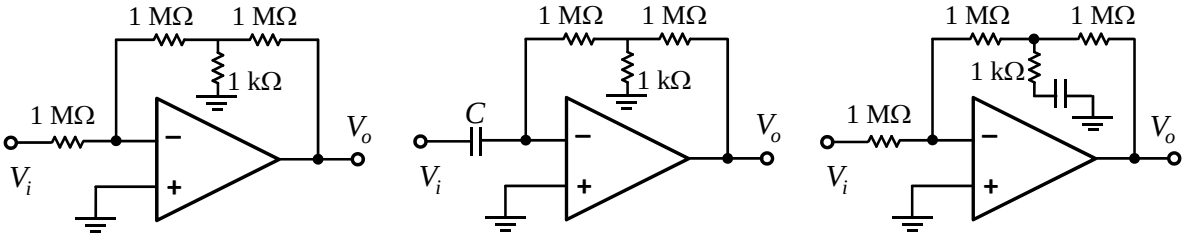

Fig. PS7.6