Name_____

SID_____

| Prob.	Score
1	/20
2	/8
3	/18
4	/12
5	/10
6	/28
7	/24
Total	/122

1) [20] You have a two-stage Miller compensated op-amp with a low-frequency gain of 10^6 and a pole at 1Hz. The second pole is at 100kHz, and all other poles and zeros are at much higher frequency, but start contributing a few degrees of negative phase around 1MHz.

    a. Is the op-amp unity gain stable?

    b. If you put it in feedback with f=0.1

          i.   What is the phase margin?

          ii. What is the approximate (1 sig-fig) low-frequency closed-loop gain?

          iii. What is the low-frequency gain error?

          iv. If you double the capacitance at C1, C2 or Cc, how will the poles move (answers should be of the form "4x lower", "a little higher", etc.) You can assume C_1 and C_c are comparable, and C_2 is much bigger than both.

if you:	ω_{p1} will move	ω_{p2} will move
double C_1		
double C_2		
double C_c		

2) [8] In the op-amp below, what is the output swing (V_{min}, V_{max}), and maximum input common mode value, $V_{icm,max}$? Assume that all transistors have the same overdrive voltage V_{ov}. (n.b. There is one new wire added to the hw8 design)

(V_{min}, V_{max})= $V_{icm,max}$ =

If you double the output capacitance, how will the dominant pole move?

3) [18] The circuit below is from a 100W stereo power amplifier (eleccircuit.com).
    a. Circle the differential amplifier and label "DIFF"
    b. Circle the second stage gain stage and label "2"
    c. Circle the compensation capacitor and label "Cc"
    d. Estimate the common mode gain of the first stage

    e. Estimate the tail current if the preamp input signal is at ground. You can ignore the zener diode if you want – just state your assumptions. 1 sig-fig

    f. Estimate the differential gain of the first stage. 1 sig-fig

    g. What is the low-frequency feedback factor?

    h. What is the high-frequency feedback factor?
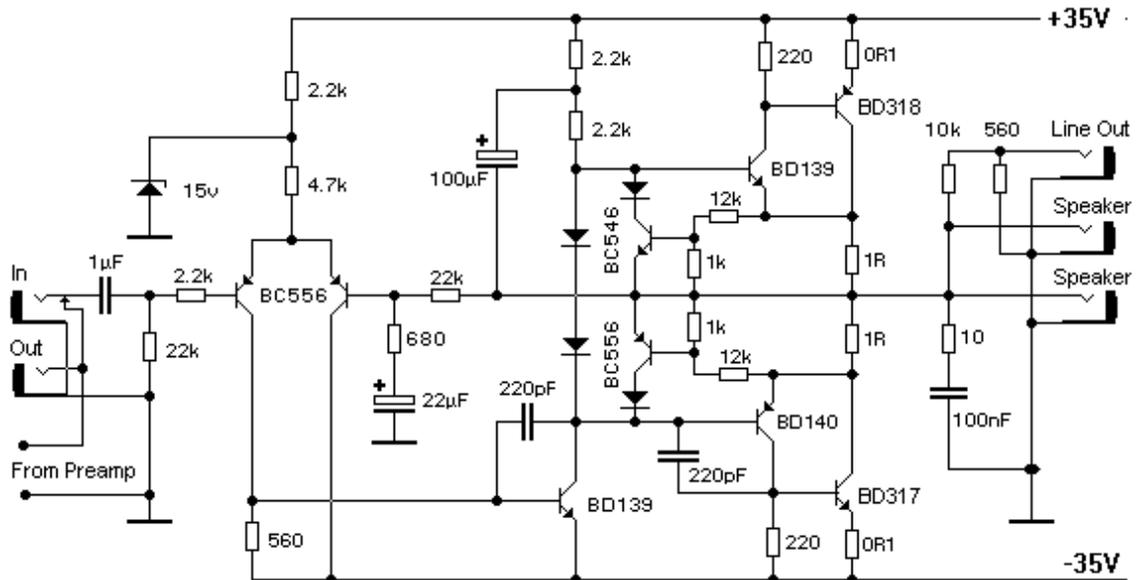
4) [12] The TI OPA334 is a single-ended CMOS op-amp similar to what you've been designing in class. The frequency response from the datasheet is shown below.

    a. What is the open loop gain?

    b. What is the lowest frequency pole?

    c. What is the phase margin?

    d. Is the amplifier unity-gain stable?

    e. With a 0 to 5V supply, the input common mode range for the OPA334 is from - 0.1V to 3.5V. Based on the different op-amp topologies that you know (single stage, two stage, folded cascode),

   i.   which topologies could this op-amp use?

           ii. Is the input differential pair made with NMOS or PMOS transistors?

OPEN-LOOP GAIN/PHASE vs FREQUENCY
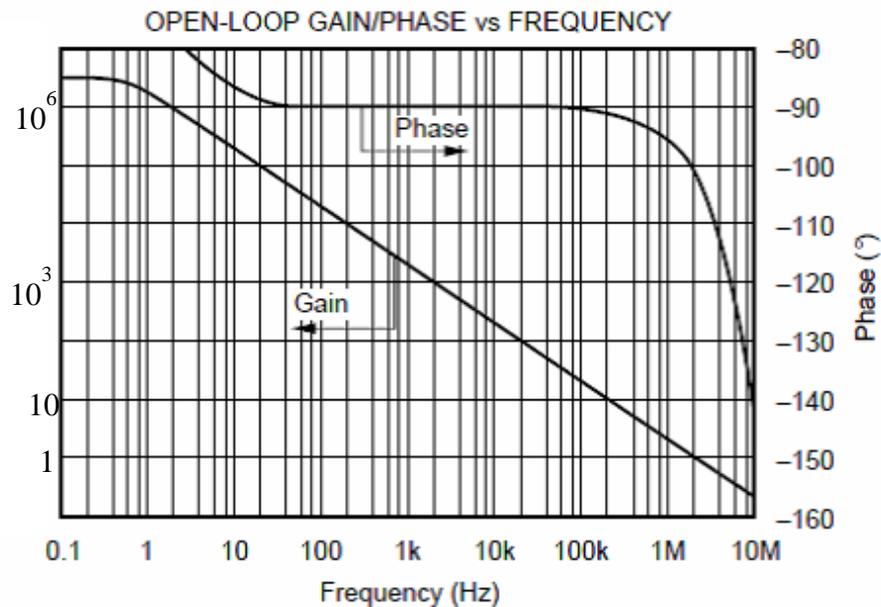
5) [10] In a two-stage op-amp, consider the following circuit for eliminating the RHP zero associated with C_c. What is the small-signal current i_c as a function of v_{o1}? Does this circuit look like a capacitor to the first stage? If so, what is the effective capacitance?
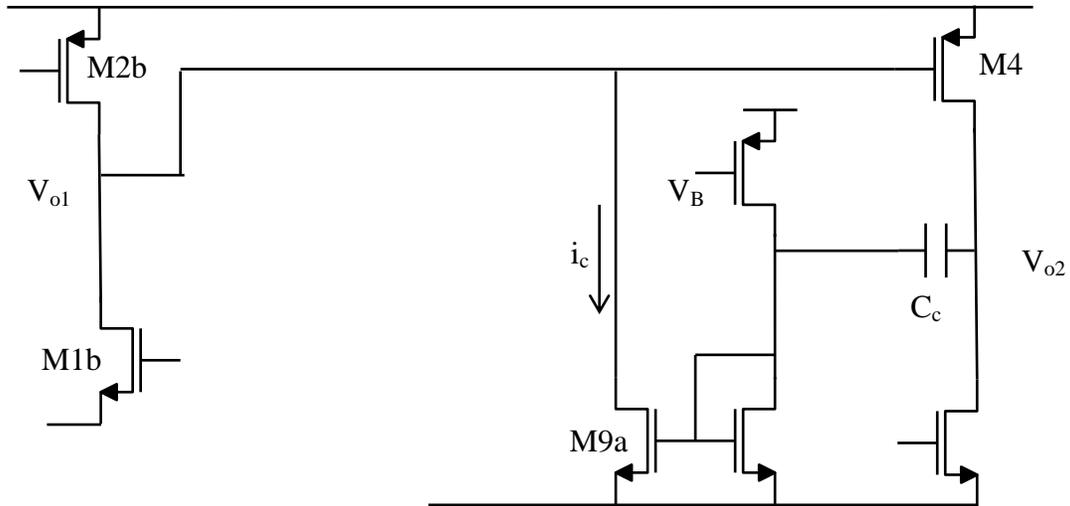

Now consider this circuit. What is the small-signal current i_c as a function of v_{o1}? Does this circuit provide pole-splitting? Does this circuit remove the RHP zero?
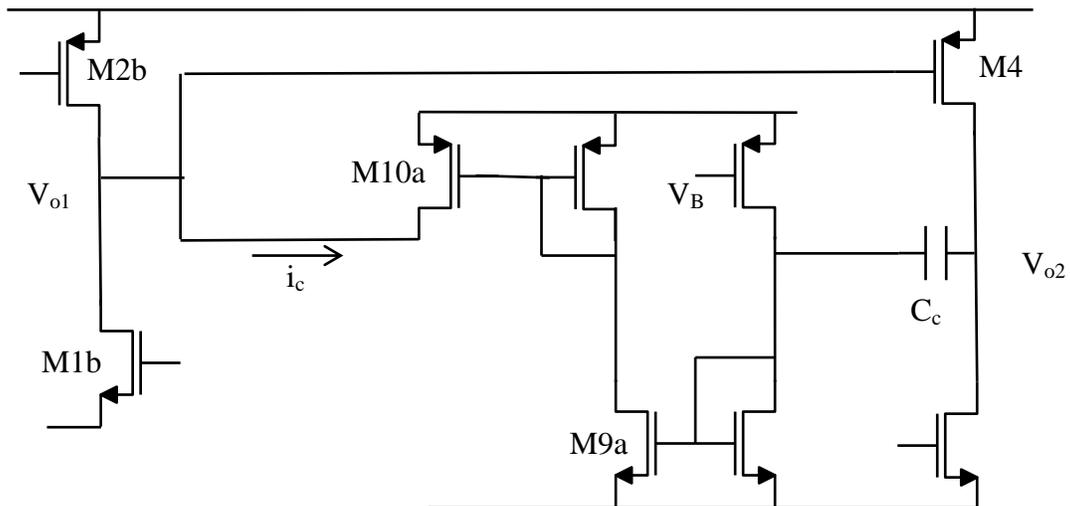
6) [28] In the two-stage op-amp below, assuming $I_{ref}=10uA$ and $(W/L)_6= (10u/1u)$, design the amplifier so that the tail current is 20uA, the second stage current is 100uA, and the PMOS devices have $V_{ov}=100mV$.

  a. What are the W/L values for all devices?
  b. What are gm1, Ro1, gm4, Ro4?
  c. What is the gain of the 1st stage, and gain of the 2nd stage?

Process specs $\mu_nC_{ox}=200\mu A/V^2$, $\mu_pC_{ox}=100\mu A/V^2$, $\lambda=1/(10V)$, $-V_{tp}=V_{tn}=0.5V$, $V_{DD}=2V$, $L_{min}=1um$, $C_{ox}=5fF/um^2$, $C'_{ol}=0$.
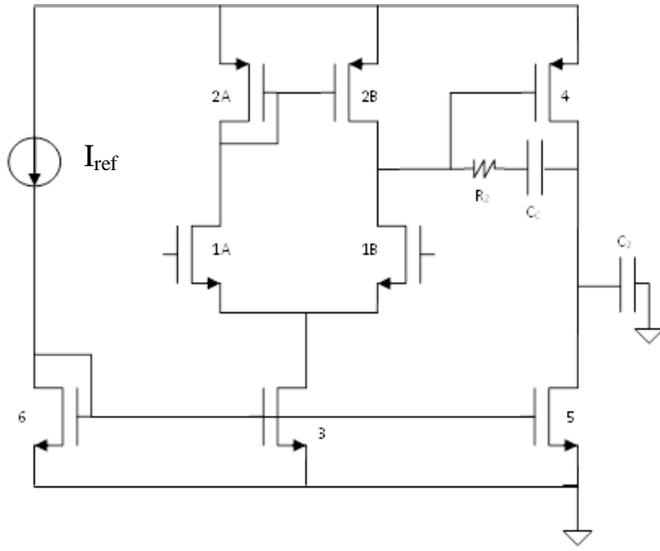
(W/L)$_1$	
(W/L)$_2$	
(W/L)$_3$	
(W/L)$_4$	
(W/L)$_5$	
(W/L)$_6$	10u/1u

g_{m1}	
R_{o1}	
g_{m4}	
R_{o2}	
A_{v1}	
A_{v2}	

7) [24] A different design of the same 2-stage op-amp has the following parameters

g_{m1}	R_{o1}	g_{m4}	R_{o2}	C_2	C_C	C_{gs4}
1µS	100M	10µS	100M	1pF	10fF	100fF

   a. What are the uncompensated (Cc=0) DC gain and pole locations of the two stages?
   b. What is the frequency of the RHP zero?

$A_{v1,0}$	
ω_{p1}	
$A_{v2,0}$	
ω_{p2}	
$\omega_{z,RHP}$	

On the next page, on the top axes plot the magnitude of
   c. the impedance of C_1, C_c by itself, and the total impedance seen at the first stage output
On the middle axes plot the magnitude of
   d. the compensated first and second stage gains, and the overall gain. You may assume that the value of R_z has been chosen to place the RHP zero at infinity.
On the bottom axes plot
   e. The phase of the overall gain.

Plot 1: Impedance

|Z_{C1}|
|Z_{Cc}|
|Z_{o1}|

100M

1M

1K

1   1k   1M   1G

Plot 2: Gain

10^5

|A_{v1}|
|A_{v2}|
|A_v|

10^3

10^2

1

1   1k   1M   1G

Plot 3: Phase

0

phase(A_v)

-90

-180

1   1k   1M   1G