EECS140 Midterm 2
Spring 2017

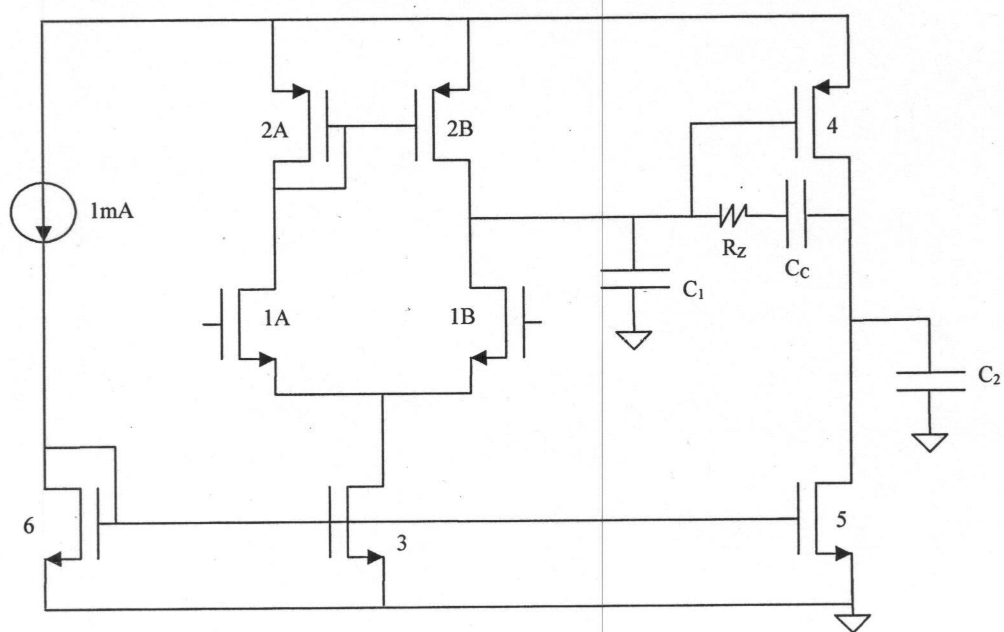
Name Key

SID

Prob.	Score
1a-e	/10
1f-l	/25
2, 3	/30
4	/15
Total	/80

1) Unless otherwise indicated, you may make the following assumptions:

- All transistors are biased in saturation with V_{ov}=0.2V
- V_{DD}=3V, V_{tn}=1V, V_{tp}=-1V
- M3, and M6 are identical, M5 is 10 times wider
- All capacitors are assumed to be zero except C_C, C_1, and C_2 .



a. What is the common mode input range (min and max)?

+1 min = 1.4V max = 2.8 V +1

b. What is the output swing (min and max)?

+1 min = 0.2V max = 2.8 V. +1

c. If C_1=0, C_2=1 pF, and C_c=1 pF, what is the positive slew rate?

$\frac{I_{d3}}{C_c}$ +1 = 10^9 V/s +1

d. If C_1=0, C_2=2 pF, and C_c=1 pF, what is the negative slew rate?

$\frac{I_{d3}}{C_c}$ +1 = 10^9 V/s +1

e. If C_1=0, C_2=1,000 pF, and C_c=1 pF, what is the negative slew rate?

+1 $\frac{I_{d5}}{C_2} = \frac{10^{-2} A}{10^{-9} F}$ = 10^7 V/s +1

A different amplifier with the same topology has the following parameters. You may ignore the pole/zero doublet from the mirror.

$g_{m1,2}$	R_{o1}	g_{m4}	R_{o2}	C_1	C_C	C_2
1mS	1M	1mS	100k	10p	1p	100p

f. If Cc=0 (magically we will assume no Cgd4 for this part only), what are the uncompensated poles?

$\omega_{p1,u}$= 10^5 rad/s	$\omega_{p2,u}$= 10^5 rad/s

On the following pages,

g. what is the location of the RHZ zero? ω_z= 10^9 rad/s

h. plot the magnitude of the second stage gain

i. plot the overall impedance seen at the first stage output (including R_{o1}, C_1, C_C, and any effects of Miller multiplication),

j. plot the magnitude of the first stage gain,

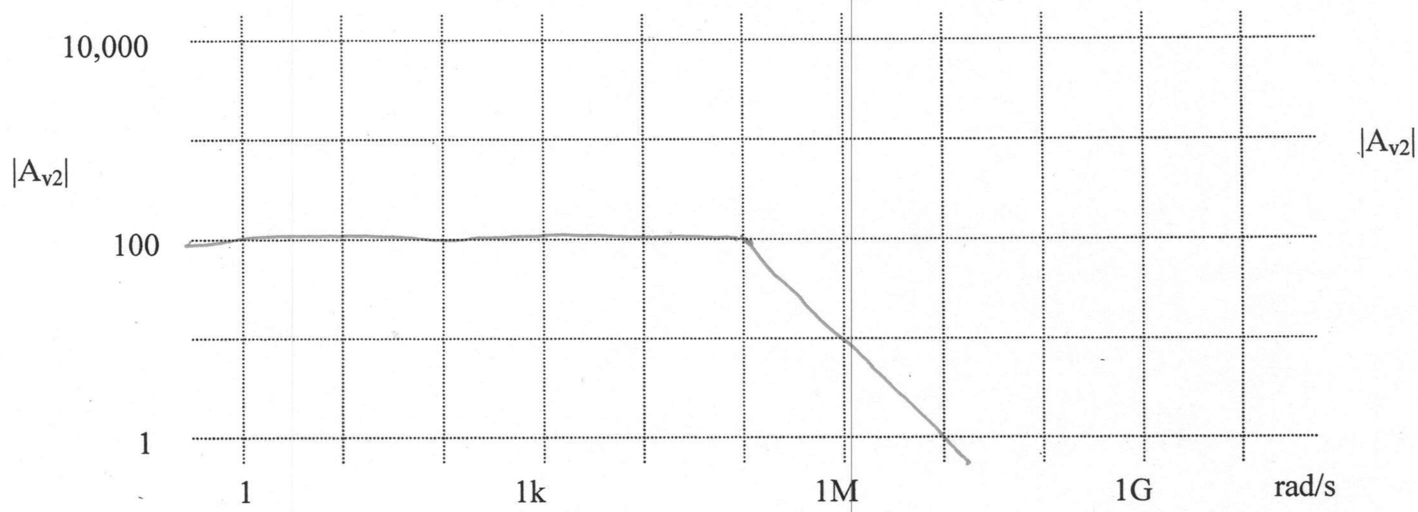
k. plot the magnitude and phase of the overall gain. **Label any poles and zeros clearly.**

l. Estimate the phase margin for this value of C_C. PM= 0

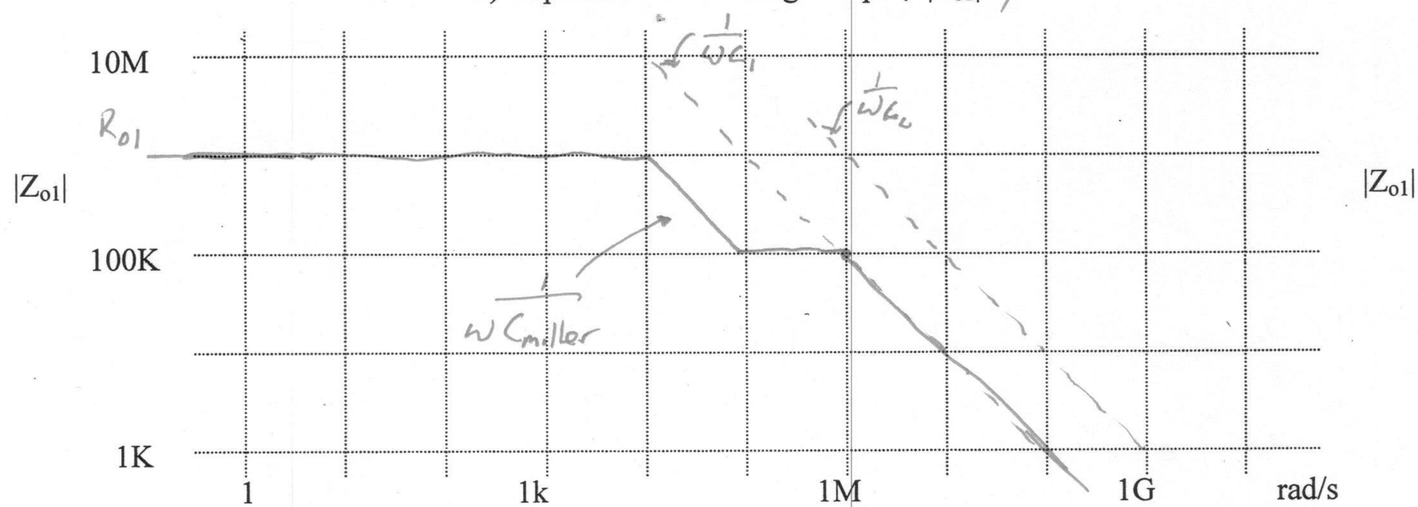
m. What is the maximum feedback factor and closed loop gain for which the amplifier has a 45 degree phase margin?

f= 10^{-3}	A_{cl}= 10^3

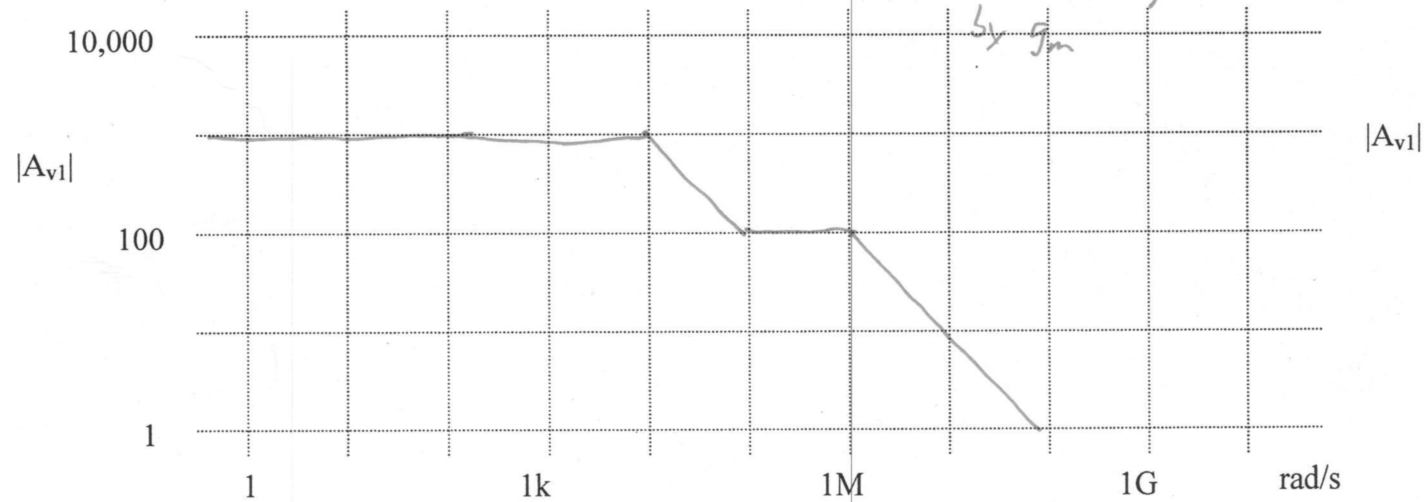
1h) Second stage gain – $|A_{v2,0}|$ 2



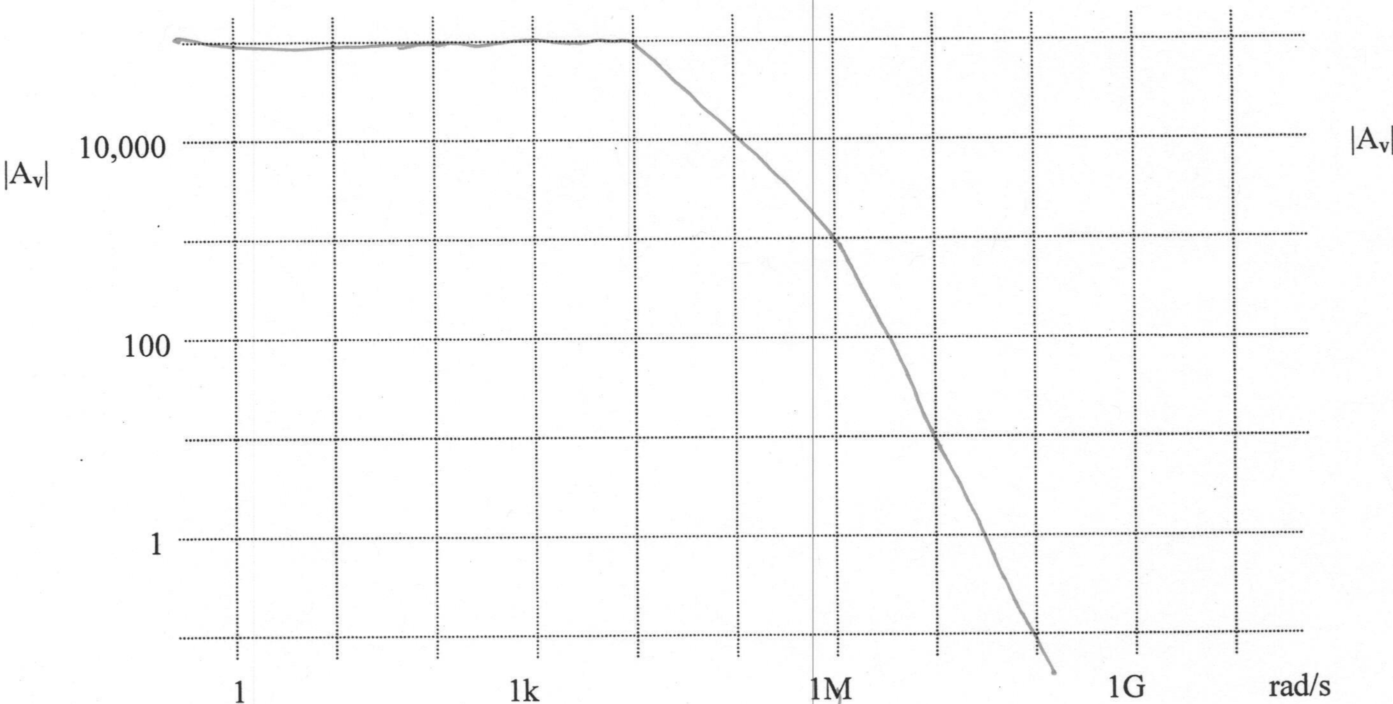
1i) Impedance at first stage output, $|Z_{o1}|$ 4



1j) First stage gain, $|A_{v1}|$ 2 pts for multiplying whatever is up here by g_m



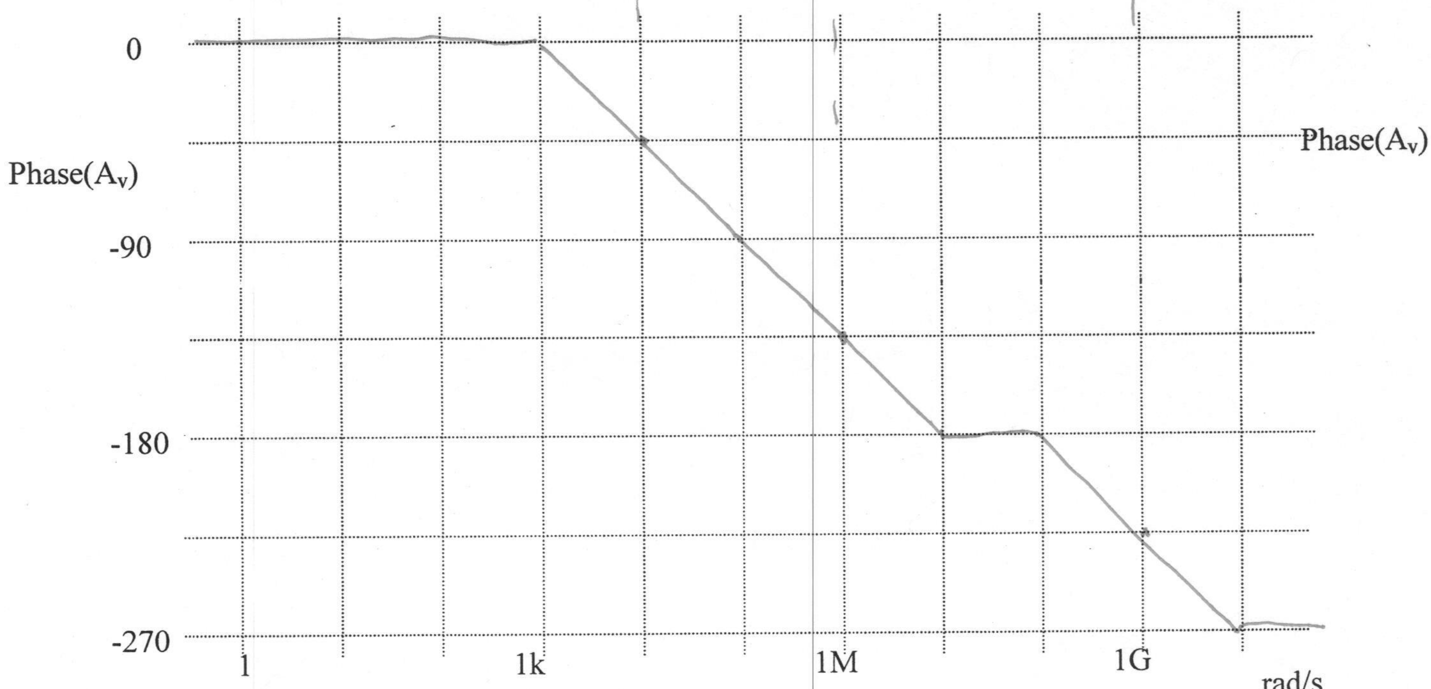
1kl) op amp Bode plot 5 total



$\omega_{p1,L}$ $\omega'_{p2,L}$

Label any poles and zeros clearly!

$\omega_{Z\,RHP}$



2) [8] A single-pole amplifier has a gain of 1,000 and a pole at 1MHz. It is used in feedback with a feedback factor f=0.01 .

a. What is the approximate closed-loop gain, $A_{CL} \approx \frac{1}{f} = 100$ V/V +1

b. percent gain error, $\frac{-1}{Af} \times 100\% = -10\%$ +1 +1

c. closed-loop pole location, $f_{CL} = GBW/A_{CL} = 10$ MHz +1 +1

d. and time constant of the step response?

$\tau = 1/\omega_{CL} = \frac{1}{2\pi} \cdot 10^{-7}$ s +1 +1

3) [22] A particular diode D1 has a saturation current of 1pA, and at 1mA current at room temperature the diode voltage has a temperature coefficient of -2mV/K. You are using copies of this diode to make a bandgap reference as in Lab 4, with D2 composed of seven copies of D1. You can use the approximation that ln(7) ~= 2. Assuming that the current in both diodes is maintained at 1mA at room temperature

a. What is the voltage on D1 at room temperature?

(9 decades)(60 mV/decade) = 0.54 V

b. What is the voltage on D2 at room temperature?

$\ln(7) V_{TH}$ smaller ≈ 0.490 V

c. What is the different between the two diode voltages at 200K, 300K, and 400K?

300K ≈ 52mV 400K ≈ 70mV

200K ≈ 35mV

d. What is the temperature coefficient of the voltage on D2?

$-\frac{2mV}{K} - \frac{52mV}{300K} \approx -2.17$

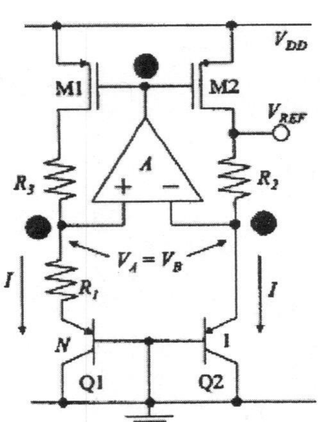
e. Roughly what is the right value for R1?

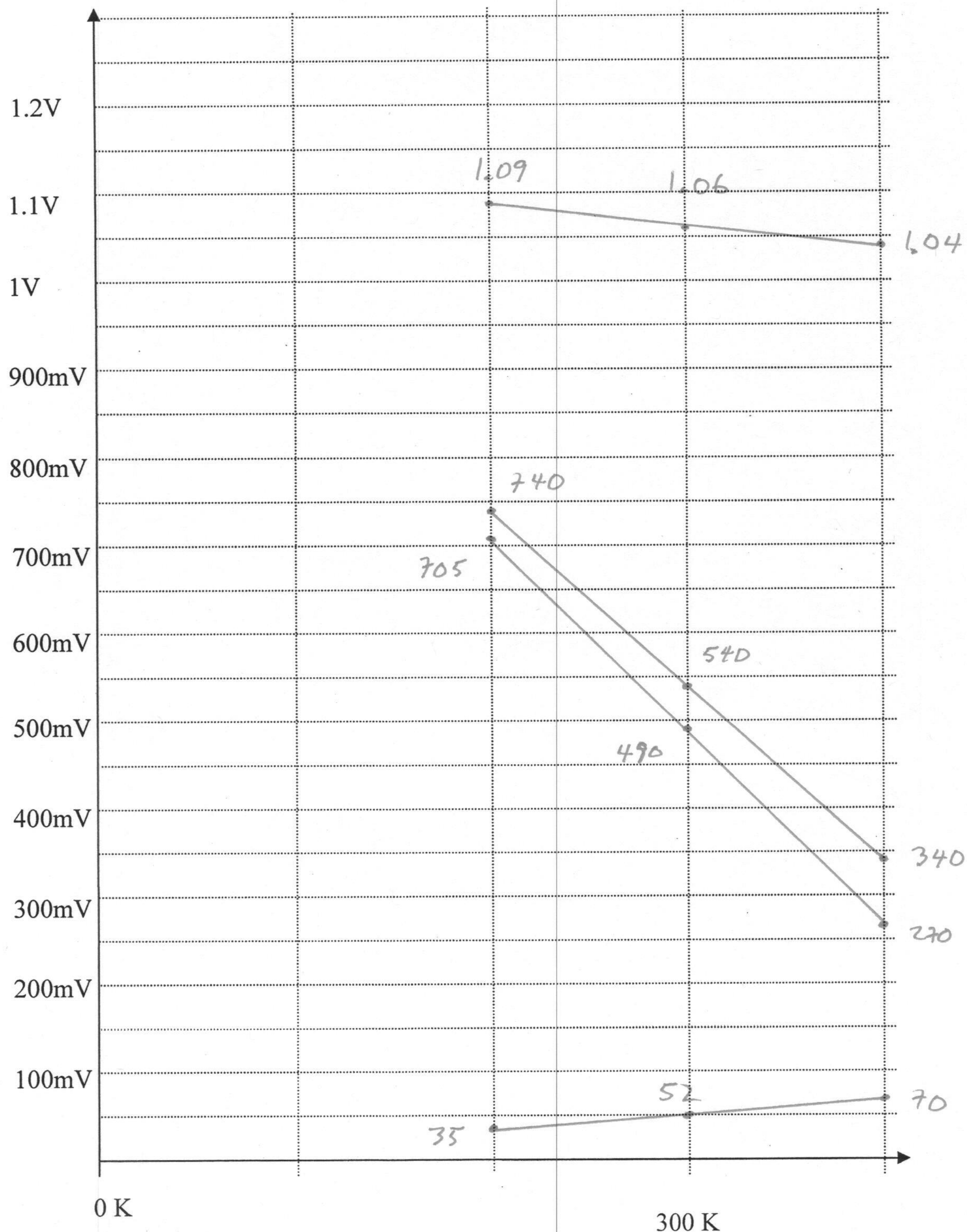
$\frac{52mV}{1mA} = 52\Omega$

f. On the following page, carefully sketch by hand the voltage on D1, the voltage on D2, and the difference between them as a function of temperature from 200K to 400K.

g. On the same plot, if $R_3=R_2=10\ R_1$, sketch V_{ref} vs. temperature from 200K to 400K.

2 pts for each line





It will help your grade if you draw carefully and label the voltage values of any dots that you draw.

10(70) + 340 = 1,040

10(52) + 540 = 1,060

10(35) + 740 = 1,090

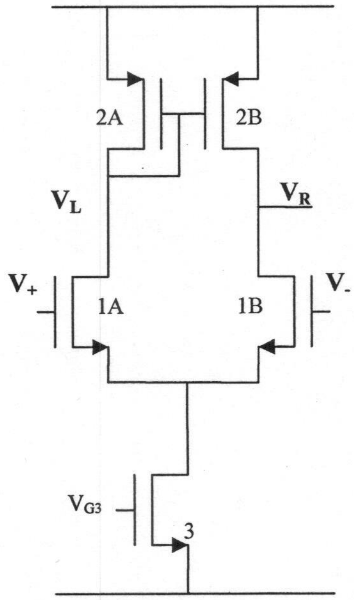
4) [15] For the differential amplifier in the figure below, estimate the change in V_{TAIL}, I_{TAIL}, V_L, and V_R due to

a. An increase of ΔV in both V+ and V-

b. An increase of ΔV in just V+

c. An increase of ΔV in just V-

Give your answers in terms of g_{mi}, r_{oj}, and assume that $g_m * r_o >> 1$ for all i,j combinations.



	V_{TAIL}	I_{TAIL}	V_L	V_R
ΔV in both V+ and V-	ΔV	$\frac{\Delta V}{r_{o3}}$	$\frac{-\Delta V}{2 r_{o3} g_{m2}}$	$\frac{-\Delta V}{2 r_{o3} g_{m2}}$
ΔV in just V+	$\Delta V/2$	$\frac{\Delta V}{2 r_{o3}}$	$\frac{-\Delta V g_{m1}}{2} \cdot \frac{1}{g_{m2}}$	$\Delta V g_{m1} r_{o1} // r_{o2}$
ΔV in just V-	$\Delta V/2$	$\frac{\Delta V}{2 r_{o3}}$	$\frac{\Delta V g_{m1}}{2} \cdot \frac{1}{g_{m2}}$	$-\Delta V g_{m1} r_{o1} // r_{o2}$

+1 each box

+1 for correct signs in each row