BIASING METHODS

The box symbol B used in figure 2 denotes some source of dc voltage and its polarity. For most applications, a bias adjustment is necessary and may be applied in any of several ways. Some recommended methods of biasing are illustrated in figure 3.

When using any of these methods, set the potentiometer for zero d-c error under feedback.

When setting the potentiometer, ground the input of the computing network if possible.

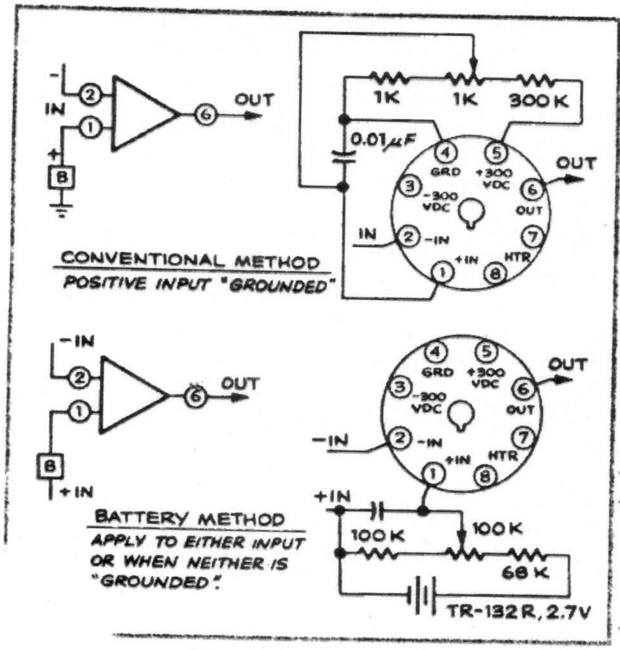


Figure 3. Biasing Methods

> **CAUTION**
>
> Avoid prolonged short-circuiting of the output. The K2-W is designed to tolerate temporary overloads such as output shorted to ground. However, such fault currents, if prolonged, can overheat and thereby shorten the life of K2-W and cause relatively large drifts.

The K2-W and its load may dissipate 8 watts. Unless there is plenty of free air under 30°C (86°F) around the unit, forced ventilation will probably be necessary. The K2-W is not recommended for those applications where either the ventilation is poor or the ambient temperature high. For such applications the MIL equivalent K2-WJ is recommended.

> **CAUTION**
>
> Do NOT allow the temperature of any part of the case to exceed 65°C (149°F). Avoid severe overloading.

INSTALLATION

Wire the desired external circuitry to an octal socket or GAP/R Manifold. Plug the K2-W into the socket or Manifold. (Information about GAP/R Manifolds is available upon request.)

MAINTENANCE

Preventive Maintenance

1. During operation:
   a. Make sure that tubes are firmly seated.
   b. Make sure that the K2-W is firmly seated.

Trouble Shooting

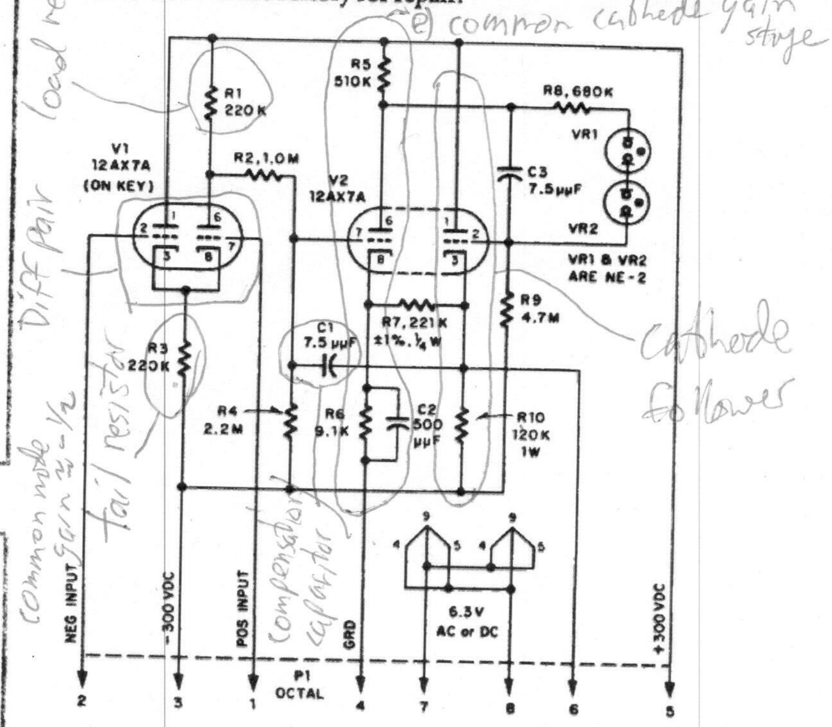
If trouble in the K2-W is suspected:

1. Check for loose connections, grounds, and/or shorts in the associated circuitry.
2. Check the tubes by substitution.
3. Check the plug-in by substitution.

Corrective Maintenance

1. Replace defective parts.
2. Do NOT open the sealed case.

Opening the case voids the guarantee. The unit should be returned to the factory for repair.



NOTE UNLESS OTHERWISE STATED RES. ARE ±5%, 1/2 W

Figure 4. Schematic Diagram

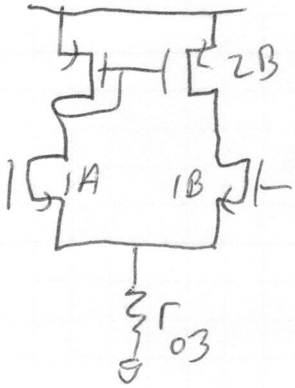
NOTE: For further information on the utility of Philbrick Plug-ins, refer to the "Applications Manual" available upon request.

R7 is positive feedback

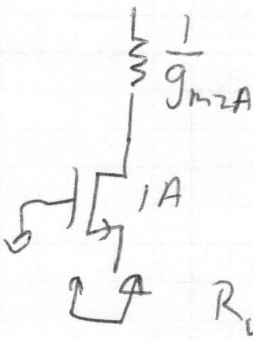
#1) 7 pts
1 each for a,b,d,e,f
2 pts for c (1 for tail resistor, 1 for common mode gain)

HW6 problem 2

#2) 7 pts
1 pt for each part

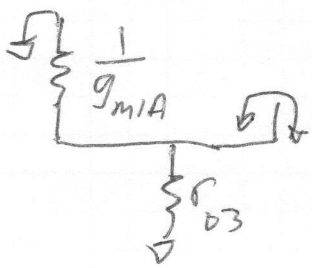


a)



$$R_{UP,1A} = \frac{1}{g_{m1A}} + \frac{R_D}{g_{m1A} r_{o1A}} \approx \frac{1}{g_{m1A}}$$

b)



$$R_{S,1B} = \frac{1}{g_{m1A}} \| r_{o3} \approx \frac{1}{g_{m1A}}$$

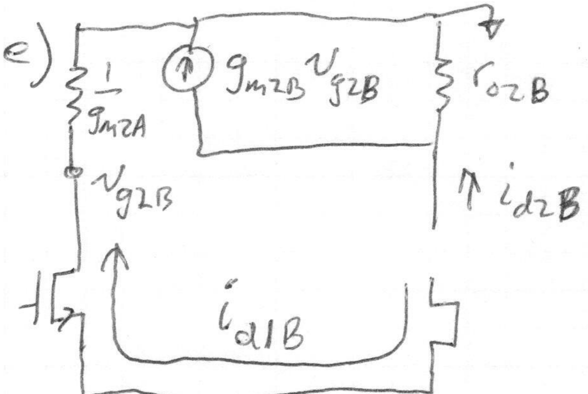
c)

$$R_{DN,1B} = r_{o_B}(1 + g_{m1B} R_S) + R_S$$

$$= r_{o1B}(1 + 1) + \frac{1}{g_{m1A}} \approx 2 r_{o1B}$$

d) $i_{d1B} = \frac{v_o}{2 r_{o1B}}$

e)



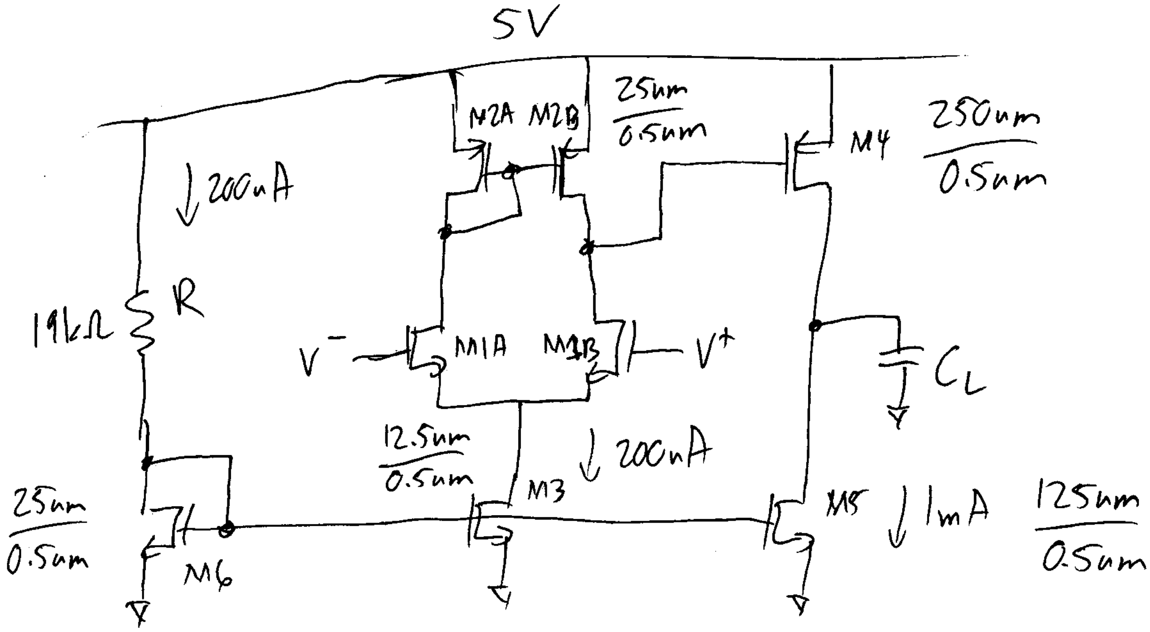
$$i_{d2B} = \frac{v_o}{r_{o2B}} + \left(i_{d1B} \frac{1}{g_{m2A}}\right) g_{m2B}$$

$$= v_o \left(\frac{1}{r_{o2B}} + \frac{1}{2 r_{o1B}}\right)$$

f) $i_o = \frac{v_o}{2 r_{o1B}} + v_o\left(\frac{1}{r_{o2B}} + \frac{1}{2 r_{o1B}}\right) = v_o\left(\frac{1}{r_{o2B}} + \frac{1}{r_{o1B}}\right)$

g) $R_o = \frac{v_o}{i_o} = \frac{1}{\frac{1}{r_{o2B}} + \frac{1}{r_{o1B}}} = \frac{r_{o1B} r_{o2B}}{r_{o1B} + r_{o2B}} = r_{o1B} \| r_{o2B}$!

(3)



#3) 10 pts
+2 pts for drawing schematic
+2 for choosing correct Vov for swing
+6 for table with W, L, Id, and Vov for each device

V_{ov4} and $V_{o5} \leq 200mV$

Upper input limit:

$$(V_{DD} - |V_{tp}| - V_{ov2}) - (4.8V - V_{tn} - V_{ov1}) \geq V_{ov1}$$

$$V_{ov1} = V_{ov2} \leq 200mV$$

Lower input limit:

$$1.4V - V_{tn} - V_{ov1} \geq V_{ov3} \qquad V_{ov3} \leq 200mV$$

Choose all $V_{ov} = 200mV$ Choose $L = 0.5um$ for all

$$I_D = \frac{uC_{ox}}{2}\frac{W}{L}V_{ov}^2 \qquad gm = \frac{2I_D}{V_{ov}}$$

$$C_{gs} = \frac{2}{3}WLC_{ox} + C_{ol} \cdot W \qquad r_o = \frac{1}{\lambda I_D}$$

(See table)

$$C_{gd} = C_{ol} \cdot W$$

④ a) $\Delta V_{in} = 4.8 - 1.4 = 3.4\,V$

I_{d3} will vary by $\Delta V_{in} \cdot \lambda = (3.4V)(0.1\,V^{-1}) = 34\%$

#4) 18 pts
a) 1 pt
b) 5 pts for correct values in table
c) 2 pts - one each for differential and common mode
d) 2 pts - one for each pole location
e) 3 pts - one for Cc, and 1 each for pole locations
f) 5 pts - one each for the three poles and two zeros
Must have both magnitude and phase plots correct for full points

b) See table

c) Differential Mode

$$A_{v,DM} = \underbrace{g_{m1} \cdot r_{o1} // r_{o2}}_{\text{1st stage}} \cdot \underbrace{g_{m4} \cdot r_{o4} // r_{o5}}_{\text{2nd stage}}$$

$A_{v,DM,1} = 50\ V/V$

$A_{v,DM,2} = 50\ V/V$

$A_{v,DM} = 2500\ V/V$

Common Mode

$$A_{v,CM} = \frac{-1}{g_{m2}\, r_{o3}} = -0.02 \quad \text{(From 1st stage)}$$

This is then amplified by the second stage

$$A_{v,CM} = -50 \cdot -0.02 = 1\ V/V$$

d) $C_L = 1pF$

$$\omega_{p1} = \frac{1}{R_{o1}\left(A_{v2} C_{gd4} + C_{gs4}\right)} = \frac{1}{r_{o2}//r_{o1} \cdot \left(\left(g_{m4} \cdot r_{o4}//r_{o5}\, C_{gd4}\right) + C_{gs4}\right)}$$

$\omega_{p1} \approx 3.3 \cdot 10^6$ rad/s

$$\omega_{p2} = \frac{g_{m4}}{C_{gs4} + C_L + \frac{C_{gs4} \cdot C_L}{C_{gd4}}}$$

$\omega_{p2} \approx 2.1 \cdot 10^9$ rad/s

e) for $PM = 45^\circ$, want $\omega_{p2} = \omega_{p1,\mu} = \frac{g_{m1}}{C_{gd4} + C_c}$

$$\frac{g_{m1}}{C_{gd4} + C_c} = \frac{g_{m4}}{C_{gs4} + C_L + \frac{C_{gs4} \cdot C_L}{C_{gd4} + C_c}}$$

Solve for C_c:

$C_c \approx 180fF$

$$\omega_{p1,c} = \frac{1}{r_{o2}//r_{o1} \cdot \left(\left(g_{m4} \cdot r_{o4}//r_{o5} \cdot (C_{gd4} + C_c)\right) + C_{gs4}\right)} \approx 1.4 \cdot 10^6 \frac{rad}{s}$$

$$\omega_{p2,c} \approx \frac{g_{m4}}{C_{gs4} + C_L + \frac{C_{gs4} + C_L}{C_{gd4} + C_c}} \approx 3.8 \cdot 10^9 \text{ rad/s}$$

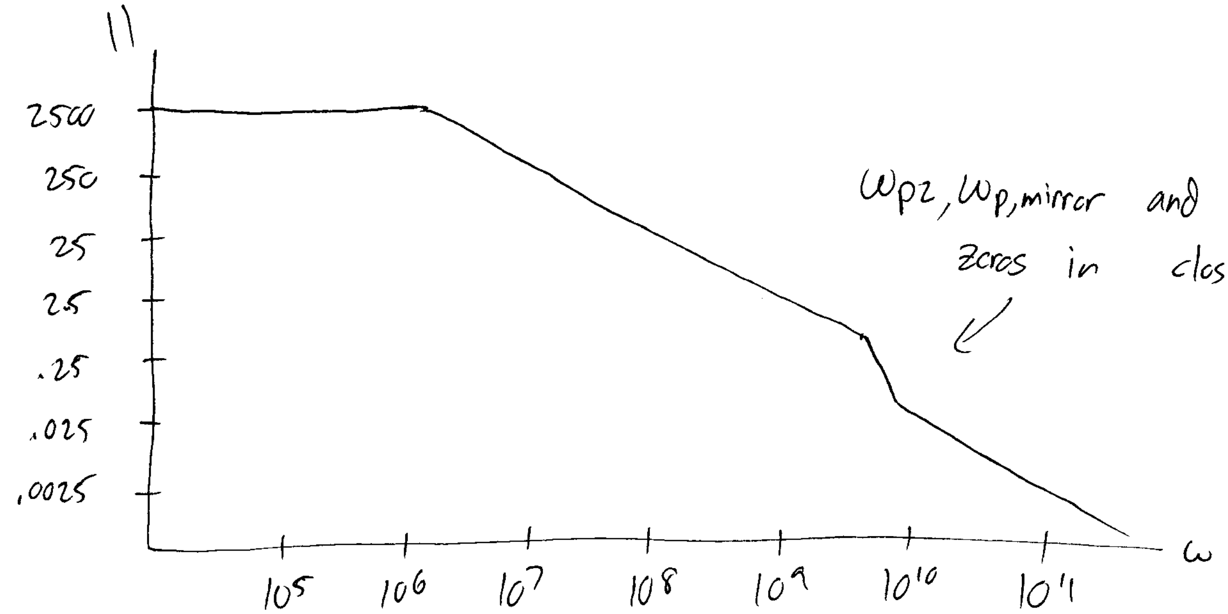
$$\omega_{z,RHP} = \frac{g_{m4}}{C_{gd4} + C_c} = 4.1 \cdot 10^{10} \text{ rad/s}$$

$$\omega_{p,mirror} = \frac{g_{m2}}{2C_{gs2}} = 1 \cdot 10^{10} \text{ rads}$$

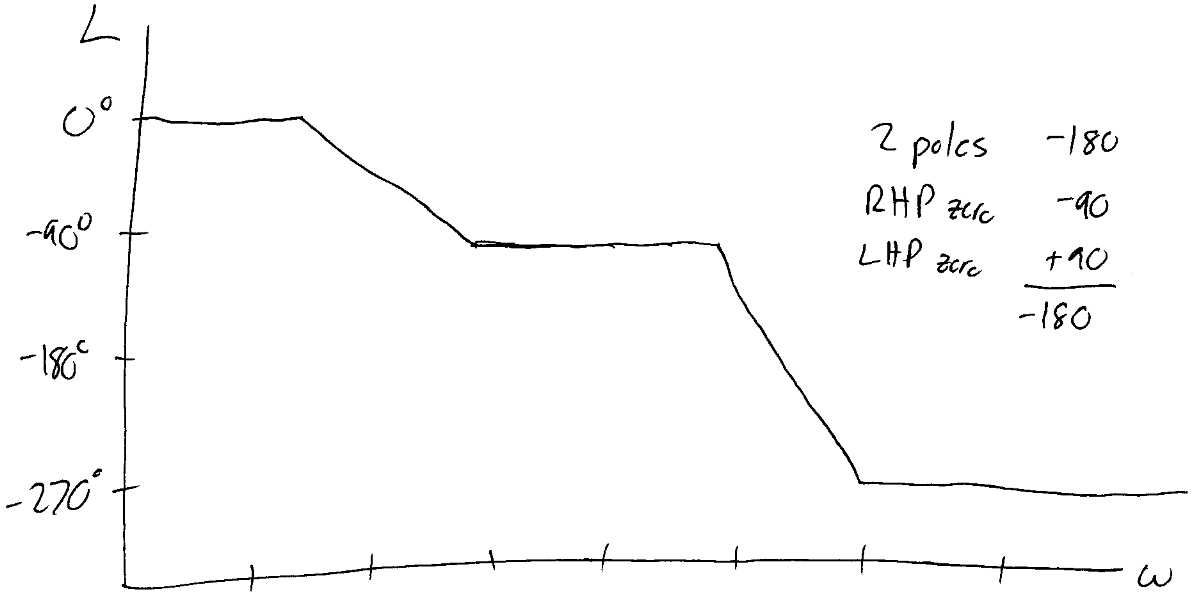
$$\omega_{z,mirror} = \frac{g_{m2}}{C_{gs2}} = 2.1 \cdot 10^{10} \text{ rad/s}$$

$\omega_{p1} = 1.4 \cdot 10^{6}$ rad/s

$\omega_{p2} = 3.8 \cdot 10^{9}$ rad/s



ω_{p2}, $\omega_{p,mirror}$ and the two zeros in close proximity



2 poles	−180
RHP zero	−90
LHP zero	+90
	−180

3)

Ignoring lamba for calculating dimensions:

	W	L	Id	Vov	W/L
M1A	1.25E-05	5.00E-07	1.00E-04	0.2	25
M1B	1.25E-05	5.00E-07	1.00E-04	0.2	25
M2A	2.50E-05	5.00E-07	1.00E-04	0.2	50
M2B	2.50E-05	5.00E-07	1.00E-04	0.2	50
M3	2.50E-05	5.00E-07	2.00E-04	0.2	50
M4	2.50E-04	5.00E-07	1.00E-03	0.2	500
M5	1.25E-04	5.00E-07	1.00E-03	0.2	250
M6	2.50E-05	5.00E-07	2.00E-04	0.2	50

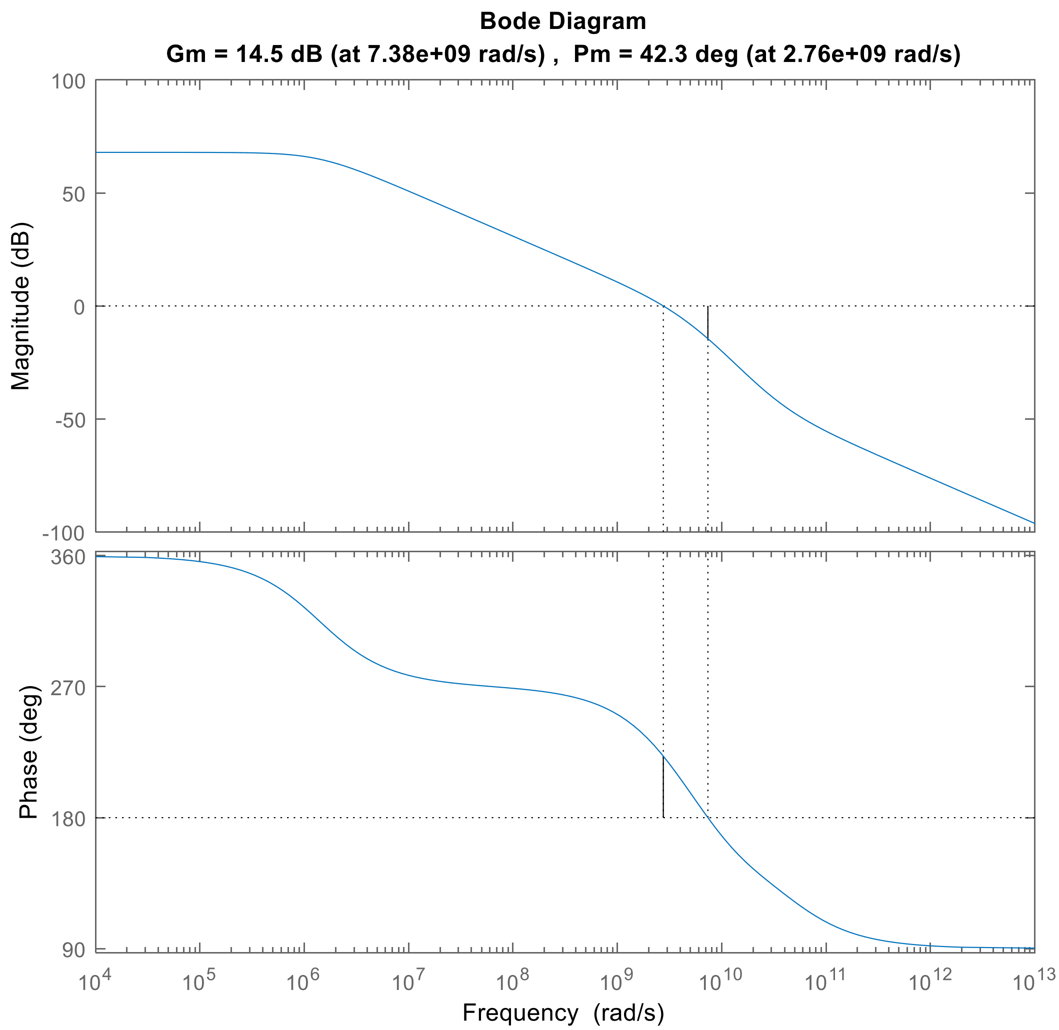
R = (Vdd – (Vtn + Vov6))/200e-6 = 19kΩ

4)

b) Assuming Vic=2.5V

	W	L	Id	Vov	gm	ro	Cgs	Cgd	W/L
M1A	1.25E-05	5.00E-07	1.13E-04	0.2	1.13E-03	8.85E+04	2.71E-14	6.25E-15	25
M1B	1.25E-05	5.00E-07	1.13E-04	0.2	1.13E-03	8.85E+04	2.71E-14	6.25E-15	25
M2A	2.50E-05	5.00E-07	1.13E-04	0.2	1.13E-03	8.85E+04	5.42E-14	1.25E-14	50
M2B	2.50E-05	5.00E-07	1.13E-04	0.2	1.13E-03	8.85E+04	5.42E-14	1.25E-14	50
M3	2.50E-05	5.00E-07	2.26E-04	0.2	2.26E-03	4.42E+04	5.42E-14	1.25E-14	50
M4	2.50E-04	5.00E-07	1.25E-03	0.2	1.25E-02	8.00E+03	5.42E-13	1.25E-13	500
M5	1.25E-04	5.00E-07	1.25E-03	0.2	1.25E-02	8.00E+03	2.71E-13	6.25E-14	250
M6	2.50E-05	5.00E-07	2.00E-04	0.2	2.00E-03	5.00E+04	5.42E-14	1.25E-14	50

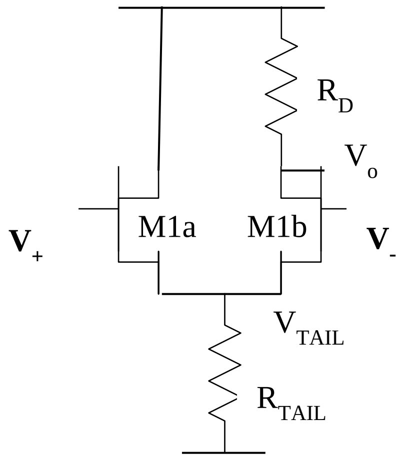
f) The high frequency poles and zeros are closely spaced, so to sanity check our hand drawn bode plot:



The actual phase margin turns out to be ~42 degrees, so our hand estimate is pretty close.

5. For the differential amplifier in the figure below, estimate the change in Vtail, Itail, Id1a, Id1b, and Vo 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-
d. What is the common mode rejection ratio of this amplifier?



All results assume $R_D << r_o$

	V_{tail}	I_{tail}	I_{d1a}	I_{d1b}	V_o
both	ΔV	$\Delta V/R_{tail}$	$\Delta V/(2R_{tail})$	$\Delta V/(2R_{tail})$	$-\Delta V\ R_D/(2R_{tail})$
just V+	$\Delta V/2$	$\Delta V/(2R_{tail})$	$+g_{m1a}\Delta V/2$	$-g_{m1b}\Delta V/2$	$+\Delta V\ g_{m1b}R_D/2$
just V-	$\Delta V/2$	$\Delta V/(2R_{tail})$	$-g_{m1b}\Delta V/2$	$+g_{m1b}\Delta V/2$	$-\Delta V\ g_{m1b}R_D/2$

d) common mode gain is $R_D/(2R_{tail})$. Differential gain is $g_{m1b}R_D/2$. Common mode rejection ratio is differential over common, or $g_{m1b}R_{tail}$

#5) 9 pts
a,b,c) - 2 pts for each part
d) 3 pts - one for Av_DM, Av_CM, and CMRR

(240 only)
#6) 5 pts