Problem Session #2

Problem 2 – **(25 points)**

a) Sketch the Bode (both magnitude & phase) plot for: {label all critical values for both magnitude and phase and show all your work}

$$H(s) = \frac{-10(s^2)}{(s+10k)^2}$$

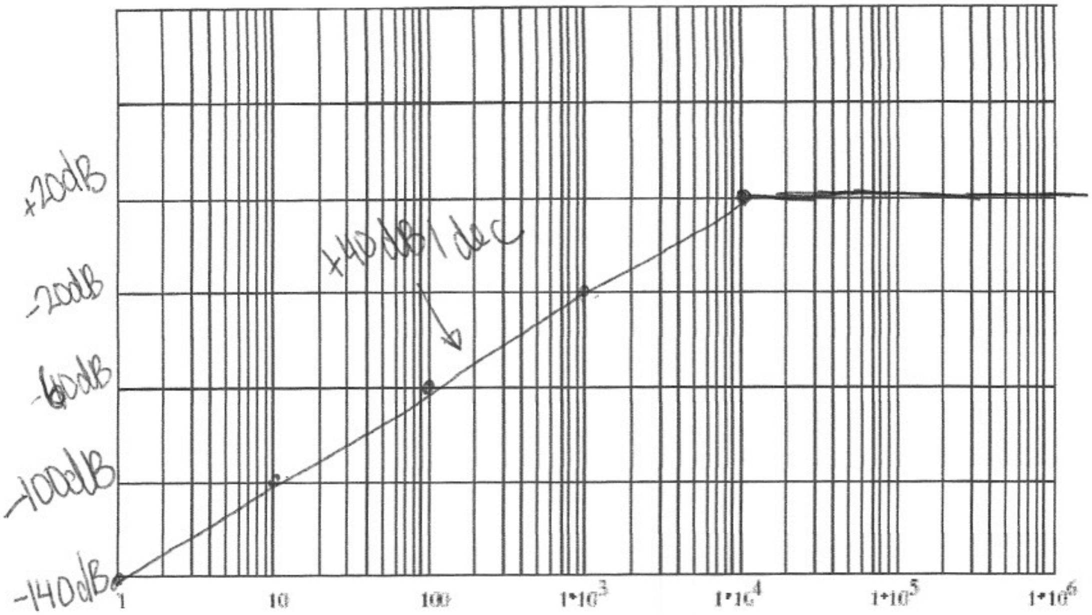
b) What is the estimated magnitude value at ω=50k rad/sec (in dB):

20dB

c) What range of frequency will this circuit operate correctly:

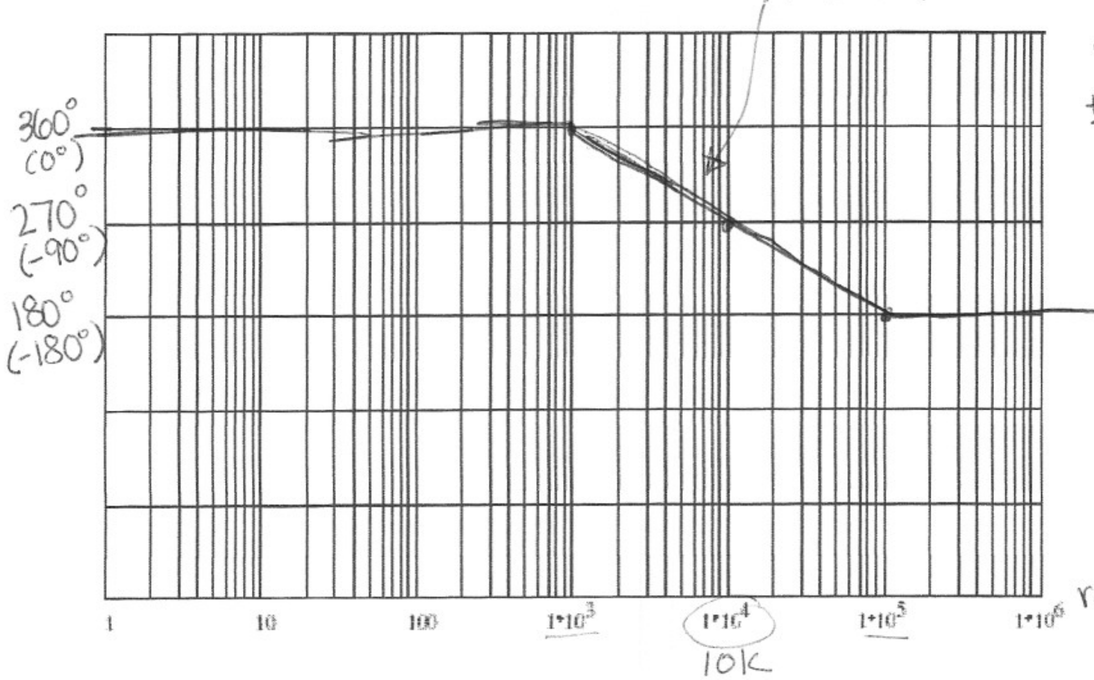
$\omega \geq 10K$

$$H(s) = \frac{-10(s^2)}{(s+10k)^2} = \frac{-10s^2}{(10k)^2\left(\frac{s}{10k}+1\right)^2}$$



- magnitude plot starts at $\omega=1$: $20\log\left(\frac{10}{10k^2}\right) = -140\text{dB}$
- slopes at +40dB/dec because of s^2

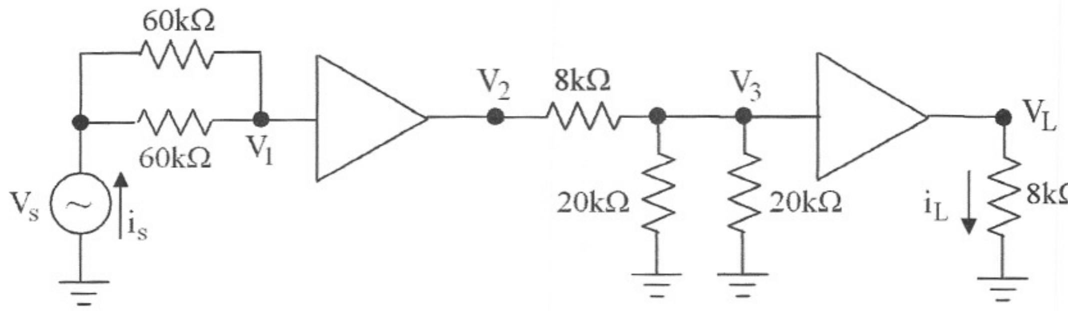
-90° slope/dec due to 2 poles at 10k



- phase starts at ±180° due to (-) sign
- The s^2 adds +180° additional phase
- ∴ starts at 360°

Problem 4 – (15 points)

v_s is an AC signal. Both amplifiers have the following characteristics:
$A_{vo}=20$, $R_i=10k\Omega$, $R_o=2k\Omega$, Clipping levels: $L=\pm 12V$ (unloaded)

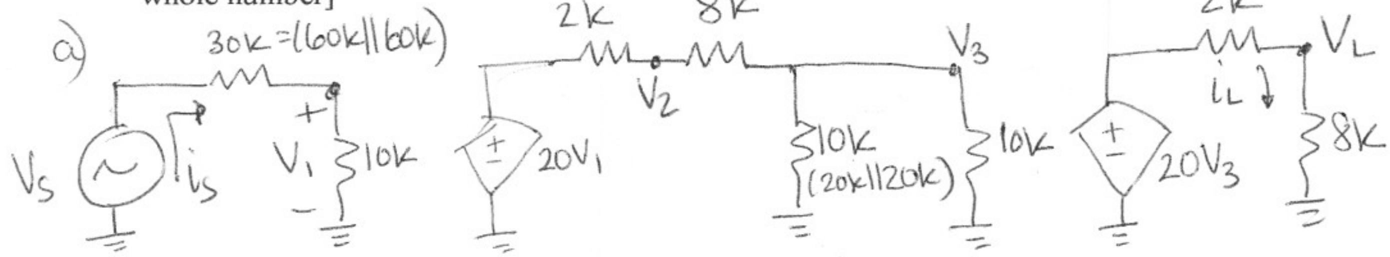


(a) Redraw this 2 stage amplifier using the amplifier model. Make sure to label V_S, V_1, V_2, V_3, and V_O on the schematic.

(b) Find $A_v = {}^{v_L}/_{v_S}$. Express your answer as a ratio(V/V) and in dB. [Round answer to the nearest whole number]

(c) Find $A_i = {}^{i_L}/_{i_S}$. Express your answer as a ratio(A/A) and in dB. [Round the answer to the nearest whole number]

a)



b) $V_L = \frac{8K \cdot 20V_3}{10K} = \frac{4}{5} \cdot 20V_3$

$V_3 = \frac{5K \cdot 20V_1}{5K + 10K} = \frac{1}{3} \cdot 20V_1$

$V_1 = \frac{V_S \cdot 10K}{40K} = \frac{1}{4} \cdot V_S$

$\frac{V_L}{V_S} = \left(\frac{4}{5}\right)(20)\left(\frac{1}{3}\right)(20)\left(\frac{1}{4}\right)$

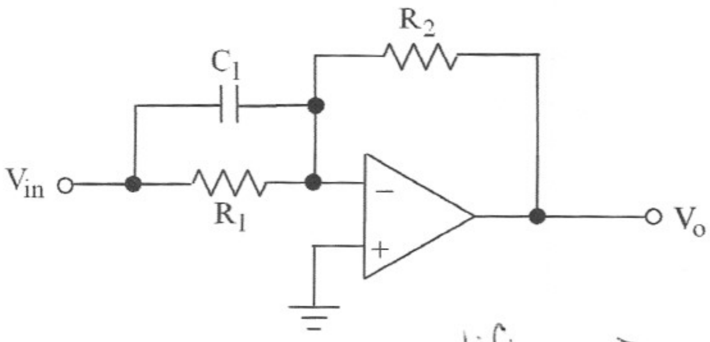
$\frac{V_L}{V_S} = \frac{4}{3}(20) = \boxed{\frac{80}{3} V/V \approxeq 29dB}$

c) $V_L = i_L \cdot 8K$, $V_S = i_S (40K)$

$\therefore \frac{V_L}{V_S} = \frac{i_L \cdot 8K}{i_S \cdot 40K} = \frac{80}{3}$ $\quad\therefore \frac{i_L}{i_S} = \frac{80}{3}\left(\frac{40}{8}\right) = \boxed{\frac{400}{3} V/V \approxeq 43dB}$

Problem 5 – (10 points)

Analyze the circuit below to obtain the transfer function, V_o/V_{in}. Assume ideal opAmp.



Inverting amplifier ⟹

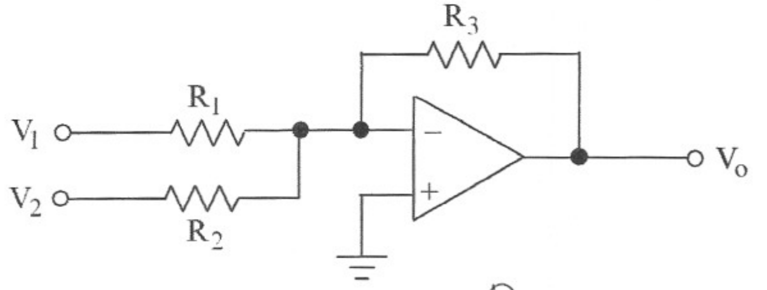
$$\frac{V_o}{V_{in}} = -\frac{R_2}{R_1 \| 1/C_1 s}$$

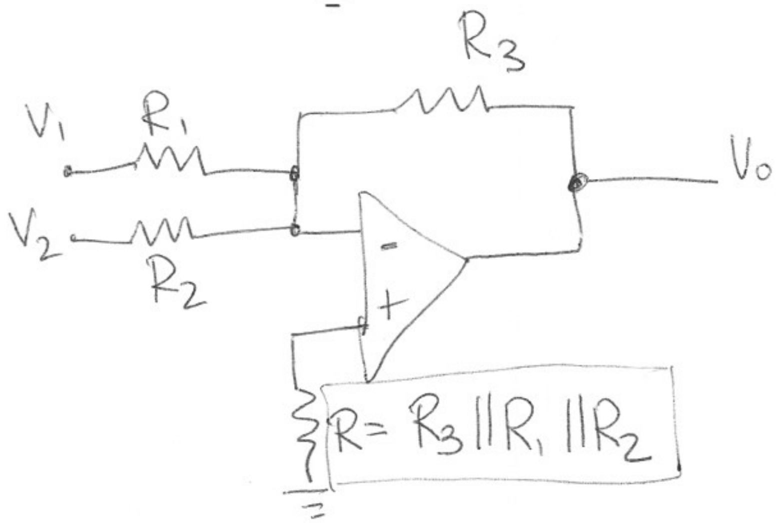
$$R_1 \| 1/C_1 s = \left[\frac{R_1\left(\frac{1}{C_1 s}\right)}{R_1 + \frac{1}{C_1 s}}\right]\frac{C_1 s}{C_1 s} = \frac{R_1}{(R_1 C_1 s + 1)}$$

$$\therefore \boxed{\frac{V_o}{V_{in}} = -\frac{R_2(R_1 C_1 s + 1)}{R_1}}$$

Problem 6 – **(5 points)**

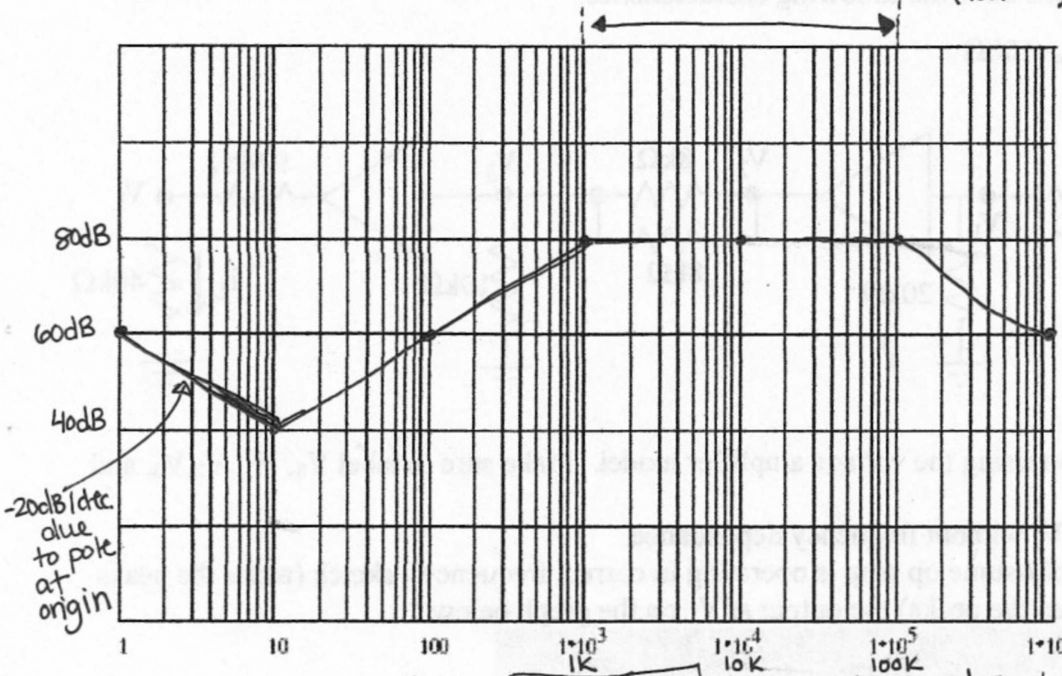
Explain in detail, by giving exact values and drawing any schematics, the technique used to reduce the **input bias current** for the circuit below.





(2)

$$H(s) = \frac{1\times10^9 (s+10)^2}{s(s+100k)(s+1k)} = \frac{1\times10^9 (10)(10)\left(\frac{s}{10}+1\right)\left(\frac{s}{10}+1\right)}{s\cdot 100K\cdot 1K\left(\frac{s}{100K}+1\right)\left(\frac{s}{1K}+1\right)} = \frac{1{,}000\left(\frac{s}{10}+1\right)\left(\frac{s}{10}+1\right)}{s\left(\frac{s}{100K}+1\right)\left(\frac{s}{1K}+1\right)}$$



@ 10 ⇒ +20dB/dec *2
+45°*2 between ω = 1 to 100

1K ⇒ -20dB/dec.
-45° between ω = 100 to 10K

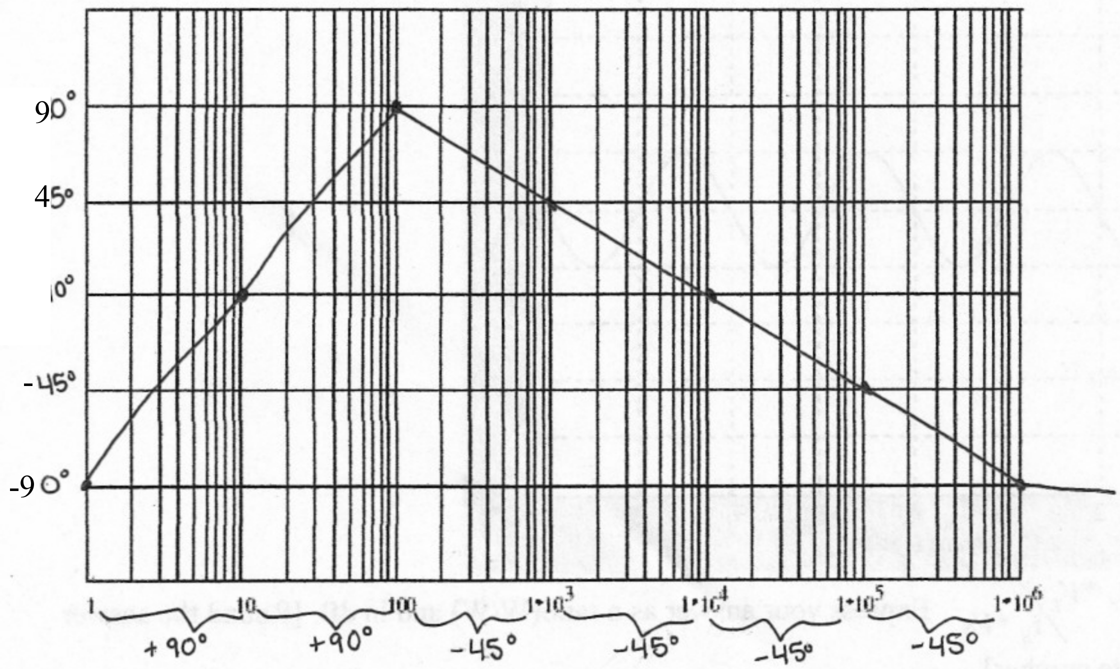
100K ⇒ -20dB/dec.
-45° between ω = 10K to 1 Meg.

magnitude at ω = 1 ⇒

$$\frac{1{,}000\left[\sqrt{\left(\frac{1}{10}\right)^2+1^2}\right]^2}{1\cdot\sqrt{\left(\frac{1}{100k}\right)^2+1^2}\cdot\sqrt{\left(\frac{1}{1k}\right)^2+1^2}} = 1{,}000 = 60dB$$

slope is -20dB/dec through ω = 1 at 60dB

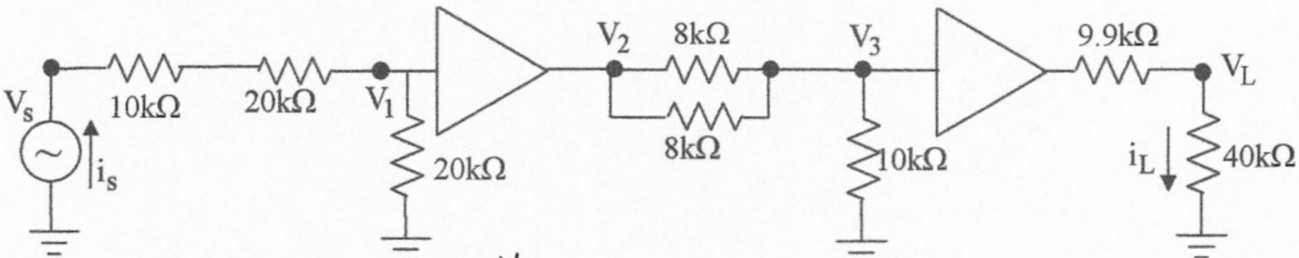
at ω = 20K, magnitude = 80dB = 100 V/V ∴ circuit operates between ω = 1K to ω = 100K

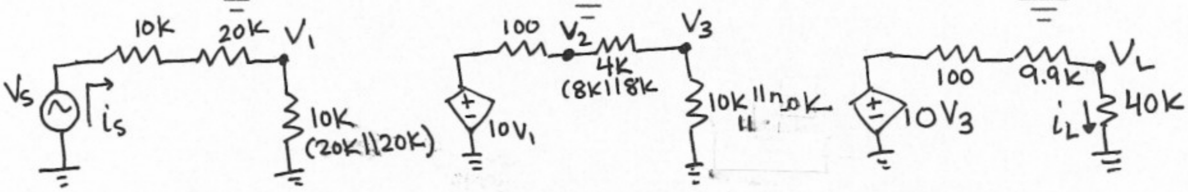


Problem 3 – (20 points)

V_s is an AC signal. Both amplifiers have the following characteristics:

$A_{vo}=10$, $R_{in}=20k\Omega$, $R_o=100\Omega$





$V_L = \frac{10V_3(40K)}{50K} = 8V_3$

$V_3 = \frac{10V_1(6.7K)}{6.7K+100+4K} \cong 6.2V_1$

$V_1 = \frac{V_s \cdot 10K}{10K+30K} = \frac{1}{4}V_s$

$\frac{V_L}{V_s} = 8 \cdot 6.2 \cdot \frac{1}{4} \cong$ **12.4 V/V**

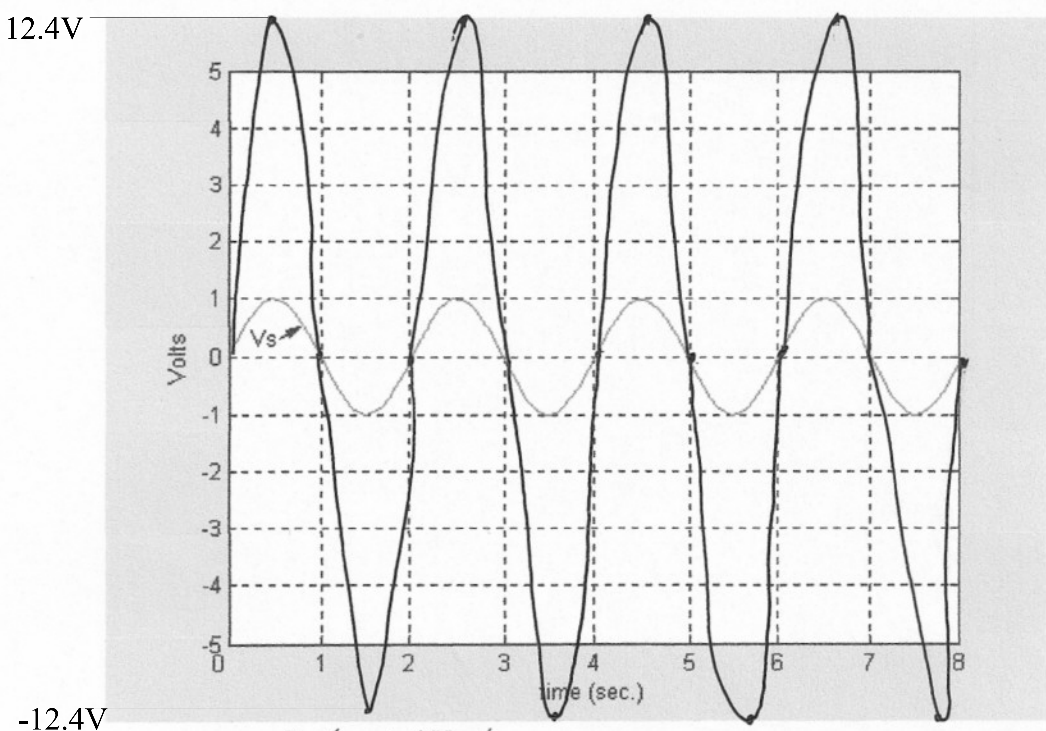
$i_L = \frac{V_L}{40K}$

$i_s = \frac{V_s}{40K}$

$\therefore A_p = \frac{i_L \cdot V_L}{i_s \cdot V_s} = \frac{V_L}{40K} \cdot \frac{V_L}{V_s} \cdot \frac{40K}{V_s}$

$A_p = (12.4)^2 \cong$ **154 W/W**

$10 \log(154) \cong$ **22 dB**

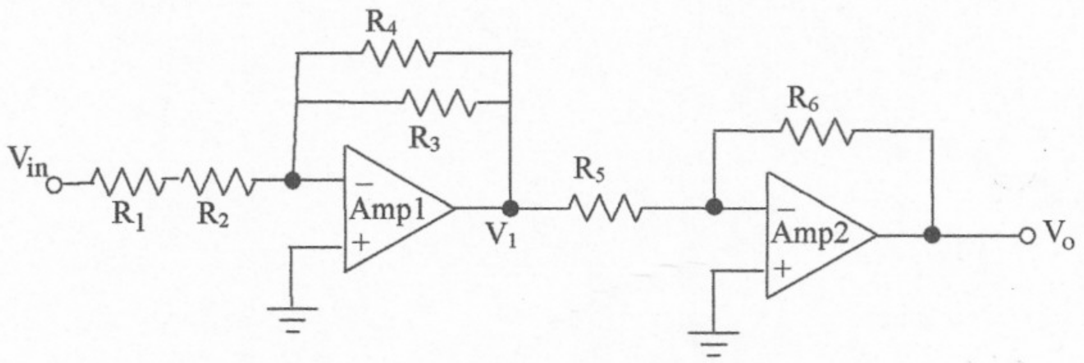


No clipping on output signal if power supply voltages are > 12.5V Otherwise, the output will clip.

(a) Find $A_P = \frac{P_L}{P_S} = \frac{i_L * V_L}{i_s * Vs}$. Express your answer as a ratio(W/W) and in dB. [Round the answer to the nearest whole number]

Problem 4 – (15 points)

Use the circuit below:



Use f_T=5MHz for both amplifiers.

State the overall transfer function (V_o/V_{in}) in terms of R_1, R_2, R_3, R_4, R_5, and R_6.

$$\frac{V_o}{V_{in}} = \frac{+\,{R_6}/{R_5} \cdot \frac{(R_4 \| R_3)}{R_1+R_2}}{\left(1+\frac{s}{\left(\frac{5MHz}{R_6/R_5}\right)}\right)\left(1+\frac{s\,(R_4\|R_3)}{5M(R_1+R_2)}\right)}$$

Problem 5 – (10 points)

Redraw or add to the schematic below to show how to reduce the effect of the **input bias current**. State the symbolic value(s) of any components added to the schematic. State the answer in terms of R_1, R_2, R_3, and R_4.