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}

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

b) What is the estimated magnitude value at \( \omega = 50 \text{ k rad/sec} \) (in dB):

\[ 20 \text{ dB} \]

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

\[ \omega \geq 10 \text{ k} \]
\[ H(s) = \frac{-10(s^2)}{(s + 10k)^2} = \frac{-10s^2}{10k^2(s + 10k^2 + 1)^2} \]

- **Magnitude plot**
  - Starts at \( w = 1 \):
    - \( 20 \log \left( \frac{10}{10^2} \right) = -140 \text{dB} \)
    - Slopes at +40 dB/dec because of \( s^2 \)

- **90° slope/dec due to 2 poles at 10k**

- **Phase starts at \( \pm 180° \) due to (-) sign**
  - The \( s^2 \) adds +180° additional phase
  - \( \therefore \) starts at 360°
Problem 4 – (15 points)

\( v_s \) is an AC signal. Both amplifiers have the following characteristics:
\( A_v = 20, \quad R_1 = 10 \, \text{k}\Omega, \quad R_o = 2 \, \text{k}\Omega, \quad \text{Clipping levels: } L = \pm 12 \, \text{V (unloaded)} \)

(a) Redraw this 2 stage amplifier using the amplifier model. Make sure to label \( V_s, V_1, V_2, V_3, \text{ and } V_o \) on the schematic.

(b) Find \( A_v = \frac{V_L}{V_s} \). Express your answer as a ratio \((V/V)\) and in \(
\text{dB}\). [Round answer to the nearest whole number]

(c) Find \( A_i = \frac{i_L}{i_s} \). Express your answer as a ratio \((A/A)\) and in \(
\text{dB}\). [Round the answer to the nearest whole number]

\[
\begin{align*}
&b) \quad V_L = \frac{8 \, \text{k} \cdot 20 V_3}{10 \, \text{k}} = \frac{4}{5} \cdot 20 V_3, \\
&V_3 = \frac{5 \, \text{k} \cdot 20 V_1}{5 \, \text{k} + 10 \, \text{k}} = \frac{1}{3} \cdot 20 V_1, \\
&V_1 = \frac{V_s \cdot 10 \, \text{k}}{40 \, \text{k}} = \frac{1}{4} \cdot V_s \\
&c) \quad V_L = i_L \cdot 8 \, \text{k}, \quad V_s = i_s \cdot (40 \, \text{k})
\end{align*}
\]

\[
\begin{align*}
\frac{V_L}{V_s} &\Rightarrow \frac{V_L}{V_s} = \frac{\frac{4}{5} \cdot 20}{\frac{1}{3}}, \\
&= \frac{80}{3} \approx 29 \, \text{dB} \\
\frac{i_L}{i_s} &\Rightarrow \frac{i_L}{i_s} = \frac{80 \cdot \frac{40}{3}}{3} = \frac{400}{3} \approx 48 \, \text{dB}
\end{align*}
\]
Problem 5 – (10 points)

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

Inverting amplifier ⇒

\[
\frac{V_o}{V_{in}} = -\frac{R_2}{R_1 \parallel \frac{1}{C_i s}}
\]

\[
R_1 \parallel \frac{1}{C_i s} = \frac{R_1}{R_1 + \frac{1}{C_i s}} \cdot \frac{C_i s}{C_i s} = \frac{R_1}{(R_1 C_i s + 1)}
\]

\[
\frac{V_o}{V_{in}} = -\frac{R_2}{R_1}
\]
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.

\[
\begin{align*}
V_1 & \quad R_1 \\
V_2 & \quad R_2 \\
R_3 & \\
V_0 & \\
\end{align*}
\]
\[ H(s) = \frac{1 \times 10^9 (s + 10)^2}{s(s + 100k)(s + 1k)} = \frac{1 \times 10^9 (10)(10)}{5 \times 100k \cdot 1k} \left( \frac{s+1}{10k} \right) \left( \frac{s+1}{1k} \right) = \frac{1,000 \left( \frac{s}{10} + 1 \right) \left( \frac{s}{10k} + 1 \right)}{5 \left( \frac{s}{10k} + 1 \right) \left( \frac{s}{1k} + 1 \right)} \]

\[ 10 \Rightarrow +20\text{dB/dec} \times 2 \]
\[ +45^\circ \times 2 \text{ between } w = 1 \text{ to } 100 \]

\[ 1k \Rightarrow -20\text{dB/dec}. \]
\[-45^\circ \text{ between } w = 100 \text{ to } 10k \]

\[ 100k \Rightarrow -20\text{dB/dec}. \]
\[-45^\circ \text{ between } w = 10k \text{ to } 1 Meg. \]

\[ \text{magnitude at } w = 1 \Rightarrow \]
\[ 1,000 \left[ \sqrt{\left( \frac{1}{10k} \right)^2 + 1^2} \right]^2 = 1,000 \]
\[ 1 \cdot \left( \frac{1}{10k} \right)^2 + 1^2 = 90^\circ \text{ and } 100\text{dB} \]

\[ \text{slope is } -20\text{dB/dec} \]
\[ \text{through } w = 1 \text{ at } 60\text{dB} \]

\[ \text{circuit operates between } w = 1k \text{ to } w = 100k \]

At \( w = 20k \), magnitude = \[ 80\text{dB} = 100 \sqrt{\frac{\text{dB}}{w}} \]

\[ 90^\circ \]
\[ 45^\circ \]
\[ 10^\circ \]
\[ -45^\circ \]
\[ -90^\circ \]

\[ -45^\circ \]
\[ -45^\circ \]
\[ -45^\circ \]
\[ -45^\circ \]
Problem 3 – (20 points)

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

$A_v = 10, \quad R_{in} = 20k\Omega, \quad R_o = 100\Omega$

![Circuit Diagram](image)

\[
V_L = \frac{10V_3 (40k)}{50k} = 8V_3
\]

\[
V_3 = \frac{10V_1 (6.7k)}{6.7k + 100k} \approx 6.2V_1
\]

\[
V_1 = \frac{V_s \cdot 10k}{10k + 30k} = \frac{1}{4}V_s
\]

\[
V_L = 8 \cdot 6.2 \cdot \frac{1}{4} \approx 12.4V/V
\]

\[
\frac{V_L}{V_s} = \frac{i_L \cdot V_L}{i_s \cdot V_s}
\]

\[
A_p = (12.4)^2 \approx 154 \text{ W/W}
\]

\[
10 \log (154) \approx 22 \text{ dB}
\]

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

(a) Find $A_p = \frac{P_L}{P_s} = \frac{i_L \cdot V_L}{i_s \cdot V_s}$ 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 $f_t=5\text{MHz}$ 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 $R_6$.

\[
\frac{V_o}{V_{in}} = \frac{\frac{R_6}{R_5} \frac{R_4 R_3}{R_1 + R_2}}{\left(1 + \frac{S}{5\text{MHz}}\right)\left(1 + \frac{S}{5\Omega (R_1 + R_2)}\right)}
\]
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 $R_4$.

\[ R = R_1 \parallel (R_3 + R_4) \parallel R_2. \]