ECE2280 **Review For EXAM 1** **SPRING 2010**

The material we have covered so far this semester is summarized (but NOT limited to) below:

1. Understand the difference between AC & DC signals.
2. Understand how to analyze circuit (with or without cap in it) to obtain transfer function.
3. Understand how to plot the Bode plots from an equation or circuit.
4. Amplifiers:
   a) Understand how to apply Amplifier models (voltage, current, etc.) to multistage amplifiers
   b) Analyze single input Amplifier (with model) for transfer function.
   c) Analyze amplifier's gain in different configurations (inverting, noninverting, voltage follower)
   d) Understand frequency response of amplifiers for single amplifiers
   e) Compensation of real op-amp imperfections (Slew Rate, Clipping, Input bias currents, Voltage offset, frequency limitations, finite gain)
5. Diodes:
   a) Analyze diode circuit using ideal model
   b) Analyze diode circuit using constant voltage drop model
   c) Analyze diode circuit with both DC and AC signals

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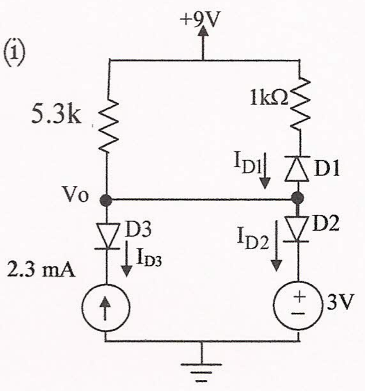
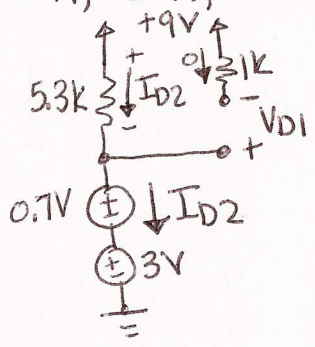
1. (a) Find I_{D1}, I_{D2}, I_{D3}, and Vo using constant voltage drop method with n=1, V_T=25mV, and V_{D0}=0.7V.
(b) Find Vo_{total} if the 3V source has 0.5sin(wt) noise.

(i)



D1 off, D2 on, D3 off:



• D3 has to be off because current is not allowed to flow in that direction through the diode.

$$+9 - I_{D2}(5.3k) - 3.7 = 0$$

$$I_{D2} = \frac{(9-3.7)}{5.3k} = \frac{5.3}{5.3k} = 1mA \checkmark > 0$$

∴ D2 on

Check V_{D1}:

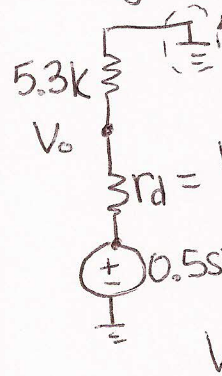
$$+3V + 0.7 - V_{D1} - 9 = 0$$

$$V_{D1} = -9 + 3 + 0.7 = -5.3 < 0.7$$

∴ D1 is off

$$\boxed{\begin{array}{l} I_{D1} = 0 \\ I_{D2} = 1mA \\ I_{D3} = 0 \\ V_o = 3.7V \end{array}}$$

AC analysis: remove DC source (V=0 is a wire)

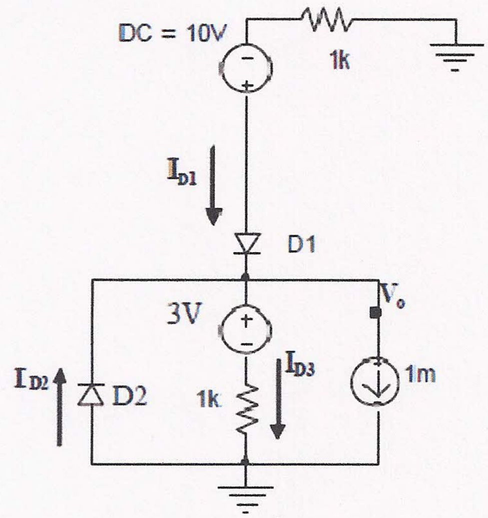


$$r_d = \frac{nV_T}{I_D} = \frac{(1)(25m)}{1m} = 25\Omega$$

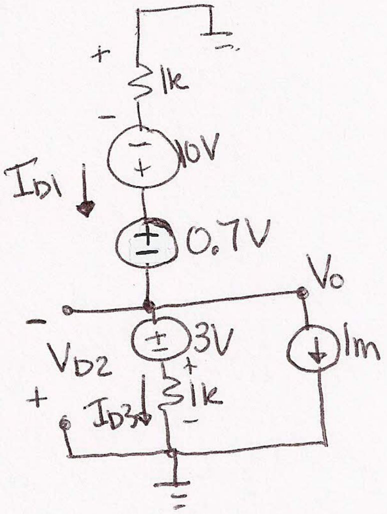
$$V_o = \frac{0.5\sin(\omega t)5.3k}{5.3k + 25} \approx 0.5\sin(\omega t)$$

$$\boxed{V_{total} = 3.7 + 0.5\sin(\omega t)\ V}$$

(ii)



Assume D1 on, D2 off:



$V_o = +3 + I_{D3}(1k)$

V-loop:

$-I_{D1}(1k) + 10 - 0.7 - 3 - I_{D3}(1k) = 0$

OR

use node-voltage

ΣI:

$-I_{D1} + 1m + I_{D3} = 0$

$I_{D1} = (1m + I_{D3})$

$\therefore -(1m + I_{D3})(1k) + 6.3 - I_{D3}(1k) = 0$

$-1 \; (-2k) I_{D3} + 6.3 = 0$

$I_{D3} = \frac{5.3}{2k} = 2.65m > 0$

$\therefore$ D3 is on $\Rightarrow V_o = 3 + 1k(2.65m)$

$V_o = 5.65V$

$$\frac{V_o - 3}{1k} + 1m + \frac{-(10-0.7) + V_o}{1k} = 0$$

$$V_o\left(\frac{1}{1k} + \frac{1}{1k}\right) = 3m - 1m + 9.3m$$

$$\therefore V_o = \frac{11.3m}{\frac{1}{1k} + \frac{1}{1k}} = \underline{5.65V}$$

$I_{D3}(1k) + 3 - V_o = 0$

$I_{D3} = \frac{V_o - 3}{1k} = \frac{2.65}{1k} = 2.65m$

Check V_{D2}:

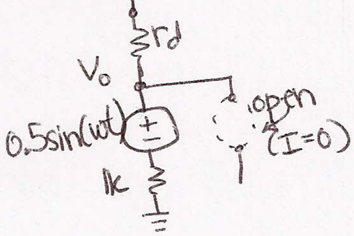
$-V_{D2} - 3 - I_{D3}(1k) = 0$

$V_{D2} = -3 - 1k(2.65m) = -5.65 < 0.7$

$\therefore$ D2 is off

$I_{D1} = 1m + 2.65m = 3.65m$
$I_{D2} = 0$
$I_{D3} = 2.65m$
$V_o = 5.65V$

AC analysis: $r_d = \frac{nV_T}{I_{D3}} = \frac{(1)(25m)}{2.65m} = 9.4\Omega$



$$V_{o_{AC}} = \frac{0.5\sin(wt)(1k + r_d)}{(1k + r_d) + 1k} \cong 0.25\sin(wt)$$

$$\boxed{V_{o\,total} = 5.65 + 0.25\sin(wt)}$$

2. Sketch Bode Plots for (a) $H(s) = \dfrac{-1x10^{14}(s^2)}{(s+10k)^2(s+100k)}$ $\Rightarrow$ Standard Form: $\dfrac{-1\times10^{14}(S^2)}{(10k)^2\left(\frac{S}{10k}+1\right)^2(100k)\left(\frac{S}{100k}+1\right)}$

critical frequencies: origin(x2), 10k(x2), 100k

at $\omega=1$: $\dfrac{-1\times10^{14}(1)}{(10k)^2(100k)\left(\sqrt{\frac{1}{10k}+1}\right)^2\left(\sqrt{\frac{1}{100k}+1}\right)} = 10\,V/V \Rightarrow 20\log(10) = \underline{20dB}$

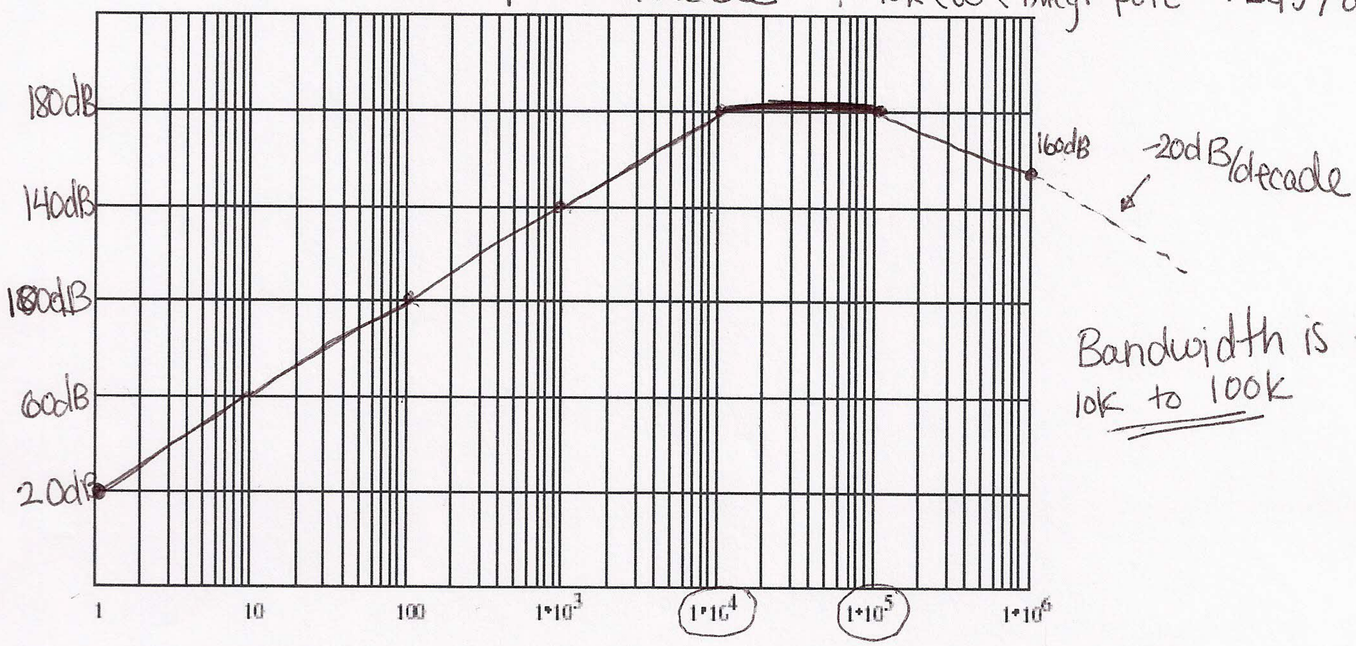
magnitude:

2 at origin	zeroes	+2(+20dB/decade)
10k (x2)	pole	2(-20dB/decade)
100k	pole	-20dB/decade

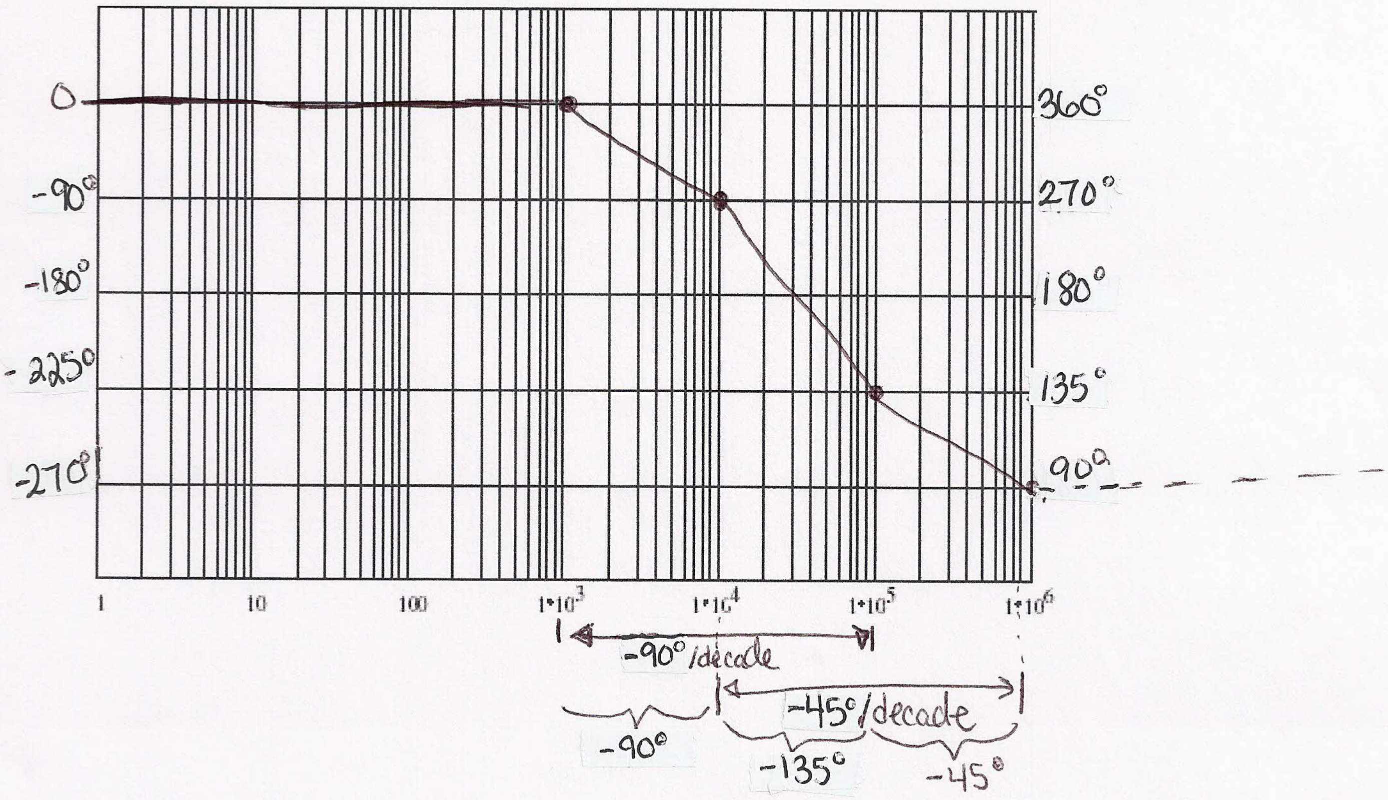
phase:

(−) sign starts phase at ±180°

2 at origin	zeroes	2(+90) = +180°
1k < ω < 100k	pole	(-45°/decade x2)
10k < ω < 1Meg	pole	-45°/decade

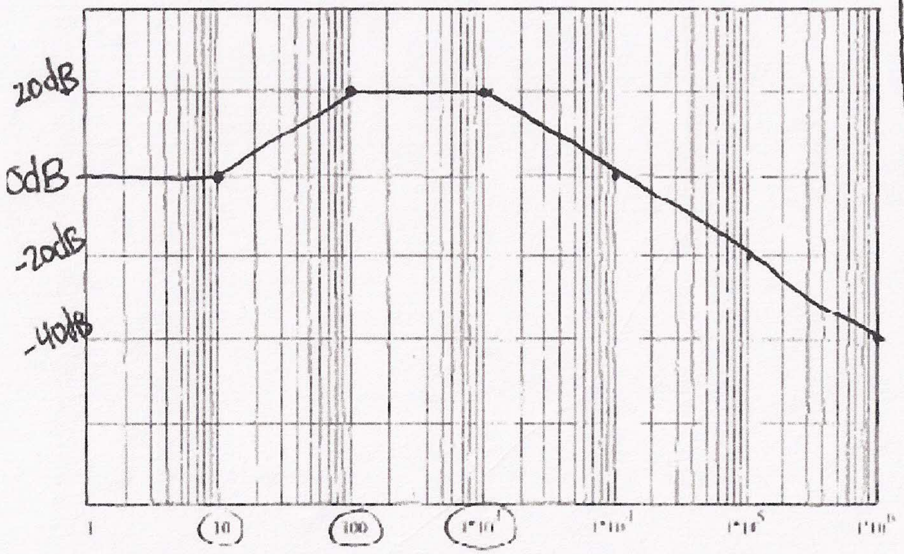


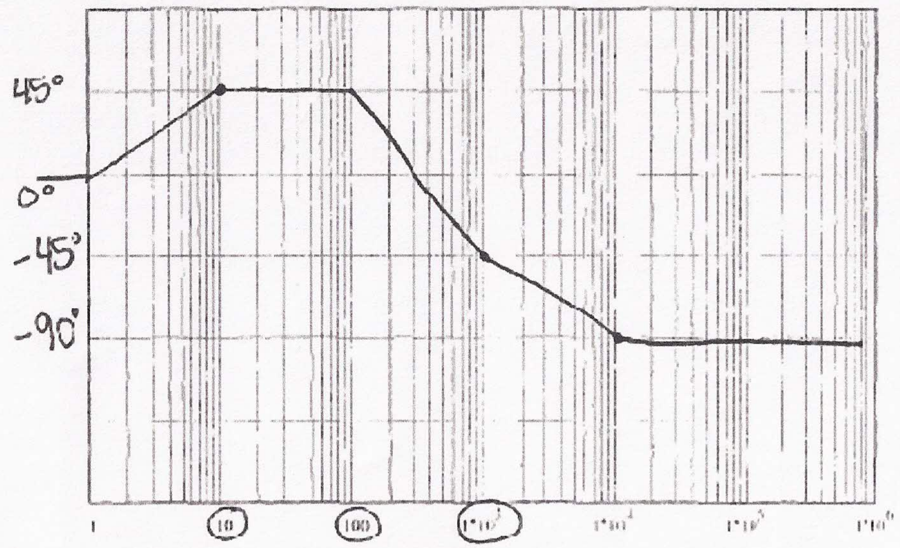
Bandwidth is from 10k to 100k



4. b $H(s)=\dfrac{10k(10)(\frac{s}{10}+1)}{1k(\frac{s}{1k}+1)(100)(\frac{s}{100}+1)} = \dfrac{(\frac{s}{10}+1)}{(\frac{s}{1k}+1)(\frac{s}{100}+1)}$

Break freq: $\omega = 10, 100, 1k$





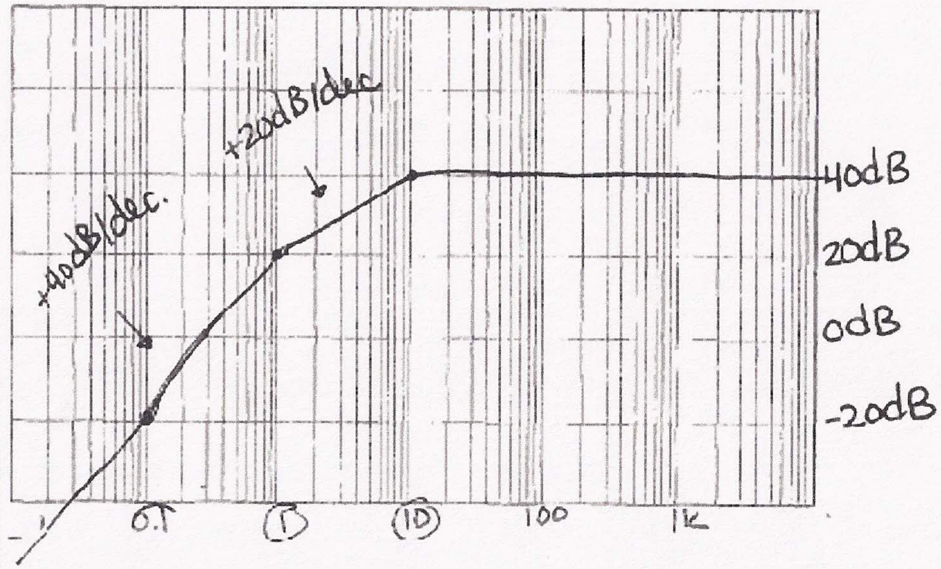
5. $H(s)=\dfrac{100s^2}{(s+1)10(\frac{s}{10}+1)} = \dfrac{10s^2}{(s+1)(\frac{s}{10}+1)}$

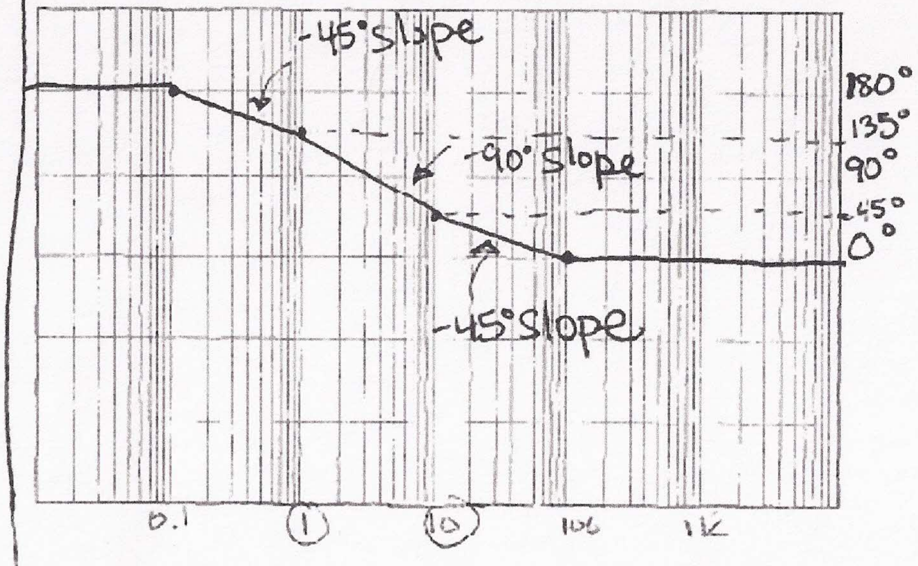
Break freq: $\omega = 1, 10$

phase starts at 180°

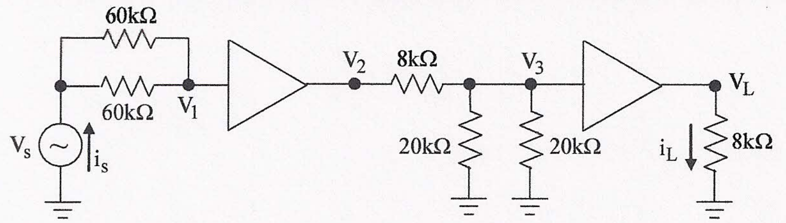
slope starts at +40dB/dec.

@ $\omega=1 \Rightarrow 20\log(10)=20$dB



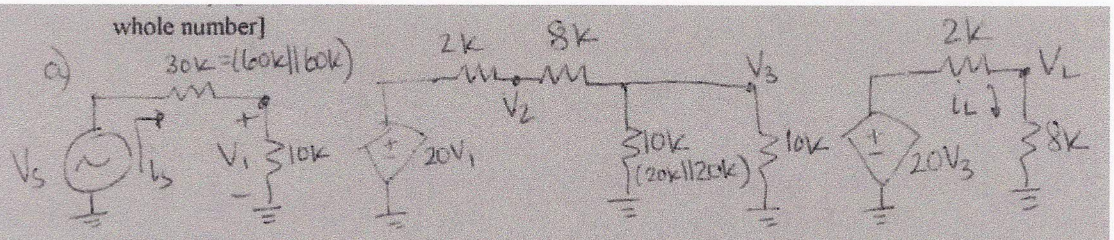


3. (a) Use voltage amplifier model to find voltage gain. A_{vo}=20, R_i=10kΩ, R_o=2kΩ.



whole number]

a)



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

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

$V_1 = \dfrac{V_s \cdot 10K}{40K} = \dfrac{1}{4} \cdot V_s$

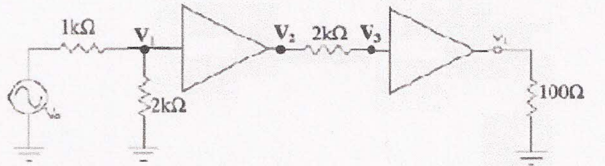
$\dfrac{V_L}{V_s} = \left(\dfrac{4}{5}\right)(20)\left(\dfrac{1}{3}\right)(20)\left(\dfrac{1}{4}\right)$

$\dfrac{V_L}{V_s} = \dfrac{4}{3}(20) = \boxed{\dfrac{80}{3} V/V \cong 29dB}$

(b)

- Both amplifiers have the following characteristics:

  A_{vo}=40 R_i=2kΩ R_o=4kΩ Clipping levels: L=±12V (unloaded)

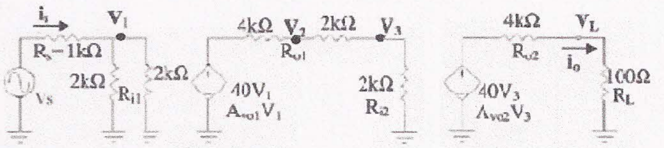


(a) Redraw this 2 stage amplifier using the amplifier model. Make sure to label V_1, V_2, V_3, and V_L on the schematic.

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

(c) For the input V_S= sin(ωt). State the maximum output value at V_L.

(a)



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

$$\frac{V_L}{V_s} = A_v = \left(\frac{R_{i1}}{R_S + R_{i1}}\right) \cdot A_{vo1} \cdot \left(\frac{R_{i2}}{R_{o1} + R_{i2}}\right) \cdot A_{vo2} \cdot \left(\frac{R_L}{R_{o2} + R_L}\right)$$

$R_{i1} = \dfrac{1}{\frac{1}{2k} + \frac{1}{2k}} = 1K$ R_{o1} = 4k+2k=6k

$A_v = \dfrac{1k}{1k+1k} \cdot 40 \cdot \dfrac{2k}{6k+2k} \cdot 40 \cdot \dfrac{100}{100+4000}$ =4.878 (rounded = 5V/V) or 20log(5) = 13.979

(c) Amplitude => maximum output will be the peak value: gain=V_L/V_s = 5V/V V_L = 5*Vs_peak = +5V

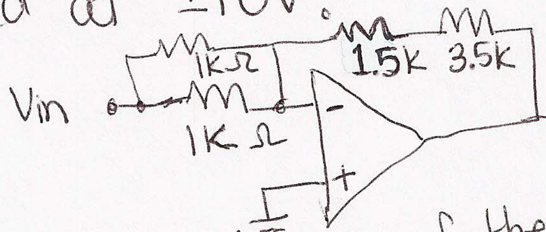
checking for clipping ⇒ $\dfrac{V_2}{V_S} = \dfrac{40 \cdot (1K)}{2K} \cdot \dfrac{4K}{8K} = 10V < \pm 12V$

→ No clipping at 1st amp if V_s = 1V max.

4 (a) You are given the following characteristics for a real amplifier:

Input offset voltage, $V_{ios} = 4mV$
Input offset current, $I_{os} = 100nA$
Input bias current $I_{IB} = 1\mu A$
Input Resistance, $R_i = 1M\Omega$
Output Resistance, $R_o = 50\Omega$
Open-loop gain, $A_{Vo} = 180dB$
Unity-gain bandwidth, $f_T = 11MHz$
Output swing limits, within 2Volts of supply
Slew Rate, $SR = 2 V/\mu sec$.

Given the following circuit with the operational amplifier powered at $\pm 10V$:



i) Find the ideal gain of the above circuit:

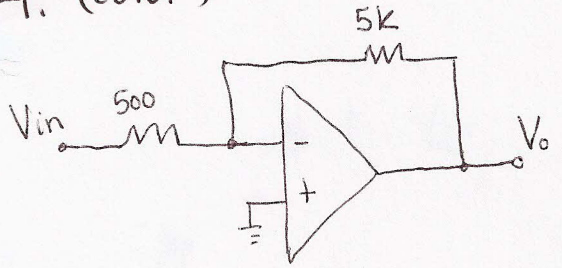
$$\frac{V_o}{V_{in}} = \frac{-5k}{500} = -10 \, V/V \Rightarrow \underline{20dB}$$

ii) For small input signals, what is the bandwidth of the circuit: $f_{3dBnew} = \frac{11MHz}{1+(10)} = \underline{1MHz}$

iii) If a circuit needs to operate up to 5MHz, what is the maximum gain I can achieve using an inverting amplifier configuration?

$$f_{3dBnew} = 5MHz = \frac{11MHz}{\left(1+\frac{R_2}{R_1}\right)} \Rightarrow \left|\frac{R_2}{R_1}\right| = \frac{11}{5} - 1 = \underline{1.2 V/V}$$

4. (cont)



iv) If the above circuit is operated to produce the maximum possible peak voltage,

a) what is the bandwidth?

b) what is the maximum peak voltage value for the input?

a) $f_{max} = \frac{SR}{V_p \cdot 2 \cdot \pi} = \frac{2}{1\times10^{-6}\times(8)(2)\pi} = \underline{39.8\,KHz}$

b) maximum peak voltage = +8V output max.

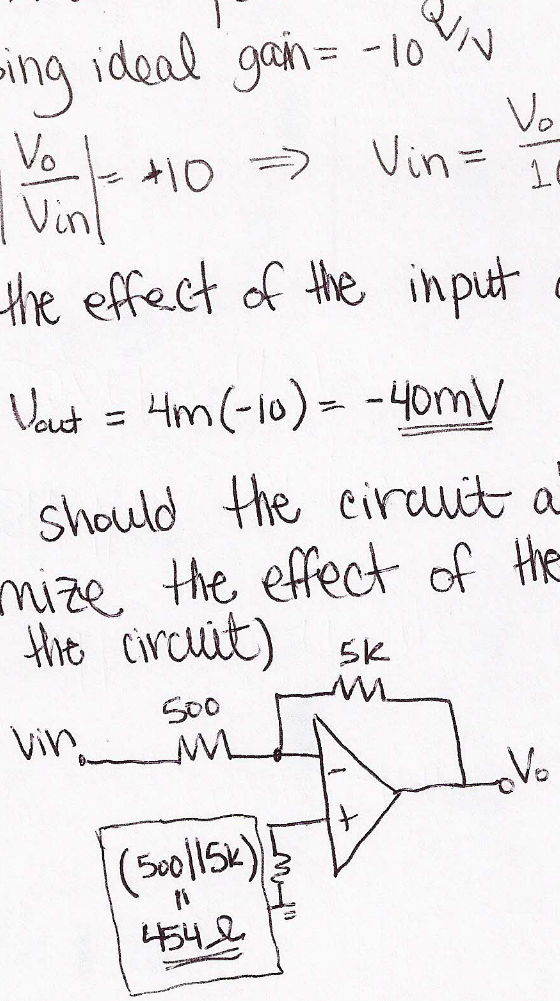
Using ideal gain = $-10\ ^V/_V$

$\left|\frac{V_o}{V_{in}}\right| = +10 \Rightarrow V_{in} = \frac{V_o}{10} = \frac{8}{10} = \underline{0.8V\ max}$

v) Find the effect of the input offset voltage when Vin=0V.

$V_{out} = 4m(-10) = \underline{-40mV}$

vi) How should the circuit above be modified to minimize the effect of the input bias current? (Draw the circuit)



4. (b) You are given the following characteristics for a real amplifier:

Input offset voltage,	V_{ios}=3mV
Input offset current,	I_{os}=100nA
Input bias current,	I_{ib}=1μA
Input Resistance,	R_i=1MΩ
Output Resistance,	R_o=50Ω
Open-loop gain,	A_{vo}=180dB
Unity-gain bandwidth,	f_T=15MHz
Output swing limits,	within 2Volts of power supply
Slew Rate,	SR=$4\frac{V}{\mu sec}$

If a circuit needs to operate at 5MHz using the above specifications for an operational amplifier and having a power supply of ± 15V, what is the maximum gain that can be achieved using an:

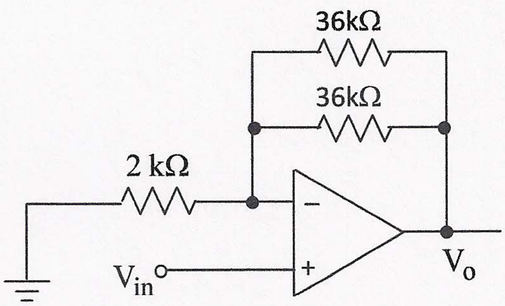
i) Inverting amplifier

$$f_{3dBnew}=\frac{15x10^6}{\left(1+\frac{R_2}{R_1}\right)}=5MHz \Rightarrow -\frac{R_2}{R_1}=-\left(\frac{15x10^6}{5x10^6}-1\right)=-2\frac{V}{V}$$

ii) Non-inverting amplifier

$$f_{3dBnew}=\frac{15x10^6}{\left(1+\frac{R_2}{R_1}\right)}=5MHz \Rightarrow \left(1+\frac{R_2}{R_1}\right)=\frac{15x10^6}{5x10^6}=3\frac{V}{V}$$

Given the following circuit with the operational amplifier powered at ± 15V.



i) Find the ideal gain of the above circuit:

$$\frac{V_o}{V_{in}}=\left(1+\frac{18k}{2k}\right)=10\frac{V}{V}$$

ii) For small input signals, what is the bandwidth of the circuit

$$f_{3dBnew}=\frac{15x10^6}{10}=1.5MHz$$

iii) What is the bandwidth when the circuit is operated to produce the maximum possible peak voltage value?

$$f=\frac{4}{10^{-6}(13\cdot\pi)}=98kHz$$

iv) What is the maximum amplitude of the input ?

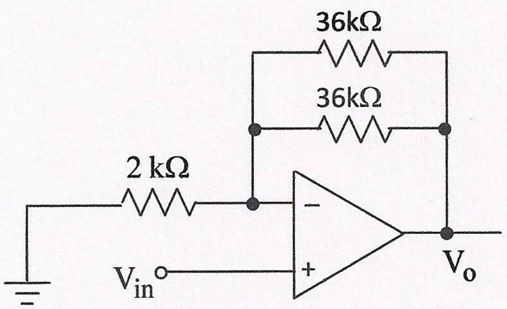
$$\frac{V_o}{V_{in}}=10\frac{V}{V} \Rightarrow V_{in}=\frac{V_o}{10}=\frac{13}{10}=1.3V$$

v) For V_{in}=0.001sin($2\pi 90kt$), what is the ideal value for the peak to peak voltage value at the output?

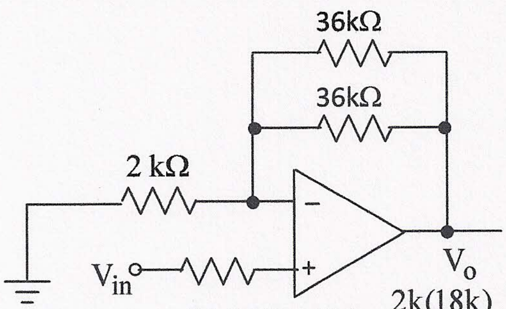
Vo_{pp}=2(0.001)(10)=0.02V_{pp}

vi) For V_{in}=0.001sin($2\pi 90kt$), what is the peak to peak voltage value at the output considering the input offset voltage?

Vo_{pp}=2(0.001)(10)+3m(10)=.02+.030=.05V_{pp}



vii) How should the circuit above be modified to minimize the effect of the input bias current? Draw the schematic of the modified circuit and state values of added component(s).



$$2\,k \,||\, 18k \,||\, 1M \approx \frac{2k(18k)}{20k} = 1.8k\Omega$$