1) ⓐ An amplifier is a device whose output voltage is the same as its input voltage multiplied by some constant gain.

ⓑ R_i is the input resistance, that is the resistance between the input terminals.

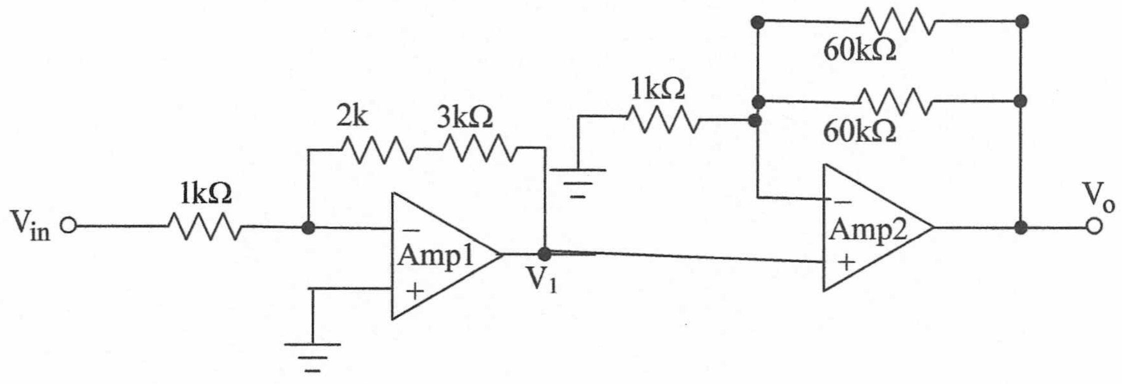
ⓒ R_o is the output resistance, a resistor in series with the voltage output. It can load the circuit and reduce the gain of the amplifier.

2) ⓐ Ideal Characteristics for an amplifier are $A_{vo} = \infty$, $R_i = \infty$, and $R_o = 0$.

ⓑ A buffer amplifier is a voltage follower. It tracks the input voltage to the output terminals. They are used as impedance transformers or power amplifiers. It requires $A_{vo} = 1 V/V$.

ⓒ The gain-bandwidth product is the bandwidth achieved when a unity gain is desired. If we double the gain, we get half the bandwidth. The gain-bandwidth is specified on the op-amps' datasheets.

3. Use the circuit below:



Amp1 is a CA3140 and Amp2 is an LM741. (See attached datasheet information)

(a) State each amplifiers frequency response transfer function (V_1/V_{in} and V_o/V_1)
(b) State the overall transfer function (V_o/V_{in})

(a) Amp 1: $f_T = 4.5MHz$, $f_{3db} = \frac{4.5MHz}{5} = 900KHz$

DC gain: $\frac{V_1}{V_{in}} = \frac{-5K}{1K} = -5 V/V$

frequency: $\frac{-5}{\left(1+\frac{s}{900KHz}\right)} = \frac{V_1}{V_{in}}$

Amp 2: $f_T = 1MHz$, DC gain: $\frac{V_o}{V_1} = \left(\frac{30K}{1K}+1\right)$

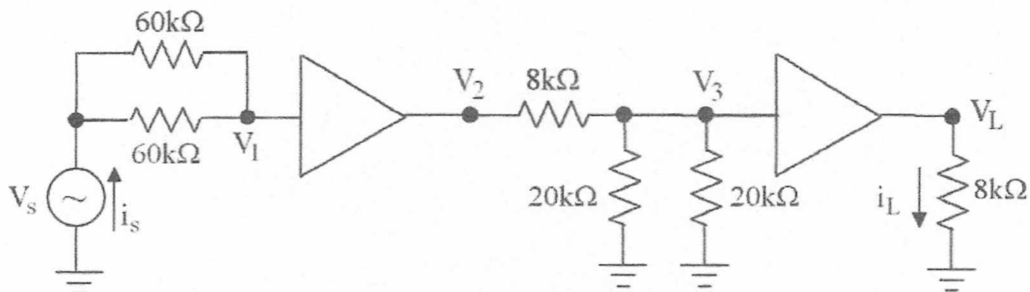
$\frac{V_o}{V_1} = 31$

$f_{3db} = \frac{1M}{31} = 32.3KHz$

frequency: $\frac{V_o}{V_1} = \frac{31}{\left(1+\frac{s}{32.3KHz}\right)}$

(b) $\frac{V_o}{V_{in}} = \frac{V_o}{V_1} \cdot \frac{V_1}{V_{in}} = \frac{-155}{\left(1+\frac{s}{900KHz}\right)\left(1+\frac{s}{32.3KHz}\right)}$

4. 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)

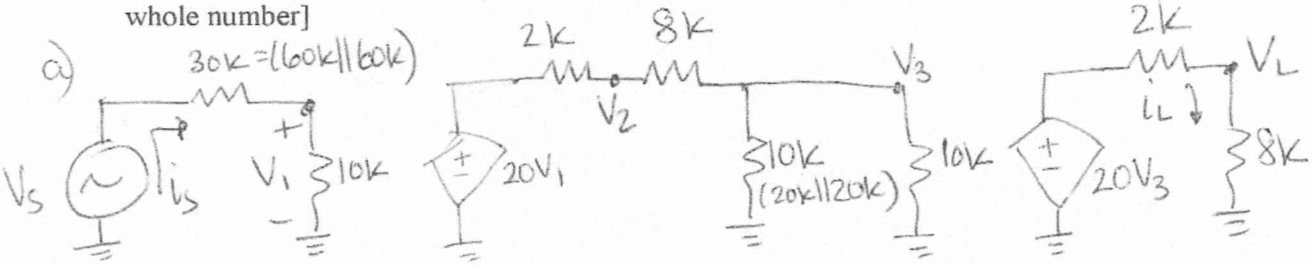


(a) Redraw this 2 stage amplifier using the amplifier model. Make sure to label V_S, V_1, V_2, V_3, and V_O on the schematic.

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

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

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

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

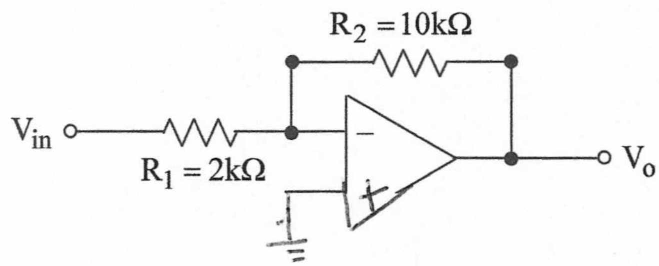
$\dfrac{V_L}{V_S} = \dfrac{4}{3}(20) = \boxed{\dfrac{80}{3} V/V \approx 29dB}$

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

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

5. (a) Use the circuit shown below for this problem and #6. The amplifier is a CA3140
   (i) If Vin = 1mV, what will Vo measure (do not consider any imperfections)?
   (ii) If the finite gain, A_o is considered, what will Vo measure?
(b) For small input signals, what is the 3db bandwidth of the circuit (in Hz)?

6. (a) For an output signal of 2sin(10t), considering the slew rate effect, what is the limiting frequency of the circuit?
   (b) For Vin=1mV, consider the effect of the input offset voltage (v_{in}=0V). (i.e. find output value when input =0) and state the resultant value for Vo.
   (c) How should the circuit be modified to minimize the effect of the input bias current? Redraw the circuit showing the modifications.



5. a. i. $\frac{V_o}{V_{in}} = -\frac{10K}{2K} = -5 V/V$ ∴ $V_o = -5(1mV) = \boxed{-5mV}$

ii. $\frac{V_o}{V_{in}} = \frac{-R_2/R_1}{1+(1+R_2/R_1)/A}$ (pg. 71)

$\frac{V_o}{V_{in}} = \frac{-5}{1+(1+5)/100K} = -4.99$

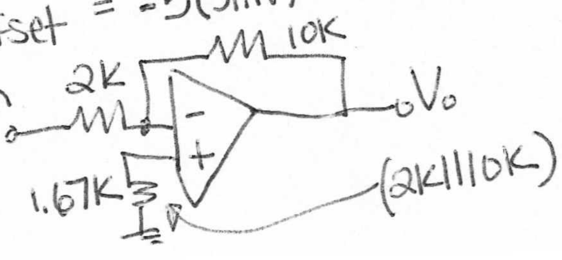
$V_o = -4.99(1mV) = \boxed{-4.99mV}$

b. $f_{3db} = \frac{4.5M}{5} = \boxed{900KHz}$

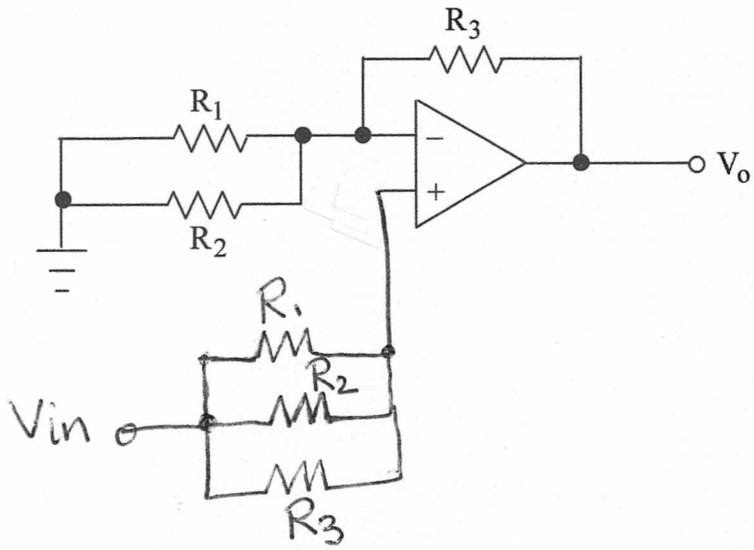
6. a. $f_{max} = \frac{9/10^{-6}}{2(2)\pi} = \boxed{716KHz}$

b. $V_o offset = -5(5mV) = -25mV$ $V_o = 1m(-5) - 25mV = \boxed{-30mV}$

c.



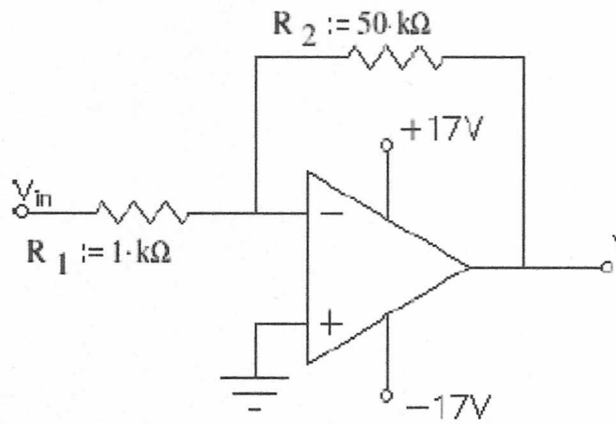
7. Redraw or add to the schematic below to show how to reduce the **input bias current**. State the symbolic value(s) of any components added to the schematic.



8. You are given the following characteristics for a real amplifier along with the circuit on the right.

Op amp Characteristics

Input offset voltage:	$V_{ios} := 2.0 \cdot mV$
Input offset current:	$I_{os} := 100 \cdot nA$
Input bias current:	$I_{iB} := 500 \cdot nA$
Input resistance:	$R_i := 2 \cdot M\Omega$
Output resistance:	$R_o := 75 \cdot \Omega$
Open-loop gain:	$A_{o1} = 106 \cdot dB$
Unity-gain bandwidth:	$f_T := 4 \cdot MHz$
Output swing limits:	within 2 V of supplies L+ = V+ - 2V L- = V- + 2V
Slew rate:	$SR := 2 \cdot \frac{V}{\mu s}$



(a) What is the voltage gain of the circuit? (make sure the sign is right)
(b) For small input signals, what is the bandwidth of the circuit?
(c) For an output signal of 12Vpp, what is the bandwidth of the circuit?

9. (a) What is the maximum peak-to-peak output you can get without clipping?
(b) What is the input impedance?
(c) What is the output impedance?
Hint: Express A_{o1} as a factor, then use the following expression to find the output impedance with feedback

$$R_{owf} = \frac{R_o}{1 + A_{o1} \cdot \frac{R_1}{R_1 + R_2}}$$

(d) Find the effect of the input offset voltage (v_{in}=0V).
(e) How should the circuit be modified to minimize the effect of the input bias current? Show the modification on the schematic above and find the value of any added parts.

8.a. $A_v = -\frac{R_2}{R_1} = \boxed{-50}$

b. $f_{3dB} = \frac{4M}{50} = \boxed{80KHz}$

c. $f_{max} = \frac{2/1e^{-6}}{12 \cdot \pi} = \boxed{53.1KHz}$

9. a. $2(17-2) = \boxed{30Vpp}$

b. $R_{input} = 2M \| 1k \| 50K \cong \boxed{1K\Omega}$

C. $A_{o1} = 10^{\frac{106}{20}} = 1.995 \times 10^5$

$R_{owf} = \frac{R_o}{1 + A_{o1} \frac{R_1}{R_1 + R_2}} = \boxed{.019\Omega}$

d. $V_o = 50(2m) = \boxed{100mV}$

e.