1 ☑ 5 ☑
2 ☑ 6 ☐
3 ☑ 7 ☑
4 ☑

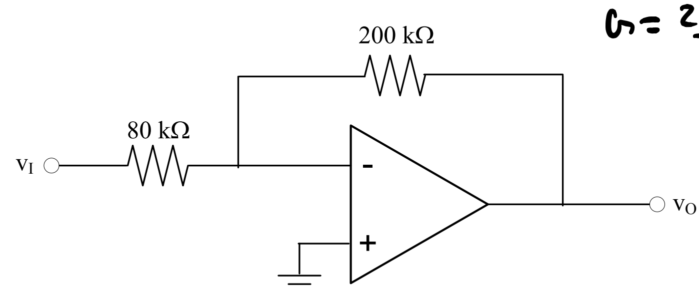
EE 315

Module 2

1. For the following circuits, find the closed loop voltage gain and the input resistance. Assume ideal op-amps.

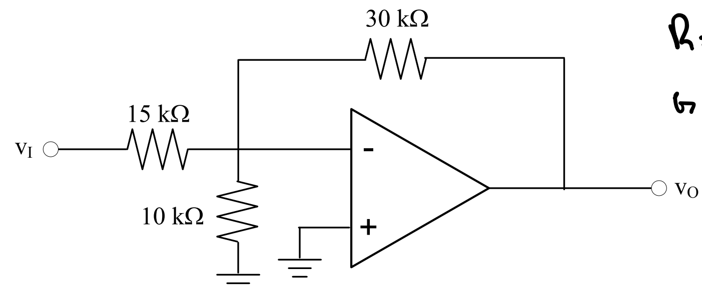
$R_i = 80k\Omega$

$G = \frac{200}{80} = 2.5 V/V$



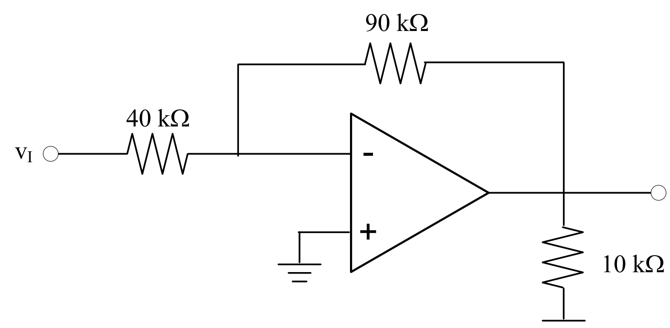
$R_i = 15k\Omega$

$G = \frac{30}{15} = 2 V/V$



$R_i = 40k\Omega$

$G = \frac{90}{40} = 2.25 V/V$



2. Design an ideal inverting amplifier with a closed loop gain of -5V/V. The output voltage is limited to –10 V≤ v_O≤ 10V, and the maximum current in any resistor is limited to 50µA.

3. Using the standard inverting configuration with an ideal op-amp, design for a closed loop gain of -1000 V/V. The maximum resistor value allowed in 100 kΩ. What is the input resistance? Use the circuit with the T resistor feedback and the same maximum resistor value, design the circuit for the same closed-loop gain of -1000 V/V. What is the input resistance for this circuit?

$G = -1000 V/V$

max $R = 100k\Omega$

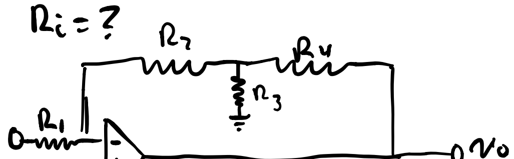
$R_i = ?$

$G = -R_2/R_1$

$1000 = \frac{R_2}{R_1} \rightarrow 100k\Omega$

$R_i = R_1 = 10k\Omega$

$R_2 = 100k\Omega$



$\frac{v_O}{v_I} = -\frac{R_2}{R_1}\left(\frac{R_4}{R_2} + \frac{R_4}{R_3} + 1\right)$

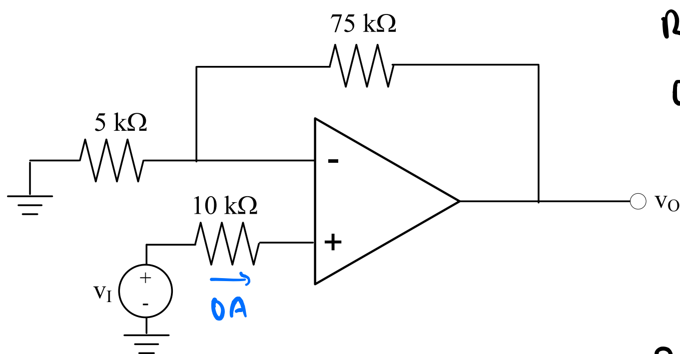
Let $R_1 = R_2 = R_4 = 100k\Omega$ $\frac{v_O}{v_I} = 1\left(1 + \frac{100\times10^3}{R_3} + 1\right) \rightarrow R_i = 100k\Omega$

$1000 = 2 + \frac{100\times10^3}{R_3}$ $\frac{100\times10^3}{R_3} = 998$ $R_3 = 100.20\,\Omega$

4. Design a weighted summer circuit for the following equations:
   a. $v_O = -2v_1 - 8v_2$
   b. $v_O = -12v_1 - 3v_2 + 2v_3$

   Resistors should range between 10kΩ and 1MΩ

5. For the following circuits, find the closed loop voltage gain and the input resistance. Assume ideal op-amps.

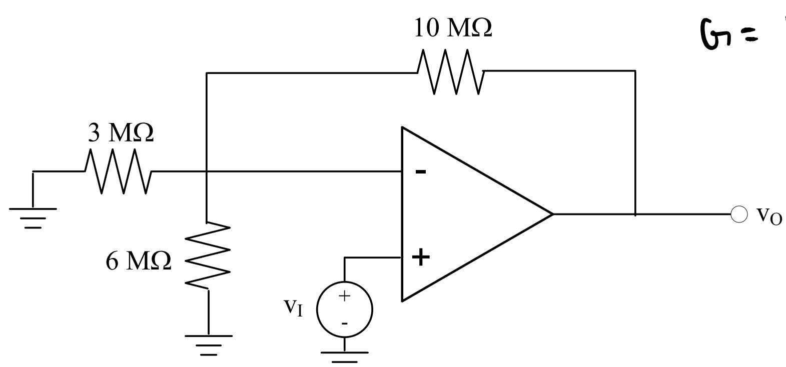


$R_i = \infty$

$G = 1 + \frac{75}{5} = 16\ V/V$

$R_i = \infty$

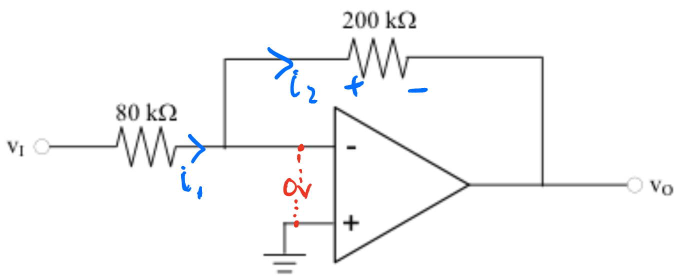
$G = 1 + \frac{10}{2} = 6\ V/V$



6. We worked an example where a potentiometer was used to divide the resistance between R1 and R2 for a typical non-inverting amplifier configuration. We found that the range of gain was 1 to infinity. For this problem, consider how you might add a fixed resistor to the circuit to prevent the gain from increasing above 11 V/V. Draw the circuit and show how you calculated the new range of closed loop gain from 1 to 11 V/V.

7.

1. For the following circuits, find the closed loop voltage gain and the input resistance. Assume ideal op-amps.



$R_1 = 80k\Omega$

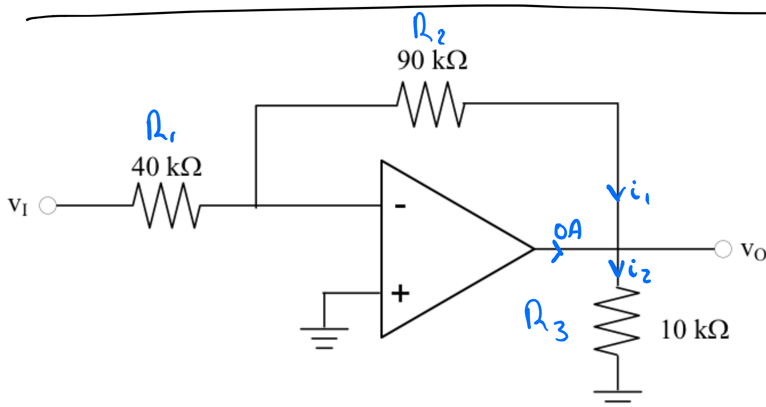
$R_2 = 200k\Omega$

v_o/v_I = Closed loop gain

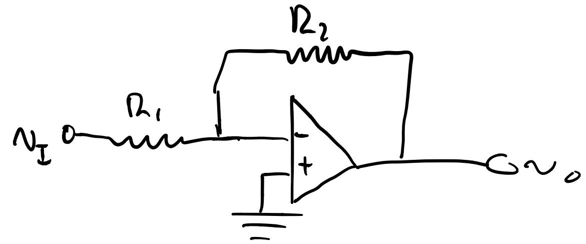
$i_1 = \frac{v_I}{R_1}$ $\quad$ $i_2 = \frac{0 - v_o}{R_2}$

$\frac{v_I}{R_1} = -\frac{v_o}{R_2} \Rightarrow \frac{v_o}{v_I} = -\frac{R_2}{R_1}$ $\quad$ • By KCL, $i_1 = i_2$.

$= -\frac{200k\Omega}{80k\Omega} = -2.5\,V/V$; $R_i = R_1 = 80k\Omega$



2. Design an ideal inverting amplifier with a closed loop gain of -5V/V. The output voltage is limited to –10 V≤ v_O≤ 10V, and the maximum current in any resistor is limited to 50µA.



$G = -5V/V$

$-10 \le v_O \le 10$

$i_{max} = 50\mu A$

$v_{O\,max} = 10V$

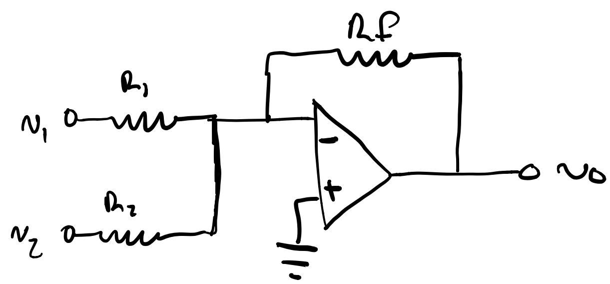
$|v_{I\,max}| = 10/5 = 2V$

$i_{max} = \frac{v_I}{R_1} = 2/R_1 = 50\times10^{-6}$

$R_1 = 40k\Omega$

4. Design a weighted summer circuit for the following equations:
   a. v_O= $-2v_1-8v_2$
   b. v_O= $-12v_1-3v_2+2v_3$

Resistors should range between 10kΩ and 1MΩ



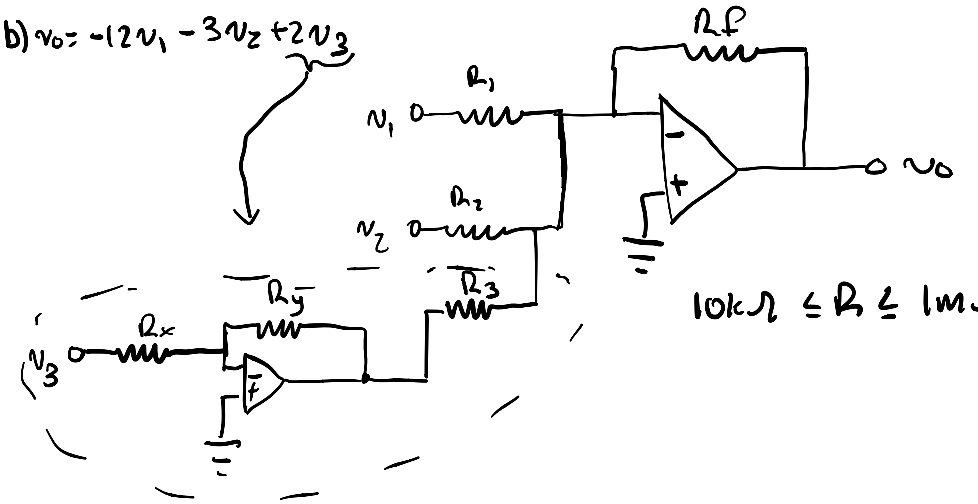
$v_O = -2v_1 - 8v_2$

$10k\Omega \le R \le 1M\Omega$

$v_O = \frac{-R_f}{R_1}v_1 - \frac{R_f}{R_2}v_2$; $\frac{R_f}{R_1} = 2$ $\frac{R_f}{R_2} = 8$

Let $R_f = 400k\Omega$ $R_1 = \frac{R_f}{2} = 200k\Omega$ $R_2 = \frac{R_f}{8} = 50k\Omega$

b) $v_o = -12v_1 - 3v_2 + 2v_3$



$10k\Omega \le R \le 1M\Omega$

$$v_3' = \frac{-R_y}{R_x} v_3 \Rightarrow v_o = -\frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_3 - \frac{R_f}{R_3} v_3'$$

$$v_o = -\frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} \cdot \frac{R_y}{R_x} v_3 \qquad \frac{R_f}{R_1} = 12 \qquad \frac{R_f}{R_2} = 3 \qquad \frac{R_y}{R_x} \frac{R_f}{R_3} = 2$$

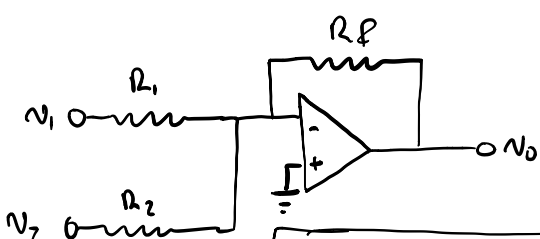
$$\left.\begin{array}{l} \text{Let } R_f = 600k\Omega \\ R_y = 10k\Omega \\ R_x = 10k\Omega \end{array}\right\} R_3 = \frac{R_y}{R_x} \cdot \frac{R_f}{2} : R_3 = 300k\Omega$$

$$R_1 = \frac{R_f}{12} = 50k\Omega \qquad R_2 = \frac{R_f}{3} = 200k\Omega$$

You can design these with different values, so as long as these values lie within the range, then it is a valid design.

$v_o = -5v_1 - 10v_2$

$10k\Omega \le R \le 1M\Omega$



$$v_o = -\frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_2$$

$$\frac{R_f}{R_1} = 5 \qquad \frac{R_f}{R_2} = 10$$

$$\boxed{\begin{array}{ll} R_f = 600k\Omega & R_1 = \frac{600}{5} = 120\,k\Omega \\ & R_2 = \frac{600}{10} = 60k\Omega \end{array}}$$

7. For both the inverting and non inverting configurations, show how the closed loop gain varies if the op-amp has finite open loop gain of. 100, 1000, 10,000, 100,000, and 1,000,000.

Inverting amp:

$R_2 = 100k\Omega$ } choose these
$R_1 = 5k\Omega$ } at random

finite: $\dfrac{-R_2/R_1}{1 + 1/A\,(1 + R_2/R_1)}$

ideal : $G = -R_2/R_1 = -20\,V/V$

A	G (V/V)
100	16.53
1000	19.59
10000	19.96
100 000	19.996
1,000,000	19.9996

Non-inverting

ideal: $R_2 = 100k\Omega$ } Choose at
$R_1 = 5k\Omega$ } random

$\dfrac{v_o}{v_I} = 1 + R_2/R_1 = 21\,V/V$

non ideal $G = \dfrac{1 + R_2/R_1}{1 + \dfrac{1 + R_2/R_1}{A}}$

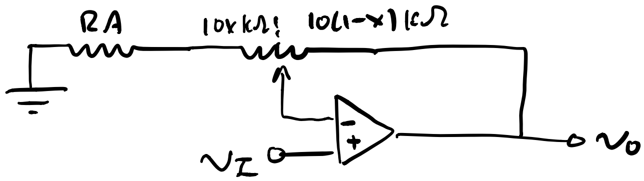
A	G (V/V)
100	17.35
1000	20.57
10,000	20.955
100,000	20.995
1,000,000	20.9996

General notes

- Closed loop voltage gain: $G = v_O/v_I$
- $R_i = R_1$ in non inverting
- $V = IR$

6. We worked an example where a potentiometer was used to divide the resistance between R1 and R2 for a typical non-inverting amplifier configuration. We found that the range of gain was 1 to infinity. For this problem, consider how you might add a fixed resistor to the circuit to prevent the gain from increasing above 11 V/V. Draw the circuit and show how you calculated the new range of closed loop gain from 1 to 11 V/V.

$1 V/V \le G \le 11 V/V$



When $x=0$ (max gain)
$R_1 = RA$
$R_2 = 10k\Omega$
$G = 11 V/V$

When $x=1$ (min gain)
$R_2 = 0$
$R_1 = 10 + RA$
$G = 1$

$$G = \frac{R_2}{R_1} + 1 = 11 \qquad \frac{R_2}{R_1} = 10 = \frac{10k\Omega}{RA} = 10; \; RA = 1k\Omega$$

Metric Prefix	Symbol	Multiplier (Traditional Notation)	Exponential	Description
Yotta	Y	1,000,000,000,000,000,000,000,000	10^{24}	Septillion
Zetta	Z	1,000,000,000,000,000,000,000	10^{21}	Sextillion
Exa	E	1,000,000,000,000,000,000	10^{18}	Quintillion
Peta	P	1,000,000,000,000,000	10^{15}	Quadrillion
Tera	T	1,000,000,000,000	10^{12}	Trillion
Giga	G	1,000,000,000	10^{9}	Billion
Mega	M	1,000,000	10^{6}	Million
kilo	k	1,000	10^{3}	Thousand
hecto	h	100	10^{2}	Hundred
deca	da	10	10^{1}	Ten
base	b	1	10^{0}	One
deci	d	1/10	10^{-1}	Tenth
centi	c	1/100	10^{-2}	Hundredth
milli	m	1/1,000	10^{-3}	Thousandth
micro	μ	1/1,000,000	10^{-6}	Millionth
nano	n	1/1,000,000,000	10^{-9}	Billionth
pico	p	1/1,000,000,000,000	10^{-12}	Trillionth
femto	f	1/1,000,000,000,000,000	10^{-15}	Quadrillionth
atto	a	1/1,000,000,000,000,000,000	10^{-18}	Quintillionth
zepto	z	1/1,000,000,000,000,000,000,000	10^{-21}	Sextillionth
yocto	y	1/1,000,000,000,000,000,000,000,000	10^{-24}	Septillionth