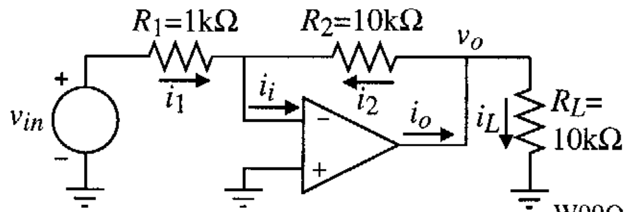
Homework Assignment No. 3 - Solution

1.) The op amps in this problem are ideal.

a.) If v_{in} = +1V, find the value the currents i_1, i_i, i_2, i_o, and i_L including the sign.



W99Q3A

$$i_1 = \frac{1V}{1k\Omega} = 1mA$$

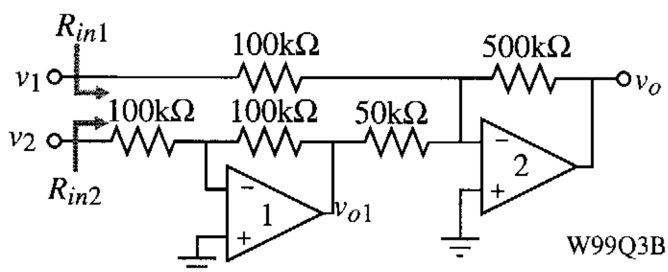
$$i_i = 0$$

$$i_2 = \frac{-10V}{10k\Omega} = -1mA$$

$$i_L = \frac{-10V}{1k\Omega} = -1mA$$

$$i_o = i_2 + i_L = -2mA$$

b.) Express v_o as a function of v_1 and v_2.



W99Q3B

Note: $v_{o1} = -v_2$

And

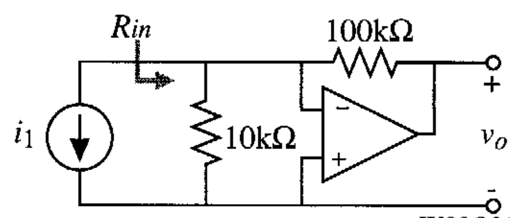
$v_o = -5v_1 - 10v_{o1}$

$\therefore\ v_o = -5v_1 - 10(-v_2) = -5v_1 + 10v_2$

$$v_o = -5v_1 + 10v_2$$

$$R_{in1} = R_{in2} = 100k\Omega$$

c.) Find R_{in} and v_o if i_1 = 0.1mA.



W99Q3C

$$R_{in} = 0$$

and

$$v_o = 100k\Omega \cdot i_1 = 100k\Omega \cdot 0.1mA = 10V$$

R_{in} and v_o if i_1 = 0.1mA.

12.24 Applying op-amp assumption 1 to the circuit on the next page, the voltage at the top of R_2 is v_{O2}, and applying op-amp assumption 2,

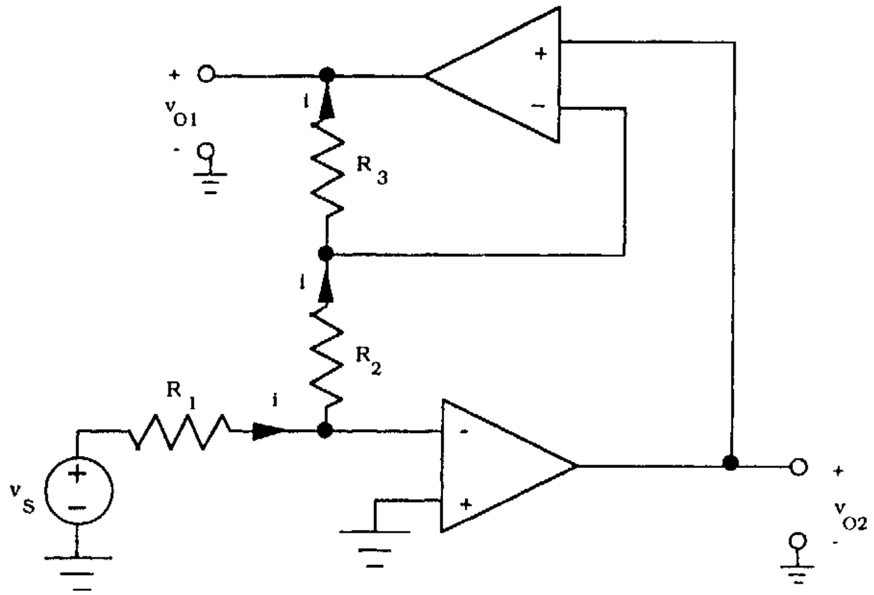
$$\frac{v_S}{R_1} = -\frac{v_{O2}}{R_2} \quad \text{or} \quad v_{O2} = -v_S \frac{R_2}{R_1}$$

Since the op-amp input currents are zero, and

$$i = \frac{v_S}{R_1}, \quad v_{O1} = -iR_2 - iR_3 = -\left(\frac{R_2}{R_1} + \frac{R_3}{R_1}\right)v_S$$

Alternatively, the voltage at the bottom of R_2 is zero, so

$$v_{O1} = \left(1 + \frac{R_3}{R_2}\right)v_{O2} = \left(1 + \frac{R_3}{R_2}\right)\left(-\frac{R_2}{R_1}\right)v_S = -\left(\frac{R_2}{R_1} + \frac{R_3}{R_1}\right)v_S$$



12.29 Taking successive Thévenin equivalent circuits at each ladder node yields:

$-\frac{V_{REF}}{16} = -0.3V$ | $-\frac{V_{REF}}{8} = -0.6V$ | $-\frac{V_{REF}}{4} = -1.2V$ | $-\frac{V_{REF}}{2} = -2.4V$

12.74

$$\beta = \frac{2k\Omega}{2k\Omega + 40k\Omega} = \frac{1}{21} \quad | \quad A\beta = \frac{10^5}{21} = 4760 >> 1$$

(a) $A_V = -\frac{R_2}{R_1} = -\frac{40k\Omega}{2k\Omega} = -20$ | $f_H = \beta f_T = \frac{3x10^6 Hz}{21} = 143kHz$

(b) $A_V = (-20)^3 = -8000$ (78dB) | $f_{H3} = 0.51 f_H = 72.9kHz$
