P6.4-5

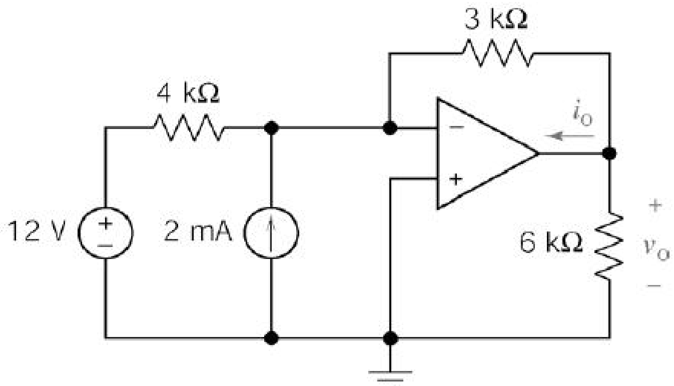
The voltages at the input nodes of an ideal op amp are equal so $v_a = 0$ V. Apply KCL at node a:

$$-\left(\frac{v_o - 0}{3000}\right) - \left(\frac{12-0}{4000}\right) - 2\cdot 10^{-3} = 0$$

$$\Rightarrow v_o = -15 \text{ V}$$

Apply KCL at the output node of the op amp:

$$i_o + \frac{v_o}{6000} + \frac{v_o}{3000} = 0 \Rightarrow i_o = 7.5 \text{ mA}$$



(checked using LNAP 8/16/02)

P6.4-8

The node voltages have been labeled using:

1. The currents into the inputs of an ideal op amp are zero and the voltages at the input nodes of an ideal op amp are equal.

2. KCL

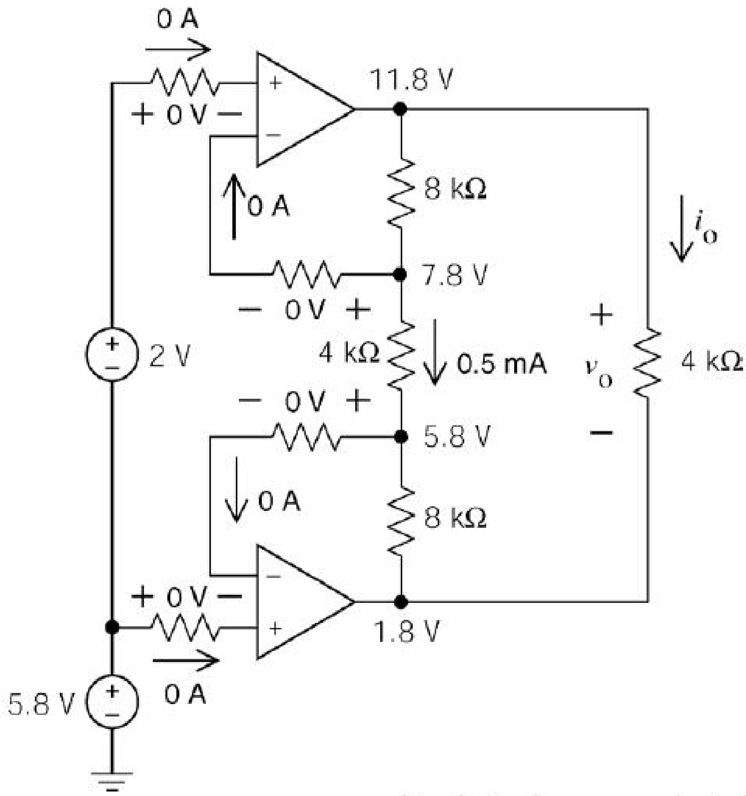
3. Ohm's law

Then

$$v_0 = 11.8 - 1.8 = 10 \text{ V}$$

and

$$i_o = \frac{10}{4000} = 2.5 \text{ mA}$$



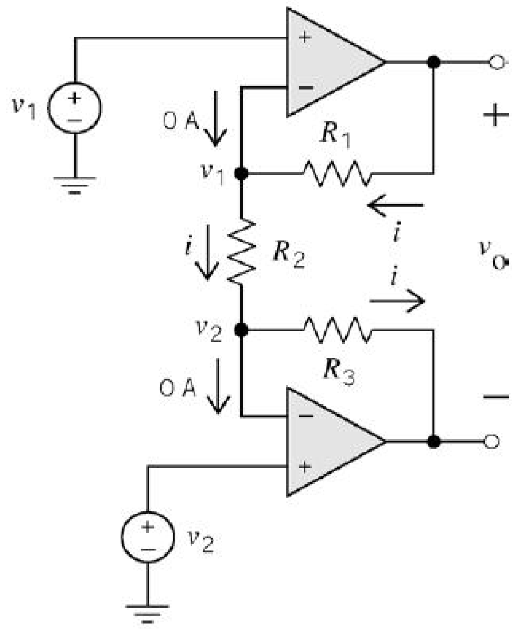
P6.5-4

Ohm's law:

$$i = \frac{v_1 - v_2}{R_2}$$

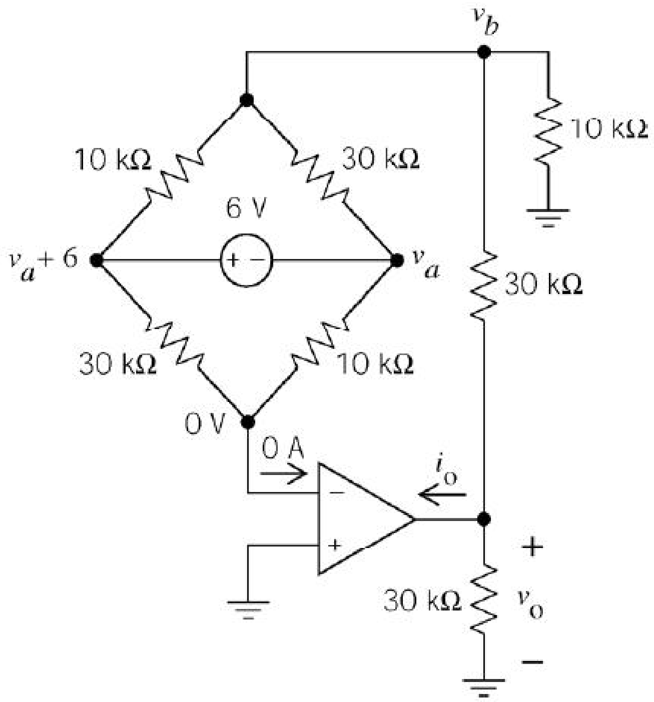
KVL:

$$v_0 = (R_1 + R_2 + R_3)\, i = \frac{R_1 + R_2 + R_3}{R_2}(v_1 - v_2)$$



P6.5-7

Apply KCL at the inverting input node of the op amp



$$-\left(\frac{v_a-0}{10000}\right)+0-\left(\frac{(v_a+6)-0}{30000}\right) = 0$$

$$\Rightarrow v_a = -1.5 \text{ V}$$

Apply KCL to the super node corresponding the voltage source:

$$\frac{v_a-0}{10000}+\frac{v_a+6-0}{30000} + \frac{v_a-v_b}{30000}+\frac{(v_a+6)-v_b}{10000} = 0$$

$$\Rightarrow \quad 3v_a+v_a+6+v_a-v_b + 3\left[(v_a+6)-v_b\right] = 0$$

$$\Rightarrow \quad v_b = 2v_a+6 = 3 \text{ V}$$

Apply KCL at node b:

$$\frac{v_b}{10000}+\frac{v_b-v_0}{30000}-\left(\frac{v_a-v_b}{30000}\right)-\left(\frac{(v_a+6)-v_b}{10000}\right) = 0$$

$$\Rightarrow \quad 3v_b+(v_b-v_0)-(v_a-v_b)-3\left[(v_a+6)-v_b\right] = 0$$

$$\Rightarrow \quad v_0 = 8v_b-4v_a-18 = \underline{12 \text{ V}}$$

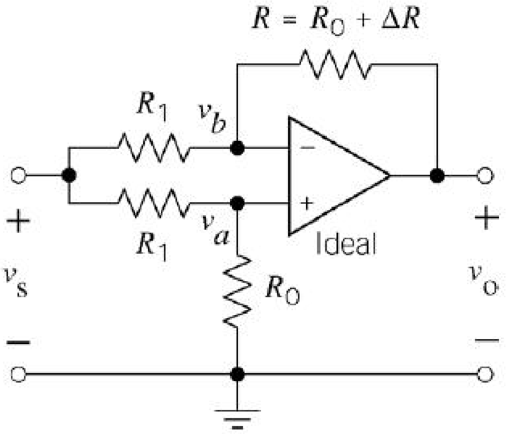
Apply KCL at the output node of the op amp:

$$i_0+\frac{v_0}{30000}+\frac{v_0-v_b}{30000} = 0 \Rightarrow i_0 = -0.7 \text{ mA}$$

P6.5-10

By voltage division (or by applying KCL at node a)

$$v_a = \frac{R_0}{R_1+R_0} v_s$$



Applying KCL at node b:

$$\frac{v_b - v_s}{R_1} + \frac{v_b - v_0}{R_0 + \Delta R} = 0$$

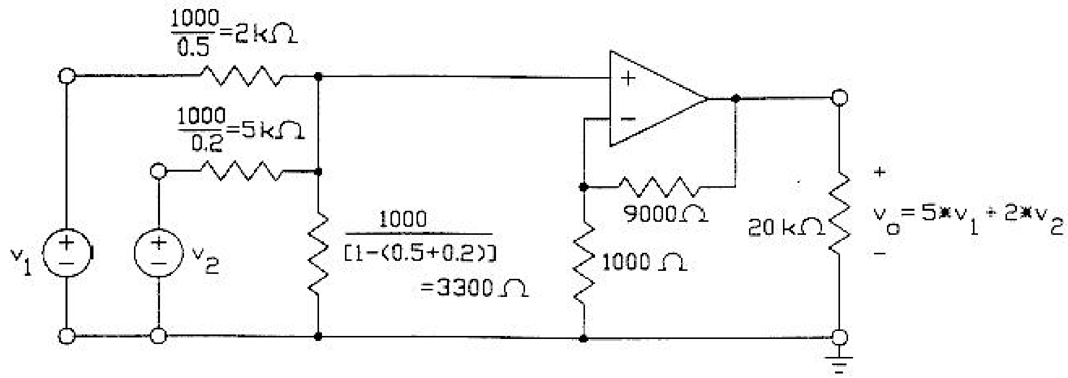
$$\Rightarrow \quad \frac{R_0+\Delta R}{R_1}(v_b - v_s) + v_b = v_0$$

The node voltages at the input nodes of an ideal op amp are equal so $v_b = v_a$.

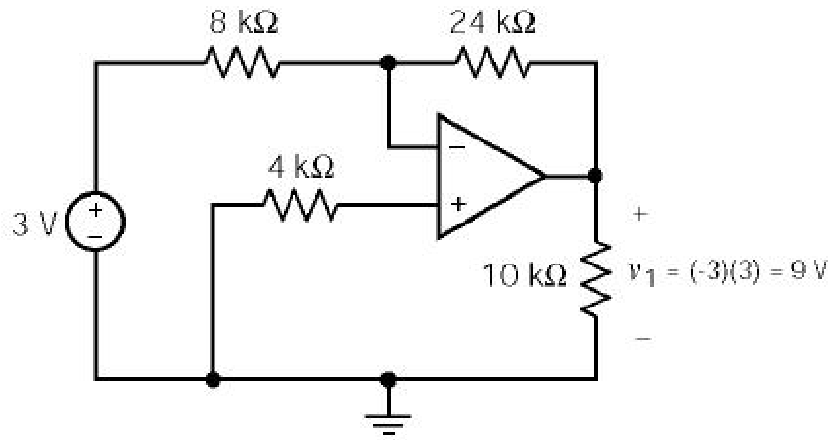
$$v_0 = \left[\left(\frac{R_0+\Delta R}{R_1}+1\right)\frac{R_0}{R_1+R_0} - \frac{R_0+\Delta R}{R_1}\right] v_s = -\frac{\Delta R}{R_1+R_0} v_s = \left(-v_s \frac{R_0}{R_1+R_0}\right)\frac{\Delta R}{R_0}$$

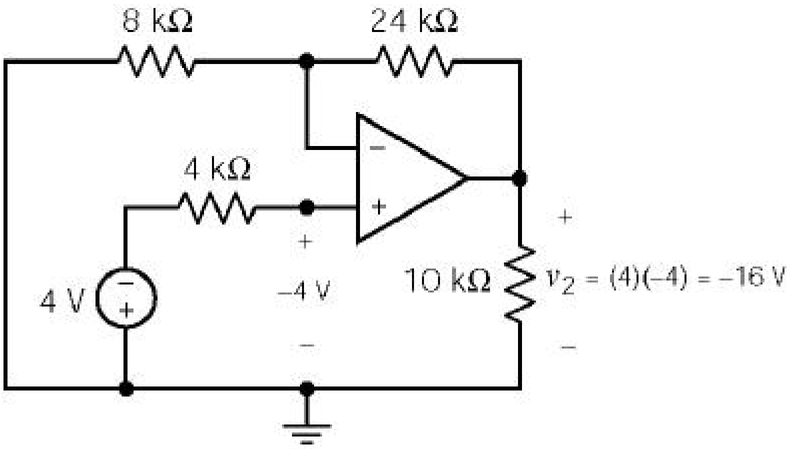
P6.6-3

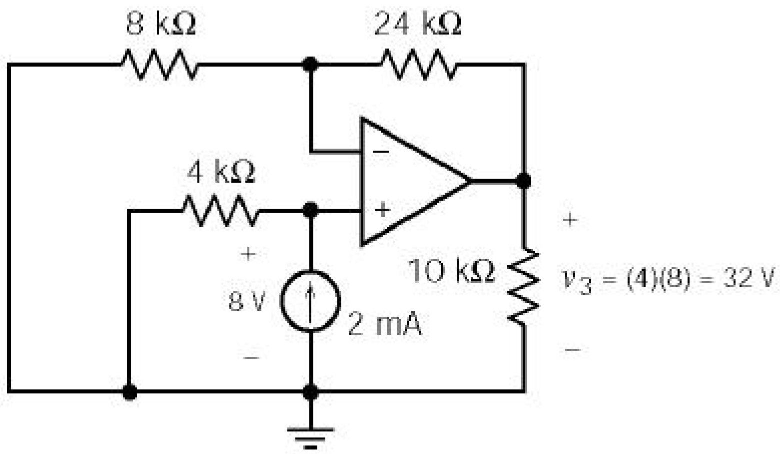
Use the noninverting summing amplifier, entry (e) in Figure 6.6-1.



P6.6-9







Using superposition, $v_o = v_1 + v_2 + v_3 = -9 - 16 + 32 = 7$ V

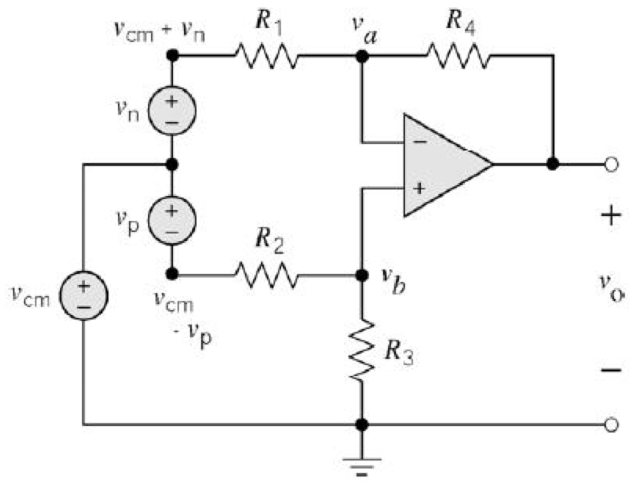
P6.8-4

a)
$$\frac{v_0}{v_{in}} = -\frac{R_2}{R_1} = -\frac{49\times10^3}{5.1\times10^3} = \underline{-9.6078}$$

b)
$$\frac{v_0}{v_{in}} = \frac{\left(2\times10^6\right)\left(75-\left(200{,}000\right)\left(50\times10^3\right)\right)}{(5\times10^3+2\times10^6)(75+50\times10^3)+(5\times10^3)(2\times10^6)(1+200{,}000)} = \underline{-9.9957}$$

c)
$$\frac{v_0}{v_{in}} = \frac{2\times10^6(75-(200{,}000)(49\times10^3))}{(5.1\times10^3+2\times10^6)(75+49\times10^3)+(5.1\times10^3)(2\times10^6)(1+200{,}000)} = \underline{-9.6037}$$

P6.8-5



Apply KCL at node b:

$$v_b = \frac{R_3}{R_2+R_3}(v_{cm}-v_p)$$

Apply KCL at node a:

$$\frac{v_a-v_0}{R_4}+\frac{v_a-(v_{cm}+v_n)}{R_1} = 0$$

The voltages at the input nodes of an ideal op amp are equal so $v_a = v_b$.

$$v_0 = -\frac{R_4}{R_1}(v_{cm}+v_n)+\frac{R_4+R_1}{R_1}v_a$$

$$v_0 = -\frac{R_4}{R_1}(v_{cm}+v_n)+ \frac{(R_4+R_1)R_3}{R_1(R_2+R_3)}(v_{cm}-v_p)$$

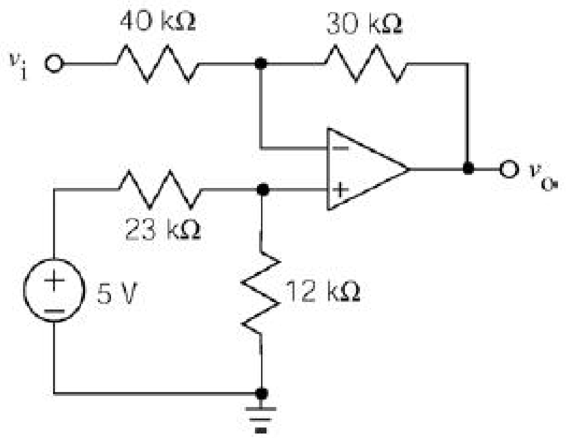
when $\frac{R_4}{R_1} = \frac{R_3}{R_2}$ then $\frac{(R_4+R_1)R_3}{R_1(R_2+R_3)} = \frac{\frac{R_4}{R_1}+1}{\frac{R_3}{R_2}+1}\times\frac{R_3}{R_2} = \frac{R_4}{R_1}$

so

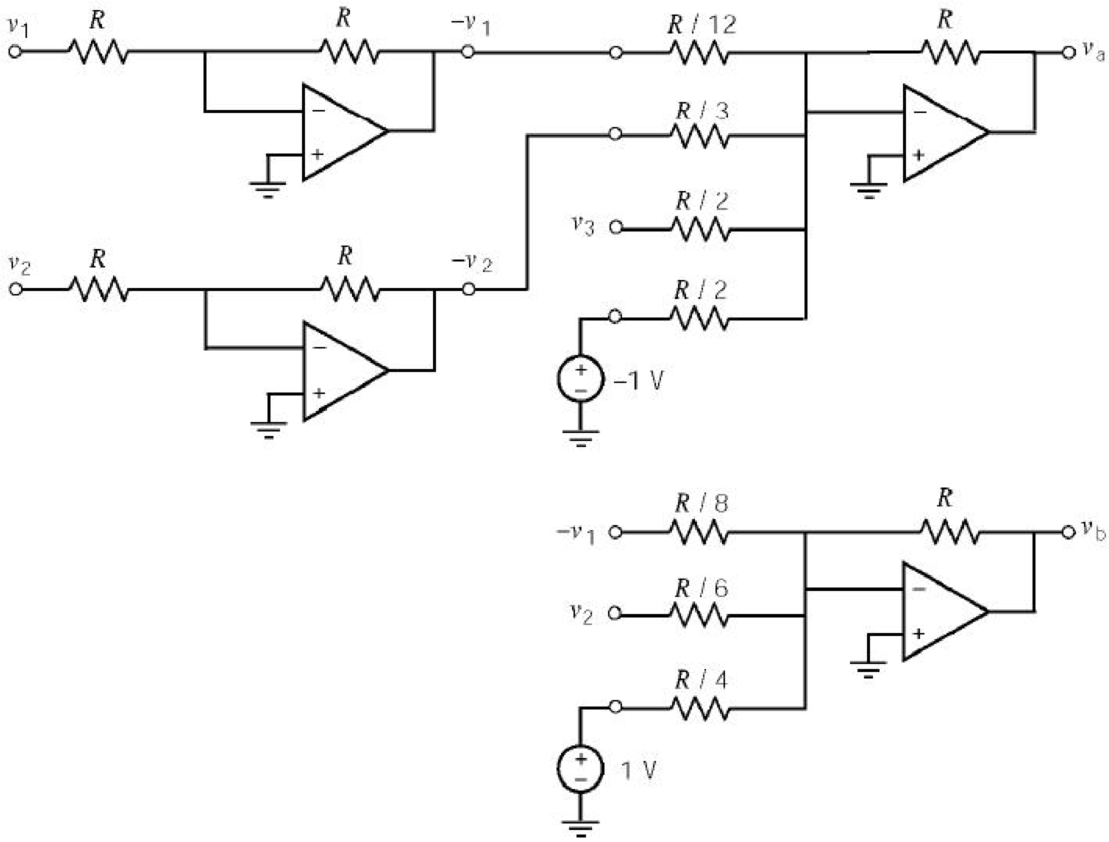
$$v_0 = -\frac{R_4}{R_1}(v_{cm}+v_n)+\frac{R_4}{R_1}(v_{cm}-v_p) = -\frac{R_4}{R_1}(v_n+v_p)$$

DP6-2

$$v_o = -\frac{3}{4}v_i + 3 = -\frac{3}{4}v_i + \left(1+\frac{3}{4}\right)\left(\frac{12}{35}\right)5 - \frac{3}{4}v_i + \left(1+\frac{3}{4}\right)\left(\frac{12}{12+23}\right)5$$

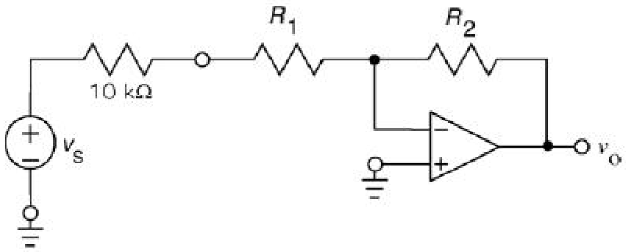


DP6-4

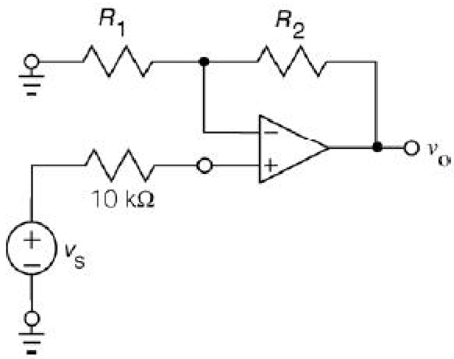


DP6-5

We require a gain of $\frac{4}{20\times10^{-3}} = 200$. Using an inverting amplifier:



Here we have $200 = \left|-\frac{R_2}{10\times10^3 + R_1}\right|$. For example, let $R_1 = 0$ and $R_2 = 1$ MΩ. Next, using the noninverting amplifier:



Here we have $200 = 1 + \frac{R_2}{R_1}$. For example, let $R_1 = 1$ kΩ and $R_2 = 199$ kΩ.

The gain of the inverting amplifier circuit does not depend on the resistance of the microphone. Consequently, the gain does not change when the microphone resistance changes.