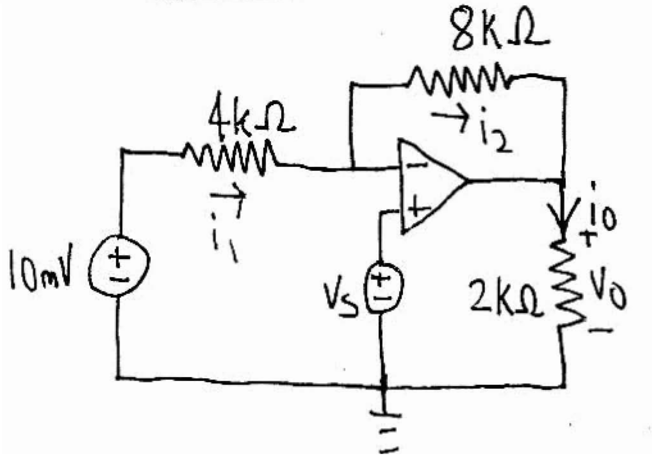
# ECE 300

## 5.5 Review

$V_s = 0$




Assume ideal op-amp

$i_1 = i_2$

$$\frac{10mV - V_s}{4k\Omega} = \frac{V_s - V_o}{8k\Omega}$$

$$\frac{10mV}{4k\Omega} = \frac{-V_o}{8k\Omega}$$

$V_o = -20mV$ $\quad$ $I_o = V_o / 2k\Omega = -10\mu A$

Book says $-10mA$. Typo in book.

## 5.6 Review

Now $V_s = 8mV$. Use same equations as before

$$\frac{2mV}{4k\Omega} = \frac{8mV - V_o}{8k\Omega}$$

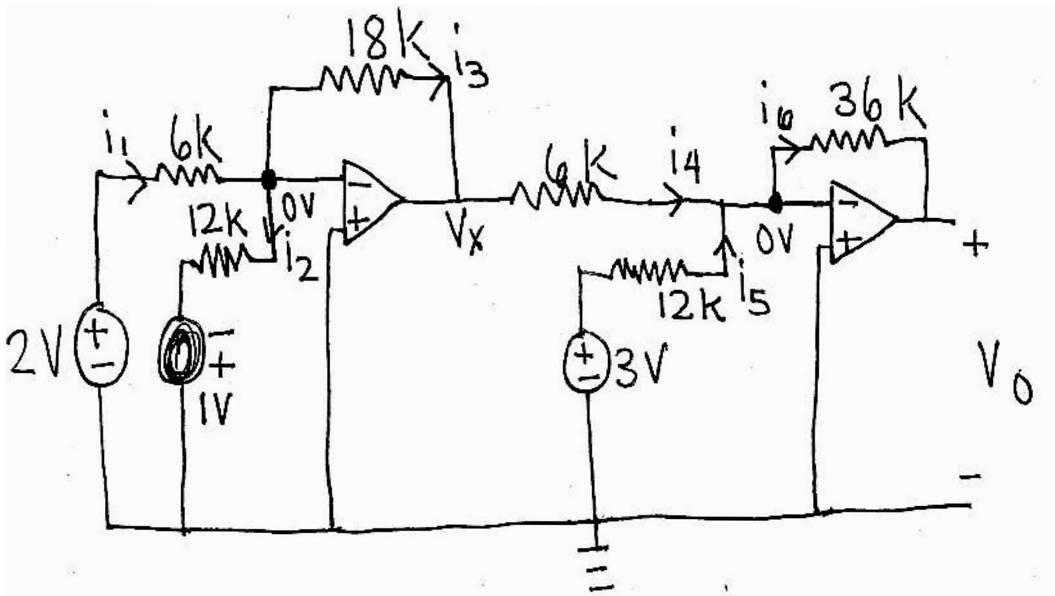
$8mV - V_o = 4mV$

$V_o = 4mV$

# ECE 300

## 5.XX

Assuming ideal op-amps




$$i_1 = i_2 + i_3$$

$$\frac{2V}{6k} = \frac{1V}{12k} + \frac{-V_x}{18k} \Rightarrow 12V = 3V - 2V_x \Rightarrow V_x = -4.5$$

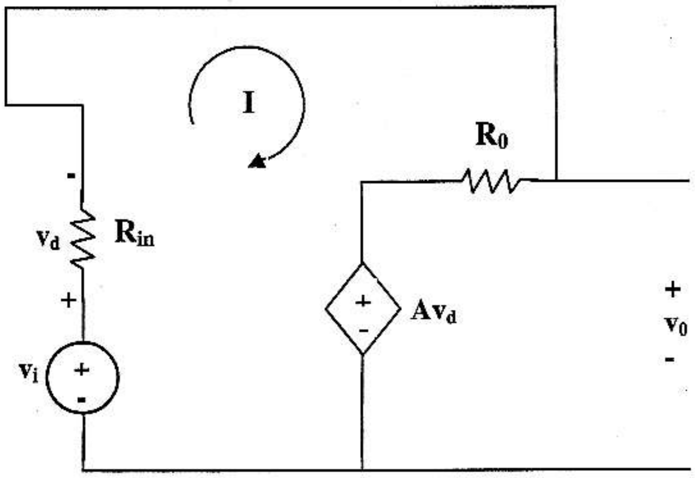
Next

$$i_4 + i_5 = i_6$$

$$\frac{V_x}{6k} + \frac{3V}{12k} = \frac{-V_0}{36k} \Rightarrow 6V_x + 9V = -V_0$$

$$V_0 = (-27 + 9) \cdot -1 = 18V$$

**Chapter 5, Solution 5.**




$$-v_i + Av_d + (R_i + R_0)\,I = 0 \qquad (1)$$

But $\quad v_d = R_iI,$

$$-v_i + (R_i + R_0 + R_iA)\,I = 0$$

$$I = \frac{v_i}{R_0 + (1+A)R_i} \qquad (2)$$

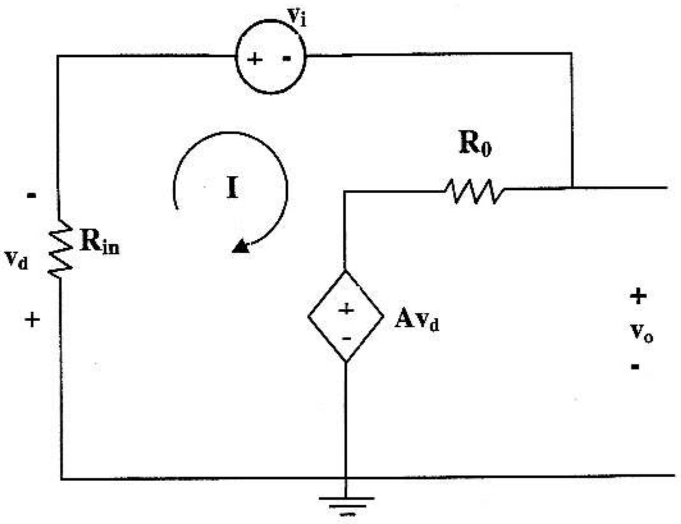
$$-Av_d - R_0I + v_0 = 0$$

$$v_0 = Av_d + R_0I = (R_0 + R_iA)I \;=\; \frac{(R_0 + R_iA)v_i}{R_0 + (1+A)R_i}$$

$$\frac{v_0}{v_i} = \frac{R_0 + R_iA}{R_0 + (1+A)R_i} = \frac{100 + 10^4 x 10^5}{100 + (1+10^5)} \cdot 10^4$$

$$\cong \frac{10^9}{(1+10^5)} \cdot 10^4 = \frac{100{,}000}{100{,}001} = \underline{\mathbf{0.9999990}}$$

**Chapter 5, Solution 6.**




$(R_O + R_i)R + v_i + Av_d = 0$

But $\quad v_d = R_iI,$

$v_i + (R_O + R_i + R_iA)I = 0$

$$I = \frac{-v_i}{R_0 + (1+A)R_i} \qquad (1)$$

$-Av_d - R_OI + v_o = 0$

$v_o = Av_d + R_OI = (R_O + R_iA)I$

Substituting for I in (1),

$$v_O = -\left(\frac{R_0 + R_iA}{R_0 + (1+A)R_i}\right)v_i$$

$$= -\frac{\left(50 + 2x10^6 x2x10^5\right)\cdot 10^{-3}}{50 + \left(1 + 2x10^5\right)x2x10^6}$$

$$\cong \frac{-200{,}000x2x10^6}{200{,}001x2x10^6} mV$$

$v_O =$ **-0.999995 mV**

**Chapter 5, Problem 9**

Determine $v_o$ for each of the op amp circuits in Fig. 5.48.

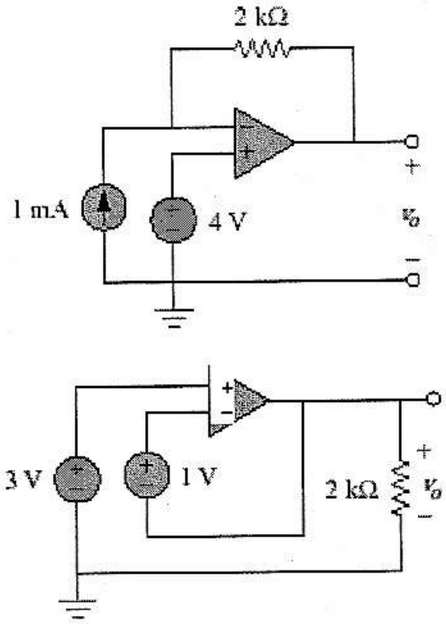



Figure 5.48 for Prob. 5.9

**Chapter 5, Solution 9.**

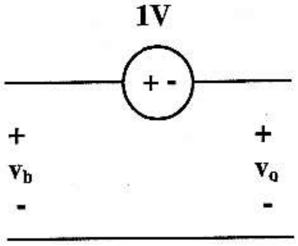
(a) Let $v_a$ and $v_b$ be respectively the voltages at the inverting and noninverting terminals of the op amp

$$v_a = v_b = 4V$$

At the inverting terminal,

$$1mA = \frac{4 - v_0}{2k} \longrightarrow v_0 = \underline{2V}$$

(b)




Since $v_a = v_b = 3V$,

$$-v_b + 1 + v_o = 0 \longrightarrow v_o = v_b - 1 = \underline{2V}$$

## Chapter 5, Problem 13

Find $v_o$ and $i_o$ in the circuit of Fig. 5.52.

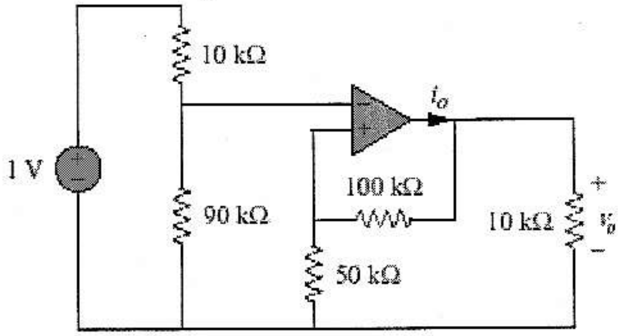
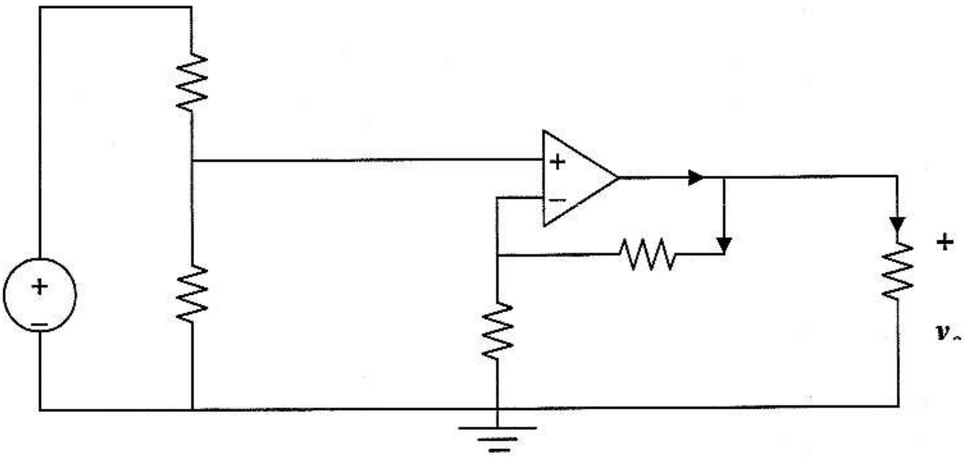



Figure 5.52 for Prob. 5.13

## Chapter 5, Solution 13.




By voltage division,

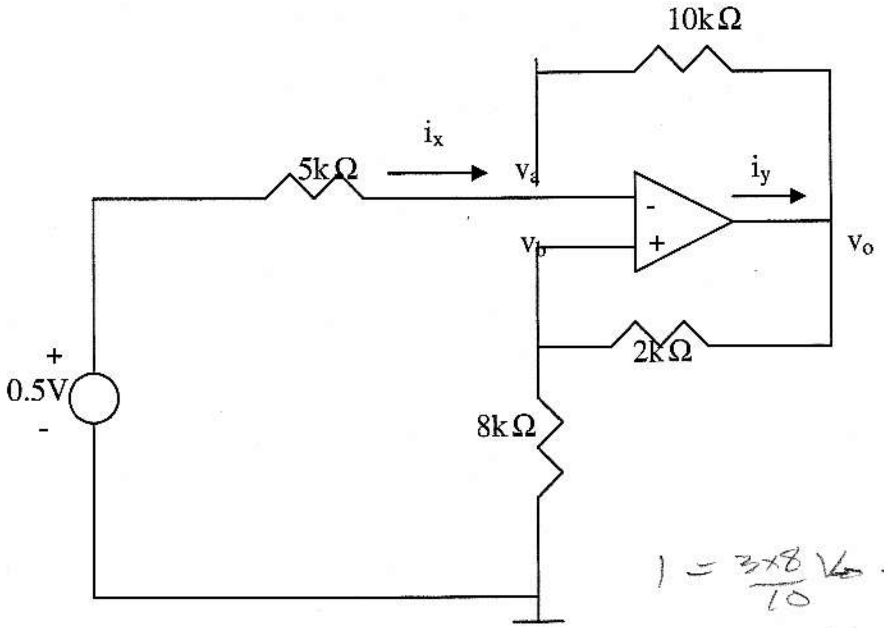
$$v_a = \frac{90}{100}(1) = 0.9\text{V}$$

$$v_b = \frac{50}{150}v_o = \frac{v_o}{3}$$

But $v_a = v_b \longrightarrow \frac{v_o}{3} = 0.9 \longrightarrow v_o = \underline{\mathbf{2.7V}}$

$$i_o = i_1 + i_2 = \frac{v_o}{10\text{k}} + \frac{v_o}{150\text{k}} = 0.27\text{mA} + 0.018\text{mA} = \underline{\mathbf{288\ \mu A}}$$

## Chapter 5, Solution 16




Let currents be in mA and resistances be in kΩ. At node a,

$$\frac{0.5 - v_a}{5} = \frac{v_a - v_o}{10} \quad \longrightarrow \quad 1 = 3v_a - v_o \qquad (1)$$

But

$$v_a = v_b = \frac{8}{8+2} v_o \quad \longrightarrow v_o = \frac{10}{8} v_a \qquad (2)$$

Substituting (2) into (1) gives

$$1 = 3v_a - \frac{10}{8} v_a \quad \longrightarrow \quad v_a = \frac{8}{14}$$

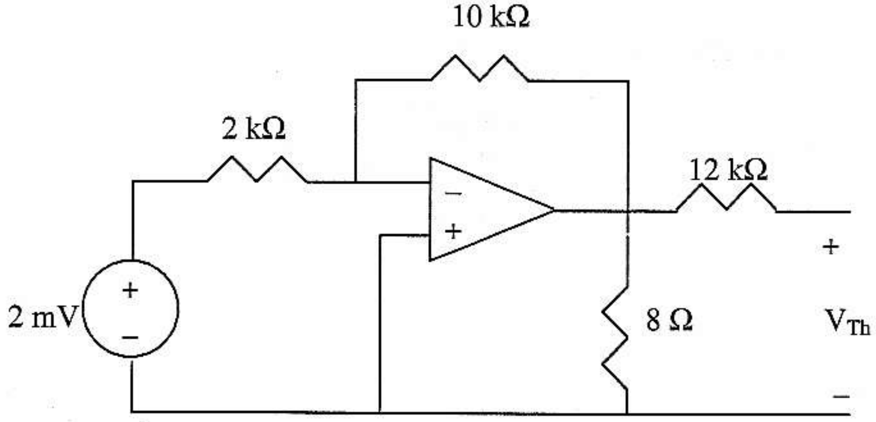
Thus,

$$i_x = \frac{0.5 - v_a}{5} = -1/70 \text{ mA} = \underline{-14.28\,\mu\text{A}}$$

$$i_y = \frac{v_o - v_b}{2} + \frac{v_o - v_a}{10} = 0.6(v_o - v_a) = 0.6(\frac{10}{8} v_a - v_a) = \frac{0.6}{4} x \frac{8}{14} \text{ mA} = \underline{85.71\,\mu}$$

**Chapter 5, Solution 18.**

We temporarily remove the 20-kΩ resistor. To find $V_{Th}$, we consider the circuit below.

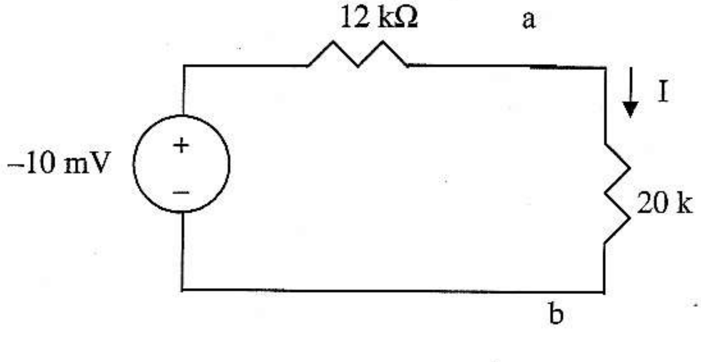



This is an inverting amplifier.

$$V_{Th} = -\frac{10k}{2k}(2mV) = \underline{-10mV}$$

To find $R_{Th}$, we note that the 8-kΩ resistor is across the output of the op amp which is acting like a voltage source so the only resistance seen looking in is the 12-kΩ resistor.

The Thevenin equivalent with the 20-kΩ resistor is shown below.




$I = -10m/(12k + 20k) = 0.3125x10^{-6}$ A

$p = I^2R = (0.3125x10^{-6})^2x20x10^3 = \mathbf{\underline{1.9531\ nW}}$

**Chapter 5, Problem 29**

Determine the voltage gain $v_o/v_i$ of the op amp circuit in Fig. 5.67.

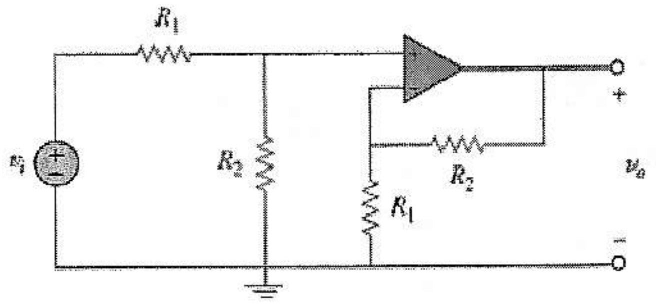
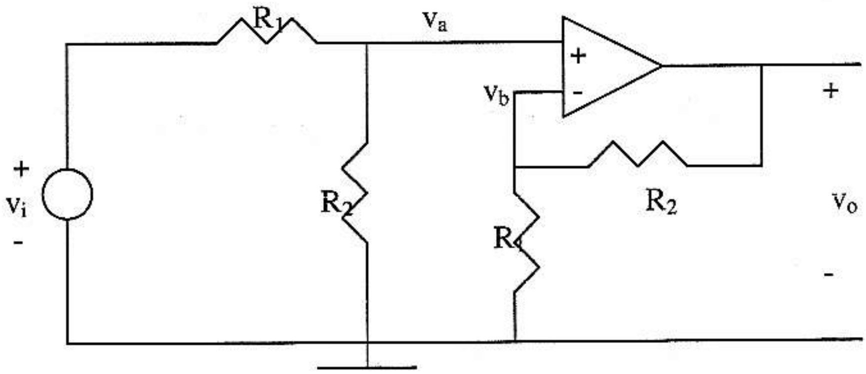



Figure 5.67

**Chapter 5, Solution 29**




$$v_a = \frac{R_2}{R_1 + R_2} v_i, \qquad v_b = \frac{R_1}{R_1 + R_2} v_o$$

But $v_a = v_b$ $\longrightarrow$ $\frac{R_2}{R_1 + R_2} v_i = \frac{R_1}{R_1 + R_2} v_o$

Or

$$\underline{\frac{v_o}{v_i} = \frac{R_2}{R_1}}$$

## Chapter 5, Problem 31

For the circuit in Fig. 5.69, find $i_x$.

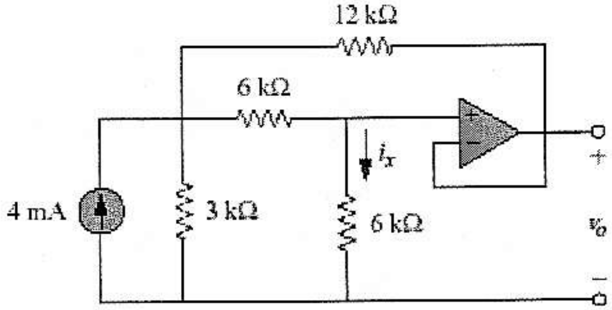
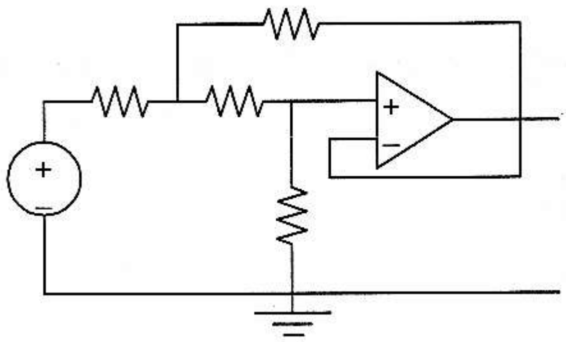



Figure 5.69

## Chapter 5, Solution 31.

After converting the current source to a voltage source, the circuit is as shown below:




At node 1,

$$\frac{12 - v_1}{3} = \frac{v_1 - v_o}{6} + \frac{v_1 - v_o}{12} \longrightarrow 48 = 7v_1 - 3v_o \qquad (1)$$

At node 2,

$$\frac{v_1 - v_o}{6} = \frac{v_o - 0}{6} = i_x \longrightarrow v_1 = 2v_o \qquad (2)$$

From (1) and (2),

$$v_o = \frac{48}{11}$$

$$i_x = \frac{v_o}{6k} = \underline{\mathbf{727.2\mu A}}$$

**Chapter 5, Problem 40.**

Find $v_o$ in terms of $v_1$, $v_2$, and $v_3$, in the circuit of Fig. 5.77.

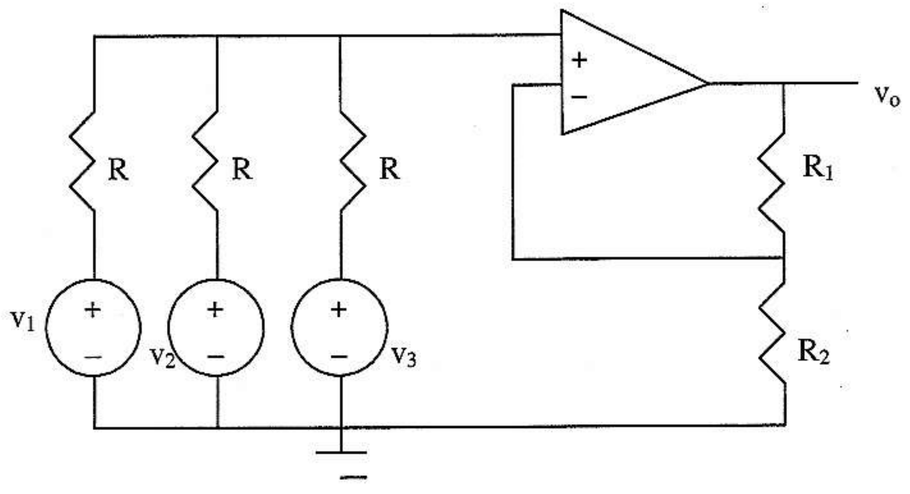



**Figure 5.77 For Prob. 5.40.**

**Chapter 5, Solution 40.**

Applying KCL at node a, where node a is the input to the op amp.

$$\frac{v_1 - v_a}{R} + \frac{v_2 - v_a}{R} + \frac{v_3 - v_a}{R} = 0 \quad \text{or} \quad v_a = (v_1 + v_2 + v_3)/3$$

$$v_o = (1 + R_1/R_2)v_a = \underline{\mathbf{(1 + R_1/R_2)(v_1 + v_2 + v_3)/3}}.$$