Op Amp Circuits

Introduction

The circuits in this problem set are popular op amp circuits. Indeed, these circuits are used so often that they have been given names: the inverting and noninverting amplifiers, the summing amplifier and the current-to-voltage converter.

To solve these problems, we identify the particular circuit, recall the equation that describes that circuit and then substitute appropriate values into that equation.

These popular op amp circuits are discussed in Section 6.6 of *Introduction to Electric Circuits* by R.C. Dorf and J.A Svoboda. In particular, Figure 6.6-1 provides a catalog of popular op amp circuits together with equations that describe those circuits.

Worked Examples

Example 1:
Consider the circuit shown in Figure 1. Find the value of voltage measured by the voltmeter.

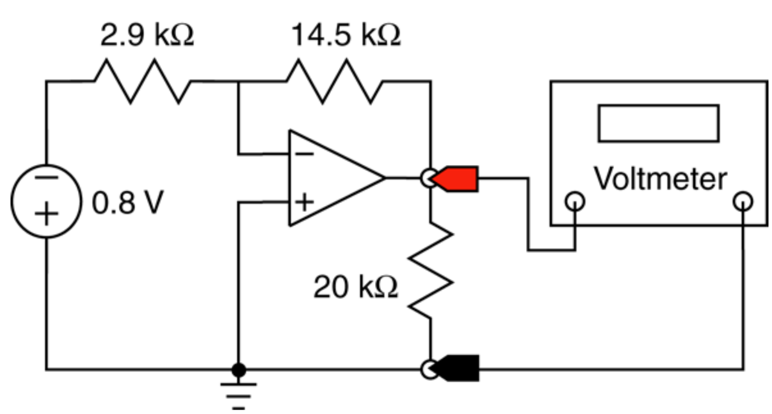

Figure 2 The circuit considered in Example 2.

Solution: Recognize that this circuit is an inverting amplifier. The inverting amplifier is described by Figure 6.6-1a in *Introduction to Electric Circuits*. Comparing Figure 1 to Figure 6.6-1a gives

$$v_{in} = -0.8 \text{ V}, \quad R_1 = 2.9 \text{ k}\Omega \text{ and } R_f = 14.5 \text{ k}\Omega$$

Also, the voltmeter in Figure 1 measures the voltage labeled as v_{out} in Figure 6.6-1a. Using this correspondence, the equation given in Figure 6.6-1a indicates that value of the voltage measured by the voltmeter is

$$v_{out} = \left(-\frac{14500}{2900}\right)(-0.8) = 4 \text{ V}$$

Example 2:

Consider the circuit shown in Figure 2. Find the value of the resistance, *R*.

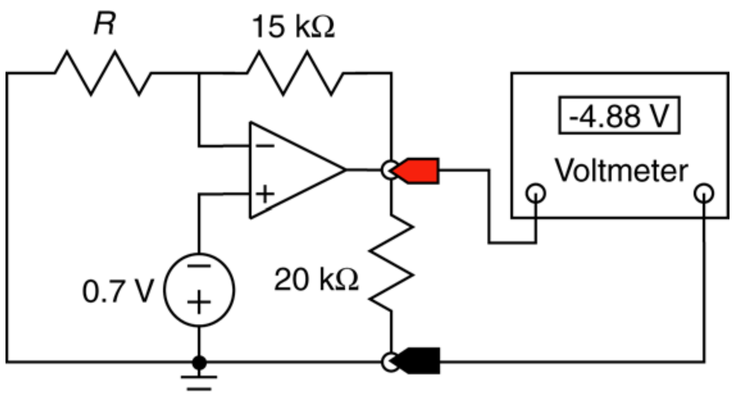

Figure 2 The circuit considered in Example 2.

Solution: Recognize that this circuit is a noninverting amplifier. The noninverting amplifier is described by Figure 6.6-1b in *Introduction to Electric Circuits*. Comparing Figure 2 to Figure 6.6-1b gives

$$v_{in} = -0.7 \text{ V},\; v_{out} = -4.88 \text{ V},\; R_1 = R \text{ and } R_f = 15 \text{ k}\Omega$$

Using this correspondence, the equation given in Figure 6.6-1b to describe the inverting amplifier indicates that

$$-4.88 = \left(1 + \frac{15000}{R}\right)(-0.7)$$

Solving for *R* gives

$$R = 2.5 \text{ k}\Omega$$

Example 3:
Consider the circuit shown in Figure 3. Find the value of voltage measured by the voltmeter. Determine the value of the power supplied by the op amp.

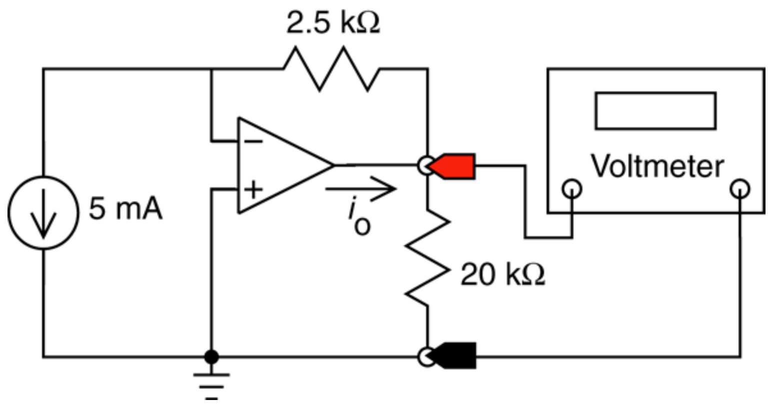

Figure 3 The circuit considered in Example 3.

Solution: Recognize that this circuit is a current-to-voltage converter. The current-to-voltage converter is described by Figure 6.6-1g in *Introduction to Electric Circuits*. Comparing Figure 3 to Figure 6.6-1g gives

$$i_{in} = -5 \text{ mA} \;\text{ and }\; R_{\text{f}} = 2.5 \text{ k}\Omega$$

Also, the voltmeter in Figure 3 measures the voltage labeled as v_{out} in Figure 6.6-1g. Using this correspondence, the equation given in Figure 6.6-1g indicates that the value of the voltage measured by the voltmeter is

$$v_{out} = -\left(2.5\times10^{3}\right)\left(-5\times10^{-3}\right) = 12.5 \text{ V}$$

To calculate the power supplied by the op amp, we first calculate the output current of the op amp, labeled as i_o in Figure 3. To determine the value i_o, apply KCL at the output node of the op amp to get

$$i_o + \frac{0 - v_{out}}{2500} = \frac{v_{out}}{20000}$$

Using v_{out} = 12.5 V gives

$$i_o + \frac{0-(12.5)}{2500} = \frac{12.5}{20000} \quad \Rightarrow \quad i_o = 5.63\times10^{-3} = 5.63 \text{ mA}$$

The power delivered by the op amp is given by

$$v_{out} \times i_o = (12.5)\left(5.63\times10^{-3}\right) = 70.38\times10^{-3} = 70.38 \text{ mW}$$

Example 4:
Consider the circuit shown in Figure 4. Find the value of voltage measured by the voltmeter.

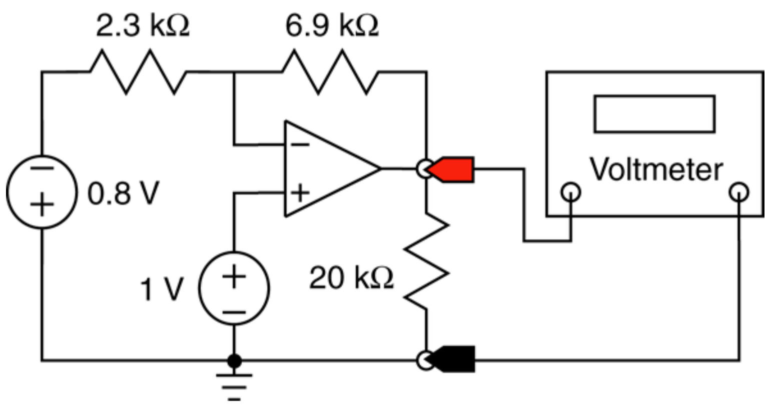

Figure 4 The circuit considered in Example 4.

Solution: The inputs to the circuit in Figure 4 are the voltages of the voltage sources and the output is the voltage measured by the voltmeter. The principle of superposition indicates that the response to two inputs working together can be calculated by determining the response to each input working separately and then adding the separate responses. Figure 5 shows the circuits used to calculate the responses to the inputs working separately.

Recognize that the circuit in Figure 5a is an inverting amplifier. The inverting amplifier is described by Figure 6.6-1a in *Introduction to Electric Circuits*. Comparing Figure 5a to Figure 6.6-1a gives

$$v_{in} = -0.8 \text{ V}, \; v_{out} = v_1, \; R_1 = 2.3 \text{ k}\Omega \text{ and } R_f = 6.9 \text{ k}\Omega$$

Using this correspondence, the equation given in Figure 6.6-1a indicates that the response to the 0.8 V source acting alone is

$$v_1 = \left(-\frac{6900}{2300}\right)(-0.8) = 2.4 \text{ V}$$

Recognize that the circuit in Figure 5b is a noninverting amplifier. The noninverting amplifier is described by Figure 6.6-1b in *Introduction to Electric Circuits*. Comparing Figure 5b to Figure 6.6-1b gives

$$v_{in} = 1.0 \text{ V}, \; v_{out} = v_2, \; R_1 = 2.3 \text{ k}\Omega \text{ and } R_f = 6.9 \text{ k}\Omega$$

Using this correspondence, the equation given in Figure 6.6-1b indicates that the response to the 1.0 V source acting alone is

$$v_2 = \left(1 + \frac{6900}{2300}\right)(1.0) = 4 \text{ V}$$

Finally, the principle of superposition indicates that the value of the voltage measured by the voltmeter is

$$v_1 + v_2 = 2.4 + 4 = 6.4 \text{ V}$$

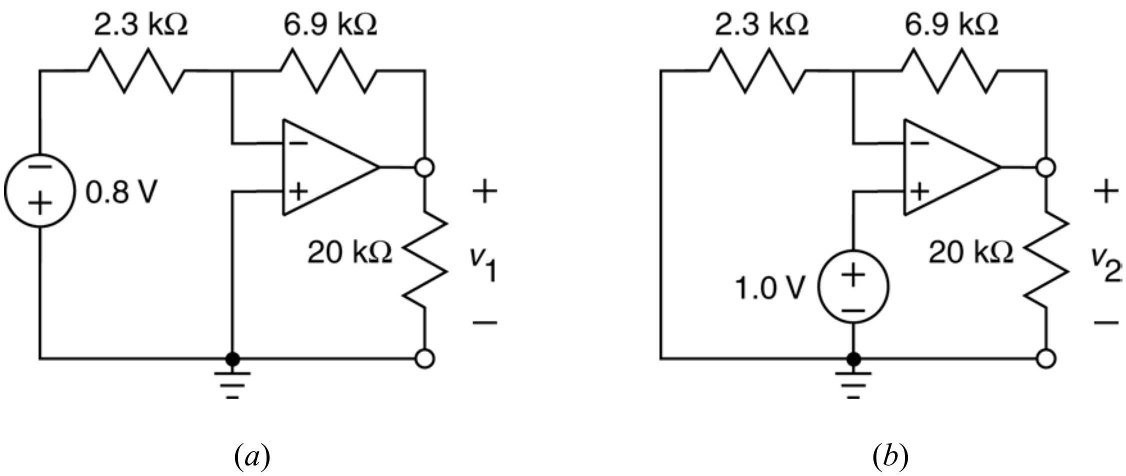

Figure 5 Applying superposition to the circuit shown in Figure 4. (b) The circuit used to calculate the response to the 0.8 V source acting alone and (b) the circuit used to calculate the response to the 1.0 V source acting alone.

Example 5:
Consider the circuit shown in Figure 6. Find the value of voltage measured by the voltmeter.

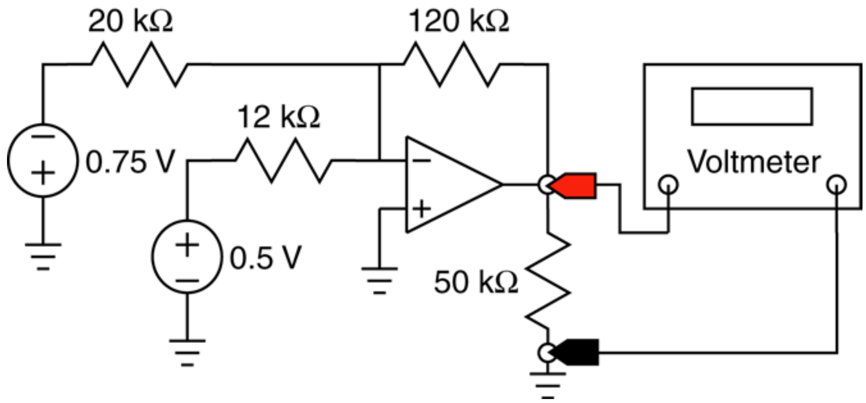

Figure 6 The circuit considered in Example 5.

Solution: Recognize that this circuit is a summing amplifier. The summing amplifier is described by Figure 6.6-1d in *Introduction to Electric Circuits*. Comparing Figure 6 to Figure 6.6-1d gives

$$v_1 = -0.75 \text{ V},\ v_2 = 0.5 \text{ V},\ R_1 = 20 \text{ k}\Omega,\ R_2 = 20 \text{ k}\Omega, \text{ and } R_f = 120 \text{ k}\Omega$$

Also, the voltmeter in Figure 6 measures the voltage labeled as v_{out} in Figure 6.6-1d. Using this correspondence, the equation given in Figure 6.6-1d indicates that the value of the voltage measured by the voltmeter is

$$v_{out} = -\left[\left(\frac{120000}{20000}\right)(-0.75) + \left(\frac{120000}{12000}\right)(0.5)\right] = -0.5 \text{ V}$$