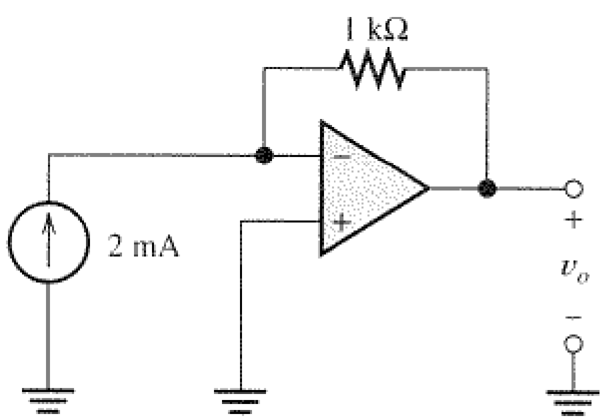
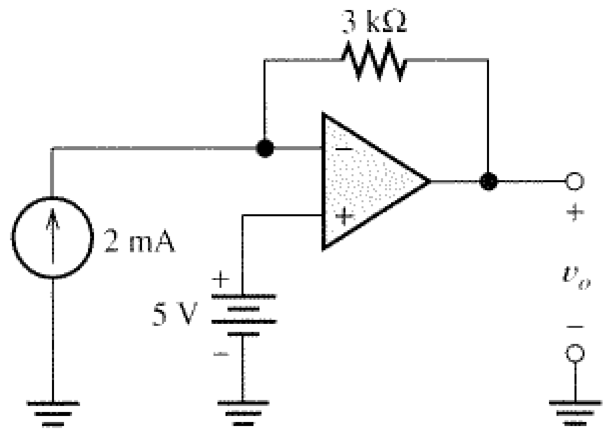
***P14.18.** The voltage follower of Figure 14.12 on page 673 has unity voltage gain so that $v_o = v_{in}$. Why not simply connect the load directly to the source, thus eliminating the op amp? Give an example of a situation in which the voltage follower is particularly good compared with the direct connection.

P14.18* If the source has non-zero series impedance, loading (reduction in voltage) will occur when the load is connected directly to the source. On the other hand, the input impedance of the voltage follower is very high (ideally infinite) and loading does not occur. If the source impedance is very high compared to the load impedance, the voltage follower will deliver a much larger voltage to the load than direct connection.

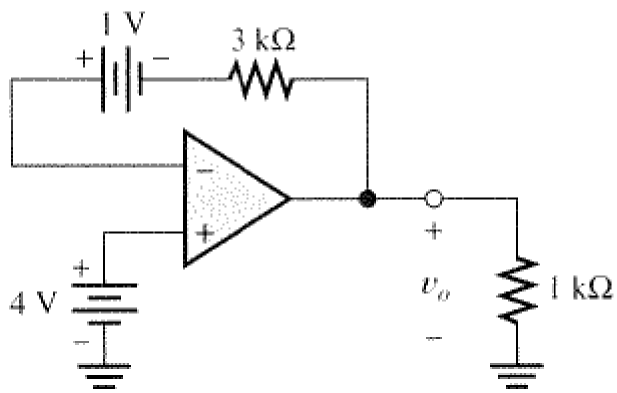
P14.20. For each of the circuits shown in Figure P14.20, assume that the op amp is ideal and find the value of v_o. Each of the circuits has negative feedback, so the summing-point constraint applies.



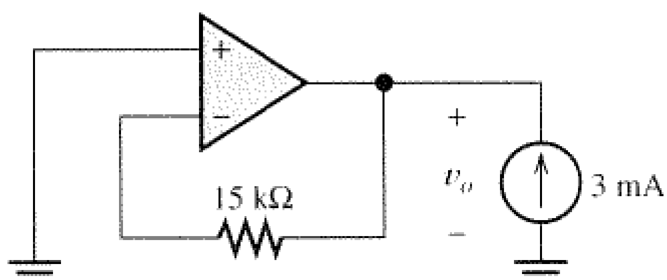
(a)



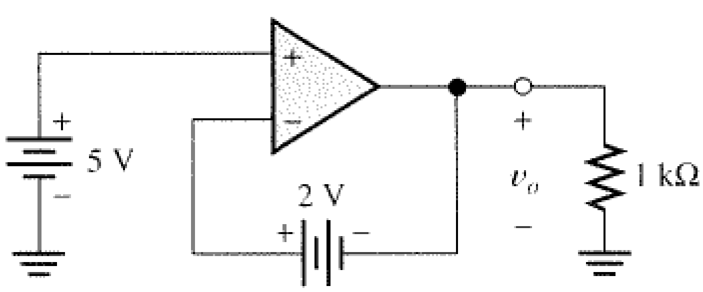
(b)



(c)

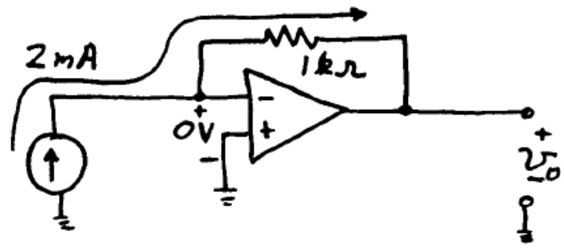


(d)

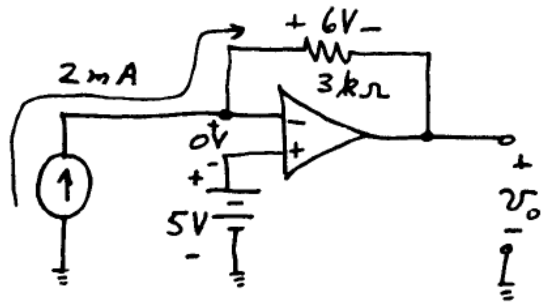


(e)

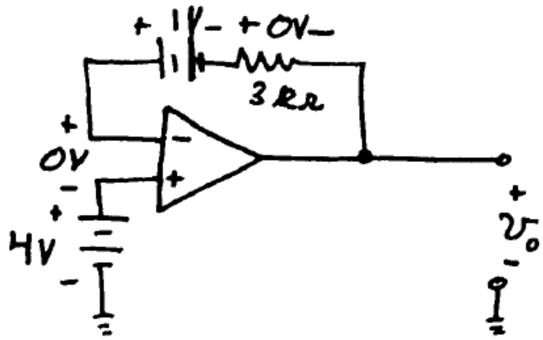
P14.20 (a) $v_o = -(1\,\text{k}\Omega) \times 2\,\text{m}A = -2\,\text{V}$



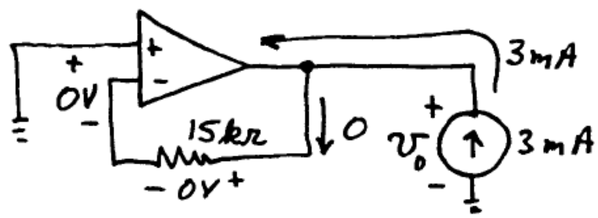
(b) $v_o = -6 + 0 + 5 = -1\,\text{V}$



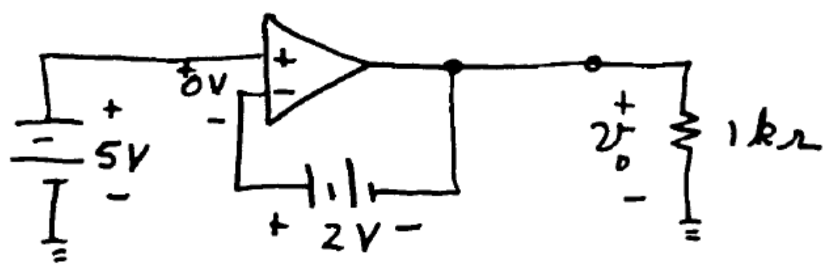
(c) No current flows through the 3-kΩ resistor. Thus $v_o = 0 - 1 + 4 = 3\text{ V}$.



(d) $v_o = 0$

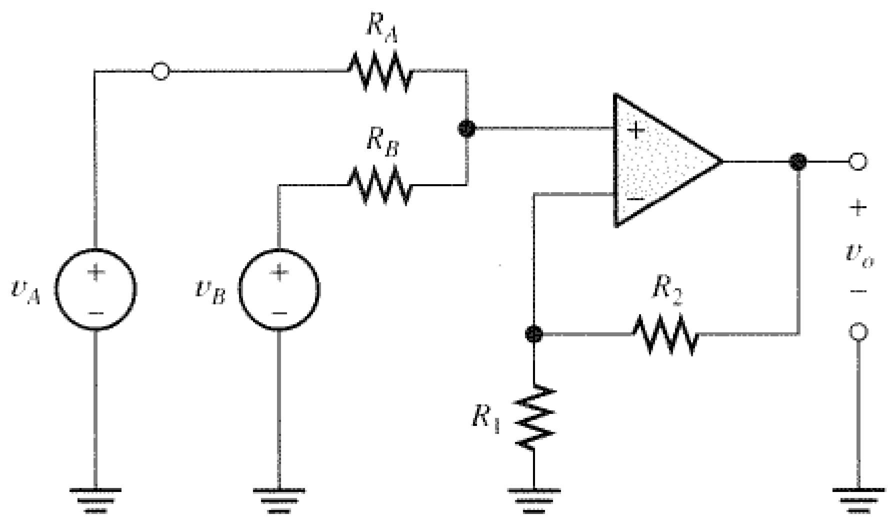


(e)

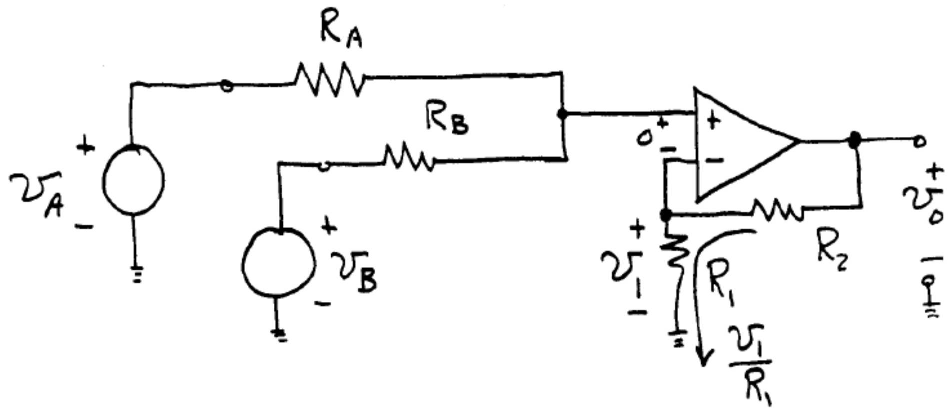


$v_o = 5 - 2 = 3\text{ V}$

***P14.21.** Analyze the ideal op-amp circuit shown in Figure P14.21 to find an expression for v_o in terms of v_A, v_B, and the resistance values.



P14.21* The circuit diagram is:



Writing a current equation at the noninverting input, we have

$$\frac{v_1 - v_A}{R_A} + \frac{v_1 - v_B}{R_B} = 0 \qquad (1)$$

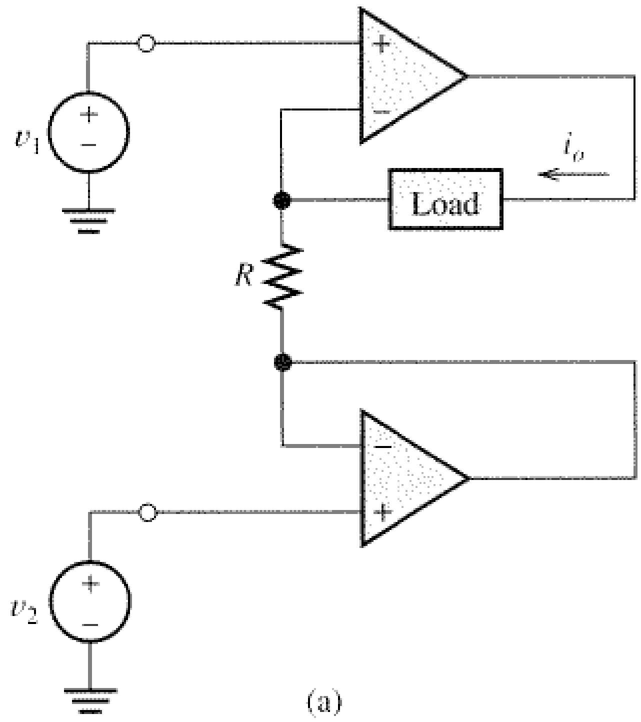
Using the voltage-division principle we can write:

$$v_1 = \frac{R_1}{R_1 + R_2} v_o \qquad (2)$$

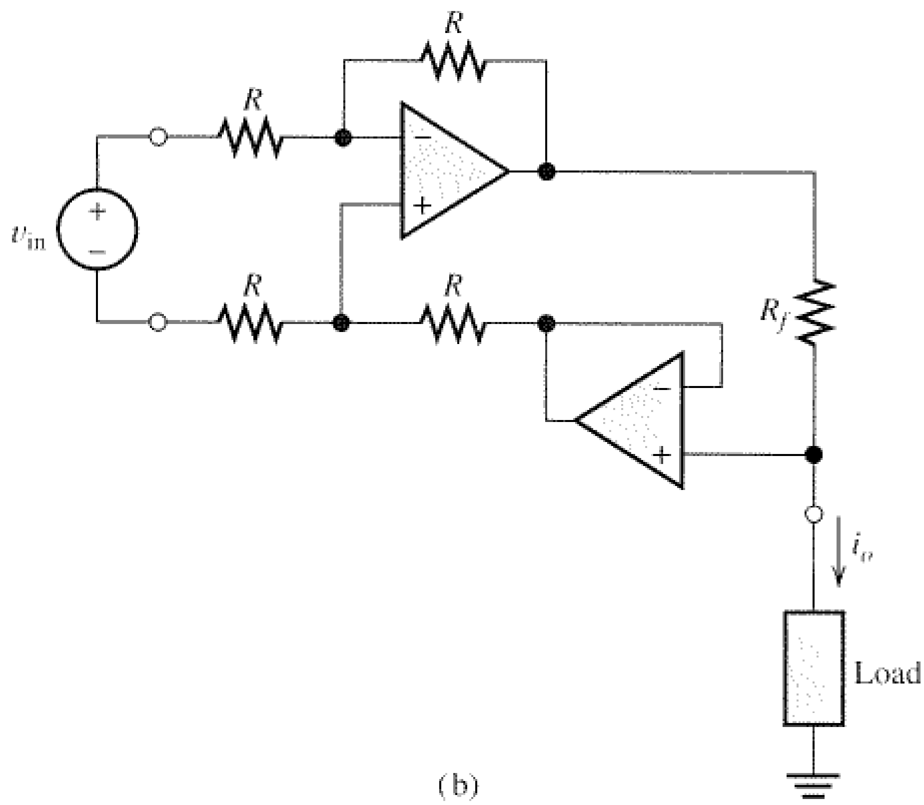
Using Equation (2) to substitute for v_1 in Equation (1) and rearranging, we obtain:

$$v_o = \left(\frac{R_1 + R_2}{R_1} \right) \frac{v_A R_B + v_B R_A}{R_A + R_B}$$

P14.23. Analyze each of the ideal-op-amp circuits shown in Figure P14.23 to find expressions for i_o. What is the value of the output impedance for each of these circuits? Why? [*Note:* The bottom end of the input voltage source is *not* grounded in part (b) of the figure. Thus, we say that this source is *floating*.]

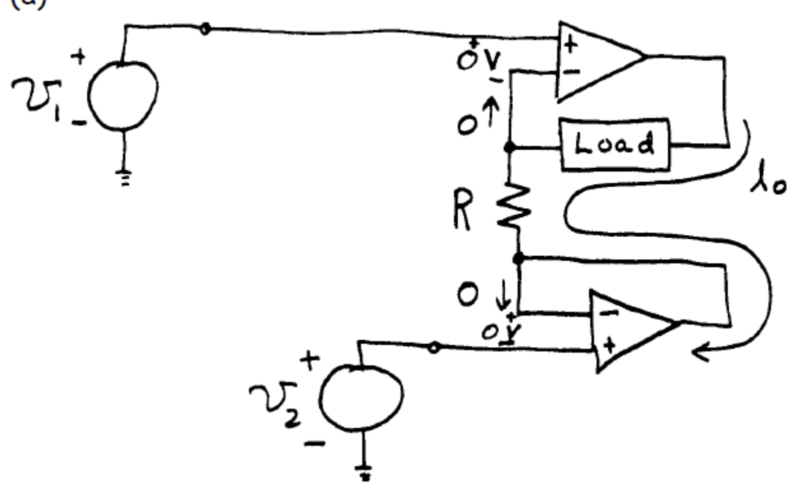


(a)



(b)

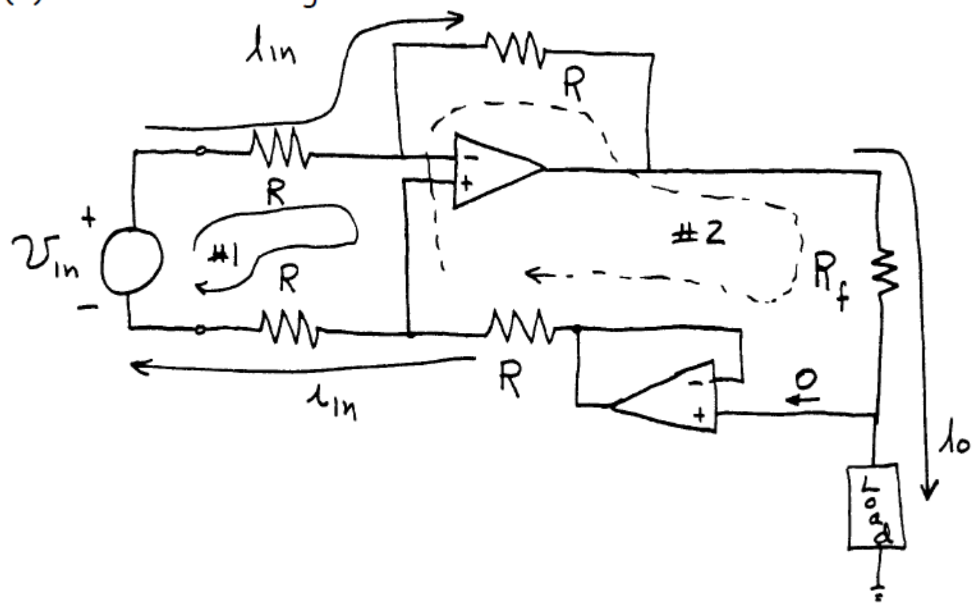
P14.23 (a)



$v_1 = 0 + Ri_o + 0 + v_2 \qquad\qquad i_o = \frac{v_1 - v_2}{R}$

Since i_o is independent of the load, the output impedance is infinite.

(b) The circuit diagram is:



Writing KVL around loop #1, we have $v_{in} = Ri_{in} + 0 + Ri_{in}$

Writing KVL around loop #2, we have $Ri_{in} + R_f i_o + Ri_{in} = 0$

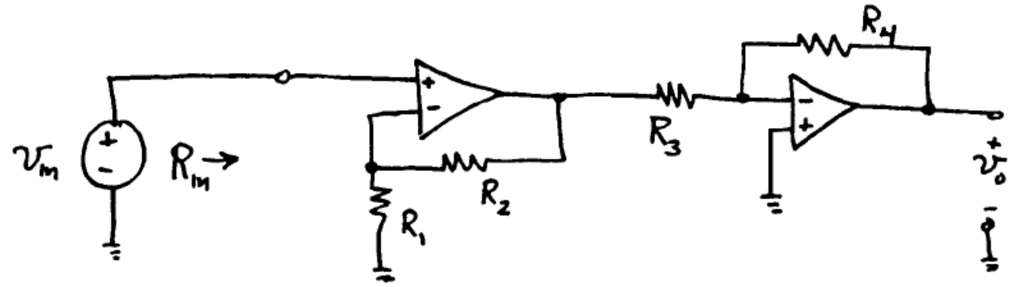
Algebra produces $i_o = -v_{in}/R_f$. Since i_o is independent of the load, the output impedance is infinite.

***P14.36.** Using the components listed in Table P14.36, design an amplifier having a voltage gain of -10 ± 20 percent. The input impedance is required to be as large as possible (ideally, an open circuit). Remember to use practical resistance values. (*Hint:* Cascade a noninverting stage with an inverting stage.)

Table P14.36. Available Parts for Design Problems

Standard 5%-tolerance resistors. (See Appendix B.)
Standard 1%-tolerance resistors. (Don't use these if a 5%-tolerance resistor will do, because 1%-tolerance resistors are more expensive.)
Ideal op amps.
Adjustable resistors (trimmers) having maximum values ranging from 100 Ω to 1 MΩ in a 1–2–5 sequence (i.e., 100 Ω, 200 Ω, 500 Ω, 1 kΩ, etc.). Don't use trimmers if fixed resistors will suffice.

P14.36* To achieve high input impedance and an inverting amplifier, we cascade a noninverting stage with an inverting stage:



The overall gain is:

$$A_v = -\frac{R_1 + R_2}{R_1} \times \frac{R_4}{R_3}$$

Many combinations of resistance values will achieve the given specifications. For example:

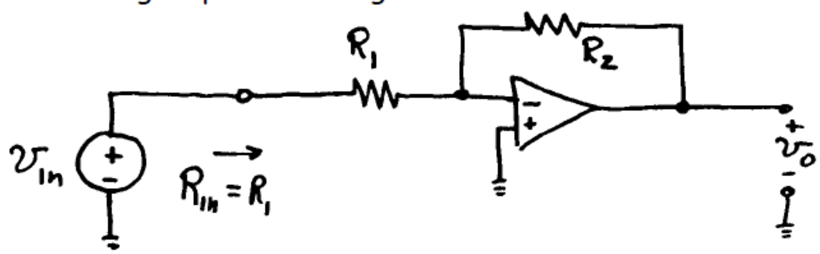
$R_1 = \infty$ and $R_2 = 0$. (Then the first stage becomes a voltage follower.) This is a particularly good choice because fewer resistors affect the overall gain, resulting in small overall gain variations.

R_4 = 100 kΩ, 5% tolerance.

R_3 = 10 kΩ, 5% tolerance.

P14.38. Using the components listed in Table P14.36, design an amplifier having an input impedance of at least 10 kΩ and a voltage gain of **a.** −10 ± 20 percent; **b.** −10 ± 5 percent; **c.** −10 ± 0.5 percent.

P14.38 Use the inverting amplifier configuration:



Pick $R_{2nom} = 10R_{1nom}$ to achieve the desired gain magnitude.
Pick $R_{1nom} > 10$ kΩ to achieve input impedance greater than 10 kΩ.
Pick R_{1nom} and $R_{2nom} < 10$ MΩ because higher values are impractical.

Many combinations of values will meet the specifications. For example:

(a) Use 5% tolerance resistors. R_1 = 100 kΩ and R_2 = 1 MΩ.

(b) Use 1% tolerance resistors. R_1 = 100 kΩ and R_2 = 1 MΩ.

(c) R_2 =1 MΩ 1% tolerance. R_1 = 95.3 kΩ 1% tolerance fixed resistor in series with a 10-kΩ adjustable resistor. After constructing the circuit, adjust to achieve the desired gain magnitude.