SUMMARY

1. An (ideal) operational amplifier is an ideal amplifier with infinite gain. When used in conjunction with negative feedback, the input voltage to an op amp is constrained to be zero volts. The input terminals of an op amp draw no current.
2. Some nonideal voltage sources can be modeled as an ideal voltage source in series with a resistance, and certain nonideal current sources can be modeled as an ideal current source in parallel with a resistance.
3. A voltage source in series with a resistance behaves as a current source in parallel with that resistance, and vice versa.
4. The effect of an arbitrary circuit on a load is equivalent to an appropriate voltage source in series with an appropriate resistance (Thévenin's theorem) or an appropriate current source in parallel with that resistance (Norton's theorem).
5. An arbitrary circuit delivers maximum power to a resistive load R_L when $R_L = R_o$, where R_o is the Thévenin-equivalent (output) resistance of the arbitrary circuit.
6. The response of a circuit having n independent sources equals the sum of the n responses to each individual independent source (the principle of superposition).

PROBLEMS FOR CHAPTER 3

3.1 For the ideal-amplifier circuit shown in Fig. DE3.1 (p. 107), (a) find an expression for v_o in terms of A, R_1, R_2, and v_s; (b) find an expression for v_1 in terms of A, R_1, R_2, and v_s; and (c) find an expression for the current directed out of the output terminal in terms of A, R_1, R_2, and v_s.

3.2 For the op-amp circuit shown in Fig. DE3.2 (p. 110), interchange the 10-kΩ and 20-kΩ resistors. Find (a) v_o; (b) the power absorbed by the op amp.

3.3 For the op-amp circuit given in Fig. DE3.3 (p. 111), find v_o.

3.4 For the op-amp circuit shown in Fig. P3.4, find the ratio v_o/i_s.

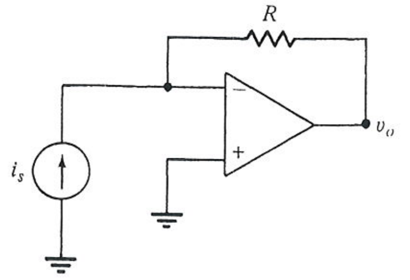

Fig. P3.4

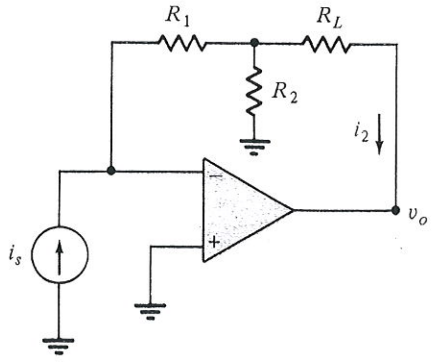

Fig. P3.5

DRILL EXERCISE 3.3

Find v_o for the **difference-amplifier** circuit shown in Fig. DE3.3 when $R_3 = R_1$ and $R_4 = R_2$.

Answer: $\frac{R_2}{R_1}(v_b - v_a)$

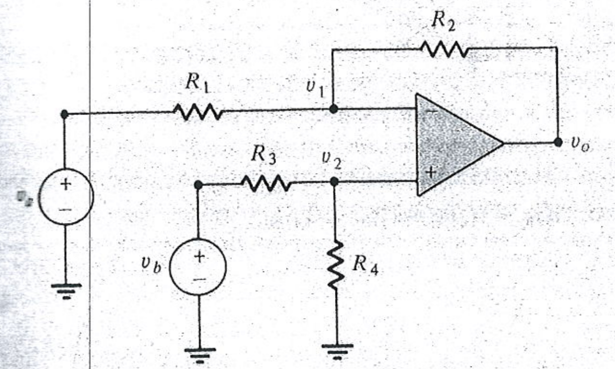

Fig. DE3.3

Analyzing circuits containing two op amps is not much more complicated than analyzing a circuit with a single op amp. As was done for the preceding op-amp circuits, the analytical procedure that is used is nodal analysis. Since a dependent source is connected between an op amp's output and the reference, when employing nodal analysis, we do not apply KCL at the output of an op amp. (After the nodal analysis is done, KCL is used to determine the current coming out of or going into the output terminal of the op amp—if this quantity is to be determined.) Instead, we apply KCL at the appropriate input terminals of op amps and at other nodes of the circuit (if required).

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EXAMPLE 3.3

Consider the circuit shown in Fig. 3.7, which contains two operational amplifiers. Let us determine v_o in terms of the conductances G, G_1, G_2, G_3, G_4, and the applied voltage v_s.

By KCL at the inverting input of the op amp on the left we get

$$G_1 v_s + G_4 v_o = -Gv$$

and, by KCL at the inverting input of the other op amp,

$$G_2 v_s + G_3 v_o = -Gv$$

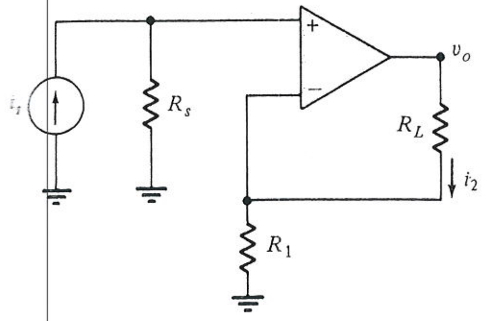

Fig. P3.6

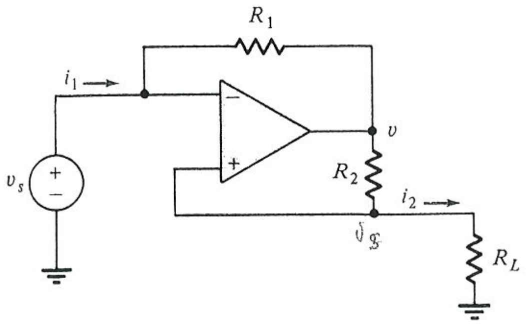

Fig. P3.8

3.5 For the op-amp circuit given in Fig. P3.5, (a) find the ratio v_o/i_s; (b) find the current gain i_2/i_s.

3.6 For the op-amp circuit shown in Fig. P3.6, find v_o/i_s.

3.7 For the op-amp circuit given in Fig. P3.6, find the current gain i_2/i_s.

3.8 For the op-amp circuit shown in Fig. P3.8, find (a) the voltage v; (b) the current gain i_2/i_1.

3.9 For the op-amp circuit given in Fig. P3.9, find the voltage gain v_o/v_s.

3.10 Find the voltage gain v_o/v_s for the op-amp circuit shown in Fig. P3.10.

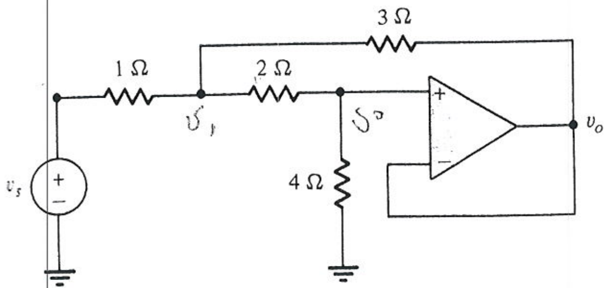

Fig. P3.9

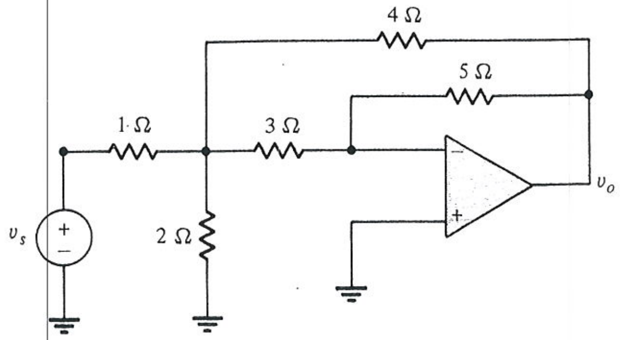

Fig. P3.10