4.84 The circuit shown in Fig. 4-49 responds to the difference of two input signals. Find an expression for $V_o$ and, hence, show that this circuit is a differential amplifier.

Since the operational amplifier is ideal, we have

$$V_+ = V_{+1} - I_R R_1 = V_{+1} - R_1 \frac{V_{+1} - V_o}{R_1 + R_2}$$

and, by voltage division,

$$V_+ = \frac{R_2}{R_1 + R_2} V_{+2} \quad \text{but} \quad V_- = V_+$$

Thus,

$$V_{+1} - R_1 \frac{V_{+1} - V_o}{R_1 + R_2} = \frac{R_2}{R_1 + R_2} V_{+2}$$

Solving for $V_o$ yields $V_o = (R_2/R_1)(V_{+2} - V_{+1}).$

5.76 For the operational amplifier circuit of Fig. 5-74, find $V_o$ by superposition. Note that $V_- = 0.$

Removing the voltages $V_2$ and $V_3$ by short-circuiting them we have

$$V_0' = -\frac{R_4}{R_1} V_1$$

Similarly,

$$V_o'' = -\frac{R_4}{R_2} V_2 \quad \text{and} \quad V_o''' = -\frac{R_4}{R_3} V_3$$

Hence,

$$V_o - V_o' + V_o'' + V_o''' = -\left(\frac{R_4}{R_1} V_1 + \frac{R_4}{R_2} V_2 + \frac{R_4}{R_3} V_3\right)$$

5.77 Find $V_o$ for the operational amplifier circuit shown in Fig. 5-75 by superposition. Given $I_+ = I_- = 0$ and $V_+ = V_-.$

Removing $V_2$ and applying $V_1$ we have

$$V_0' = -\frac{R_2}{R_1} V_1$$

Removing $V_1$ and applying $V_2$ yields (with $I_+ = I_- = 0$ and $V_+ = V_-)$

$$V_o'' = \frac{R_3}{R_1} V_2$$

Hence

$$V_o = V_o' + V_o'' = \frac{R_2}{R_1} (V_2 - V_1)$$
Using Thévenin's theorem, determine the current in the 2-Ω resistor of the network shown in Fig. 4-8a.

Fig. 4-8a

\[ \begin{align*}
5 \times 10 &= (5 + 10 + 3)I \\
I &= \frac{15}{18} = \frac{5}{6} \text{ A}
\end{align*} \]

Hence,

\[ V_{Th} = 20 + 2.5 = 22.5 \text{ V} \]

The circuit to determine \( R_{Th} \) is shown in Fig. 5-7b from which

\[ R_{Th} = \frac{(10 + 5)3}{10 + 5 + 3} = 2.5 \Omega \]

Thus,

\[ I_{2\Omega} = \frac{V_{Th}}{R_{Th} + 2} = \frac{22.5}{2.5 + 2} = 5 \text{ A} \]

5.17 Calculate the current in the 10-Ω resistor of the circuit shown in Fig. 4-23a by Thévenin's theorem.

Fig. 4-23a

\[ \begin{align*}
V_{5A} &= 5 \times 20 = 100 \text{ V} \\
50 - V_{Th} &= 100 \\
V_{Th} &= -50 \text{ V}
\end{align*} \]

Or

From Fig. 5-18b,

\[ R_{Th} = 20 + 20 = 40 \Omega \]

\[ I_{10 \Omega} = \frac{V_{Th}}{10 + R_{Th}} = \frac{-50}{10 + 40} = -1 \text{ A} \]
The circuit of Fig. 5-60a contains only a dependent source. Obtain its Norton equivalent.

First we short-circuit $AB$ as shown in Fig. 5-60b, from which

$$\frac{V}{10} + 2I + \frac{V}{4} = 0 \quad \text{or} \quad \frac{V}{10} + 2\left(-\frac{V}{10}\right) + \frac{V}{4} = 0 \quad \text{or} \quad V = 0 \quad \text{and} \quad I_{sc} = 0$$

To find $R_N$, we refer to Fig. 5-60c where

$$R_N = \frac{V_0}{I_0}$$

And at node 1,

$$\frac{V}{10} + 2\left(-\frac{V}{10}\right) + \frac{V - V_0}{4} = 0 \quad \text{or} \quad V = \frac{5}{3}V_0$$

At node 2,

$$I_0 = \frac{V_0}{5} + \frac{V_0 - V}{4} = \frac{V_0}{5} + \frac{V_0}{4} - \frac{5V_0}{12} = \frac{2V_0}{60} \quad \text{or} \quad R_N = \frac{V_0}{I_0} = 30 \Omega$$

Hence we obtain the Norton circuit of Fig. 5-60d.
First, we calculate $V_{OC}$ from Fig. 5-39b. Thus,

$$18 + V_x + 2V_x - V_{OC} = 0$$

But

$$V_x = 3 \times 1 = 3 \text{ V}$$

or

$$V_{OC} = V_{Th} = 27 \text{ V}$$

From Fig. 5-39c,

$$18 + V_x + 2V_x = 0$$

or

$$18 + 3V_x = 0$$

But

$$\frac{V_x}{l} = 3 - I_{sc} \quad \text{or} \quad I_{sc} = 9 \text{ A}$$

Thus,

$$R_{Th} = \frac{V_{OC}}{I_{sc}} = \frac{27}{9} = 3 \Omega$$

Hence

$$I_l = \frac{27}{3 + 6} = 3 \text{ A}$$

15.144 The switch in the circuit of Fig. 15-44 is moved from 1 to 2 at $t = 0$. Find $v_c$.

1

$$v_c(0^-) = v_c(0^+) = 100 \text{ V} \quad v_c(\infty) = -50 \text{ V}$$

and

$$v_c = A + Be^{-t/RC} \quad \frac{1}{RC} = 200$$

Applying the above conditions to $v_c$ yields

$$A = v_c(\infty) = -50 \quad B = v_c(0^+) - A = 100 + 50 = 150$$

Thus, $v_c = -50 + 150e^{-200t}$ V.
In the circuit of Fig. 15-41, the coil has a 10-Ω resistance and a 6-H inductance. If $R = 14 \, \Omega$, $V = 24 \, V$, and the switch is opened at $t = 0$, determine $i$.

**Forced response,**

$$i_f = \frac{24}{10 + 14} = 1 \, A$$

**Natural or source-free response,**

$$i_n = Ae^{-\frac{R}{L}t} = Ae^{-4t} \quad \text{or} \quad i = 1 + Ae^{-4t}$$

$h(0^+) = \frac{V_0}{R} = 2.4 \, A$ yields $A = 2.4 - 1 = 1.4$. Thus, $i = 1 + 1.4e^{-4t} \, A$.

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At $t = 0$ the switch in Fig. 15-47 is moving from position 1 to 2. Solve for $i$.

With switch at position 1, the capacitor is charged to the battery voltage, 20 V. Since $RC = (500 \times 10^3)(500 \times 10^{-6}) = 250 \, s$,

$$v_C = V_0e^{-t/RC} = 20e^{-t/250}$$

$$i_C = C \frac{dv_C}{dt} = (500 \times 10^{-6})[20(-250)e^{-t/250}] = -40e^{-t/250} \, \mu A$$