analysis or design of complex OP AMP circuits can be based on these building blocks provided the interconnections are made between the put of one to the input of another.

- Important applications of OP AMPs include digital-to-digital conve transducer interface circuits, and comparator circuits.

PROBLEMS

OBJECTIVE 4–1 LINEAR ACTIVE CIRCUITS (SECTS. 4–1, 4–2)

Given a circuit containing linear resistors, dependent sources, and independent sources, find selected output signal variables, input-output relationships, or input-output resistances.
See Examples 4–2, 4–3, 4–4, 4–5, 4–6, 4–7, 4–8 and Exercises 4–1, 4–2, 4–3, 4–5, 4–6

4–1 Find the voltage gain v_O/v_S and current gain i_O/i_x in Figure P4–1 for $r = 4\ \text{k}\Omega$.

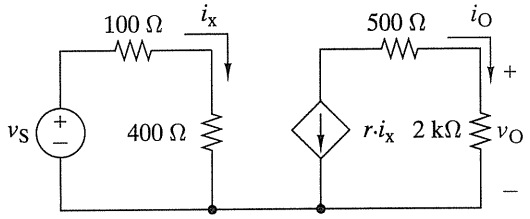

FIGURE P4–1

4–2 Find the voltage gain v_O/v_1 and the current gain i_O/i_S in Figure P4–2. For $i_S = 2\ \text{mA}$, find the power supplied by the input current source and the power delivered to the 2-kΩ load resistor.

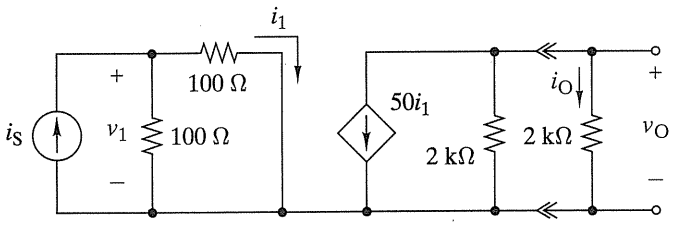

FIGURE P4–2

4–3 Find the voltage gain v_O/v_S and current gain i_O/i_x in Figure P4–3 for $g = 10^{-2}$ S.

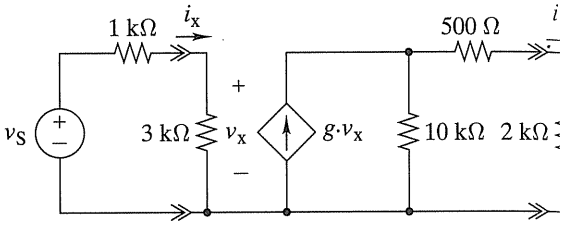

FIGURE P4–3

4–4 Find the voltage gain v_O/v_S and current gain i Figure P4–4.

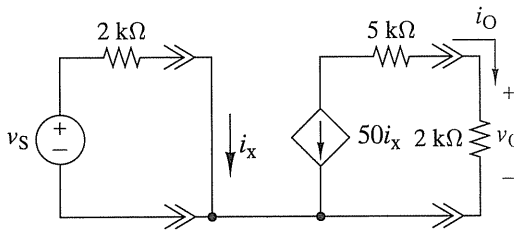

FIGURE P4–4

4–5 Find the current gain i_O/i_S in Figure P4–5.

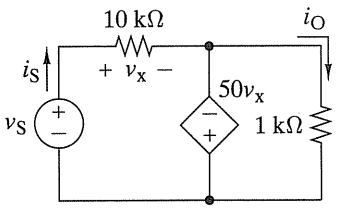

FIGURE P4–5

4–6 Find an expression for the current gain i_O/i_S in P4–6. *Hint:* Apply KCL at node A.

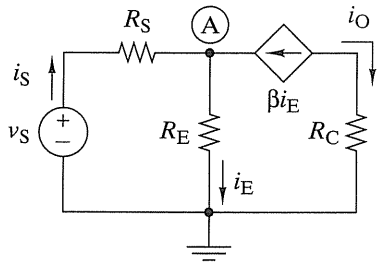

FIGURE P4–6

4–7 Find the voltage v_O in Figure P4–7.

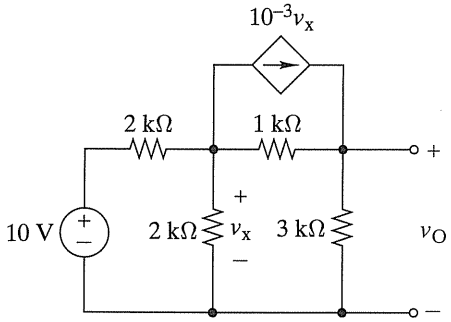

FIGURE P4–7

4–8 Find an expression for the current gain i_O/i_S in Figure P4–8.

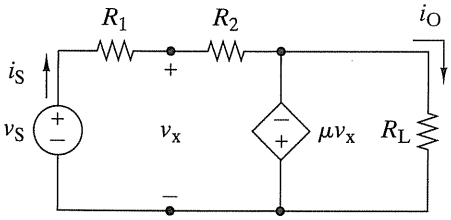

FIGURE P4–8

4–9 Find an expression for the voltage gain v_O/v_S in Figure P4–9.

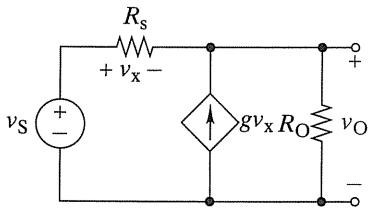

FIGURE P4–9

4–10 Find an expression for the voltage gain v_O/v_S in Figure P4–10.

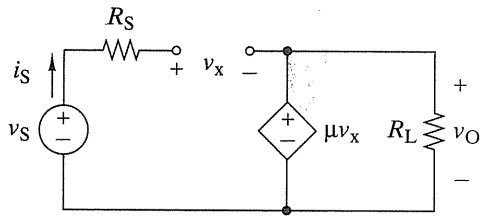

FIGURE P4–10

4–11 Find an expression for the voltage gain v_O/v_S in Figure P4–11.

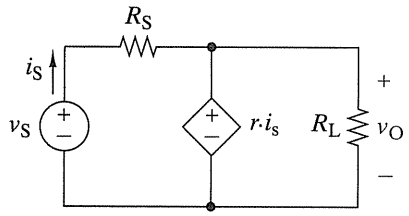

FIGURE P4–11

4–12 Find R_{IN} in Figure P4–12.

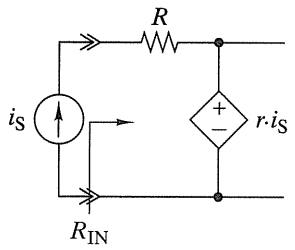

FIGURE P4–12

4–13 Find R_{IN} in Figure P4–13.

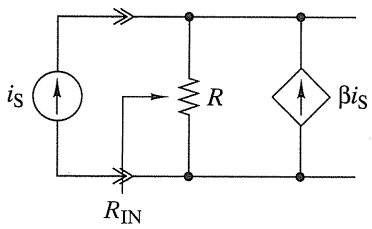

FIGURE P4–13

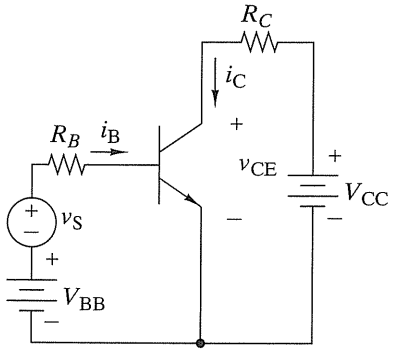

FIGURE P4–20

OBJECTIVE 4–3 OP AMP CIRCUIT ANALYSIS (SECTS. 4–4, 4–5)

Given a circuit consisting of linear resistors, OP AMPs, and independent sources, find selected output signals or input-output relationships.
See Examples 4–13, 4–14, 4–16, 4–17, 4–18, 4–19 and Exercises 4–10, 4–11, 4–12, 4–13, 4–15

4–21 Find v_O in terms of v_S in Figure P4–21.

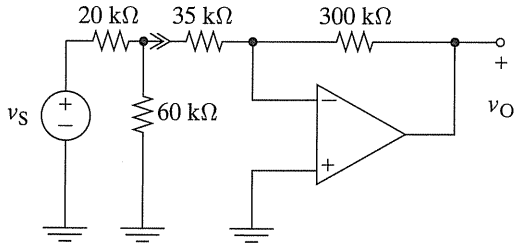

FIGURE P4–21

4–22 What is the range of the gain v_O/v_S in Figure P4–22?

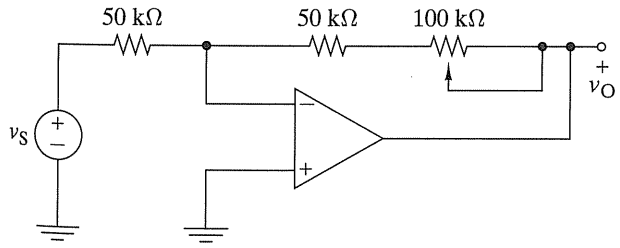

FIGURE P4–22

4–23 **(a)** Find v_O in terms of v_S in Figure P4–23.
(b) Find i_O for v_S = 1.5 V.

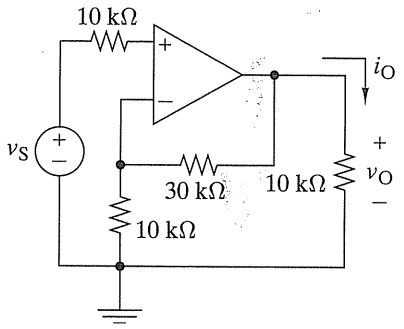

FIGURE P4–23

4–24 **(a)** Find v_O in terms of v_S in Figure P4–24.
(b) Find i_O for v_S = 2 V.

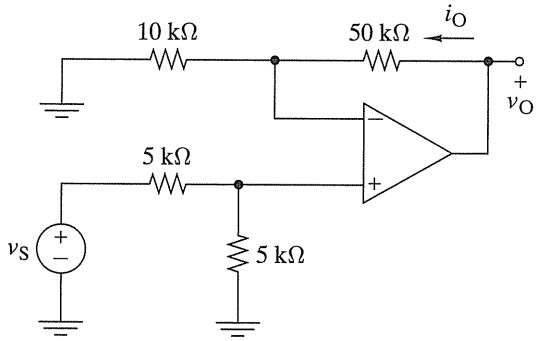

FIGURE P4–24

4–25 What is the gain v_O/v_S in Figure P4–25 when the switch is in position 1? Repeat for positions 2 and 3.

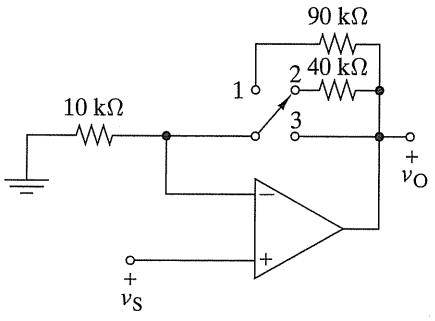

FIGURE P4–25

4–26 Find v_O in terms of the inputs v_1 and v_2 in Figure P4–26.

PROBLEMS

OBJECTIVE 5–1 BASIC WAVEFORMS (SECTS. 5–2, 5–3, 5–4)

Given an equation, graph, or word description of a linear combination of step, ramp, exponential, or sinusoid waveforms:
(a) Construct an alternative description of the waveform.
(b) Find the parameters or properties of the waveform.
(c) Construct new waveforms by summing, integrating, or differentiating the given waveform.

See Examples 5–1, 5–2, 5–3, 5–5, 5–6, 5–7, 5–8, 5–9 and Exercises 5–1, 5–2, 5–3, 5–4, 5–5, 5–6, 5–7

5–1 Sketch the following waveforms:

(a) $v_1(t) = -2u(t+1) + 4u(t-1)$ V

(b) $v_2(t) = u(t+2) - 2u(t)$ V

(c) $v_3(t) = \int_{-\infty}^{t} v_1(x)\,dx$

(d) $v_4(t) = \int_{-\infty}^{t} v_2(x)\,dx$

5–2 Sketch the following waveforms:

(a) $v_1(t) = 1 - u(t) - 2u(t-1)$ V

(b) $v_2(t) = -u(t+3) + 3u(t+1) - 2u(t)$ V

5–3 Sketch the following waveforms:

(a) $v_1(t) = -2r(t+1) + 2r(t-1)$ V

(b) $v_2(t) = r(t+1) - 2r(t-1) + r(t-3)$ V

(c) $v_3(t) = \dfrac{dv_1(t)}{dt}$

(d) $v_4(t) = \dfrac{dv_2(t)}{dt}$

5–4 Express the following signals as a sum of singularity functions.

(a) $v_1(t) = \begin{cases} 2 & t < 1 \\ -5 & 1 \le t < 2 \\ 0 & 2 \le t \end{cases}$

(b) $v_2(t) = \begin{cases} 0 & t < 0 \\ -4t & 0 \le t < 2 \\ -12 + 2t & 2 \le t < 6 \\ 0 & 6 \le t \end{cases}$

5–5 Express the waveforms in Figure P5–5 as a sum of singularity functions.

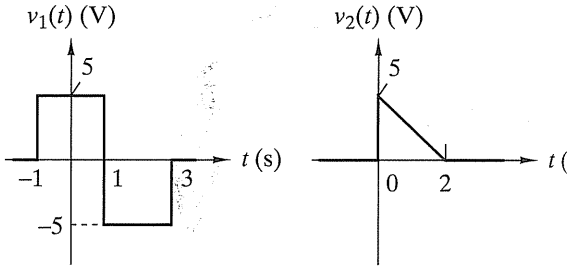

FIGURE P5–5

5–6 Write expressions for the derivatives of the waveforms in Figure P5–5.

5–7 A waveform $v(t)$ is zero for $t < 0$, rises linearly to 1 at $t = 2$ s, remains at 10 V until $t = 4$ s, and abruptly d to zero thereafter. Express the waveform as a sum of gularity functions.

5–8 Sketch the following exponential waveforms. Find amplitude and time constant of each waveform.

(a) $v_1(t) = [2\,e^{-10t}]u(t)$ V

(b) $v_2(t) = [10\,e^{-t/2}]u(t-1)$ V

(c) $v_3(t) = [5e^{-2(t-1)}]u(t-1)$ V

(d) $v_4(t) = [-10\,e^{-t/20}]u(t)$ V

5–9 Write expressions for the derivative ($t > 0$) and inte (from 0 to t) of the exponential waveform $v($ $[0.5e^{-20t}]u(t)$ V.

5–10 An exponential waveform decays to 50% of its in ($t = 0$) amplitude in 5 ms. Find the time constant of waveform.

5–11 The amplitude of an exponential waveform is 5 $t = 0$ and 3.5 V at $t = 3$ ms. What is its amplitud $t = 6$ ms?

5–12 Construct an exponential waveform that fits enti within the unshaded region in Figure P5–12.

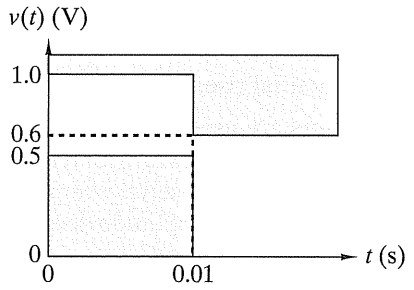

FIGURE P5–12

5–13 By direct substitution, show that the exponential fu tion $v(t) = V_A e^{-\alpha t}$ satisfies the following first-order dif ential equation.

$$\frac{dv(t)}{dt} + \alpha v(t) = 0$$

5–14 Find the period, frequency, amplitude, time shift, and phase angle of the following sinusoids:
(a) $v_1(t) = 10\cos(500\pi t) - 10\sin(500\pi t)$ V
(b) $v_2(t) = -30\cos(2000\pi t) + 20\sin(2000\pi t)$ V

5–15 Find the amplitude and phase angle of the derivative of each sinusoid in Problem 5–14.

5–16 Write an expression for the sinusoid in Figure P5–16. What are the phase angle and time shift of the waveform?

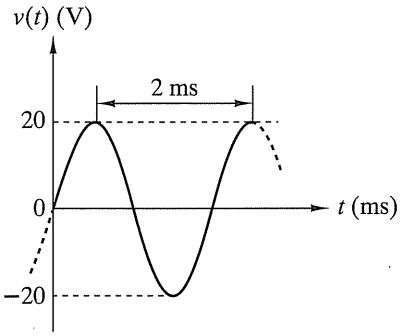

FIGURE P5–16

5–17 Find the Fourier coefficients, cyclic frequency, and radian frequency of the following sinusoids:
(a) $v_1(t) = 20\cos(500\pi t + 180°)$ V
(b) $v_2(t) = 20\cos(500\pi t - 90°)$ V

5–18 Find the sum of the two sinusoids in Problem 5–17.

5–19 Find the Fourier coefficients, cyclic frequency, and radian frequency of the following sinusoids:
(a) $v_1(t) = 30\cos(2\pi 400t + 30°)$ V
(b) $v_2(t) = 20\cos(2000\pi t - 60°)$ V

5–20 Find the time shift of each sinusoid in Problem 5–19.

OBJECTIVE 5–2 COMPOSITE WAVEFORMS (SECT. 5–5)

Given an equation, graph, or word description of a composite waveform:
(a) Construct an alternative description of the waveform.
(b) Find the parameters or properties of the waveform.
(c) Find new waveforms by integrating, or differentiating the given waveform.
See Examples 5–10, 5–11, 5–12, 5–13, 5–14, 5–15 and Exercises 5–8, 5–9

5–21 Sketch the following composite waveforms. What are the maximum and minimum values of each waveform?
(a) $v_1(t) = 10[1 - e^{-5t}]u(t)$ V
(b) $v_2(t) = 20[e^{-5t} - e^{-10t}]u(t)$ V

5–22 Sketch the following composite waveforms. What are the maximum and minimum values of each waveform?
(a) $v_1(t) = 20 - 10\sin(10\pi t)$ V
(b) $v_2(t) = 10[e^{-5t} + \sin(10\pi t)]u(t)$ V

5–23 Sketch the damped ramp $v(t) = 20\,te^{-5t}u(t)$. Find the maximum value of the waveform and the time at which it occurs.

5–24 The value of the waveform $v(t) = (V_A - V_B\,e^{-\alpha t})u(t)$ is 5 V at $t = 0$, 8 V at $t = 5$ ms, and approaches 12 V as $t \to \infty$. Find V_A, V_B, and α then sketch the waveform.

5–25 Write an expression for the composite sinusoidal waveform in Figure P5–25.

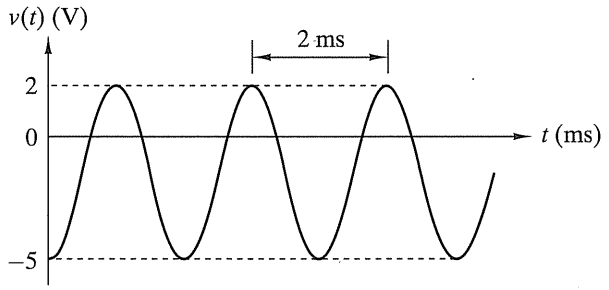

FIGURE P5–25

5–26 A waveform of the form $v(t) = 6 - 10\sin(\beta t)$ periodically reaches a minimum every 4 ms. Find the values of V_{max}, V_{min}, and β; then sketch the waveform.

5–27 Write an expression for the composite exponential waveform in Figure P5–27.

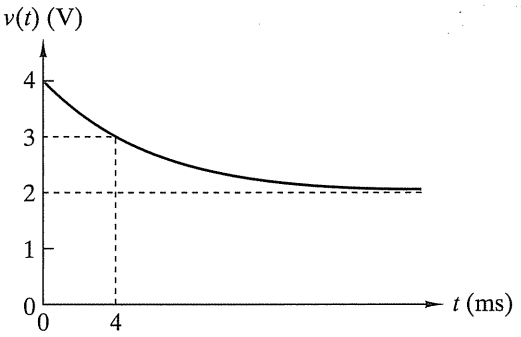

FIGURE P5–27

5–28 Sketch the double exponential $v(t) = 30(e^{-20t} - e^{-100t})u(t)$. Find the maximum value of the waveform and the time at which it occurs.

5–29 Write an expression for the damped sine waveform in Figure P5–29.