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

- Important applications of OP AMPs include digital-to-digital converters, 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 $r = 4\ \text{k}\Omega$.

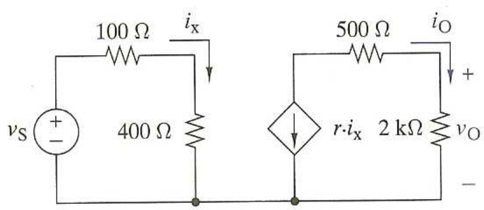


FIGURE P4–1

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

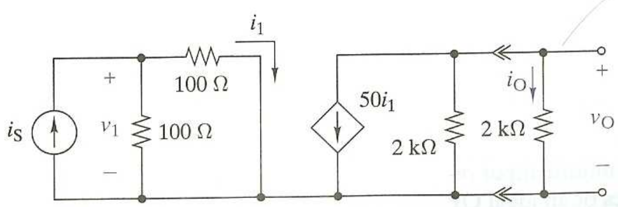


FIGURE P4–2

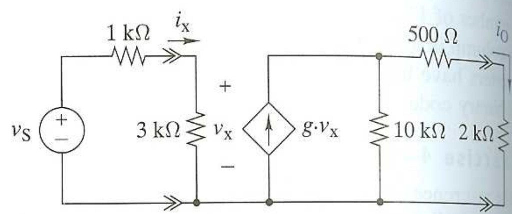


FIGURE P4–3

4–4 Find the voltage gain v_O/v_S and current gain i_O/i_x in Figure P4–4.

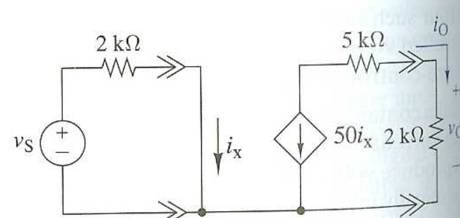


FIGURE P4–4

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

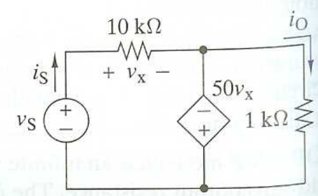


FIGURE P4–5

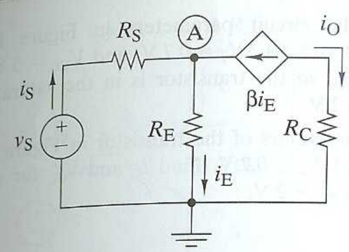


FIGURE P4–6

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

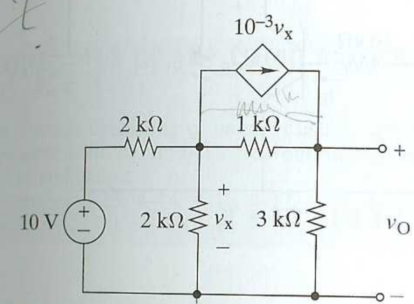


FIGURE P4–7

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

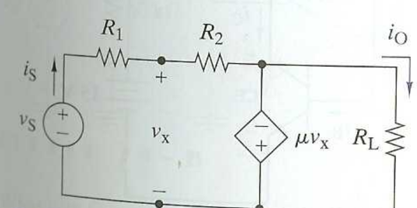
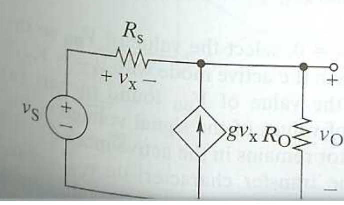


FIGURE P4–8

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



4–10 Find ... P4–10.

FI...

4–11 Find ... P4–11.

4–12 Find ...

4–13 Find ...

4–14 Find the Thévenin equivalent circuit seen by the load in Figure P4–14.

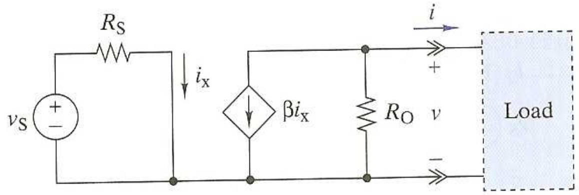


FIGURE P4–14

4–15 Find the Norton equivalent circuit seen by the load in Figure P4–15.

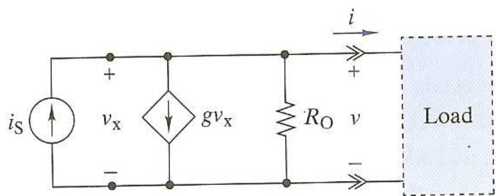
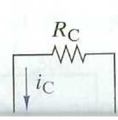


FIGURE P4–15

OBJECTIVE 4–2 TRANSISTOR CIRCUITS (SECT. 4–3)

Given a linear resistive circuit with one transistor:
(a) Find the transistor operating mode and outputs i_C and v_{CE}.
(b) Select circuit parameters to obtain a specified operating mode or output characteristics.
See Examples 4–9, 4–10, 4–11 and Exercises 4–7, 4–8

4–16 The circuit parameters in Figure P4–16 are R_B = 50 kΩ, R_C = 3 kΩ, β = 100, V_γ = 0.7 V, and V_{CC} = 15 V. Find i_C and v_{CE} for v_S = 2 V. Repeat for v_S = 5 V.



4–17 **D** The circuit parameters in Figure P4–16 are R_C = 3 kΩ, β = 50, V_γ = 0.7 V, and V_{CC} = 5 V. Select a value of R_B so the transistor is in the saturation mode when $v_S \geq 2$ V.

4–18 The parameters of the transistor in Figure P4–18 are β = 50 and V_γ = 0.7 V. Find i_C and v_{CE} for v_S = 0.8 V. Repeat for v_S = 2 V.

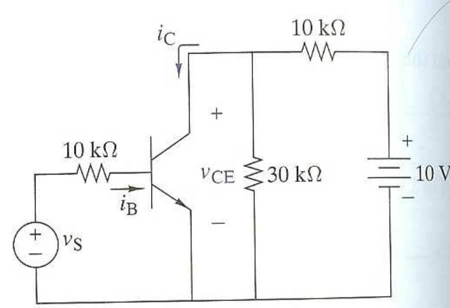


FIGURE P4–18

4–19 In Figure P4–19 the transistor parameters are β = 15[...] and V_γ = 0.7 V. Find i_C and v_{CE}.

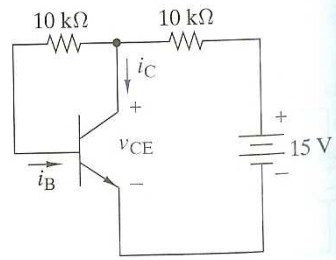


FIGURE P4–19

4–20 The input in Figure P4–20 is a series connection of a [...] source V_{BB} and a signal source v_S. The circuit parame[ters] are R_B = 500 kΩ, R_C = 5 kΩ, β = 100, V_γ = 0.7 V, [and] V_{CC} = 15 V.
(a) With v_S = 0, select the value of V_{BB} so that the tr[...]

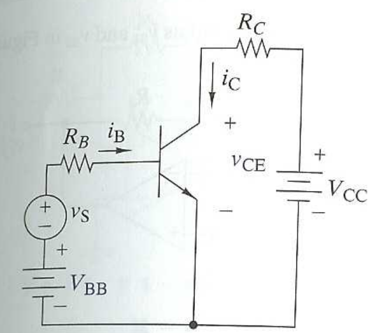


FIGURE P4–20

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.

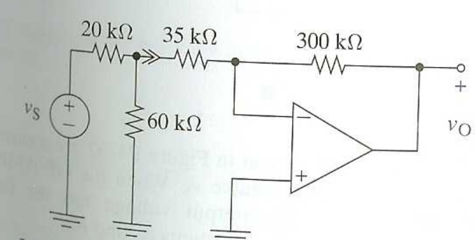
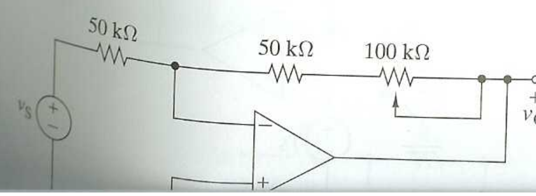


FIGURE P4–21

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



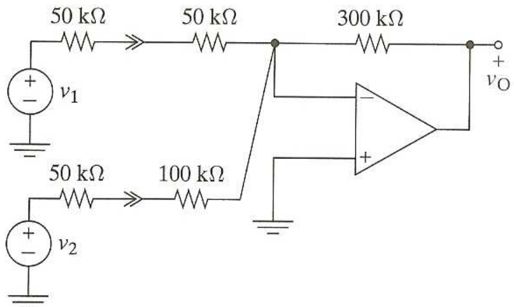


FIGURE P4–26

4–27 The input-output relationship for a three-input inverting summer is

$$v_O = -[v_1 + 2v_2 + 5v_3]$$

The resistance of the feedback resistor is 50 kΩ and the supply voltages are $V_{CC} = \pm 15$ V.

(a) Find the values of the input resistors R_1, R_2, and R_3.

(b) For $v_2 = 0.5$ V and $v_3 = -1$ V, find the allowable range of v_1 for linear operation.

4–28 Find v_O in terms of the inputs v_1 and v_2 in Figure P4–28.

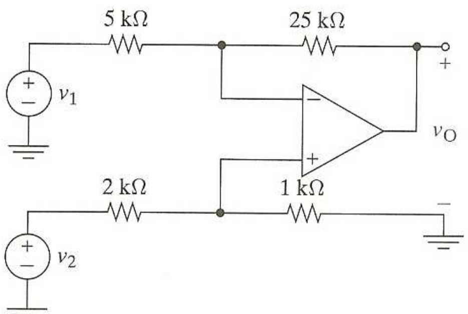
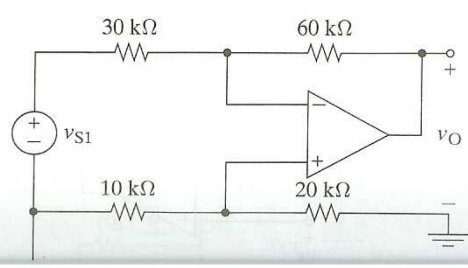


FIGURE P4–28

4–29 Find v_O in terms of the inputs v_{S1} and v_{S2} in Figure P4–29.



4–30 Find v_O in terms of the inputs v_{S1} and v_{S2} in Figure P4–30.

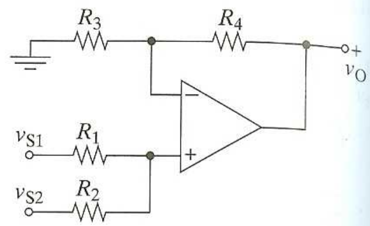


FIGURE P4–30

4–31 **E** It is claimed that $v_O = v_S$ when the switch is closed in Figure P4–31 and that $v_O = -v_S$ when the switch is open. Prove or disprove this claim.

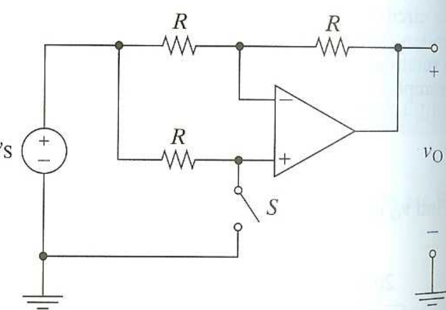


FIGURE P4–31

4–32 The inputs to the circuit in Figure P4–32 are a current source i_S and a voltage source v_S. When the OP AMP is in its linear range, the output voltage has the form $v_O = K_1 v_S + K_2 i_S$. Find the constants K_1 and K_2.

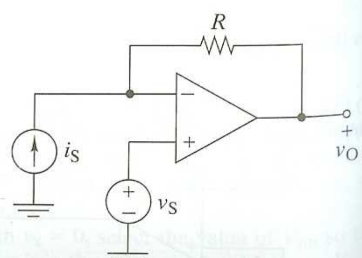


FIGURE P4–32

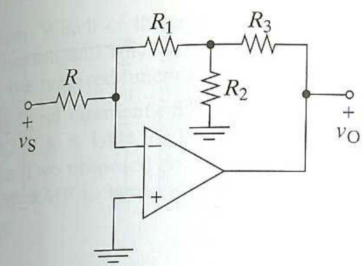


FIGURE P4–33

4–34 Use node-voltage analysis in Figure P4–34 to show that $i_O = -v_S/2R$ regardless of the load. That is, show that the circuit is a voltage-controlled current source.

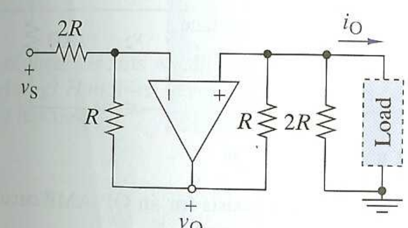


FIGURE P4–34

4–35 Find v_O in terms of the inputs v_{S1}, v_{S2}, and v_{S3}, in Figure P4–35.

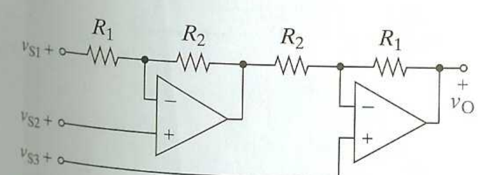
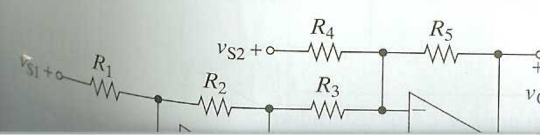


FIGURE P4–35

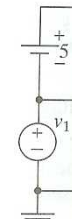
4–36 Find v_O in terms of the inputs v_{S1} and v_{S2} in Figure P4–36.



4–37

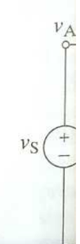
FIG

4–38



FIG

4–39



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t (b) by ap-
ormation in
t (a).

f(t) in Fig-

to find the
l in part (a).
t (b) by ap-
ormation in
t (a).

OBJECTIVE 9–2 INVERSE TRANSFORMS (SECTS. 9–4, 9–5)

Find the inverse transform of a given Laplace transform using partial-fraction expansion or basic transform properties and pairs.
See Examples 9–11, 9–12, 9–13, 9–14 and Exercises 9–7, 9–8, 9–9, 9–10, 9–11, 9–12, 9–13, 9–14

9–16 Find the inverse Laplace transforms of the following functions:

(a) $F_1(s) = \dfrac{s + 20}{s(s + 10)}$

(b) $F_2(s) = \dfrac{s^2 + 10s + 10}{s(s + 10)}$

9–17 Find the inverse Laplace transforms of the following functions:

(a) $F_1(s) = \dfrac{2(s + 5)}{s(s + 10)}$

(b) $F_2(s) = \dfrac{s^2}{(s + 5)(s + 10)}$

9–18 Find the inverse Laplace transforms of the following functions:

(a) $F_1(s) = \dfrac{20(s + 20)}{(s + 10)^2 + 400}$

(b) $F_2(s) = \dfrac{20(s - 20)}{(s + 10)^2 + 400}$

9–19 Find the inverse Laplace transforms of the following functions and sketch their waveforms for $\beta > 0$:

(a) $F_1(s) = \dfrac{\beta(s + \beta)}{s(s^2 + \beta^2)}$

(b) $F_2(s) = \dfrac{s(s + \beta)}{s^2 + \beta^2}$

9–20 Find the inverse Laplace transforms of the following functions:

(a) $F_1(s) = \dfrac{\alpha^2}{s^2(s + \alpha)}$

(b) $F_2(s) = \dfrac{\alpha^2}{s(s + \alpha)^2}$

9–21 Find the inverse Laplace transforms of the following functions:

(a) $F_1(s) = \dfrac{6\alpha^2}{(s + \alpha)(s + 2\alpha)(s + 4\alpha)}$

(b) $F_2(s) = \dfrac{6(s + 2\alpha)}{(s + \alpha)(s + 4\alpha)}$

(b) $F_2(s) = \dfrac{2(s^2 + 2)}{s(s^2 + 4)}$

9–23 Find the inverse transforms of the following functions:

(a) $F_1(s) = \dfrac{(s + 4)(s + 8)}{s(s + 2)(s + 6)}$

(b) $F_2(s) = \dfrac{3s^4 + 10s^2 + 4}{s(s^2 + 1)(s^2 + 4)}$

9–24 Find the inverse transforms for the following functions:

(a) $F_1(s) = \dfrac{30(s + 2)}{s(s^2 + 4s + 5)}$

(b) $F_2(s) = \dfrac{2s}{(s + 4)(s^2 + 4s + 8)}$

9–25 Find the inverse transforms for the following functions:

(a) $F_1(s) = \dfrac{2(s^2 + 16)}{s(s^2 + 8s + 32)}$

(b) $F_2(s) = \dfrac{s^2 + 30s + 800}{s(s^2 + 50s + 400)}$

9–26 Find the inverse transforms of the following functions:

(a) $F_1(s) = \dfrac{(s + 40)^2}{(s + 10)^2(s + 100)}$

(b) $F_2(s) = \dfrac{(s + 10)^2}{(s + 40)^2(s + 100)}$

9–27 A certain transform has a simple pole at $s = -20$, a simple zero at $s = -\gamma$, and a scale factor of $K = 1$. Select values for γ so the inverse transform is

(a) $f(t) = \delta(t) - 5e^{-20t}$
(b) $f(t) = \delta(t)$
(c) $f(t) = \delta(t) + 5e^{-20t}$

9–28 Find the inverse transforms of the following functions:

(a) $F_1(s) = \dfrac{(s + 40)e^{-2s}}{(s + 10)(s + 20)}$

(b) $F_2(s) = \dfrac{se^{-2s} + 20}{(s + 10)(s + 40)}$

9–29 Use Mathcad or MATLAB to find the inverse transform of the following function:

$$F(s) = \frac{s(s^2 + 3s + 4)}{(s + 2)(s^3 + 6s^2 + 16s + 16)}$$

9–30 Use Mathcad or MATLAB to find the inverse transform of the following function:

$$F(s) = \frac{40(s^3 + 2s^2 + s + 2)}{s(s^3 + 4s^2 + 4s + 16)}$$

(a) Determine the circuit differential equation and the initial conditions (if not given).
(b) Transform the differential equation into the s domain and solve for the response transform.
(c) Use the inverse transformation to find the response waveform.
See Examples 9–15, 9–16, 9–17, 9–18, 9–19

9–31 Use the Laplace transformation to find the $y(t)$ that satisfies the following first-order differential equations:

(a) $50\dfrac{dy}{dt} + 250y = 0$ with $y(0-) = 10$

(b) $\dfrac{dy}{dt} + 20y = 40u(t)$ with $y(0-) = -10$

9–32 Use the Laplace transformation to find the $y(t)$ that satisfies the following first-order differential equation:

$$\frac{dy}{dt} + 500y = [2500e^{-250t}]u(t) \quad \text{with} \quad y(0-) = 0$$

9–33 The switch in Figure P9–33 has been open for a long time and is closed at $t = 0$. The circuit parameters are $R = 200\ \Omega$, $L = 0.2$ H, and $V_A = 10$ V.
(a) Find the differential equation for the inductor current $i_L(t)$ and initial condition $i_L(0)$.
(b) Solve for $i_L(t)$ using the Laplace transformation.

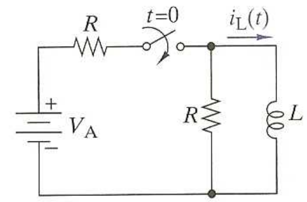

FIGURE P9–33

9–34 The switch in Figure P9–33 has been closed for a long time and is opened at $t = 0$. The circuit parameters are $R = 200\ \Omega$, $L = 200$ mH, and $V_A = 50$ V.
(a) Find the differential equation for the inductor current $i_L(t)$ and initial condition $i_L(0)$.
(b) Solve for $i_L(t)$ using the Laplace transformation.

9–35 The switch in Figure P9–35 has been open for a long time. At $t = 0$ the switch is closed.
(a) Find the differential equation for the capacitor voltage and initial condition.
(b) Find $v_O(t)$ using the Laplace transformation when $v_S(t) = 15[e^{-2500t}]u(t)$.