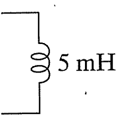
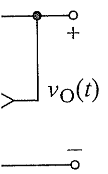
ven by 15-V dc source, :or and inductor under



measure dynamic phe- ce. These phenomena ntity of electric charge sducer (the term *piezo* mount of charge $q(t)$ is ed variable $x(t)$, that is, s needed because the he order of pC. Figure amplifier that provides the OP AMP output is lue of C so that the pC.



47 is closed and there- or is

e^{-4000t} V

:teristic to find the cur-

:teristic and $i(t)$ to find

nd the voltage $v(t)$ deliv-

(d) The $v(t)$ found in part (c) should be proportional to the $i(t)$ found in part (a). If so, what is the equivalent resistance looking into the rest of the circuit?

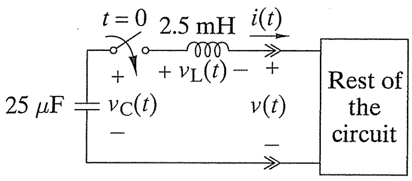


FIGURE P6–47

6–48 A Supercapacitor

Supercapacitors have very large capacitances (typically from 0.1 to 50 F), very long charge holding times, and small sizes, making them useful in nonbattery backup power applications. To measure its capacitance, a supercapacitor is charged to a initial voltage $V_0 = 5.5$ V. At $t = 0$ the device undergoes a constant current discharge of $i_D = 2$ mA. At $t = 2500$ s the voltage remaining on the capacitor is 3 V. Find the device capacitance.

6–49 D Differentiator Design

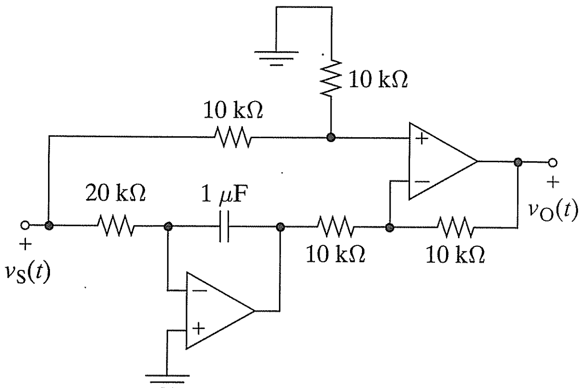
The input to the *RC* OP AMP differentiator in Figure P6–25 is a sinusoid with a peak-to-peak amplitude of 20 V. Select the values of *R* and *C* so that the OP AMP operates in its linear mode for all input frequencies less than 5 kHz. Assume the OP AMP saturates at ±15 V.

6–50 A E *RC* OP AMP Circuit Design

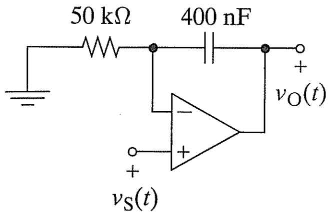
An upgrade to one of your company's robotics products requires a proportional plus integral compensator that implements the input-output relationship

$$v_O(t) = v_S(t) + 50\int_0^t v_S(x)dx$$

The input voltage $v_S(t)$ comes from an OP AMP, and the output voltage $v_O(t)$ drives a 10-kΩ resistive load. Two competing designs are shown in Figure P6–50. As the project engineer you are responsible for recommending one of these designs for production. Which design would you recommend and why? Your mentor, a wise senior engineer, suggests that you first check that both designs implement the required signal-processing function.



Design #1



Design #2

FIGURE P6–50

7-5 The switch in Figure P7–5 is closed at $t = 0$. The initial voltage on the capacitor is $v_C(0) = 30$ V. Find $v_C(t)$ and $i_O(t)$ for $t \geq 0$.

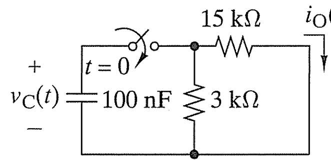


FIGURE P7–5

7-6 In Figure P7–6 the initial current through the inductor is $i_L(0) = 5$ mA. Find $i_L(t)$ and $v_O(t)$ for $t \geq 0$.

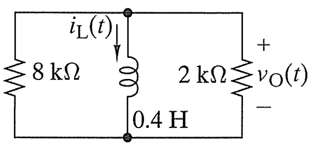


FIGURE P7–6

7-7 The switch in Figure P7–7 has been in position A for a long time and is moved to position B at $t = 0$. Find $v_C(t)$ for $t \geq 0$.

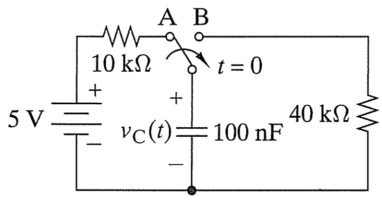


FIGURE P7–7

7-8 The switch in Figure P7–8 has been open for a long time and is closed at $t = 0$. Find $i_L(t)$ for $t \geq 0$.

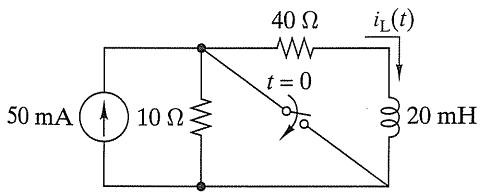


FIGURE P7–8

7-9 The circuit in Figure P7–9 is in the zero state when the input $i_S(t) = I_A u(t)$ is applied. Find the voltage $v_O(t)$ for $t \geq 0$. Identify the forced and natural components in the output.

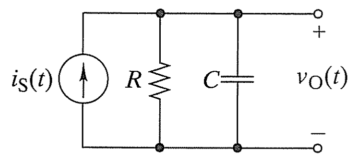


FIGURE P7–9

7–10 The circuit in Figure P7–10 is in the zero state when the input $v_S(t) = V_A u(t)$ is applied. Find $v_O(t)$ for $t \geq 0$. Identify the forced and natural components in the output.

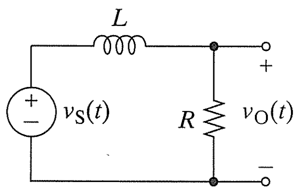


FIGURE P7–10

7–11 The circuit in Figure P7–11 is in the zero state when the input $v_S(t) = V_A u(t)$ is applied. Find $v_O(t)$ for $t \geq 0$. Identify the forced and natural components in the output.

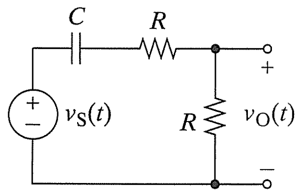


FIGURE P7–11

7–12 The circuit in Figure P7–12 is in the zero state when the input $v_S(t) = V_A u(t)$ is applied. Find $v_O(t)$ for $t \geq 0$. Identify the forced and natural components in the output.

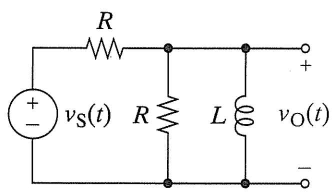


FIGURE P7–12

7–13 The switch in Figure P7–13 has been in position A for a long time and is moved to position B at $t = 0$. Find $v_C(t)$ for $t \geq 0$. Identify the forced and natural components in the response.

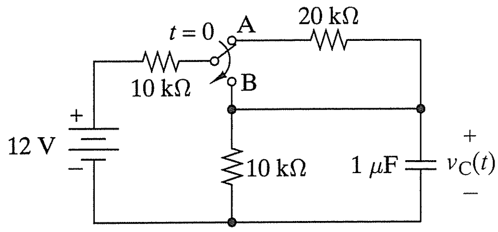


FIGURE P7–13

7–14 Repeat Problem 7–13 when the switch has been in position B for a long time and is moved to position A at $t = 0$.

7–15 Find the function that satisfies the following differential equation and the initial condition for an input $v_S(t) = 25\cos(20t)$ V:

$$\frac{dv(t)}{dt} + 10v(t) = v_S(t) \quad v(0) = 0 \text{ V}$$

7–16 Repeat Problem 7–15 for $v_S(t) = 25\sin(20t)$ V.

7–17 The input in Figure P7–17 is $v_S(t) = 30\cos(5t)$V. The switch has been open for a long time and is closed at $t = 0$. Find $i_L(t)$ for $t \geq 0$.

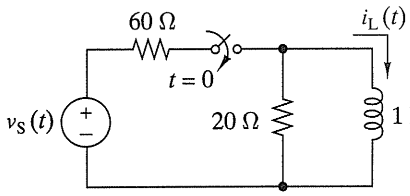


FIGURE P7–17

7–18 The switch in Figure P7–18 has been in position A for a long time and is moved to position B at $t = 0$. Find $i_L(t)$ for $t \geq 0$ and sketch its waveform.

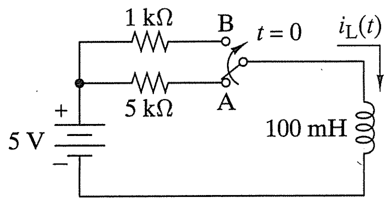


FIGURE P7–18

7–19 The switch in Figure P7–19 has been in position A fo long time and is moved to position B at $t = 0$. Find v_C for $t \geq 0$ and sketch its waveform.

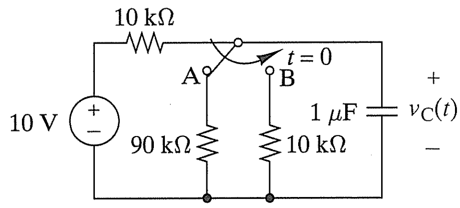


FIGURE P7–19

7–20 Switches 1 and 2 in Figure P7–20 have both been in p sition A for a long time. Switch 1 is moved to position B $t = 0$ and switch 2 is moved to position B at $t = 20$ r Find the voltage across the 0.1-μF capacitor for $t > 0$ a sketch its waveform.

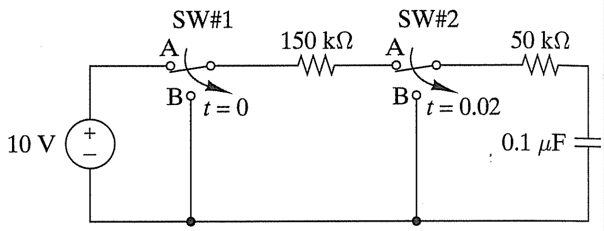


FIGURE P7–20

7–21 The switch in Figure P7–21 has been open for a lo time and is closed at $t = 0$. The switch is reopened $t = 2$ ms. Find $v_C(t)$ for $t \geq 2$ ms.

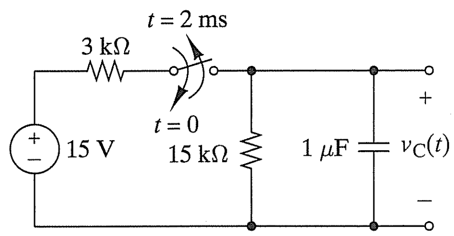


FIGURE P7–21

7–22 Find the sinusoidal steady-state response of $v_C(t)$ Figure P7–22 when the input voltage is $v_S(t)$ $V_A[\sin(\omega t)]u(t)$ V.

7–30 **D** The switch in Figure 7–29 has been in position A for a long time and is moved to position B at $t = 0$. Design the first-order RC interface circuit such that $v_O(t) = 5e^{-3000t}$ V.

OBJECTIVE 7–3 SECOND-ORDER CIRCUIT ANALYSIS (SECTS. 7–5, 7–6, 7–7, 7–8)

Given a second-order circuit:
(a) Find the circuit differential equation.
(b) Find the characteristic equation and the initial conditions (if not given).
(c) Find the zero-input response.
(d) Find the complete response for a step function input.
See Examples 7–14, 7–15, 7–17, 7–18, 7–19, 7–20, 7–21 and Exercises 7–14, 7–17, 7–19, 7–20

7–31 Find the $v(t)$ that satisfies the following differential equation and initial conditions.

$$\frac{d^2v}{dt^2} + 10\frac{dv}{dt} + 25v = 0, \quad v(0) = 0\text{ V}, \quad \frac{dv}{dt}(0) = 10\text{ V/s}$$

7–32 Find the $v(t)$ that satisfies the following differential equation and initial conditions.

$$\frac{d^2v}{dt^2} + 15\frac{dv}{dt} + 50v = 0, \quad v(0) = 5\text{ V}, \quad \frac{dv}{dt}(0) = 10\text{ V/s}$$

7–33 Find the $v(t)$ that satisfies the following differential equation and initial conditions.

$$\frac{d^2v}{dt^2} + 10\frac{dv}{dt} + 125v = 250u(t), \ v(0) = 5\text{ V}, \ \frac{dv}{dt}(0) = 25\text{ V/s}$$

7–34 Find the $i(t)$ that satisfies the following differential equation and initial conditions.

$$\frac{d^2i}{dt^2} + 4\frac{di}{dt} + 8i = 24u(t), \quad i(0) = 0, \quad \frac{dv}{dt}(0) = 0$$

7–35 The switch in Figure P7–35 has been open for a long time and is closed at $t = 0$. The circuit parameters are $L = 1$ H, $C = 0.5\ \mu$F, $R = 3$ kΩ, and $v_C(0) = 10$ V. Find $v_C(t)$ and $i_L(t)$ for $t \geq 0$. Is the circuit overdamped, critically damped, or underdamped?

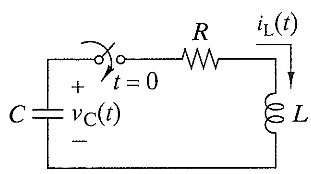


FIGURE P7–35

7–36 Repeat problem 7–35 with $R = 2$ kΩ.

7–37 The switch in Figure P7–37 has been open for a long time and is closed at $t = 0$. The circuit parameters are $L = 0.4$ H, $C = 0.25\ \mu$F, $R = 2$ kΩ, and $v_C(0) = 60$ V. Find $i_L(t)$ and $v_C(t)$ for $t \geq 0$. Is the circuit overdamped, critically damped, or underdamped?

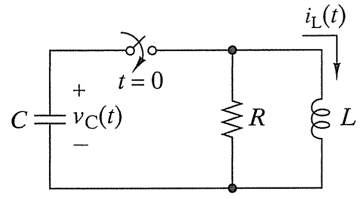


FIGURE P7–37

7–38 Repeat problem 7–37 with $C = 25$ nF.

7–39 The switch in Figure P7–39 has been open for a long time and is closed at $t = 0$. The circuit parameters are $L = 0.8$ H, $C = 1.25\ \mu$F, $R_1 = 3$ kΩ, $R_2 = 2$ kΩ, and $V_A = 15$ V. Find $v_C(t)$ and $i_L(t)$ for $t \geq 0$. Is the circuit overdamped, critically damped, or underdamped?

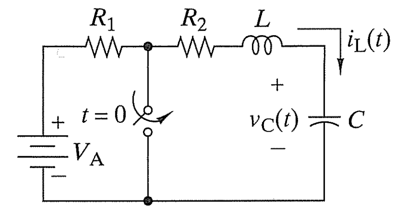


FIGURE P7–39

7–40 Repeat problem 7–39 with $L = 4$ H, $C = 0.1\ \mu$F, $R_1 = 30$ kΩ, $R_2 = 22$ kΩ, and $V_A = 9$ V.

7–41 The switch in Figure P7–41 has been open for a long time and is closed at $t = 0$. The circuit parameters are $L = 0.8$ H, $C = 50$ nF, $R_1 = 4$ kΩ, $R_2 = 4$ kΩ, and $V_A = 20$ V. Find $v_C(t)$ and $i_L(t)$ for $t \geq 0$. Is the circuit overdamped, critically damped, or underdamped?

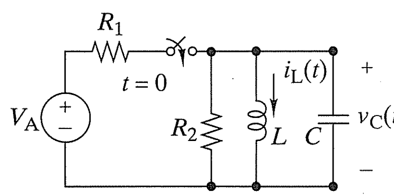


FIGURE P7–41

7–42 Repeat Problem 7–41 with $L = 1.25$ H.

7–43 The switch in Figure P7–43 has been in position A for a long time. At $t = 0$ it is moved to position B. The circuit parameters are $R_1 = 20\ \text{k}\Omega$, $R_2 = 4\ \text{k}\Omega$, $L = 1.6\ \text{H}$, $C = 1.25\ \mu\text{F}$, and $V_A = 24$ V. Find $v_C(t)$ and $i_L(t)$ for $t > 0$. Is the circuit overdamped, critically damped, or underdamped?

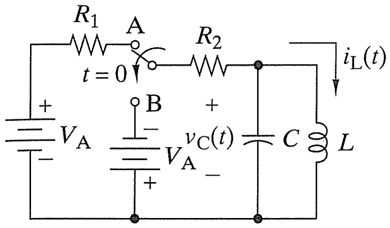


FIGURE P7–43

7–44 The switch in Figure P7–44 has been in position A for a long time and is moved to position B at $t = 0$. The circuit parameters are $R_1 = 500\ \Omega$, $R_2 = 500\ \Omega$, $L = 250$ mH, $C = 3.2\ \mu\text{F}$, and $V_A = 5$ V. Find $v_C(t)$ and $i_L(t)$ for $t > 0$. Is the circuit overdamped, critically damped, or underdamped?

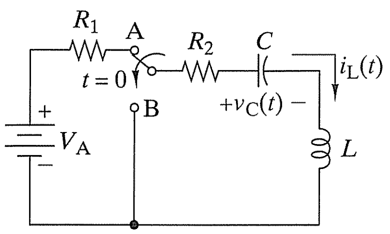


FIGURE P7–44

7–45 The switch in Figure P7–44 has been in position B for a long time and is moved to position A at $t = 0$. The circuit parameters are $R_1 = 500\ \Omega$, $R_2 = 500\ \Omega$, $L = 250$ mH, $C = 1\ \mu\text{F}$, and $V_A = 5$ V. Find $v_C(t)$ and $i_L(t)$ for $t > 0$. Is the circuit overdamped, critically damped, or underdamped?

7–46 The circuit in Figure P7–46 is in the zero state when the step function input is applied. The circuit parameters are $L = 0.4$ H, $C = 1\ \mu\text{F}$, $R = 2.2\ \text{k}\Omega$, and $V_A = 90$ V. Find $v_O(t)$ for $t > 0$.
Hint: First find the capacitor voltage.

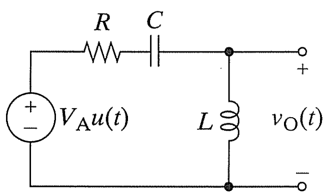


FIGURE P7–46

7–47 The circuit in Figure P7–47 is in the zero state when the step function input is applied. The circuit parameters are $R = 5\ \text{k}\Omega$, $L = 0.5$ H, $C = 250$ nF, and $V_A = 70$ V. Find $v_O(t)$ for $t > 0$.
Hint: First find the inductor current.

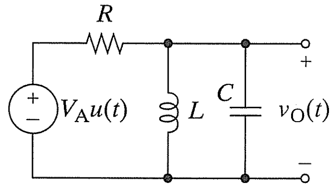


FIGURE P7–47

7–48 The circuit in Figure P7–48 is in the zero state when the step function input is applied. The circuit parameters are $R = 500\ \Omega$, $L = 2.5$ H, $C = 2.5\ \mu\text{F}$, and $V_A = 100$ V. Find $v_O(t)$ for $t > 0$.
Hint: First find the inductor current.

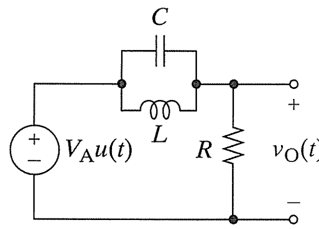


FIGURE P7–48

7–49 Derive expressions for the damping ratio and undamped natural frequency of the circuit in Figure P7–49 in terms of the circuit parameter R, L, and C.

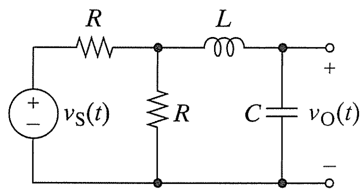


FIGURE P7–49

7–50 Repeat problem 7–49 for the circuit in Figure P7–50.

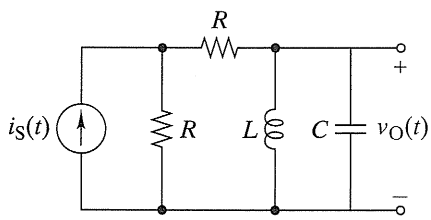


FIGURE P7–50