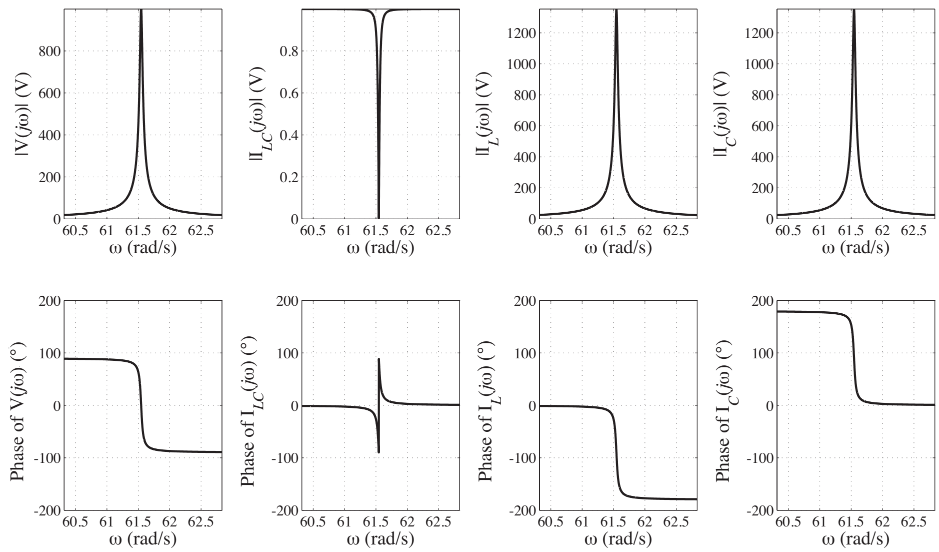
Chapter 16 Answers to Assigned Homework

2. (a) $\alpha = 0.0227\ \text{s}^{-1}$ $\omega_0 = 61.5457\ \text{s}^{-1}$

$\zeta = 3.69 \times 10^{-4}$ $f_0 = 9.7953\ \text{Hz}$

$\omega_d = 61.5457$

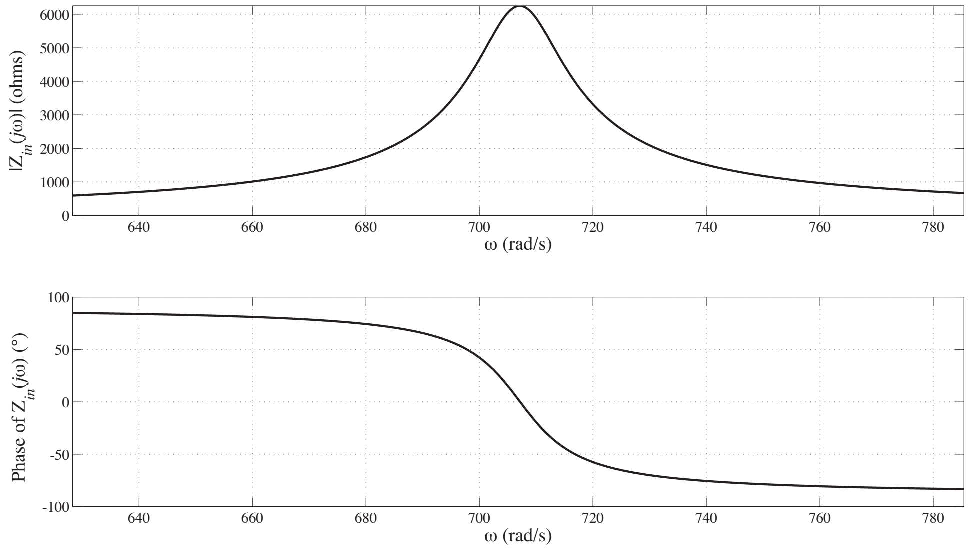
(b) $$I_{LC} = I_L + I_C = \frac{s^2 + 1/LC}{s^2 + s/RC + 1/LC}$$



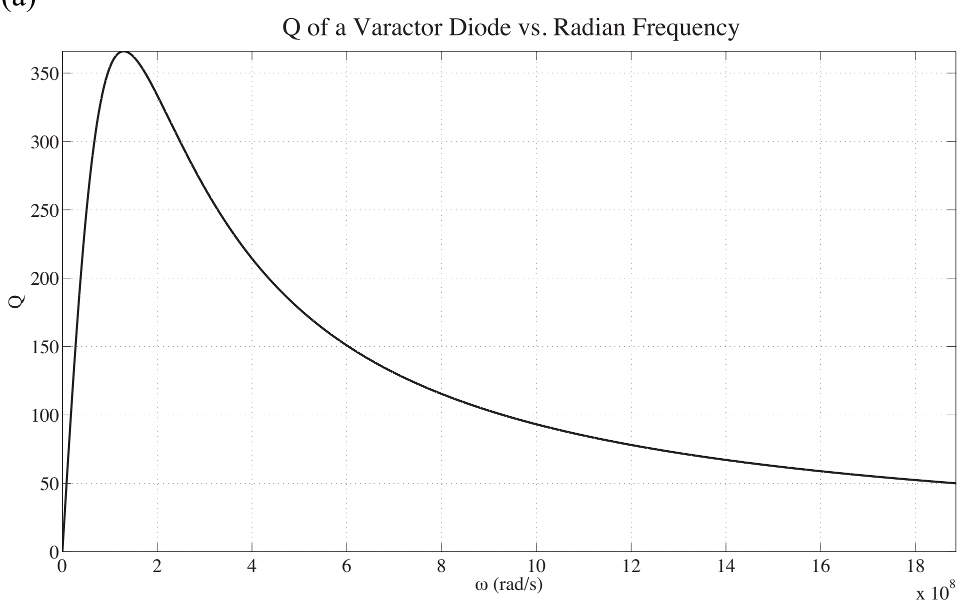
(c) At resonance, $I_L = -I_C$.

5. $$Z_{in}(j\omega) = 2\frac{-\omega^2 + j5\times10^4\omega + 2.5\times10^5}{-\omega^2 + j16\omega + 5\times10^5}$$

Close examination of a graph of the magnitude of the input impedance reveals that the frequency of maximum magnitude is 707.1. The same as the ideal to 4 significant figures.



9. (a)



(b) $$\frac{dQ}{d\omega} = C_j R_P \frac{1-\omega^2 R_S R_P C_j^2}{\left(1+\omega^2 C_j^2 R_P R_S\right)^2}$$

$$\omega = 1.2943\times 10^8 \text{ rad/s}$$

At that frequency $Q = 365.96$.

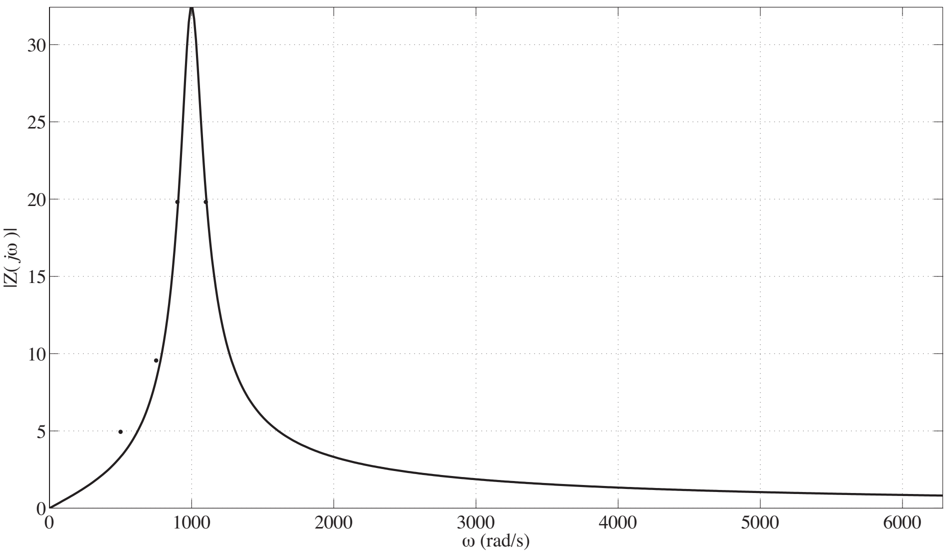
11. (a) 500 rad/s $Z(j\omega) = 4.94\angle 81.25°$

(b) 750 rad/s $Z(j\omega) = 9.558\angle 72.9°$

(c) 900 rad/s $Z(j\omega) = 19.816\angle 52.4°$

(d) 1100 rad/s $Z(j\omega) = 19.816\angle -52.4°$

(e)



14. (a) 2.5 ohms.

(b) $C = 1$ F

(c) $Q_0 = 2.5$

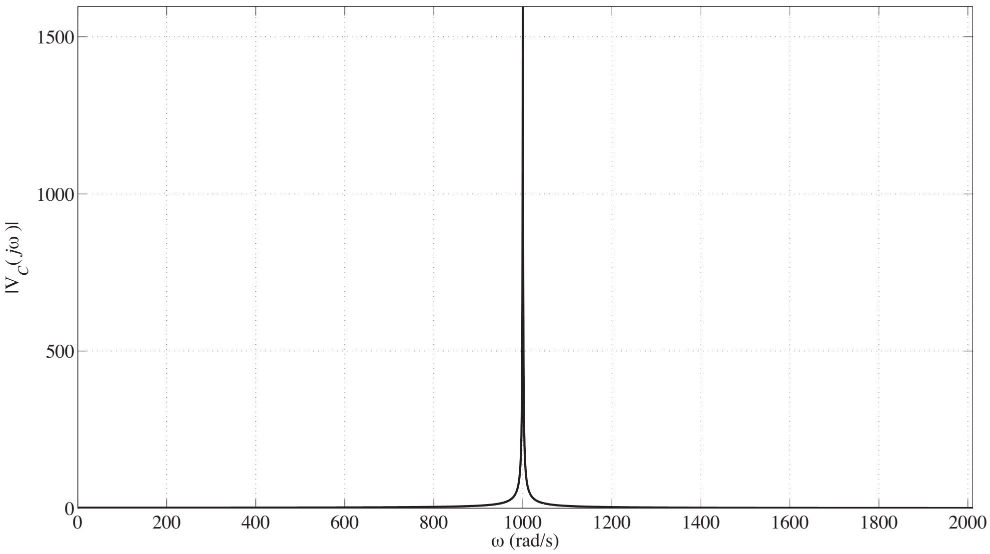
$B = 0.4 \Rightarrow \omega_1 = 0.8198$ and $\omega_2 = 1.2198$

15. (a) $\left[Z_{RLC}\right]_{\omega=500\times10^6} = 750{,}000\angle 89.99°$

(b) $I = 3.92\angle -89.99°\ \mu\text{A}$

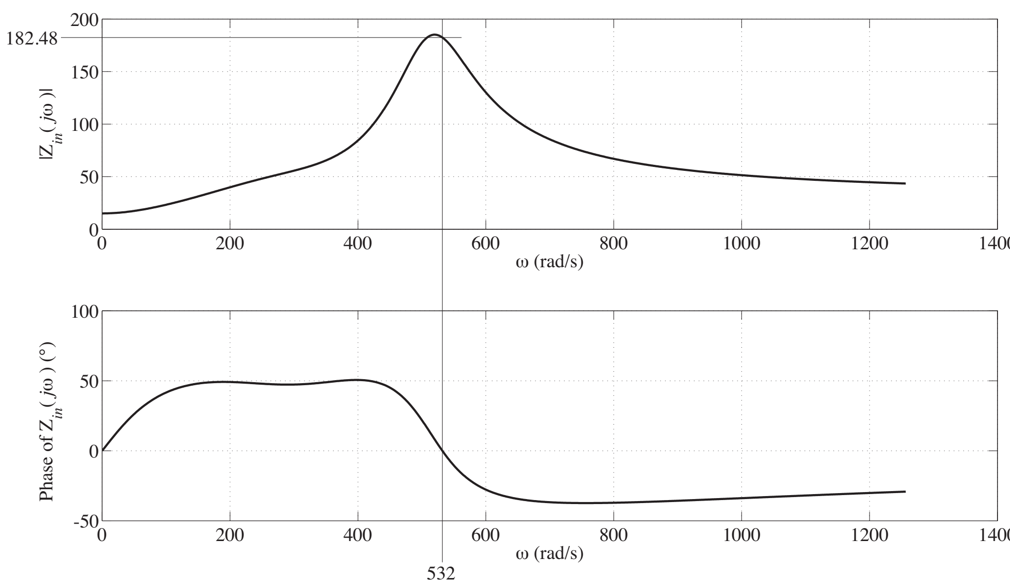
$\text{i}(t) = 3.92\cos\left(425\times10^6 t - 89.99°\right)\ \mu\text{A}$

18. $V_C = 4\times10^6 I_1 / j\omega = \dfrac{6\times10^6}{-4\omega^2 + j3.75\omega + 4\times10^6}$



20. (a) At $\omega = 700$ rad/s, $Z_{in} = 61.56\angle 0.044°$.
At $\omega = 800$ rad/s, $Z_{in} = 62.03\angle -0.0535°$.

23. $$Z_{in}(j\omega) = 32\frac{\omega^4 - j1248\omega^3 - 548125\omega^2 + j1.7959\times 10^8\omega + 1.25\times 10^{10}}{\omega^4 - j503.3s^3\omega - 4.16\times 10^5\omega^2 + j1.12\times 10^8\omega + 2.667\times 10^{10}}$$



25. (a) $R = 1\Omega$ $L = 265.3$nH $C = 2.39\mu$F
(b) $R = 500\,\text{k}\Omega$ $L = 166.67$kH $C = 6\mu$F
(c) $R = 25\Omega$ $L = 1.768\mu$H $C = 25.46$nF

26. (a) $R = 1\Omega$ $L = 74.03\mu\text{H}$ $C = 1.85\text{mF}$

(b) $R = 100\Omega$ $L = 20\text{H}$ $C = 50\text{mF}$

(c) $R = 15\text{k}\Omega$ $L = 6.367\text{mH}$ $C = 707.4\text{pF}$

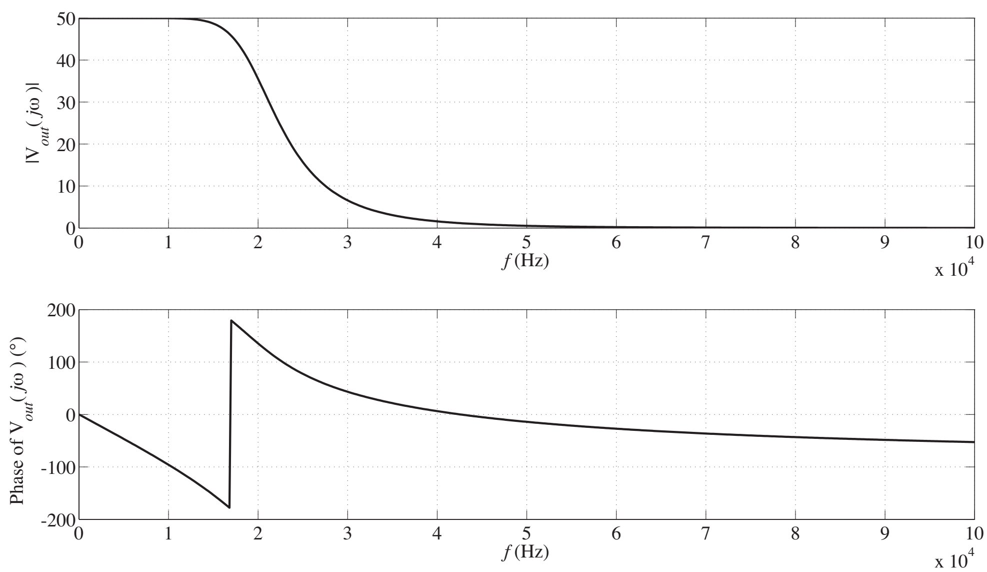
28. (a)

245.5 μH 795 μH 245.5 μH

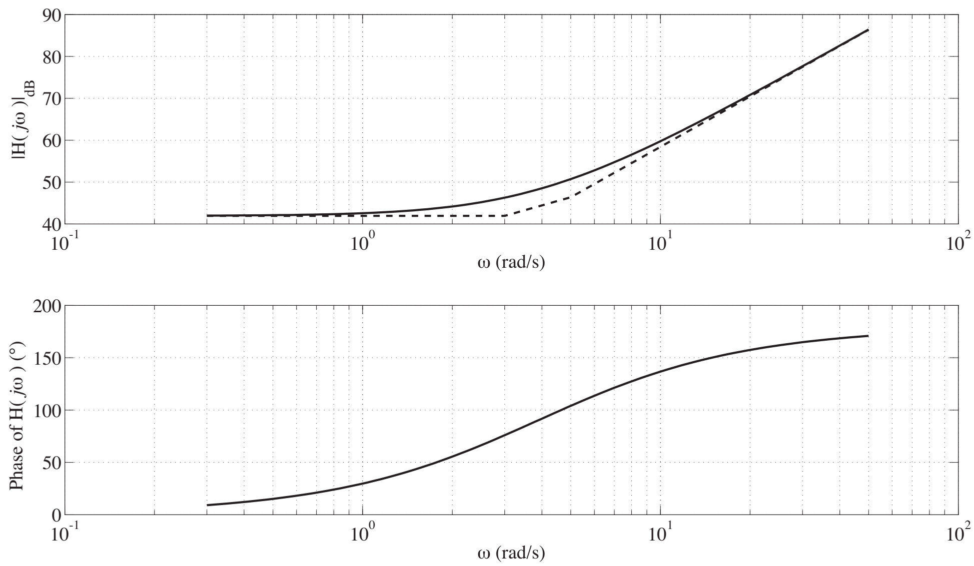
257 nF 257 nF

(b)

$$V_{out} = 50I_3 = \frac{1.58\times10^{27}}{s^5 + 4.073\times10^5 s^4 + 8.296\times10^{10} s^3 + 1.044\times10^{16} s^2 + 8.121\times10^{20} s + 3.16\times10^{25}}$$

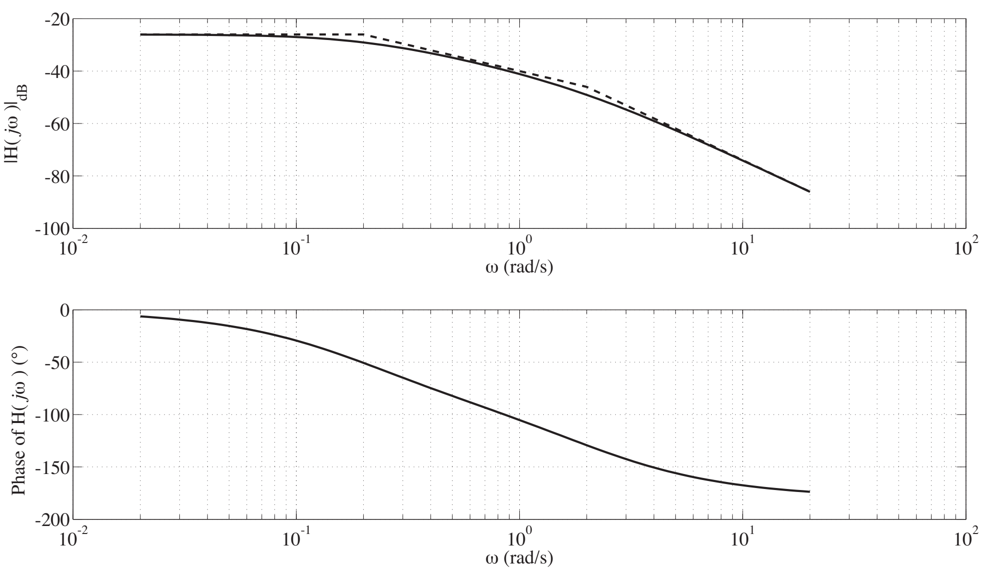


31.



|H(jω)|dB
90
80
70
60
50
40
Phase of H(jω) (°)
200
150
100
50
0
ω (rad/s)

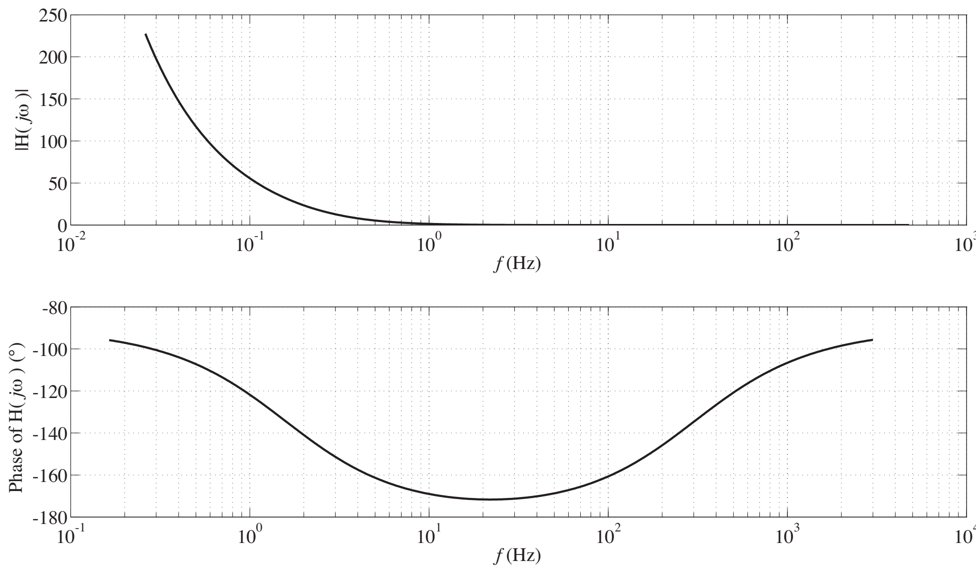
(a)



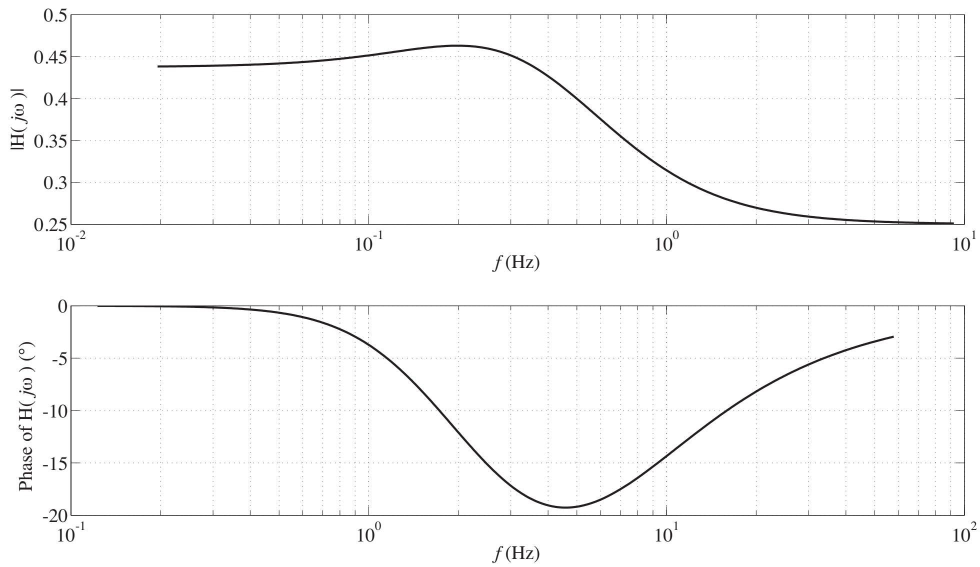
|H(jω)|dB
-20
-40
-60
-80
-100
Phase of H(jω) (°)
0
-50
-100
-150
-200
ω (rad/s)

(b)

33.

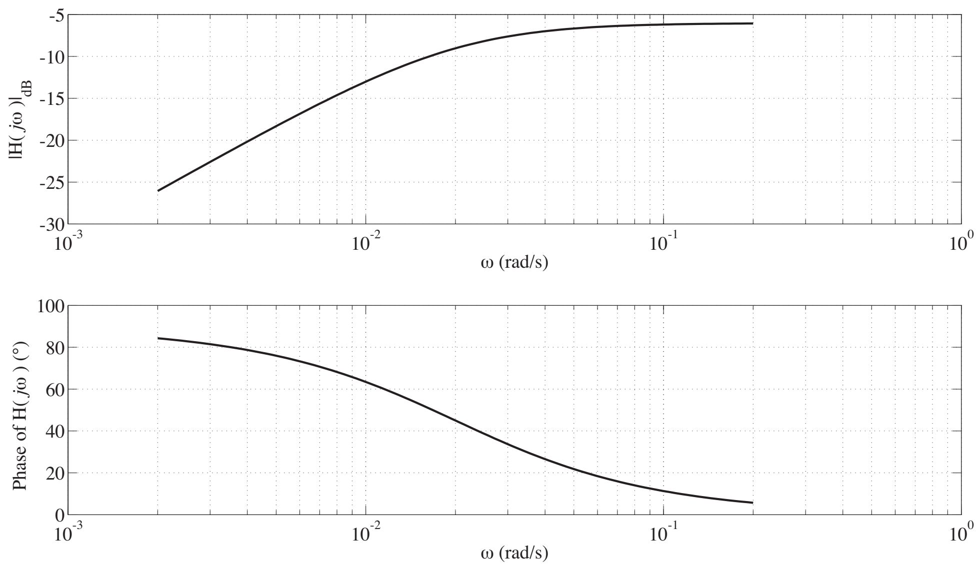

|H(jω)|
250
200
150
100
50
0
10-2
10-1
10^0
10^1
10^2
10^3
f (Hz)
Phase of H(jω) (°)
-80
-100
-120
-140
-160
-180
10-1
10^0
10^1
10^2
10^3
10^4
f (Hz)

(a)

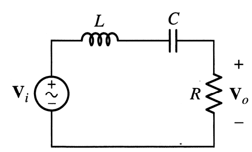

|H(jω)|
0.5
0.45
0.4
0.35
0.3
0.25
10-2
10-1
10^0
10^1
f (Hz)
Phase of H(jω) (°)
0
-5
-10
-15
-20
10-1
10^0
10^1
10^2
f (Hz)

(b)

38.



42.



■ **FIGURE 16.39** A simple bandpass filter,

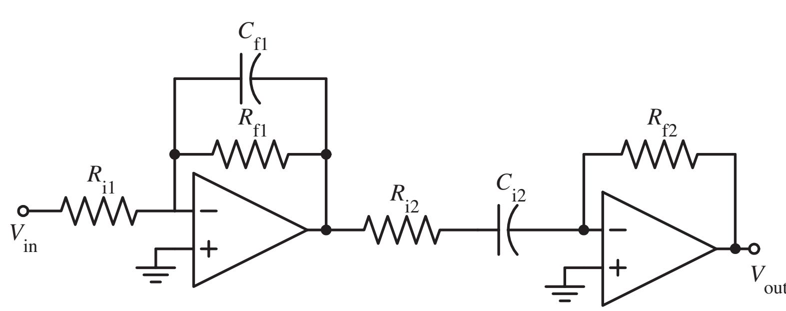
$$\omega_L = 500\pi \qquad C = 2.476\ \mu\text{F}$$

44.

$$\text{H}(j\omega) = \frac{1/LC - \omega^2}{1/LC - \omega^2 + j\omega R/L}$$

Choosing C arbitrarily to be $100\mu\text{F}$, we get $L = 70.36$ mH.

47.



$$H(s) = \frac{R_{f2}}{R_{i1}C_{f1}R_{i2}} \frac{s}{\left(s+1/R_{f1}C_{f1}\right)\left(s+1/R_{i2}C_{i2}\right)}$$

Pick R_{i2} arbitrarily to be 1000 ohms. Then

$$C_{i2} = 10\ \mu\text{F}$$

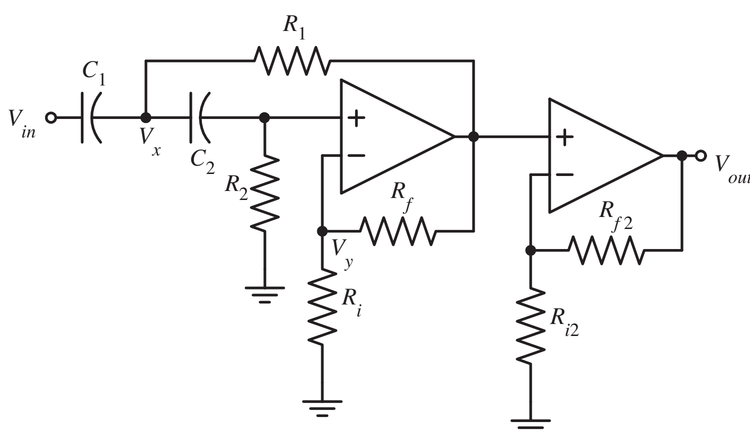
Pick R_{f2} so that the high-frequency gain is $\sqrt{10}$. Then $R_{f2} = 3162\ \Omega$.

Set the high corner frequency of the lowpass filter to 1100 rad/s. Pick $R_{f1} = 1000\ \Omega$. Then

$$C_{f1} = 909.1\ \text{nF}$$

Pick R_{i1} so that the low-frequency gain is $\sqrt{10}$. Then $R_{i1} = 316.2\ \Omega$.

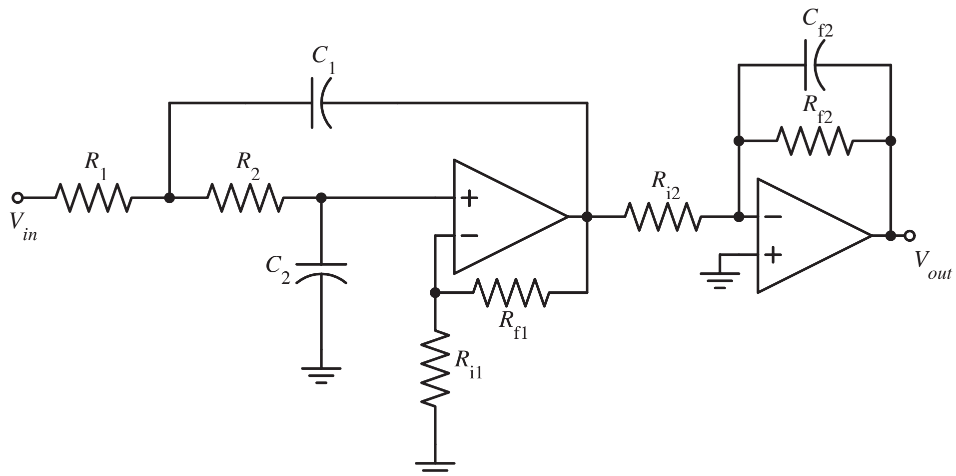
54. This can be done with one Sallen-Key highpass filter stage followed by an amplifier to set the overall gain.



$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = K \frac{s^2}{s^2 + s\left[\frac{C_1+C_2}{R_2C_1C_2} + \frac{1-K}{R_1C_1}\right] + \frac{1}{R_1R_2C_1C_2}}$$

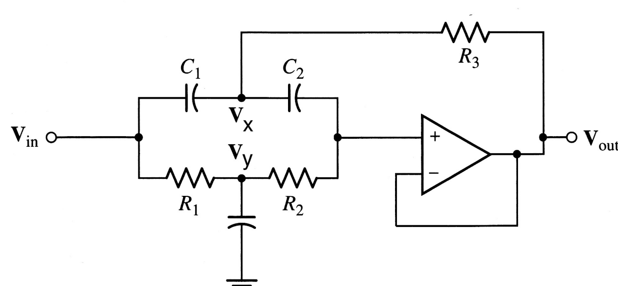
Let $R_1 = R_2 = R$ and $C_1 = C_2 = C$. Then $K = 1.5858$. Let $R = 10^7$ and $C = 10^{-7}$. Frequency scale to make $\omega_c = 4000\pi$. We can do this by reducing R by a factor of 4000π to become 795.7 ohms. Let $R_{i2} = 1000\Omega$. Then $R_{f2} = 60\Omega$.

56. This can be designed using a Sallen-Key stage followed by a single-pole stage.



Let $R_1 = R_2 = R$ and $C_1 = C_2 = C$. Then $K = 2$. Also $RC = 1$. Let $R = 10^7\ \Omega$ and $C = 10^{-7}$ F. Then in the second stage let $R_{f2} = 10^7\ \Omega$. Then $C_{f2} = 10^{-7}$ F or 100nF. Set $R_{i2} = 4.478\text{M}\Omega$. Now, scale to the correct corner frequency of 1800 Hz or 11310 rad/s. Then $R = 884.2\ \Omega$, $R_{f2} = 884.2\ \Omega$ and $R_{i2} = 396\ \Omega$.

60.

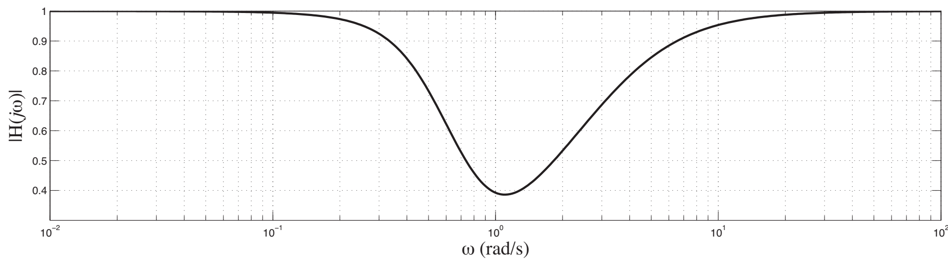


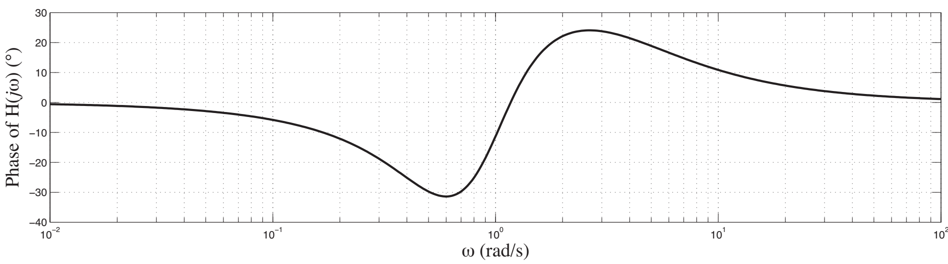
■ FIGURE 16.61

$$\frac{V_{out}}{V_{in}} = \frac{s^3 + s^2\dfrac{G_1+G_2}{C_3} + s\dfrac{G_1G_2}{C_3}\dfrac{C_1+C_2}{C_1C_2} + \dfrac{G_1G_2G_3}{C_1C_2C_3}}{s^3 + s^2\left[G_2\dfrac{C_1+C_2}{C_1C_2} + \dfrac{G_1+G_2}{C_3}\right] + sG_2\left[\dfrac{G_3}{C_1C_2} + \dfrac{G_1}{C_3}\dfrac{C_1+C_2}{C_1C_2}\right] + \dfrac{G_1G_2G_3}{C_1C_2C_3}}$$

No numerical component values were given. Let all resistors be 1 ohm and all capacitors be 1 F. Then

$$V_{out} = \frac{s^3 + 2s^2 + 2s + 1}{s^3 + 4s^2 + 3s + 1}$$





63.

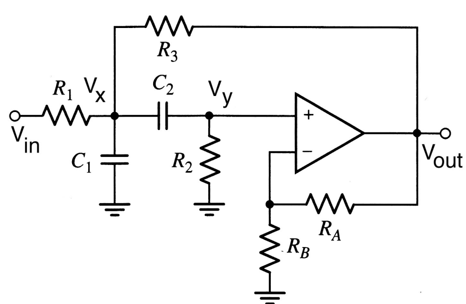
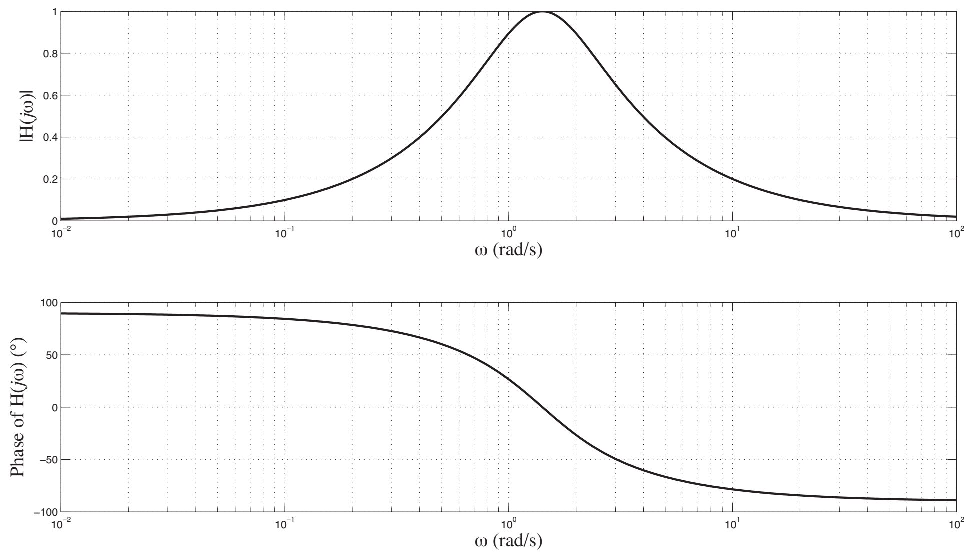


FIGURE 16.62

$$\frac{V_{out}}{V_{in}} = \frac{KG_1}{C_1} \frac{s}{s^2 + s\left[\frac{G_1 + G_2}{C_1} + \frac{G_2}{C_2} + \frac{G_3}{C_1}(1-K)\right] + \frac{G_1 + G_3}{C_1 C_2} G_2}$$

No numerical component values were given. Let all resistors be 1 ohm and all capacitors be 1 F. Then

$$\frac{V_{out}}{V_{in}} = \frac{2s}{s^2 + 2s + 2}$$



|H(jω)|
ω (rad/s)
Phase of H(jω) (°)
ω (rad/s)