CHAPTER 14

P.P.14.1 $$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{\mathbf{j\omega L}}{\mathbf{R + j\omega L}}$$

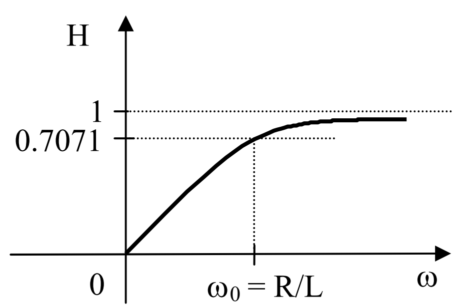
$$\mathbf{H}(\omega) = \frac{j\omega L/R}{1 + j\omega L/R} = \frac{j\omega/\omega_0}{1 + j\omega/\omega_0}$$

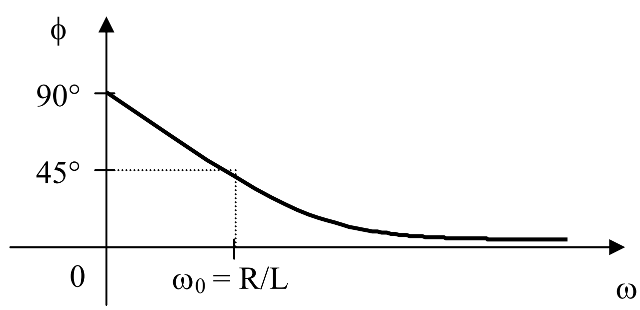
where $\omega_0 = \dfrac{R}{L}$.

$$H = \left|\mathbf{H}(\omega)\right| = \frac{\omega/\omega_0}{\sqrt{1 + (\omega/\omega_0)^2}} \qquad \phi = \angle\mathbf{H}(\omega) = \frac{\pi}{2} - \tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

At $\omega = 0$, $H = 0$, $\phi = 90°$
As $\omega \to \infty$, $H = 1$, $\phi = 0°$
At $\omega = \omega_0$, $H = \dfrac{1}{\sqrt{2}}$, $\phi = 90° - 45° = 45°$

Thus, the sketches of H and ϕ are shown below.





P.P.14.2 The desired transfer function is the input impedance.

$$\mathbf{Z}_i(s) = \frac{\mathbf{V}_o(s)}{\mathbf{I}_o(s)} = \left(10 + \frac{1}{s/20}\right) \| (6+2s)$$

$$\mathbf{Z}_i(s) = \frac{(10+20/s)(6+2s)}{10+20/s+6+2s} = \frac{10(s+2)(s+3)}{s^2+8s+10}$$

The poles are at

$$p_{1,2} = \frac{-8 \pm \sqrt{64-40}}{2} = \mathbf{-1.5505, -6.449}$$

The zeros are at

$$z_1 = \mathbf{-2}, \qquad z_2 = \mathbf{-3}.$$

P.P.14.3 $$\mathbf{H}(\omega) = \frac{1 + j\omega/2}{(j\omega)(1 + j\omega/10)}$$

$$H_{db} = 20\log_{10}\left|1 + j\omega/2\right| - 20\log_{10}\left|j\omega\right| - 20\log_{10}\left|1 + j\omega/10\right|$$

$$\phi = -90° + \tan^{-1}(\omega/2) - \tan^{-1}(\omega/10)$$

The magnitude and the phase plots are as shown in Fig. 14.14.

P.P.14.4 $$\mathbf{H}(\omega) = \frac{(50/400)j\omega}{(1 + j\omega/4)(1 + j\omega/10)^2}$$

$$H_{db} = -20\log_{10}\left|8\right| + 20\log_{10}\left|j\omega\right| - 20\log_{10}\left|1 + j\omega/4\right| - 40\log_{10}\left|1 + j\omega/10\right|$$

$$\phi = 90° - \tan^{-1}(\omega/4) - 2\tan^{-1}(\omega/10)$$

The magnitude and the phase plots are as shown in Fig. 14.16.

P.P.14.5 $$\mathbf{H}(\omega) = \frac{10/400}{(j\omega)\left(1 + \frac{j\omega 8}{40} + \left(\frac{j\omega}{20}\right)^2\right)}$$

$$H_{db} = -20\log_{10}\left|40\right| - 20\log_{10}\left|j\omega\right| - 20\log_{10}\left|1 + j\omega/5 - \omega^2/400\right|$$

$$\phi = -90° - \tan^{-1}\left(\frac{0.2\omega}{1 - \omega^2/400}\right)$$

The magnitude and the phase plots are as shown in Fig. 14.18.

P.P.14.6

The gain is = 40 db = $20\log_{10}$(gain) or the gain = 100.

A zero at $\omega = 5$, $1 + j\omega/5$

A pole at $\omega = 10$, $\dfrac{1}{1 + j\omega/10}$

Two poles at $\omega = 100$, $\dfrac{1}{(1 + j\omega/100)^2}$

Hence,

$$\mathbf{H}(\omega) = \frac{100(1 + j\omega/5)}{(1 + j\omega/10)(1 + j\omega/100)^2} = \frac{100(1/5)(5 + j\omega)}{(1/100{,}000)(10 + j\omega)(100 + j\omega)^2}$$

$$\mathbf{H}(\omega) = \frac{2{,}000{,}000\,(s + 5)}{(s + 10)(s + 100)^2}$$

P.P.14.7

(a) $Q = \dfrac{\omega_0 L}{R} \longrightarrow \omega_0 = \dfrac{QR}{L} = \dfrac{(50)(4)}{25 \times 10^{-3}} = 8 \times 10^3 \text{ rad/s}$

$$\omega_0 = \frac{1}{\sqrt{LC}} \longrightarrow C = \frac{1}{\omega_0^2 L} = \frac{1}{(64 \times 10^6)(25 \times 10^{-3})}$$

C = **0.625 μF**

(b) $B = \dfrac{\omega_0}{Q} = \dfrac{8 \times 10^3}{50} = \mathbf{160\ rad/s}$

Since $Q > 10$,

$$\omega_1 = \omega_0 - \frac{B}{2} = 8000 - 80 = \mathbf{7920\ rad/s}$$

$$\omega_2 = \omega_0 + \frac{B}{2} = 8000 + 80 = \mathbf{8080\ rad/s}$$

(c) At $\omega = \omega_0$, $P = \dfrac{V_{in}^2}{2R} = \dfrac{100^2}{8} = \mathbf{1.25\ kW}$

At $\omega = \omega_1$, $P = 0.5 \cdot \dfrac{V_{in}^2}{2R} = \mathbf{0.625\ kW}$

At $\omega = \omega_2$, $P = 0.5 \cdot \dfrac{V_{in}^2}{2R} = \mathbf{0.625\ kW}$

P.P.14.8 $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(20\times10^{-3})(5\times10^{-9})}} = 10^5 = \mathbf{100\ krad/s}$

$$Q = \frac{R}{\omega_0 L} = \frac{100\times10^3}{(10^5)(20\times10^{-3})} = \mathbf{50}$$

$$B = \frac{\omega_0}{Q} = \frac{10^5}{50} = \mathbf{2\ krad/s}$$

Since $Q > 10$,

$$\omega_1 = \omega_0 - \frac{B}{2} = 100{,}000 - 1{,}000 = \mathbf{99\ krad/s}$$

$$\omega_2 = \omega_0 + \frac{B}{2} = 100{,}000 + 1{,}000 = \mathbf{101\ krad/s}$$

P.P.14.9 $\mathbf{Z} = j\omega 0.01 + 20 \,||\, \frac{2000}{j\omega} = j\omega 0.01 + \frac{20}{1 + j\omega/100}$

$$\mathbf{Z} = j\omega 0.01 + \frac{20(1 - j\omega/100)}{1 + \omega^2/10^4}$$

$$\mathrm{Im}(\mathbf{Z}) = 0 \quad \longrightarrow \quad \omega 0.01 - \frac{0.2\omega}{1 + \omega^2/10^4} = 0$$

$$\omega = \frac{20\omega}{1 + \omega^2/10^4} \quad \longrightarrow \quad 1 + \omega^2/10^4 = 20$$

Clearly, ω = **435.9 rad/s**

P.P.14.10 $\mathbf{H}(s) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R_2 \,||\, sL}{R_1 + R_2 \,||\, sL}, \qquad s = j\omega$

$$\mathbf{H}(s) = \frac{sR_2L}{R_1R_2 + sR_1L + sR_2L}$$

$$\mathbf{H}(\omega) = \frac{j\omega R_2 L}{R_1R_2 + j\omega L(R_1 + R_2)}$$

$$H(0) = 0$$

$$H(\omega) = \lim_{\omega\to\infty} \frac{jR_2L}{R_1R_2/\omega + jL(R_1 + R_2)} = \frac{R_2}{R_1 + R_2}$$

i.e. a **highpass filter**.

The corner frequency occurs when $H(\omega_c) = \frac{1}{\sqrt{2}} \cdot H(\infty)$.

$$\mathbf{H}(\omega) = \left(\frac{R_2}{R_1 + R_2}\right)\left(\frac{j\omega L}{j\omega L + R_1 R_2/(R_1 + R_2)}\right)$$

$$\mathbf{H}(\omega) = \left(\frac{R_2}{R_1 + R_2}\right)\left(\frac{j\omega}{j\omega + k}\right), \qquad \text{where } k = \frac{R_1 R_2}{(R_1 + R_2)L}$$

At the corner frequency,

$$\frac{1}{\sqrt{2}} \cdot \frac{R_2}{R_1 + R_2} = \frac{R_2}{R_1 + R_2} \cdot \left|\frac{j\omega_c}{j\omega_c + k}\right|$$

$$\frac{1}{\sqrt{2}} = \frac{\omega_c}{\sqrt{\omega_c^2 + k^2}} \longrightarrow \omega_c = k = \mathbf{\frac{R_1 R_2}{(R_1 + R_2)L}}$$

Hence, $$\mathbf{H}(\omega) = \left(\mathbf{\frac{R_2}{R_1 + R_2}}\right)\left(\mathbf{\frac{j\omega}{j\omega + \omega_c}}\right)$$

and the corner frequency is

$$\omega_c = \frac{(100)(100)}{(100 + 100)(2 \times 10^{-3})} = \mathbf{25\ krad/s}$$

P.P.14.11 $B = 2\pi(20.3 - 20.1) \times 10^3 = 400\pi$

Assuming high Q,

$$\omega_0 = \frac{\omega_1 + \omega_2}{2} = \frac{(2\pi)(40.4 \times 10^3)}{2} = 40.4\pi \times 10^3 \text{ rad/s}$$

$$Q = \frac{\omega_0}{B} = \frac{40.4\pi \times 10^3}{400\pi} = \mathbf{101}$$

$$B = \frac{R}{L} \longrightarrow L = \frac{R}{B} = \frac{20 \times 10^3}{400\pi} = \mathbf{15.915\ H}$$

$$Q = \frac{1}{\omega_0 CR} \longrightarrow C = \frac{1}{\omega_0 QR}$$

$$C = \frac{1}{(40.4\pi \times 10^3)(101)(20 \times 10^3)} = \mathbf{3.9\ pF}$$

P.P.14.12 Given $H(\infty) = 5$ and $f_c = 2$ kHz

$$\omega_c = 2\pi f_c = \frac{1}{R_i C_i}$$

$$R_i = \frac{1}{2\pi f_c C_i} = \frac{1}{(2\pi)(2\times 10^3)(0.1\times 10^{-3})}$$

$$R_i = 795.8 \cong \mathbf{800\,\Omega}$$

$$H(\infty) = \frac{-R_f}{R_i} = -5 \quad \longrightarrow \quad R_f = 5R_i = 3{,}978 \cong \mathbf{4\,k\Omega}$$

P.P.14.13 $Q = 10$, $\omega_0 = 20\text{ krad/s}$

$$B = \frac{\omega_0}{Q} = 2\text{ krad/s}$$

$$\omega_1 = \omega_0 - \frac{B}{2} = 19\text{ krad/s}$$

$$\omega_2 = \omega_0 + \frac{B}{2} = 21\text{ krad/s}$$

Since $\omega_1 = \frac{1}{C_2 R}$,

$$C_2 = \frac{1}{\omega_1 R} = \frac{1}{(19\times 10^3)(10\times 10^3)} = \mathbf{5.263\text{ nF}}$$

$$C_1 = \frac{1}{\omega_2 R} = \frac{1}{(21\times 10^3)(10\times 10^3)} = \mathbf{4.762\text{ nF}}$$

$$K = \frac{R_f}{R_i} = 5 \quad \longrightarrow \quad R_f = 5R_i = \mathbf{50\,k\Omega}$$

P.P.14.14 $K_f = \frac{\omega'_c}{\omega_c} = \frac{2\pi\times 10^4}{1} = 2\pi\times 10^4$

$$C' = \frac{C}{K_m K_f} \quad \longrightarrow \quad K_m = \frac{C}{C' K_f} = \frac{1}{(15\times 10^{-9})(2\pi\times 10^4)} = \frac{10^4}{3\pi}$$

$$R' = K_m R = \frac{10^4}{3\pi}(1) = 1.061\text{ k}\Omega$$

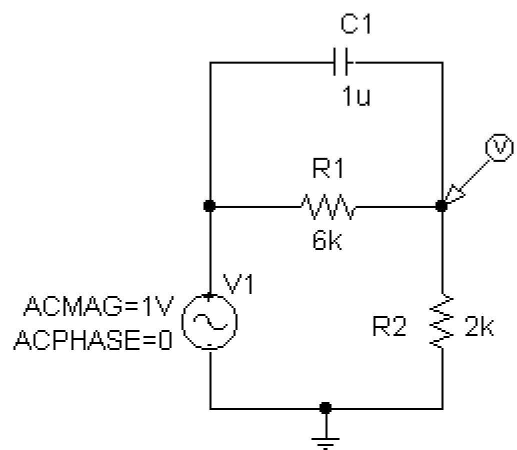
$$L' = \frac{K_m}{K_f} L = \frac{10^4}{3\pi}\cdot\frac{2}{2\pi\times 10^4} = 33.77\text{ mH}$$

Therefore,

$$R'_1 = R'_2 = \mathbf{1.061\,k\Omega}$$

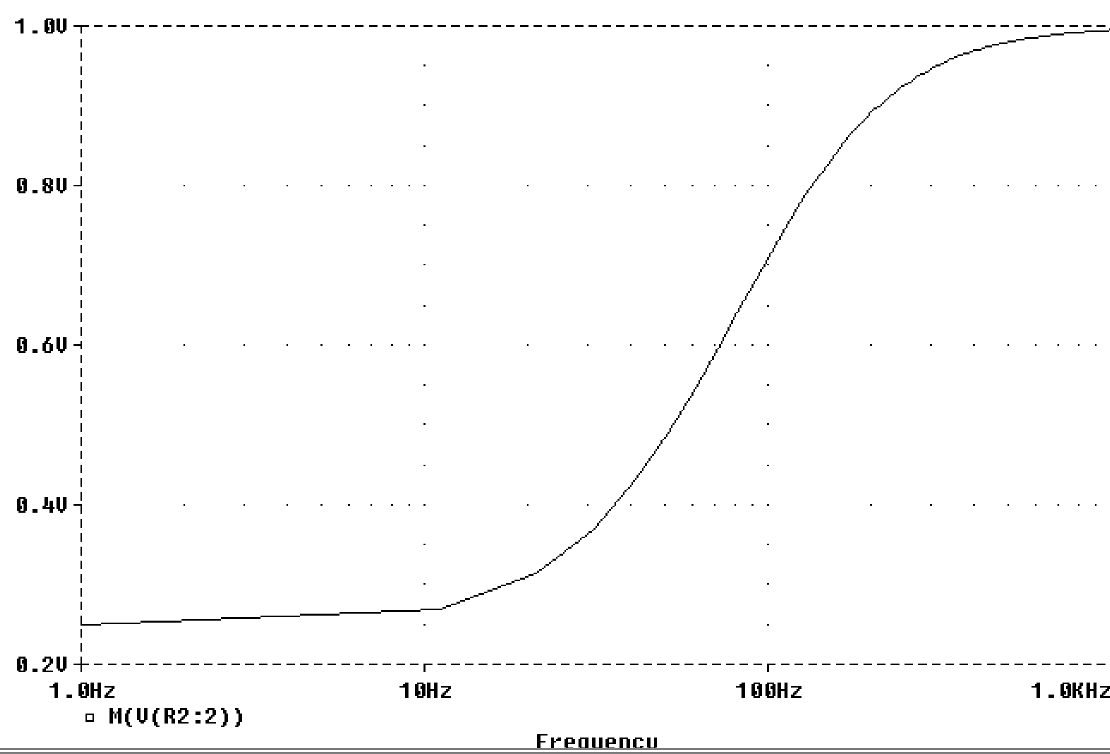
$C_1' = C_2' = \mathbf{15\ nF}$
$L' = \mathbf{33.77\ mH}$

P.P.14.15 The schematic is shown in Fig. (a).

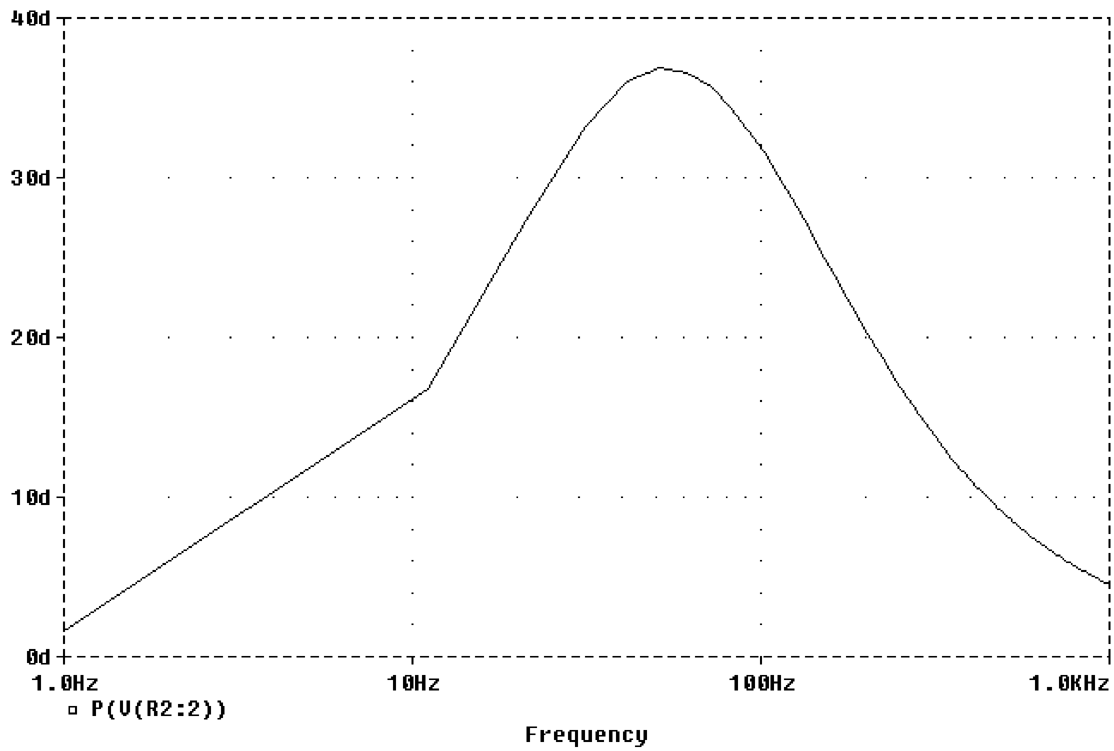


(a)

Use the **AC Sweep** option of the **Analysis Setup**. Choose a *Linear* sweep type with the following *Sweep Parameters* : *Total Pts* = 100, *Start Freq* = 1, and *End Freq* = 1K. After saving and simulating the circuit, we obtain **the magnitude and phase plots are shown in Figs. (b) and (c)**.

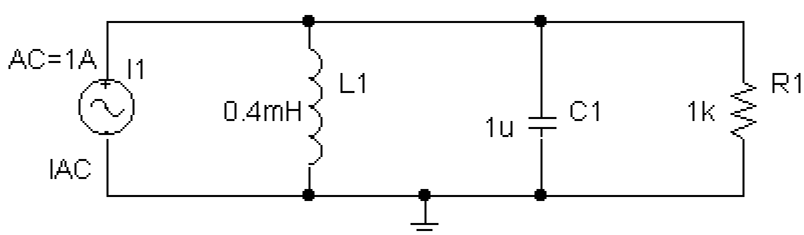


(b)



(c)

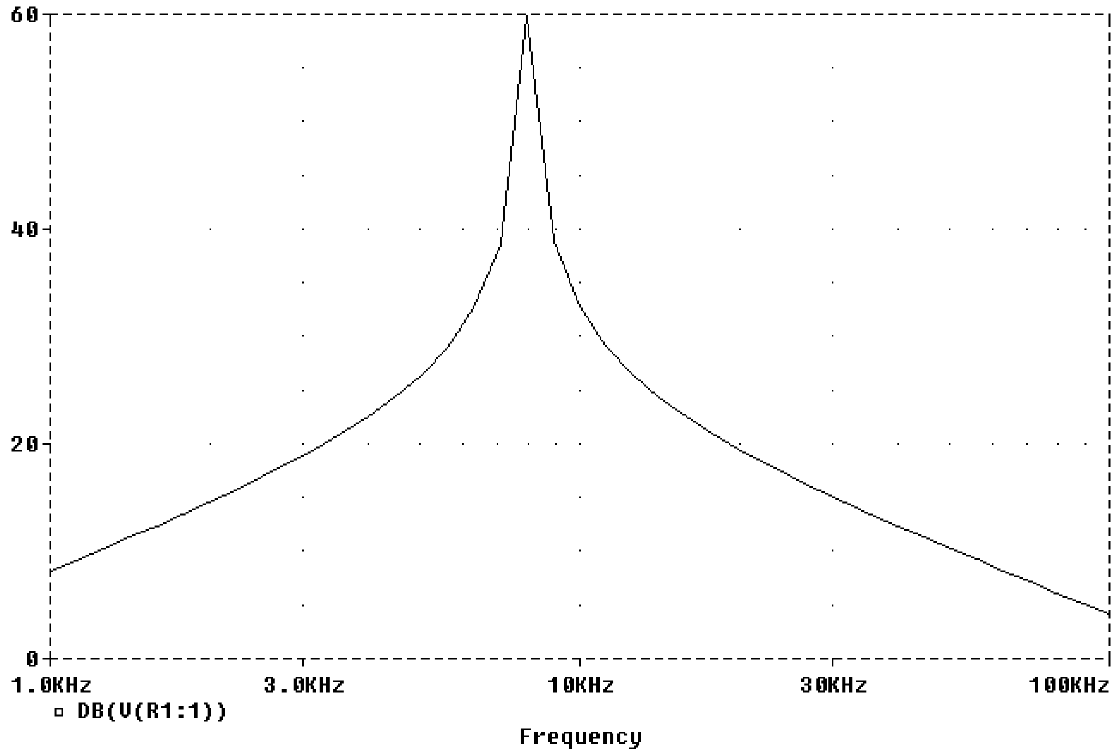
P.P.14.16 The schematic is shown in Fig. (a).



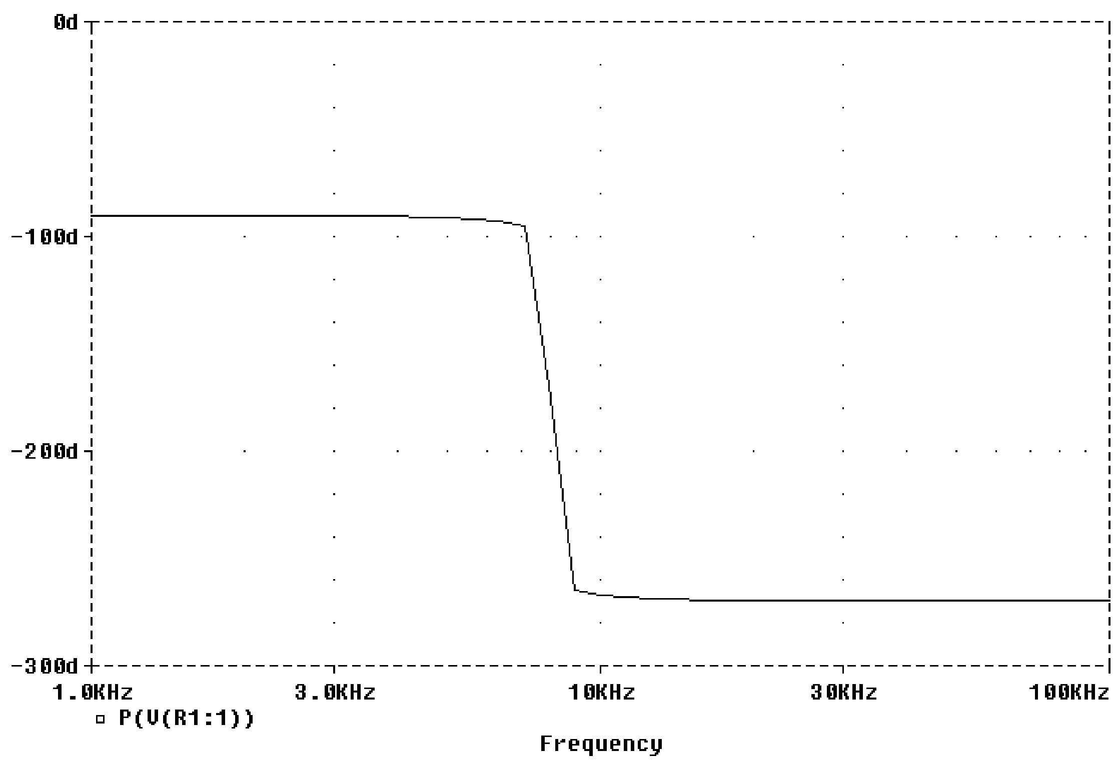
(a)

Use the **AC Sweep** option of the **Analysis Setup**. Choose a *Decade* sweep type with these *Sweep Parameters* : *Pts/Decade* = 20, *Start Freq* = 1K, and *End Freq* = 100K. Save and simulate the circuit.

For the magnitude plot, choose DB( ) from the **Analog Operators and Functions** list. Then, select the voltage V(R1:1) and OK. Another option would be to type DB(V(R1:1)) as the **Trace Expression**. For the phase plot, choose P( ) from the **Analog Operators and Functions** list. Then, select the voltage V(R1:1) and OK. Another option would be to type VP(R1:1) as the **Trace Expression**. **The resulting magnitude and phase plots are shown in Figs. (b) and (c)**.


60
40
20
0
1.0KHz
3.0KHz
10KHz
30KHz
100KHz
DB(V(R1:1))
Frequency

(b)


0d
-100d
-200d
-300d
1.0KHz
3.0KHz
10KHz
30KHz
100KHz
P(V(R1:1))
Frequency

(c)

P.P.14.17 $\omega_0 = 2\pi f_0 = \dfrac{1}{\sqrt{LC}}$

or $C = \dfrac{1}{4\pi^2 f_0^2 L}$

For the high end of the band, $f_0 = 108$ MHz

$$C_1 = \frac{1}{4\pi^2 (108^2 \times 10^{12})(4 \times 10^{-6})} = 0.543 \text{ pF}$$

For the low end of the band, $f_0 = 88$ MHz

$$C_2 = \frac{1}{4\pi^2 (88^2 \times 10^{12})(4 \times 10^{-6})} = 0.818 \text{ pF}$$

Therefore, C must be adjustable and be in the range **0.543 pF to 0.818 pF**.

P.P.14.18

For BP_6, $f_0 = 1336$ Hz and it passes frequencies in the range $1209 \text{ Hz} < f < 1477 \text{ Hz}$.

$$B = 2\pi(1477 - 1209) = 1683.9$$

$$L = \frac{R}{B} = \frac{600}{1683.9} = \mathbf{356\ mH}$$

$$C = \frac{1}{4\pi^2 f_0^2 L} = \frac{1}{4\pi^2 (1336)^2 (0.356)} = \mathbf{39.83\ nF}$$

P.P.14.19 $C = 10\ \mu\text{F}$ and $R_1 = R_2 = 8\ \Omega$

$$2\pi f_c = \frac{1}{R_1 C} \longrightarrow f_c = \frac{1}{2\pi R_1 C} = \frac{1}{(2\pi)(8)(10 \times 10^{-6})} = \mathbf{1.989\ kHz}$$

$$L = \frac{R_2}{2\pi f_c} = \frac{8}{(2\pi)(1.989 \times 10^3)} = \mathbf{0.64\ mH}$$