Chapter 17/Problem 1

(a) Without L present and with $\hat{V}_1 = \hat{V}_{IN}$

$$Z(j\omega) = \frac{1}{j\omega C + \frac{1}{R_L}} = \frac{R_L}{1 + j\omega R_L C}$$

and

$$\hat{V}_{out} = \frac{-g_m R_L \hat{V}_{IN}}{1 + j\omega R_L C}$$

With $\omega = 10^7$ rad/s, $C = 40 \times 10^{-12}F$, $g_m = 0.004S$ and $R_L = 40{,}000\Omega$

$$\hat{V}_{out} = \frac{-0.004(40{,}000)\hat{V}_{IN}}{1 + j(2\pi \times 10^7)(40{,}000)(40 \times 10^{-12})} = \frac{-160\hat{V}_{IN}}{1 + j32\pi} = \frac{-160\angle 0^\circ \hat{V}_{IN}}{100.54\angle 89.43^\circ}$$

$$\hat{V}_{out} = -1.592 \angle 89.43^\circ \hat{V}_{IN}$$

Set the reference for $\hat{V}_{IN}$ at 0°

$$\hat{V}_{out} = (-1.592\angle 89.53^\circ)(0.2\angle 0^\circ) = 0.318 \angle 89.43^\circ$$

The magnitude of V_{out} is

$$|V_{out}| = 0.318$$

(b) Now with L present

$$Y(j\omega) = \frac{1}{j\omega L} + j\omega C + \frac{1}{R_L} = \frac{R_L - \omega^2 R_L L C + j\omega L}{j\omega R_L L}$$

with element values inserted

$$Y(j\omega) = \frac{40{,}000 - 1.6 \times 10^{-6} L\omega^2 + j\omega L}{j40{,}000\omega L}$$

and

$$Z(j\omega) = \frac{j40{,}000\omega L}{40{,}000 - 1.6 \times 10^{-6} L\omega^2 + j\omega L}$$

With

$$V_{out}(j\omega) = -Z(j\omega) g_m V_{IN}(j\omega)$$

$V_{out}(j\omega)$ is maximized by making the denominator of $Z(j\omega)$ as small as possible

17/1 Cont'd

<u>dn</u> $Z(j\omega)$

$$Z(j\omega) = \frac{j40{,}000\,\omega L}{40{,}000 - 1.6\times10^{-6} L\omega^2 + j\omega L}$$

Set

$$1.6\times10^{-6} L\omega^2 = 40{,}000$$

$$L = \frac{40000}{1.6\times10^{-6}(2\pi\times10^7)^2} = 6.332\times10^{-6}\ H \leftarrow$$

Then with $L = 6.332\times10^{-6}$ H

$$\hat{V}_{out} = -g_m Z(j\omega)\hat{V}_{IN}$$

$$= -0.004\left(\frac{j40{,}000}{j397.8}\right)\hat{V}_{IN}$$

$$= -0.004(100.53)\hat{V}_{IN}$$

$$= -0.4021$$

Again with $\hat{V}_{IN} = 0.2\angle 0^\circ$ V

$$\hat{V}_{OUT} = (-0.4021)(0.2\angle 0^\circ)\ V$$

with

$$|\hat{V}_{OUT}| = -0.1206\,V$$

Compare this with part (a)

Chapter 17/Problem 2

By a voltage divider with L present

$$Z_p(j\omega) = \frac{\frac{j\omega L}{j\omega C}}{j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= \frac{-j\frac{L}{C}}{\omega L - \frac{1}{\omega C}}$$

Fig P17.2

Then
$$\hat{V}_1 = \frac{Z_p(j\omega)\hat{V}_{IN}}{R_S + Z_p(j\omega)} = \frac{\frac{-jL/C}{\omega L - 1/\omega C}\hat{V}_{IN}}{R_S + \frac{-jL/C}{\omega L - 1/\omega C}} = \frac{\frac{-jL/C}{\omega L - 1/\omega C}\hat{V}_{IN}}{\frac{R_S(\omega L - 1/\omega C) - jL/C}{\omega L - 1/\omega C}}$$

$$V_1 = \frac{\frac{L}{C}\hat{V}_{IN}}{\frac{L}{C} - jR_S\left(\omega L - \frac{1}{\omega C}\right)}$$

$\hat{V}_{out}$ will be maximized when $\hat{V}_1$ is maximized and this is accomplished by setting

$$\omega L - \frac{1}{\omega C} = 0$$

or setting

$$\omega_r = \omega_0 = \frac{1}{\sqrt{LC}}$$

with $\omega_r = 2\pi \times 10^7$ rad/s and $C = 20\times 10^{-12}$F

$$L = \frac{1}{\omega_r^2 C} = \frac{1}{(2\pi\times 10^7)^2(20\times 10^{-12})}$$

$$L = 1.267\times 10^{-5}\ H$$

Then

$$\hat{V}_{out} = -g_m R_S \hat{V}_{IN} = (-0.004)(20{,}000)\hat{V}_{IN}$$

$$= -80\hat{V}_{IN}$$

No value of V_{IN} was given in the problem statement

Chapter 17/Problem 3

Fig P17.3a

(a) In Fig 17.3a

$$Y_p(j\omega) = \frac{1}{R_2} + j\omega C + \frac{1}{j\omega L}$$

Fig P17.3b

and

$$Z(j\omega) = R_2 + Z_p(j\omega)$$

$$= R_2 + \frac{1}{\frac{1}{R_2} + j\left(\omega C - \frac{1}{\omega L}\right)}$$

To make the impedance entirely real which is a condition of resonance

$$\omega_r C - \frac{1}{\omega_r L} = 0$$

$$\omega_r^2 = \frac{1}{LC}$$

$$\omega_r = \omega_0 = \frac{1}{\sqrt{LC}}$$

and then

$$Z(j\omega) = R_1 + R_2$$

(b) In fig 17.3b

$$Z_p(j\omega) = R_2 + j\omega L + \frac{1}{j\omega C}$$

$$Y_p = \frac{1}{R_2 + j\left(\omega L - \frac{1}{\omega C}\right)}$$

and

$$Y_{in}(j\omega) = \frac{1}{R_1} + \frac{1}{R_2 + j\left(\omega L - \frac{1}{\omega C}\right)}$$

Again, to make $Y(j\omega)$ entirely real

$$\omega_r = \omega_0 = \frac{1}{\sqrt{LC}}$$

and

$$Y_{in}(j\omega) = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 R_2}{R_1 + R_2}$$

and $Z_{in}(j\omega) = \frac{R_1 R_2}{\ldots}$

Chapter 17/Problem 4

If $Z(j\omega_r) = Re[Z(j\omega_r)] + Im[Z(j\omega_r)]$

The value of ω_r is found by setting $Im[Z(j\omega_r)] = 0$ so that the impedance at resonance is entirely real.

$$Z_{IN}(j\omega) = \frac{a+j\omega}{8-\omega^2+j4\omega} = \frac{(a+j\omega)(8-\omega^2+j4\omega)}{(8-\omega^2+j4\omega)(8-\omega^2-j4\omega)}$$

$$= \frac{(8-\omega^2)a - 4\omega^2 + j(8\omega-\omega^3+4a\omega)}{(8-\omega^2)^2-16\omega^2}$$

Thus

$$Re[Z_{IN}(j\omega)] = \frac{(8-\omega^2)a-4\omega^2}{(8-\omega^2)^2-16\omega^2}$$

and

$$Im[Z_{IN}(j\omega)] = \frac{8\omega-\omega^3+4a\omega}{(8-\omega^2)^2-16\omega^2}$$

(a) To find ω_r, set $Im[Z_{IN}(j\omega)] = 0$. with $a=1$

$$8\omega - \omega^3 + 4a\omega = 0$$

$$\omega^2 = 4 - 8 = 4$$

$$\omega = \omega_r = 2 \text{ rad/s}$$

Then $Z_{IN}(j\omega_r)$ is found from the real part. With $a=1$

$$Z_{IN}(j\omega_r) = \frac{(8-4)(1)-4(4)}{(8-4)^2-16(4)} = \frac{4-16}{16-64} = \frac{-12}{-48} = \frac{1}{4}\,\Omega$$

(b) Look at part (a) where

$$8\omega_r - \omega_r^3 + 4a\omega_r = 0$$

and observe that to make ω_r real and positive

$$\omega_r^2 = 8-4a$$

$$8-4a = 0$$

$$a = 2$$

Hence

$$0 \le a \le 2$$

Chapter 17/Problem 5

Here

$$Y_{IN}(s) = Cs + 1 + \frac{2s+1}{s^2+1}$$

$$= \frac{Cs^3 + Cs + s^2 + 2s + 2}{s^2+1}$$

Then

$$Y(j\omega) = \frac{2-\omega^2 + j(C\omega - C\omega^3 + 2\omega)}{1-\omega^2}$$

$$Re[Y(j\omega)] = \frac{2-\omega^2}{1-\omega^2}$$

$$Im[Y(j\omega)] = \frac{C(\omega-\omega^3)+2\omega}{1-\omega^2}$$

At $\omega_r = 3$ rad/s, set $Im[Y(j3)] = 0$

$$\frac{3C(1-9)+2(3)}{1-9} = 0$$

$$-24C = -6$$

$$C = \frac{1}{4}F$$

and obtain Y_{IN}, use $Re[Y_{IN}(j\omega_r)]$

$$Y_{IN}(j3) = \left.\frac{2-\omega^2}{1-\omega^2}\right|_{\omega=3\,rad/s} = \frac{2-9}{1-9} = \frac{-7}{-8} = \frac{7}{8}\,\mho$$

Chapter 17 / Problem 6

Fig P17.6

Equation (17.4) gives the resonant frequency

$$\omega_r = \sqrt{\frac{1}{LC} - \left(\frac{R}{L}\right)^2}$$

$$LC = 2(0.02) = 0.04$$

$$\frac{R}{L} = \frac{2.8}{2} = 1.4$$

$$\omega_r = \sqrt{25 - (1.4)^2} = \sqrt{25 - 1.96} = \sqrt{23.04} = 4.8 \text{ rad/s}$$

Then from eq (17.5)

$$Z(j\omega_r) = \frac{L}{RC} = \frac{2}{2.8(0.02)} = 35.71\,\Omega$$

Chapter 17/Problem 7

Fig P17.7

Consider the parallel portion of the network with $C = 10\mu F$ and $L = 0.1H$. Equations 17.4 and 17.5 indicate that

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{R_L^2}{L^2}}$$

and $$Z_p(j\omega_r) = \frac{L}{R_L C}$$

with $$LC = 0.1(10\times10^{-6}) = 1\times10^{-6}$$

and $$\frac{1}{LC} = 10^6$$

$$\omega_r = \sqrt{10^6 - 100R_L^2}$$

$$Z_p(j\omega_r) = \frac{10{,}000}{R_L}\,\Omega$$

At resonance the total impedance (resistance) will be

$$Z_{IN}(j\omega_r) = 125\Omega + \frac{10{,}000}{R_L}\,\Omega$$

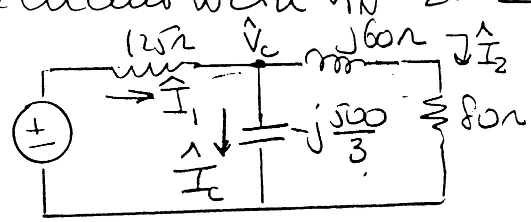
(a) when $R_L = 80\Omega$

$$\omega_r = \sqrt{10^6 - 100(80)^2} = \sqrt{360{,}000} = 600\,\text{rad/s}$$

and

$$Z_{IN}(j\omega_r) = 125 + \frac{10{,}000}{80} = 125 + 125 = 250\Omega$$

The circuit with $\hat{V}_{IN} = 250\angle 0°$ and at $\omega_r = 600$ rad/s is shown



$$\hat{I}_1 = \frac{250\angle 0°}{250} = 1\angle 0°\,A$$

$$\hat{V}_c = 250\angle 0° - 125(1\angle 0°) = 125\angle 0°\,V$$

$$\hat{I}_c = \frac{\hat{V}_c}{-j\frac{500}{3}} = \frac{125\angle 0°}{\frac{500}{3}\angle -90°} = \frac{3}{4}\angle 90°\,A$$

and $$\hat{I}_2 = \hat{I}_1 - \hat{I}_c = 1\angle 0° - \frac{3}{4}\angle 90° = 1 + j0 - \left(0 + j\frac{3}{4}\right) = 1 - j\frac{3}{4}\,A$$

or $$\hat{I}_2 = 1.25\angle -36.87°\,A$$

17/1 Contd ②

The power (in watts) delivered to $R_L = 80\Omega$ will be

$$P_{80} = (1)^2(80) = 80W$$

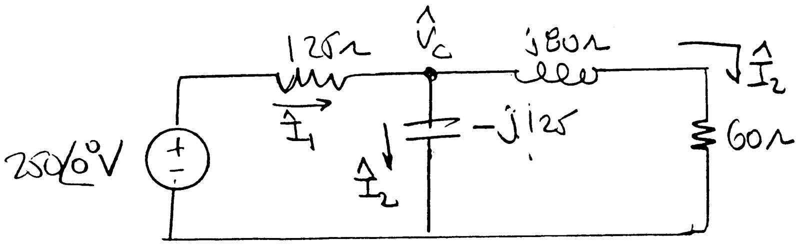
(b) When $R_L = 60\Omega$

$$\omega_r = \sqrt{10^6 - 100(60)^2} = \sqrt{10^6 - 360{,}000} = \sqrt{640{,}000} = 800 rad/s$$

and

$$Z_{IN}(j\omega_r) = 125 + \frac{10{,}000}{60} = 291.67\Omega$$

The circuit at $\omega_r = 800 rad/s$ is shown



$$\hat{I}_1 = \frac{250\angle 0^\circ}{291.67^0} = 0.857\angle 0^\circ$$

$$\hat{V}_c = 250\angle 0^\circ - (125\angle 0^\circ)(0.857\angle 0^\circ)$$
$$= 142.86\angle 0^\circ$$

$$\hat{I}_c = \frac{\hat{V}_c}{-j125} = \frac{142.86\angle 0^\circ}{125\angle -90^\circ} = \frac{8}{7}\angle 90^\circ A$$

$$\hat{I}_2 = \hat{I}_1 - \hat{I}_c = \frac{6}{7}\angle 0^\circ - \frac{8}{7}\angle 90^\circ = \frac{6}{7} - j\frac{8}{7}$$

or

$$\hat{I}_2 = \frac{10}{7}\angle -53.13^\circ A$$

The power (in watt) delivered to $R_L = 60\Omega$ will be

$$P_{60} = \left(\frac{6}{7}\right)^2(60) = \frac{2160}{49} W$$

Chapter 17/Problem 9

Fig P17.9

Here

$$Z(j\omega) = j\omega L + \frac{\frac{R}{j\omega C}}{R + \frac{1}{j\omega C}}$$

$$= j\omega L + \frac{R}{1 + j\omega RC}$$

$$= \frac{j\omega L - RLC\omega^2 + R}{1 + j\omega RC}\left[\frac{1 - j\omega RC}{1 - j\omega RC}\right]$$

$$= \frac{j\omega L - RLC\omega^2 + R + jRLC\omega^2 + j\omega^3 R^2 LC^2 - jR^2 C\omega}{1 + (\omega RC)^2}$$

$$Re[Z(j\omega)] = \frac{R}{1 + (\omega RC)^2}$$

$$Im[Z(j\omega)] = \frac{\omega L + \omega^3 R^2 LC^2 - \omega R^2 C}{1 + (\omega RC)^2}$$

From the imaginary part

$$Im[Z(j\omega_r)] = 0 = \omega_r^2 R^2 LC^2 - (R^2 C - L) = 0$$

$$\omega_r^2 = \frac{R^2 C - L}{R^2 LC^2} = \frac{1}{LC} - \frac{1}{R^2 C^2}$$

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{1}{R^2 C^2}} \leftarrow$$

with

$$\omega_0^2 = \frac{1}{LC}$$

$$\omega_r = \sqrt{\frac{1}{LC}\left(1 - \frac{L}{R^2 C}\right)}$$

$$= \omega_0 \sqrt{1 - \frac{L}{R^2 C}}$$

17/9 Cont'd

From

$$\mathrm{Im}\left[Z(j\omega_r)\right] = \frac{R}{1+\omega_r^2(R^2C^2)}$$

$$= \frac{R}{1+R^2C^2\left(\frac{1}{LC}-\frac{1}{R^2C^2}\right)}$$

$$= \frac{R}{1+\frac{R^2C}{L}-1} = \frac{RL}{R^2C} = \frac{L}{RC} \leftarrow$$

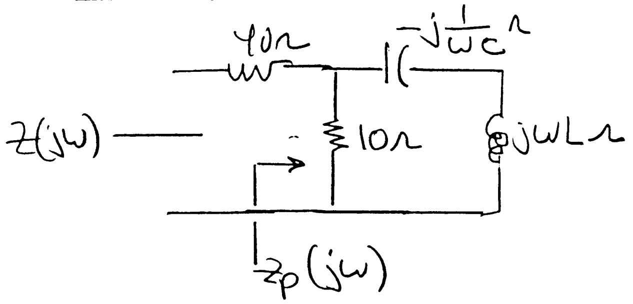
Chapter 17/Problem 11

Solution Available on Disc

Chapter 17 / Problem 12

Fig P17.12

For input across terminals a-b



$$Y_p(j\omega) = \frac{1}{10} + \frac{1}{j\omega L - j\frac{1}{\omega C}}$$

$$= \frac{j10\left(\omega L - \frac{1}{\omega C}\right) + 10}{j10\left(\omega L - \frac{1}{\omega C}\right)}$$

$$Z_p(j\omega) = \frac{j10\left(\omega L - \frac{1}{\omega C}\right)}{10 + j10\left(\omega L - \frac{1}{\omega C}\right)}$$

and

$$Z(j\omega) = 40\Omega + \frac{j10\left(\omega L - \frac{1}{\omega C}\right)}{10 + j10\left(\omega L - \frac{1}{\omega C}\right)}$$

To make $Z(j\omega)$ entirely resistive which is a condition of resonance, set

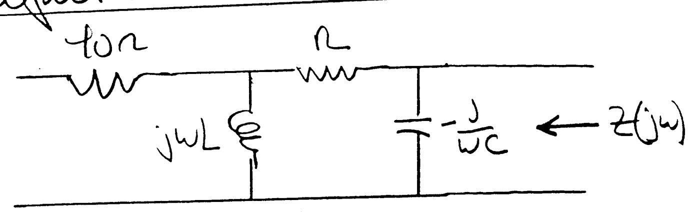
$$\omega L - \frac{1}{\omega C} = 0$$

$$\omega_r^2 = \frac{1}{LC}$$

and

$$\omega_r = \omega_0 = \sqrt{\frac{1}{LC}} = \sqrt{\frac{1}{0.8(0.002)}} = \sqrt{625} = 25\,\text{rad/s}$$

For input across terminals b-c



Observe that the 40Ω resistor is not connected

$$Z(j\omega) = \frac{(R + j\omega L)\left(-j\frac{1}{\omega C}\right)}{R + j\left(\omega L - \frac{1}{\omega C}\right)} = \frac{\frac{L}{C} - j\frac{R}{\omega C}}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

Let $A = \omega L - \frac{1}{\omega C}$

17/12 Cont'd

$$Z(j\omega) = \frac{\frac{L}{C} - j\frac{R}{\omega C}}{R+jA} \cdot \frac{R-jA}{R-jA} = \frac{R\frac{L}{C} - j\frac{L}{C}A - j\frac{R^2}{\omega C} + \frac{RA}{\omega C}}{R^2+A^2}$$

$$\mathrm{Im}\left[Z(j\omega)\right] = -\frac{\left(\frac{L}{C}A + \frac{R^2}{\omega C}\right)}{R^2+A^2}$$

For resonance, set $\mathrm{Im}\left[Z(j\omega)\right] = 0$

$$\frac{L}{C}A + \frac{R^2}{\omega C} = 0$$

$$\frac{L}{C}\left(\omega L - \frac{1}{\omega C}\right) = -\frac{R^2}{\omega C}$$

$$\frac{L}{C}\left(\frac{\omega^2 LC - 1}{\omega C}\right) = -\frac{R^2}{\omega C}$$

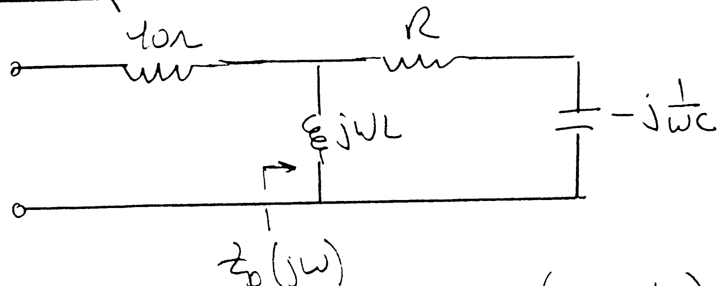
$$\frac{L^2}{C}\omega^2 = \frac{L}{C^2} - \frac{R^2}{C}$$

$$\omega^2 = \frac{C}{L^2}\left[\frac{L}{C^2} - \frac{R^2}{LC}\right] = \frac{1}{LC} - \left(\frac{R}{L}\right)^2$$

$$\omega_r = \sqrt{\frac{1}{LC} - \left(\frac{R}{L}\right)^2} = \sqrt{625 - 156.25}$$

$$\omega_r = \sqrt{468.75} = 21.65 \text{ rad/s}$$

For input across terminals a-c



$$Z_p(j\omega) = \frac{j\omega L\left(R - \frac{1}{j\omega C}\right)}{R + j\left(\omega L - \frac{1}{\omega C}\right)} = \frac{j\omega LR + \frac{L}{C}}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

let $A = \omega L - \frac{1}{\omega C}$

$$Z_p(j\omega) = \frac{\frac{L}{C} + j\omega RL}{R + jA} \cdot \frac{R - jA}{R - jA}$$

$$= \frac{\frac{RL}{C} + j\omega R^2 L - j\frac{L}{C}A + \omega RLA}{R^2 + A^2}$$

$$\mathrm{Im}\left[Z_p(j\omega)\right] = \frac{\omega R^2 L - \frac{L}{C}A}{R^2 + A^2}$$

For resonance

$$\mathrm{Im}\left[Z_p(j\omega)\right] = 0 = \frac{\omega R^2 L - \frac{L}{C}A}{R^2 + A^2}$$

$$\omega_r R^2 L = \frac{L}{C}\left(\omega_r L - \frac{1}{\omega C}\right)$$

$$= \frac{L}{\omega_r C^2}\left(LC\omega_r^2 - 1\right)$$

$$\omega_r^2 R^2 C^2 = LC\omega_r^2 - 1$$

$$\omega_r^2 (LC - R^2 C^2) = 1$$

$$\omega_r^2 = \frac{1}{LC - (RC)^2} = \frac{1}{0.0016 - 0.0004}$$

$$\omega_r = \sqrt{\frac{1}{0.0012}} = \sqrt{833.33} = 28.87 \text{ rad/s}$$

Chapter 17/ Problem 15

Fig P17.15a

Fig P17.15b

For either figure

$$\omega_r^2 = \frac{1}{LC}$$

$$L = \frac{1}{\omega_r^2 C}$$

With

$$f_r = 10{,}000 \text{ Hz}$$

$$\omega_r = 2\pi(10{,}000) \text{ rad/s}$$

and

$$\omega_r^2 = 4\pi^2 \times 10^8 \text{ rad}^2/\text{s}^2$$

Thus with $C = 10^{-7}$ F

$$L = \frac{10^7}{4\pi^2 \times 10^8} = 2.533 \text{ mH}$$

Chapter 17 / Problem 16

fig P17.16a

fig P17.16b

(a) For fig P17.16a use eq 17.4

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

If $f_r = 1560$ Hz, then

$$\omega_r = 2\pi(1560) = 9801.77 \text{ rad/s}$$

and $$\omega_r^2 = 9.607468 \times 10^7 \text{ rad}^2/\text{s}^2$$

Then with $C = 10^{-7}$ F and $R = 510\,\Omega$

$$9.607468 \times 10^7 = \frac{10^7}{L} - \frac{2.601 \times 10^5}{L^2}$$

This leads to a quadratic

$$L^2 - 0.104086L + 2.707269 \times 10^{-3} = 0$$

There are two roots

$$L = 53.14 \text{ mH}$$

$$L = 50.94 \text{ mH}$$

(a) for fig P.17.16b, it is shown in Problem 17.9 that

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{1}{R^2C^2}}$$

Then

$$9.607468 \times 10^7 = \frac{10^7}{L} - 3.844675 \times 10^8$$

$$L = \frac{10^7}{4.805422 \times 10^8} = 20.81 \text{ mH}$$

17/17

Bandwidth and Q
differ from answers
listed with problem statement

Chapter 17/Problem 16

fig P17.17

The maximum value is at resonance

$$\omega_M = \omega_0 = 10^6 \text{ rad/s} \doteq \frac{1}{\sqrt{LC}}$$

and

$$Z(\omega_M) = R = 20{,}000\,\Omega$$

The magnitude at any ω is given by eq (17.9b).

$$10^8 = \frac{1}{\frac{1}{R^2} \pm \left(\omega C - \frac{1}{\omega L}\right)^2}$$

$$= \frac{1}{2.5\times10^{-9} \pm \left(0.9\times10^6 C - \frac{1}{0.9\times10^6 L}\right)^2}$$

$$10^{-8} = 2.5\times10^{-9} \pm \left(0.9\times10^6 C - \frac{1}{0.9\times10^6 L}\right)^2$$

$$\left(7.5\times10^{-9}\right)^{1/2} = \pm\,\frac{0.81\times10^{12} LC - 1}{0.9\times10^6 L}$$

With $LC = 10^{-12}$

$$\left(8.660\times10^{-5}\right)\left(0.9\times10^6 L\right) = \pm(0.810 - 1)$$

To make L real

$$77.94 L = 0.19$$

$$L = 0.002438 \qquad (2.438\text{ mH})$$

$$C = \frac{1}{L\omega_M^2} = \frac{10^{-12}}{0.002438} = 4.101\times10^{-10}\text{ F}$$

$$(410.2\text{ pF})$$

then

$$B_W = \frac{1}{RC} = \frac{1}{40{,}000(410.1\times10^{-12})} = 60{,}960 \text{ rad/s}$$

and

$$Q = \frac{\omega_M}{B_W} = \frac{10^6}{60{,}960} = 16.40$$

Chapter 17 / Problem 18

(a)

$L = 100\mu H$

$\omega_m = 2.08\pi \times 10^6$ rad/s

$B_w = 2\pi \times 10^4$ rad/s

$\omega_m = \frac{1}{LC}$

$B_w = \frac{1}{RC}$

Fig P17.18

$$C = \frac{1}{L\omega_m^2} = \frac{1}{(100\times10^{-6})(2.08\pi\times10^6)^2} = 234.2\times10^{-12}\,F \quad (234.2\,pF)$$

$$R = \frac{1}{CB_w} = \frac{1}{(234.2\times10^{-12})(2\pi\times10^4)} = 67{,}959\,\Omega \quad (67.96\,k\Omega)$$

(b)

$C = 250\,pF$

$\omega_m = 1.84\pi \times 10^6$ rad/s

$B_w = 2\pi \times 10^4$ rad/s

$$L = \frac{1}{C\omega_m^2} = \frac{1}{(250\times10^{-12})(1.84\pi\times10^6)^2} = 1.197\times10^{-4}\,H \quad (119.7\,\mu H)$$

$$R = \frac{1}{CB_w} = \frac{1}{(250\times10^{-12})(2\pi\times10^4)} = 63.66\times10^3 \quad (63.66\,k\Omega)$$

Chapter 17 / Chapter 19

$\boxed{\text{Prob } P17.19}$

(a) Select $L = 300\mu H$ (middle of range available)

Specification:

lowend

$f_M = 550{,}000\ Hz$; $\omega_M = 1.1\pi \times 10^6\ rad/s$

highend

$f_M = 1{,}650{,}000\ Hz$; $\omega_M = 3.3\pi \times 10^6\ rad/s$

For the lowend

$$C = \frac{1}{L\omega_M^2} = \frac{1}{(300\times10^{-6})(1.1\pi\times10^6)^2} = 279.12\times10^{-12} F$$

For the high end

$$C = \frac{1}{L\omega_M^2} = \frac{1}{(300\times10^{-6})(3.3\pi\times10^6)^2} = 31.01\times10^{-12} F$$

Select $C = 30-300\,pF$

If

$f_M = 920{,}000\ Hz$; $\omega_M = 1.84\pi\times10^6\ rad/s$

$B_f = 20{,}000\ Hz$; $B_\omega = 4\pi\times10^4\ rad/s$

Then

$$Q = \frac{\omega_M}{B_\omega} = 46 = R\sqrt{\frac{C}{L}}$$

with C tuned to

$$C = \frac{1}{L\omega_M^2} = \frac{1}{(300\times10^{-6})(1.84\pi\times10^6)^2} = 99.76\times10^{-12} F$$

$$R = 46\sqrt{\frac{L}{C}} = 46\sqrt{\frac{300\times10^{-6}}{99.76\times10^{-12}}} = 46\sqrt{3.007\times10^6}$$

$$R = 46(1734.2) = 79{,}771\,\Omega = 79.77\,k\Omega$$

17/19 Cont'd

With the components of (b)

Low end

$L = 300\,\mu H$

$R = 79.77\,k\Omega$

$C = 279.1\ pf$

$W_m = 1.1\pi \times 10^6\ rad/s$

$$B_w = \frac{1}{RC} = \frac{1}{(79.77\times10^3)(279.12\times10^{-12})} = 44.91\times10^3\ rad/s$$

$$B_f = \frac{44.91\times10^3}{2\pi} = 7.15\times10^3\ Hz \qquad (7.15\ kHz)$$

High end

$L = 300\,\mu F$

$R = 79.77\,k\Omega$

$C = 31.01\ pf$

$W_m = 3.3\pi\times10^6\ rad/s$

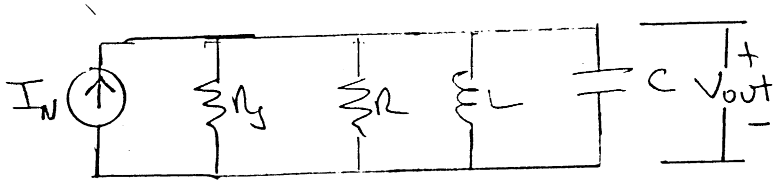
$$B_w = \frac{1}{(79.77\times10^3)(31.01\times10^{-12})} = 404.3\times10^3\ rad/s$$

$$B_f = \frac{404.3\times10^3}{2\pi} = 64.34\ Hz$$

Chapter 17/Problem 20

First make a voltage to current source transformation

Fig P17.20



$R_s = 40\,k\Omega$
$R = 10\,k\Omega$
$C = 1\,\mu F$
$L = 0.01\,H$

$$R_{eq} = \frac{R R_s}{R + R_s} = \frac{(10k\Omega)(40k\Omega)}{50k\Omega}$$

$$R_{eq} = 8k\Omega$$

(a) $$f_m = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = \frac{1}{2\pi}\frac{1}{(0.01)(1\times10^{-6})} = \frac{1}{2\pi}\frac{1}{\sqrt{10^{-8}}}$$

$$f_m = 1591.5\,Hz$$

$$|H(j\omega_m)| = \frac{V_{out}}{V_{in}} = \frac{R}{R_s + R} = \frac{10k\Omega}{50k\Omega} = 0.20$$

(b) The exact 3-db bandwidth is

$$B_\omega = \frac{1}{R_{eq}C} = \frac{1}{(8000)(1\times10^{-6})} = 125\,rad/s$$

$$B_f = \frac{125}{2\pi} = 19.89\,Hz$$

(c) approximate values

$$f_2, f_1 = 1591.5 \pm \frac{19.89}{2} = 1601.5,\ 1581.6$$

Exact value

$$f_2 = \frac{1}{2\pi}\left[\frac{1}{2R_{eq}C} + \sqrt{\left(\frac{1}{2R_{eq}C}\right)^2 + \frac{1}{LC}}\right]$$

with $$R_{eq}C = 8000(1\times10^{-6}) = 0.008$$

$$\frac{1}{2R_eC} = \frac{125}{2} = 62.50$$

17/20 Cont'd $LC = (0.01)(1\times10^{-6}) = 10^{-8}$ ②

$$\frac{1}{LC} = 10^{8}$$

Let $\Lambda = \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = \sqrt{(62.5)^2 + 10^8} = 10000.2$

Then

$$f_2 = \frac{1}{2\pi}\left[+62.5 + 10000.2\right] = \frac{1}{2\pi}(10062.7) = 1601.5$$

$$f_1 = \frac{1}{2\pi}\left[-62.5 + 10000.2\right] = \frac{1}{2\pi}(9937.7) = 1581.6$$

Compare exact and approximate and find negligible difference

(d) $Q = \frac{\omega_m}{B_\omega} = \frac{f_m}{B_f} = \frac{1591.5}{19.89} = 80$

(e)

Chapter 17/Problem 21

Fig P17.21

Given data

$$f_r = 10{,}000 \text{ Hz}$$

$$\omega_0 = \omega_r = 20{,}000\pi \text{ rad/s}$$

$$C = 10^{-7} \text{ F}$$

$$B_f = 3000 \text{ Hz}$$

Then

$$L = \frac{1}{C\omega_0^2} = \frac{1}{(10^{-7})(20{,}000\pi)^2} = 2.533\times10^{-3} \text{ H} \quad (2.533 \text{ mH})$$

and

$$Q = \frac{\omega_0}{B_\omega} = \frac{f_0}{B_f} = \frac{10{,}000 \text{ Hz}}{3{,}000 \text{ Hz}} = \frac{10}{3} = R\sqrt{\frac{C}{L}}$$

$$R = \frac{10}{3}\sqrt{\frac{L}{C}} = \frac{10}{3}\sqrt{\frac{2.533\times10^{-3}}{1\times10^{-7}}}$$

$$R = \frac{10}{3}\sqrt{25.33\times10^{3}} = \frac{10}{3}(159.16) = 530.5\ \Omega$$

Chapter 17/ Problem 22

Fig P17.22

Here $\omega_0 = \frac{1}{\sqrt{LC}}$

and

$$Z(j\omega_0) = R$$

So that with $\hat{I}_{IN} = I_m \angle 0°$

$$\hat{V}_C = \hat{V}_L = R I_m$$

(a) $w_C(t) = \frac{1}{2} C [v_C(t)]^2 = \frac{1}{2} C [R^2 I_m^2 \cos^2 \omega_0 t] = \frac{1}{2} C R^2 I_m^2 \cos^2 \omega_0 t$ W

(b) With $i_L(t) = \frac{1}{L}\int v_C(t) = \frac{R I_m}{\omega_0 L} \sin \omega_0 t$ A

then $w_L(t) = \frac{1}{2} L [i_L(t)]^2 = \frac{1}{2} L \left[\frac{R^2 I_m^2}{\omega_0^2 L^2} \sin^2 \omega_0 t\right]$

$$w_L(t) = \frac{1}{2} \frac{R^2 I_m^2}{\omega_0^2 L} \sin^2 \omega_0 t \quad \text{W}$$

(c) $w_C(t) + w_L(t) = \frac{1}{2} R^2 I_m^2 C \left[\cos^2 \omega_0 t + \frac{1}{\omega_0^2 LC} \sin^2 \omega_0 t\right]$

But $\omega_0^2 = \frac{1}{LC}$

So that with $\cos^2 \omega_0 t + \sin^2 \omega_0 t = 1$

$$w_C(t) + w_L(t) = \frac{1}{2} R^2 I_m^2 C$$

12/22 Cont'd

(2)

(d) Over one cycle between 0 and T (T is the period)

$$W_R(0,T) = R\int_0^T i_R^2(t)\,dt = R\int_0^T I_m^2 \cos^2 w_0 t\,dt$$

$$= RI_m^2 \int_0^T \frac{1}{2}\left[t + \cos 2w_0 t\right] dt$$

$$= \frac{RI_m^2}{2}T + \frac{RI_m^2}{4w_0}\left[\sin 2w_0 t\right]_0^T$$

$$= \frac{RI_m^2}{2}T$$

and with $T = \frac{2\pi}{w_0}$

$$W_R(0,T) = \frac{RI_m^2 \pi}{w_0}$$

(e)

$$Q = 2\pi \frac{\text{max energy stored}}{\text{energy dissipated over one period}}$$

$$= 2\pi \frac{\frac{1}{2}R^2 I_m^2 C}{\frac{RI_m^2 \pi}{w_0}}$$

$$= 2\pi \frac{R^2 I_m^2 C w_0}{2RI_m^2 \pi} = w_0 RC$$

also with

$$w_0^2 = \frac{1}{LC}$$

$$w_0 C = \frac{1}{w_0 L}$$

and $$Q = \frac{R}{w_0 L}$$

Chapter 17/Problem 24

Fig P17.24

With

$f_0 = f_r = 10{,}000\ Hz$

$\omega_0 = \omega_r = 20{,}000\pi\ rad/s$

and

$C = 1\times10^{-7} F$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$L = \frac{1}{\omega_0^2 C} = \frac{1}{(20000\pi)^2(1\times10^{-7})} = 2.533\times10^{-3}\ (2.533\ mH)$$

$$Q = \frac{\omega_m}{B_\omega} = \frac{f_0}{B_f} = \frac{10{,}000}{3{,}000} = \frac{10}{3}$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$R = \frac{1}{Q}\sqrt{\frac{L}{C}} = \frac{3}{10}\sqrt{\frac{2.533\times10^{-3}}{1\times10^{-7}}} = 0.3\sqrt{25330}$$

$$R = 47.75\Omega$$

Chapter 17/ Problem 25

(a) By voltage division

fig P17.25

$$H(s) = \frac{V_{out}(s)}{V_{IN}(s)} = \frac{R_2}{Ls + R_1 + R_2 + \frac{1}{Cs}}$$

$$= \frac{R_2 Cs}{LCs^2 + (R_1+R_2)Cs + 1}$$

$$= \frac{\frac{R_2}{L}s}{s^2 + \frac{R_1+R_2}{L}s + \frac{1}{LC}}$$

With component values

$$H(s) = \frac{200\,s}{s^2 + 250s + 10^6}$$

(b) The maximum voltage gain occurs at ω_m

$$\omega_m = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-6}}} = \frac{1}{10^{-3}} = 1000 \text{ rad/s}$$

$$H(j\omega_m) = \frac{200\,(j1000)}{10^6 - 10^6 + 250(j1000)} = \frac{200}{250} = 0.80$$

$$f_M = \frac{\omega_M}{2\pi} = \frac{1000}{2\pi} = 159.15 \text{ Hz}$$

(c) The exact value of the bandwidth is ($R = 160 + 40 = 200\Omega$)

$$B_\omega = \frac{R}{L} = \frac{200}{0.8} = 250 \text{ rad/s}$$

$$B_f = \frac{B_\omega}{2\pi} = 39.79 \text{ Hz}$$

(d) The exact values of the half power frequencies depend on Q.

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{200}\sqrt{\frac{0.8}{1.25\times10^{-6}}} = \frac{1}{200}\sqrt{.64\times10^6}$$

$$Q = \frac{800}{200} = 4$$

$$W_2 = W_M\left[\sqrt{1+\left(\frac{1}{2Q}\right)^2}+\frac{1}{2Q}\right]$$

$$= 1000\left[\sqrt{1+\frac{1}{64}}+\frac{1}{8}\right] = 1000\left[\sqrt{1.01563}+0.125\right]$$

$$W_2 = 1000(1.00778+0.125) = 1132.78 \text{ rad/s}$$

$$W_1 = 1000(1.00778-0.125) = 882.78 \text{ rad/s}$$

$$f_2 = \frac{1132.78}{2\pi} = 180.29 \text{ Hz}$$

$$f_1 = \frac{882.78}{2\pi} = 140.50 \text{ Hz}$$

Note that $B_f = f_2 - f_1 = 39.79$ Hz

(e) From part (d)

$$Q = 4$$

Chapter 25/Problem 26

(a) From Problem 25

$$H(s) = \frac{V_{out}(s)}{V_{IN}(s)} = \frac{\frac{R_2}{L}s}{s^2 + \frac{R_1+R_2}{L}s + \frac{1}{LC}}$$

With component values

$$H(s) = \frac{250s}{s^2 + 312.5s + 1.5625\times10^6}$$

(b)

$$\omega_m = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1.28(0.5\times10^{-6})}} = \frac{1}{\sqrt{0.64\times10^{-6}}} = \frac{1}{8\times10^{-4}} = 1250\,\text{rad/s}$$

$$f_m = \frac{1250}{2\pi} = 198.94\,\text{Hz}$$

$$H(j\omega_m) = \frac{250(j1250)}{1.5625\times10^6 - 1.5625\times10^6 + 312.5(j1250)} = \frac{250}{312.5} = 0.80$$

(c) With $R = R_1 + R_2 = 80 + 320 = 400\,\Omega$

$$B_\omega = \frac{R}{L} = \frac{400}{1.28} = 312.5\,\text{rad/s}$$

$$B_f = \frac{312.5}{2\pi} = 49.74\,\text{Hz}$$

(d)

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{400}\sqrt{\frac{1.28}{0.5\times10^{-6}}} = \frac{1}{400}\sqrt{2.56\times10^6}$$

$$Q = \frac{1600}{400} = 4$$

$$\omega_2 = 1250(1.00778 + 0.125) = 1415.98\,\text{rad/s}$$

$$\omega_1 = 1250(1.00778 - 0.125) = 1103.48\,\text{rad/s}$$

$$f_2 = \frac{1415.98}{2\pi} = 225.36\,\text{Hz}$$

$$f_1 = \frac{1103.48}{2\pi} = 175.62\,\text{Hz}$$

Note that $B_f = f_2 - f_1 = 49.74\,\text{Hz}$ ✓

Chapter 17 / Problem 27 ①

Fig P17.27

(a) $$I_L(s) = \frac{V_s(s)}{Ls + R + \frac{1}{Cs}}$$

$$= \frac{Cs\,V_s(s)}{LCs^2 + RCs + 1}$$

$$H_1(s) = \frac{I_L(s)}{V_s(s)} = \frac{s}{L(s^2 + \frac{R}{L}s + \frac{1}{LC})}$$

then by voltage division

$$V_C(s) = \frac{\frac{1}{Cs}V_s(s)}{Ls + R + \frac{1}{Cs}} = \frac{\frac{1}{Cs}V_s(s)}{\frac{LCs^2 + RCs + 1}{Cs}}$$

$$H_2(s) = \frac{\frac{1}{LC}}{LC(s^2 + \frac{R}{L}s + \frac{1}{LC})}$$

(b) $$H_1(j\omega) = \frac{j\omega}{L(\frac{1}{LC} - \omega^2) + j\frac{R}{L}\omega}.$$

To make $|H_1(j\omega)|$ maximum set

$$\omega_m^2 = \frac{1}{LC}$$

$$\omega_m = \frac{1}{\sqrt{LC}}$$

Then $$H_1(\omega_m) = \frac{j\omega_m}{L\frac{R}{L}j\omega_m} = \frac{1}{R}$$

$$B_\omega = \frac{R}{L}$$

and

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Chapter 17/27 Contd

(c)

$$|H_2(j\omega)| = \frac{\frac{1}{LC}}{\sqrt{\left(\frac{1}{LC}-\omega^2\right)^2+\left(\frac{R}{L}\omega\right)^2}}$$

$$|H_2(j\omega)|^2 = \frac{\left(\frac{1}{LC}\right)^2}{\left(\frac{1}{LC}-\omega^2\right)^2+\left(\frac{R}{L}\omega\right)^2} = \frac{1}{(1-LC\omega^2)^2+(RC\omega)^2}$$

To maximize $|H_2(j\omega)|$ minimize

$$\phi(C) = (1-LC\omega^2)^2 + (RC\omega)^2$$

$$\frac{d\phi(C)}{dC} = 2(\omega^2 LC-1)L\omega^2 + 2C(\omega R)^2 = 0$$

$$C = \frac{L}{R^2(\omega L)^2} = \frac{1}{L\omega^2}\left[\frac{1}{\frac{R^2}{L^2\omega^2}+1}\right]$$

The Q of the coil is defined as

$$Q_{coil} = \frac{\omega L}{R}$$

and if Q_{coil} is high

$$C = \frac{1}{L\omega^2}\left[\frac{1}{(Q_{coil})^2}+1\right] \rightarrow \frac{1}{L\omega^2}$$

Then with

$$\frac{1}{LC} = \frac{1}{L\left(\frac{1}{L\omega^2}\right)} = \omega^2$$

$$|H_2(j\omega)|_{max} = \frac{\omega^2}{\sqrt{(\omega^2-\omega^2)^2+\left(\frac{R}{L}\omega\right)^2}} = \frac{\omega^2}{\frac{R}{L}\omega} = \frac{\omega L}{R} = Q_{coil}$$

Thus $|\dot{V}_{out}|_{max} = |\dot{V}_C|_{max} = Q_{coil}|\dot{V}_S|$

Chapter 17/ Problem 29

In example 17.10, it is shown that

Fig P17.29

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{-\frac{s}{R_1 C_2}}{s^2 + \left(\frac{1}{R_2 C_1} + \frac{1}{R_2 C_2}\right)s + \frac{1}{R_1 R_2 C_1 C_2}}$$

This is in the form of eq (17.18)

$$H(s) = K \frac{s}{s^2 + 2\zeta\omega_p s + \omega_p^2}$$

With $f_m = 1000$ Hz and $B_f = 12.5$ Hz, then by eqs (17.19a) and (17.19d)

$$\omega_m = \omega_p = \frac{1}{R_1 R_2 C_1 C_2} = 2000\pi \text{ rad/s}$$

and

$$B_W = \frac{1}{R_2 C_1} + \frac{1}{R_2 C_2} = 25\pi \text{ rad/s}$$

Let $C_1 = C_2 = 1\mu f$ $(10^{-6} F)$

Then

$$B_W = 25\pi = \frac{2 \times 10^6}{R_2}$$

$$R_2 = \frac{2 \times 10^6}{25\pi} = 25{,}465\,\Omega \quad (25.46\,k\Omega)$$

And

$$\frac{1}{R_1 R_2 C_1 C_2} = 2000\pi$$

$$\frac{10^{12}}{R_1 (25{,}465)} = 2000\pi$$

$$R_1 = \frac{10^{12}}{2000\pi(25{,}465)} = 6250\,\Omega$$

Chapter 17/Problem 30

Fig P17.30

(a)

$$H(s) = \frac{V_{OUT}(s)}{V_{IN}(s)} = -\frac{Z_f(s)}{Z_{IN}(s)} = -\frac{Y_{IN}(s)}{Y_f(s)}$$

$$H(s) = -\frac{\frac{1}{R_{IN}}}{Cs + \frac{1}{R_f} + \frac{1}{Ls}} = -\frac{\frac{Ls}{R_{IN}}}{LCs^2 + \frac{L}{R_f}s + 1} = -\frac{s}{R_{IN}C\left(s^2 + \frac{1}{R_fC}s + \frac{1}{LC}\right)}$$

This is in the form

$$H(s) = K\frac{s}{s^2 + 2\sigma_p + \omega_p^2}$$

(b) Here

$$K = -\frac{1}{R_{IN}C}$$

$$\sigma_p = \frac{1}{2R_fC}$$

and

$$\omega_p^2 = \frac{1}{LC} \rightarrow \omega_p = \frac{1}{\sqrt{LC}}$$

$$B_W = 2\sigma_p = \frac{1}{R_fC}$$

$$Q = Q_p = \frac{\omega_p}{B_W} = \frac{\frac{1}{\sqrt{LC}}}{\frac{1}{R_fC}} = R_f\sqrt{\frac{C}{L}}$$

(c) From eq (17.19c)

$$\omega_1, \omega_2 = \pm\sigma_p + \sqrt{\sigma_p^2 + \omega_p^2} = \pm\sigma_p + \omega_p\left(\sqrt{1 + \left(\frac{1}{2Q_p}\right)^2} \pm \frac{1}{2Q_p}\right)$$

$$= \pm\frac{1}{2R_fC} + \frac{1}{\sqrt{LC}}\left(\sqrt{1 + \frac{4L}{R_f^2C}} \pm \frac{2}{R_f}\sqrt{\frac{L}{C}}\right)$$

17/30 Cont'd

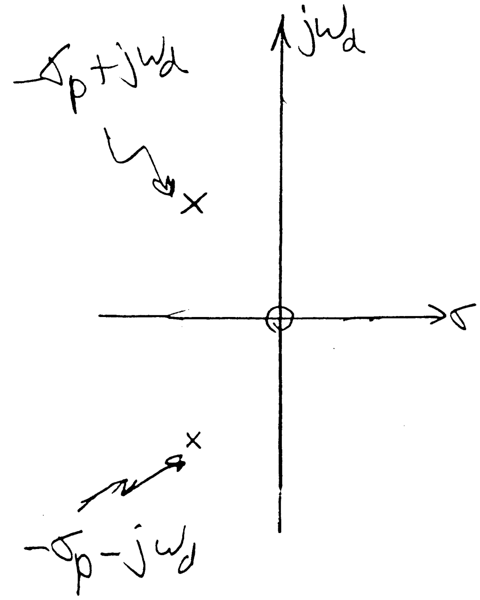
(d) One zero at $s_z = 0$

Two poles

$$s^2 + 2\sigma_p + \omega_p^2 = 0$$

$$s^2 + 2\sigma_p + \sigma_p^2 + \omega_p^2 - \sigma_p^2 = 0$$

$$(s+\sigma_p)^2 + \omega_d^2 = 0$$



If $\omega_p > \sigma_p$, then

$$\omega_d^2 = \omega_p^2 - \sigma_p^2 > 0$$

and

$$s_{1z}, s_{2z} = -\sigma_p \pm j\omega_d$$

(e) With $\omega_m = \omega_p$ [eq (17.19a)], eq (17.19b) gives

$$H_m = |H(j\omega)|_{max} = \frac{|K|\,Q_p}{\omega_m} = \frac{\left(\frac{1}{R_{IN}C}\right)\left(R_f\sqrt{\frac{L}{C}}\right)}{\frac{1}{\sqrt{LC}}} = \frac{R_f L}{R_{IN}C}$$

(f) If $v_{IN}(t) = 100 \sin 10^3 t$ mV

$$|V_{IN}| = 100$$

$$H(j1000) = -\frac{j10^3}{R_{IN}C\left(\frac{1}{LC} - 10^6 + j\frac{10^3}{R_fC}\right)}$$

$$|H(j1000)| = \frac{10^3}{R_{IN}C\sqrt{\left(\frac{1}{LC}-10^6\right)^2 + 10^6\left(\frac{1}{R_fC}\right)^2}}$$

and

$$|V_{out}| = \frac{10^5}{R_{IN}C\sqrt{\left(\frac{1}{LC}-10^6\right)^2 + 10^6\left(\frac{1}{R_fC}\right)^2}}$$

Chapter 17/Problem 31

(a)

$$H(s) = K\frac{s+a}{s^2+2\sigma_p s+\omega_p^2}$$

$$|H(j\omega)| = K\sqrt{\frac{a^2+\omega^2}{(\omega_p^2-\omega^2)^2+4\sigma_p^2\omega^2}}$$

The radical is a nuisance

$$|H(j\omega)|^2 = K^2\left[\frac{a^2+\omega^2}{(\omega_p^2-\omega^2)^2+4\sigma_p^2\omega^2}\right]$$

Note that the bracketed term is a function of ω^2. In the optimization process

$$\frac{df(\omega^2)}{d\omega^2} = 0$$

the factor K need not be considered

$$\frac{df(\omega^2)}{d\omega^2} = v\,du - u\,dv = 0$$

$$0 = \frac{1}{[(\omega_p^2-\omega^2)^2+4\sigma_p^2\omega^2]} - \frac{(a^2+\omega^2)[-2(\omega_p^2-\omega^2)+4\sigma_p^2]}{[(\omega_p^2-\omega^2)^2+4\sigma_p^2\omega^2]}$$

As long as

$$(\omega_p^2-\omega^2)^2+4\sigma_p^2\omega^2 \neq 0$$

this can be written as

$$(\omega_p-\omega^2)^2+4\sigma_p^2\omega^2-(a^2+\omega^2)[-2(\omega_p^2-\omega^2)+4\sigma_p^2]=0$$

$$\omega_p^4-2\omega_p^2\omega^2+\omega^4+4\sigma_p^2\omega^2+4\sigma_p^2\omega^2+2(a^2+\omega^2)(\omega_p^2-\omega^2)-4(a^2+\omega^2)\sigma_p^2=0$$

Let

$$\omega_p^4-2\omega_p^2\omega^2+\omega^4+4\sigma_p^2\omega^2=A$$

$$A+2a^2\omega_p^2-2a^2\omega^2+2\omega_p^2\omega^2-2\omega^4-4a^2\sigma_p^2-4\sigma_p^2\omega^2$$
$$=-\omega^4-2a^2\omega^2+\omega_p^4+2a^2\omega_p^2-4a^2\sigma_p^2$$

This reduces to

$$\omega^4 + 2a^2\omega^2 = \omega_p^4 + 2a^2\omega_p^2 - 4a^2\sigma_p^2$$

and after a^4 is added to both side of the equation

$$\omega^4 + 2a^2\omega^2 + a^4 = \omega_p^4 + 2a^2\omega_p^2 - 4a^2\sigma_p^2 + a^4$$

completing the square gives

$$\omega^2 = -a^2 \pm \sqrt{(\omega_p^2 + a^2)^2 - (2a\sigma_p)^2}$$

and to produce a positive value of ω

$$\omega = \sqrt{-a^2 + \sqrt{(\omega_p^2 + a^2)^2 - (2a\sigma_p)^2}}$$

(b)

$$\frac{1}{H(s)} = \frac{s^2 + 2\sigma_p s + \omega_p^2}{K(s+a)} = \frac{s^2 + 2\sigma_p(s+a) - 2\sigma_p a + \omega_p^2}{K(s+a)}$$

$$= \frac{2\sigma_p}{K} + \frac{s^2 - 2\sigma_p a + \omega_p^2}{K(s+a)}$$

The first term is entirely real. For zero phase shift, the second term must be real. Hence with

$$\frac{1}{H_1 s} = \frac{s^2 - 2\sigma_p a + \omega_p^2}{K(s+a)}$$

and

$$\frac{1}{H_1(j\omega)} = \frac{\omega_p^2 - \omega^2 + 2\sigma_p a}{K(a + j\omega)}\left[\frac{a - j\omega}{a + j\omega}\right]$$

So that

$$\mathrm{Im}\left[\frac{1}{H_1 j\omega}\right] = \frac{\omega^3 - \omega\omega_p^2 + 2\sigma_p a\omega}{K(a^2 + \omega^2)}$$

17/31 Cont'd

For $\mathrm{Im}\left[\frac{1}{H(j\omega)}\right] = 0$

$$\omega^2 = \omega_p^2 - 2\sigma_p a$$

and

$$\omega = \sqrt{\omega_p^2 - 2\sigma_p a}$$

This is subject to

$$\omega_p^2 \geq 2\sigma_p a$$

Problem 17/33

Text lists solution for part (b)

$$\omega_M = 8.55 \text{ rad/s}$$

We get

$$\omega_M = 9.01 \text{ rad/s}$$

We did get

$$\omega_1 = 8.55 \text{ rad/s}$$

for lower half power frequency

Chapter 17/Problem 33

(a) From fig P.17.32 and Problem 32

$$H(s) = Z_{IN}(s) = \frac{\frac{1}{C}\left(s+\frac{R_s}{L}\right)}{s^2+\left(\frac{1}{R_pC}+\frac{R_s}{L}\right)s+\left(1+\frac{R_s}{R_p}\right)\frac{1}{LC}}$$

and with the given circuit element

$$\frac{1}{R_pC} = \frac{1}{50(1/9)} = \frac{9}{50} = 0.18$$

$$\frac{R_s}{L} = \frac{0.08}{1/9} = 0.72$$

$$\frac{1}{R_pC}+\frac{R_s}{L} = 0.18+0.72 = 0.90$$

$$\frac{R_s}{R_p} = \frac{0.08}{50} = 0.0016$$

$$\frac{1}{LC} = \frac{1}{(1/9)(1/9)} = 81$$

$$\left(1+\frac{R_s}{R_p}\right)\frac{1}{LC} = (1.0016)(81) = 81.1296$$

$$H(s) = \frac{9(s+0.72)}{s^2+0.90s+81.1296}$$

This is in the form

$$H(s) = K\frac{s+a}{s^2+2\sigma_p s+\omega_p^2}$$

where

$$K = 9$$

$$a = 0.72$$

$$\sigma_p = \frac{0.90}{2} = 0.45$$

$$\omega_p^2 = 81.1296$$

and

$$\omega_p = 9.0072$$

(a) With

$$\sigma_p = \frac{\omega_p}{Q_p}$$

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{9.0072}{0.90} = 10.008 > 10$$

and the circuit is high Q. Moreover, $a \leq \omega_p$

$$0.72 \leq 9.0072$$

(b) Using eq (17.28)

$$\omega_M = \sqrt{-a^2 + \sqrt{(\omega_p^2 + a^2)^2 - (2\sigma_p a)^2}}$$

$$= \sqrt{-(0.72)^2 + \sqrt{[81.1296 + (0.72)^2]^2 - [2(0.45)(0.72)]^2}}$$

$$= \sqrt{-0.5184 + \sqrt{(81.6480)^2 - (0.648)^2}}$$

$$= \sqrt{-0.5184 + \sqrt{6665.976}} = \sqrt{-0.5184 + 81.6454}$$

$$= \sqrt{81.1270} = 9.0071 \approx 9.0072$$

Hence

$$\omega_M \approx \omega_p$$

Then the maximum gain derives from eq (17.30)

$$H_M \approx \frac{|K|}{2\sigma_p} = \frac{9}{0.90} = 10$$

(c) From eq (17.30)

$$B_W \approx 2\sigma_p = 2(0.45) = 0.90 \text{ rad/s}$$

$$\omega_1 \approx \omega_M - \frac{B_W}{2} = 9.0071 - 0.45 = 8.557 \text{ rad/s}$$

$$\omega_2 = \omega_M + \frac{B_W}{2} = 9.0071 + 0.45 = 9.457 \text{ rad/s}$$

(d) $|V_{out}(j\omega_M)| = |I_{in}(j\omega_M)|\, H_M = (1)(10) = 10\text{V}$

Chapter 17/Problem 34 ①

This is a repeat of Problem 33 with different circuit elements

$$\frac{1}{R_pC} = \frac{10^9}{60{,}000} = 16{,}667$$

$$\frac{R_s}{L} = \frac{25}{0.001} = 25{,}000$$

$$\frac{1}{R_pC} + \frac{R_s}{L} = 41667$$

$$\frac{R_s}{R_p} = \frac{25}{60{,}000} = 4.167\times10^{-4}$$

$$\frac{1}{LC} = \frac{10^9}{0.001} = 1\times10^{12}$$

$$\left(1+\frac{R_s}{R_p}\right)\frac{1}{LC} = (1.000417)(1\times10^{12}) = 1.000417\times10^{12}$$

$$H(s) = \frac{10^9(s+25{,}000)}{s^2+41{,}667s+1.000417\times10^{12}}$$

This is in the form

$$H(s) = \frac{K(s+a)}{s^2+2\sigma_p s+\omega_p^2}$$

where

$$K = 10^9$$

$$a = 25{,}000$$

$$\sigma_p = 20{,}833$$

$$\omega_p^2 = 1.000417\times10^{12}$$

and

$$\omega_p = 1.00021\times10^6$$

17/34 Cont'd

(a) With $\sigma_p = \frac{\omega_p}{Q_p}$

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{1.00021 \times 10^6}{41{,}667} = 24.01 > 10$$

and the circuit is indeed high Q. Moreover $a \le \omega_p$

$$25{,}000 \le 1.00021 \times 10^6$$

(b) Using eq (17.28)

$$\omega_M = \sqrt{-a^2 + \sqrt{(\omega_p^2 + a^2)^2 - (2\sigma_p a)^2}}$$

$$= \sqrt{-(25{,}000)^2 + \sqrt{[1.000417 \times 10^{12} + (25{,}000)^2]^2 - [2(20{,}833)(25{,}000)]^2}}$$

$$= \sqrt{6.25 \times 10^8 + \sqrt{(1.00104 \times 10^{12})^2 - (1.04165 \times 10^9)^2}}$$

$$= \sqrt{6.25 \times 10^8 + \sqrt{1.00209 \times 10^{24} - 1.08503 \times 10^{18}}}$$

$$= \sqrt{6.25 \times 10^8 + \sqrt{1.00208 \times 10^{24}}}$$

$$= \sqrt{6.25 \times 10^8 + 1.00104 \times 10^{12}} = \sqrt{1.00167 \times 10^{12}}$$

$$\omega_M = 1.00083 \times 10^6 \approx \omega_p$$

(c) The maximum gain derive from eq (17.28)

$$H_M = \frac{|K|}{2\sigma_p} = \frac{10^9}{41{,}667} = 24{,}000$$

(d) From eq (17.30)

$$B_\omega = 2\sigma_p = 41{,}667 \text{ rad/s} \quad ($$

$$\omega_1 = \omega_M - \frac{B_\omega}{2} = 1.00083 \times 10^6 - \frac{41{,}667}{2} = 979{,}996 \text{ rad/s}$$

$$\omega_2 = \omega_M + \frac{B_\omega}{2} = 1.00083 \times 10^6 + \frac{41{,}667}{2} = 1{,}021{,}663 \text{ rad/s}$$

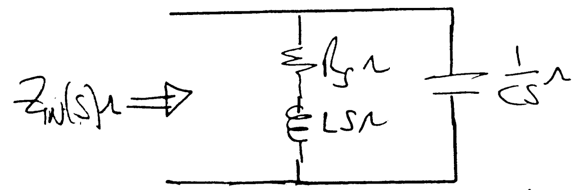
(e)

$$|V_{out}(j\omega_M)| = |I_{IN}(j\omega_M)| H_M = (1)(24{,}000) = 24{,}000 \text{ V}$$

Chapter 17/Problem 35

Fig P17.32

(a) Remove R_p from consideration



$$Y_{IN}(s) = Cs + \frac{1}{Ls+R_s} = \frac{LCs^2 + R_sCs + 1}{Ls + R_s}$$

$$Z_{IN}(s) = \frac{L\left(s+\frac{R_s}{L}\right)}{LC\left(s^2+\frac{R_s}{L}s+\frac{1}{LC}\right)} = \frac{\frac{1}{C}\left(s+\frac{R_s}{L}\right)}{s^2+\frac{R_s}{L}s+\frac{1}{LC}}$$

Then

$$Z_{IN}(j\omega) = \frac{\frac{1}{C}\left(\frac{R_s}{L}+j\omega\right)}{\frac{1}{LC}-\omega^2+j\frac{R_s}{L}\omega}$$

With

$$A = \frac{1}{LC} - \omega^2$$

$$Z_{IN}(j\omega) = \frac{\frac{1}{C}\left(\frac{R_s}{L}+j\omega\right)}{\left(A+j\frac{R_s}{L}\omega\right)}\left[\frac{A-j\frac{R_s\omega}{L}}{A-j\frac{R_s\omega}{L}}\right]$$

$$\mathrm{Im}[Z(j\omega)] = \frac{\omega A - \frac{1}{C}\left(\frac{R_s}{L}\right)^2\omega}{A^2+\left(\frac{R_s}{L}\right)^2}$$

With

$$\mathrm{Im}[Z(j\omega_r)] = 0 = \frac{\omega_r}{C}\left(\frac{1}{LC}-\omega_r^2\right) - \frac{1}{C}\left(\frac{R_s}{L}\right)^2\omega_r = 0$$

$$\frac{1}{LC} - \omega_r^2 = \left(\frac{R_s}{L}\right)^2$$

$$\frac{1}{LC} = \frac{R_s^2}{L^2} + \omega_r^2$$

at $\omega_r = 2\pi\times10^5$ rad/s

$$Q_{COIL} = \frac{\omega_r L}{R_s} = \frac{2\pi\times10^5 L}{R_s} = 40$$

$$\frac{R_s}{L} = \frac{2\pi\times10^5}{40} = 1.571\times10^4$$

So that

$$\frac{1}{LC} = \left(\frac{R_s}{L}\right)^2 + \omega_r^2$$

$$= (1.571\times10^4)^2 + (6.283\times10^5)^2$$

$$= 3.950\times10^{11}$$

$$\frac{1}{C} = 3.950\times10^{8}$$

and

$$C = 2.531\times10^{-9} \qquad (2.531\,nF)$$

(b) With R_p back in the circuit, the transfer function is given in the problem statement of Problem 33. It is in the form

$$H(s) = \frac{\frac{1}{C}\left(s+\frac{R_s}{L}\right)}{s^2+2\sigma_p s+\omega_p^2}$$

For the bandwidth to be approximately $B_\omega = 20{,}000\pi$ rad/s and width

$$2\sigma_p = \frac{1}{R_pC} + \frac{R_s}{L}$$

then

$$20{,}000\pi = \frac{1}{R_pC} + 1.571\times10^4$$

$$\frac{1}{R_pC} = 6.283\times10^4 - 1.571\times10^4$$

$$= 47{,}122$$

and

$$R_p = \frac{1}{47{,}122\,C} = \frac{10^9}{47{,}122(2.531)} = 8385\,\Omega$$

12/35 Cont'd

(3)

Then

$$Q_p = Q_{cir} = \frac{\omega_m}{B_W} = \frac{2\pi(100{,}000)}{2\pi(10{,}000)} = 10$$

and this is high Q

B 17/36

I am getting

$Q_{cr} < 10$

for the lower value of $C = 8.174\,nF$

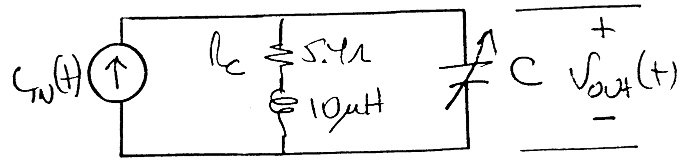
Is it possible that

$L = 10\,\mu H$ is erroneous?

Chapter 17 / Problem 36

A maximum $|V_{out}|$ occurs in the circuit

Fig P17.36



when, as shown in problem 35

$$\omega_r = \sqrt{\frac{1}{LC} - \left(\frac{R_C}{L}\right)^2} \quad \text{or} \quad C = \frac{1}{L\left[\left(\frac{R_C}{L}\right)^2 + \omega_r^2\right]}$$

With

$$\frac{R_C}{L} = \frac{5.4}{10^{-5}} = 5.4\times10^5$$

$$C = \frac{10^5}{(2.916\times10^{11} + \omega_r^2)}$$

At $\omega_r = 1.1\pi\times10^6$ rad/s (550 kHz) calling $C = C_0$

$$C_0 = \frac{10^5}{(1.1\pi\times10^6)^2 + 2.916\times10^{11}} = \frac{10^5}{1.223\times10^{13}}$$

$$C_0 = 8.174\times10^{-9}\,F \qquad (8.174\,nF)$$

At $\omega_r = 3.3\pi\times10^6$ rad/s (1650 kHz) calling $C = C_1$

$$C_1 = \frac{10^5}{(3.3\pi\times10^6)^2 + 2.916\times10^{11}} = \frac{10^5}{1.078\times10^{14}}$$

$$C_1 = 9.279\times10^{-10}\,F \qquad (92.789\,nF)$$

The range

$$C_0 \le C \le C_1$$

is

$$8.174\,nF \le C \le 92.789\,nF$$

17/36 Cont'd

For the full circuit shown in Fig P17.36, the transfer function can be written as

$$H(s) = \frac{K(s+a)}{s^2 + 2\sigma_p s + \omega_p^2}$$

and for high Q $\quad \omega_m \simeq \omega_p$ and $a \ll \omega_p$

Here

$$a = \frac{R_c}{L} = \frac{5.4}{10^{-5}} = 5.4 \times 10^5$$

$$2\sigma_p = \frac{1}{RC} + \frac{R_c}{L} = \frac{1}{10{,}000C} + 5.4\times10^5$$

$$\omega_p^2 = \left(1+\frac{R_c}{R}\right)\frac{1}{LC} = 1.00054\left(\frac{10^5}{C}\right) = \frac{100{,}054}{C}$$

At $C = C_0$ (550 kHz)

$$B_\omega = 2\sigma_p = \frac{10^9}{10{,}000(8.174)} + 5.4\times10^5$$

$$= 1.224\times10^4 + 5.4\times10^5$$

$$= 5.522\times10^5 \text{ rad/s}$$

$$\omega_p = \sqrt{\frac{100{,}054}{8.174\times10^{-9}}} = \sqrt{1.2241\times10^{13}} = 3.4986\times10^6 \text{ rad/s}$$

Note that with $\omega_m = 1.1\pi\times10^5$ $= 3.456\times10^6$ rad/s

$$\omega_m \approx \omega_p$$

With $\omega_m \approx \omega_p$

$$Q_{cir} = \frac{\omega_m}{2\sigma_p} = \frac{3.498\times10^6}{5.522\times10^5} = 6.335$$

$$Q_{cir} < 10$$

Chapter 17 / Problem 37

Fig P17.27

(a)

$$I_L(s) = Y_{IN}(s) V_{IN}(s)$$

$$H(s) = Y_{IN}(s) = \frac{V_{IN}(s)}{I_L(s)}$$

$$Z_{IN}(s) = Ls + \frac{1}{Cs + \frac{1}{R}} = Ls + \frac{R}{RCs+1} = \frac{RLCs^2 + Ls + R}{RCs+1}$$

$$Z(s) = \frac{RLC\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right)}{RC\left(s + \frac{1}{RC}\right)} = \frac{L\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right)}{s + \frac{1}{RC}}$$

$$H(s)\ Y(s) = \frac{\frac{1}{L}\left(s + \frac{1}{RC}\right)}{s^2 + \frac{1}{RC}s + \frac{1}{LC}}$$

This is in the form

$$H(s) = Y(s) = \frac{K(s+a)}{s^2 + 2\sigma_p s + \omega_p^2}$$

(b) With the given circuit elements

$$a = \frac{1}{RC} = \frac{10^5}{2000} = 50$$

$$2\sigma_p = 50$$

$$\sigma_p = 25$$

$$\omega_p^2 = \frac{1}{LC} = 10^6$$

$$\omega_p = 1000 \text{ rad/s}$$

$$K = \frac{1}{L} = \frac{1}{0.1} = 10$$

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{1000}{50} = 20 > 10$$

This is indeed high Q. Moreover

$$a \leq \omega_p \quad (50 < 1000)$$

17/37 Cont'd

(c) $\omega_m = \sqrt{-a^2 + \sqrt{[\omega_p^2 + a^2]^2 - (2\sigma_p a)^2}}$

$= \sqrt{-2500 + \sqrt{(10^6 + 2500)^2 - (2500)^2}}$

$= \sqrt{-2500 + \sqrt{1.0050 \times 10^{12} - 6.25 \times 10^6}}$

$= \sqrt{-2500 + 1.002497 \times 10^6} = \sqrt{9.9999 \times 10^5}$

$\omega_m = 999.99 \text{ rad/s} \approx \omega_p$

Thus $H_m = \dfrac{|K|}{2\sigma_p} = \dfrac{10}{50} = 0.20$

(d) $B_\omega \approx 2\sigma_p = 50 \text{ rad/sec}$

$\omega_2 = \omega_m + \dfrac{B_\omega}{2} = 1000 + 25 = 1025 \text{ rad/s}$

$\omega_1 = \omega_m - \dfrac{B_\omega}{2} = 1000 - 25 = 975 \text{ rad/s}$

Chapter 17 / Problem 38

Fig P17.38

(a) $H(S) = \dfrac{I_{out}(s)}{V_{IN}(s)} = Y(s) = \dfrac{1}{Z(s)}$

$$Z(S) = LS + R_S + \frac{\frac{R_L}{CS}}{R_L + \frac{1}{CS}}$$

$$= LS + R_S + \frac{R_L}{R_L CS + 1} = \frac{R_L LCS^2 + (R_L R_S C + L)S + R_L + R_S}{R_L CS + 1}$$

$$H(s) = Y(s) = \frac{\frac{1}{L}\left(s + \frac{1}{R_L C}\right)}{s^2 + \left(\frac{1}{R_L C} + \frac{R_S}{L}\right) + \frac{1}{LC}\left(1 + \frac{R_S}{R_L}\right)}$$

(b) With the circuit elements inserted

$$R_L C = 200(10 \times 10^{-6}) = 0.002$$

$$\frac{1}{R_L C} = \frac{1}{0.002} = 500 \qquad \frac{R_S}{R_L} = \frac{0.5}{200} = 2.5 \times 10^{-3}$$

$$\frac{R_S}{L} = \frac{0.50}{0.001} = 500$$

$$\frac{1}{LC} = \frac{1}{0.001(10 \times 10^{-6})} = 10^8$$

$$\left(1 + \frac{R_S}{R_L}\right)\left(\frac{1}{LC}\right) = 1.0025 \times 10^8$$

and the transfer function becomes

$$H(s) = \frac{1000(s + 500)}{s^2 + 1000s + 1.0025 \times 10^8}$$

This is in the form

$$H(s) = \frac{K(s + a)}{s^2 + 2\sigma_p s + \omega_p^2}$$

and if $Q_{circ} \approx Q_p > 10$, the approximations of eqs (17.28) through (17.30) apply

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{\sqrt{1.0025 \times 10^8}}{1000} = \frac{10012.5}{1000} = 10.01 > 10$$

17/38 Cont'd

Moreover

$$a = 500 \ll \omega_p = 10012.5$$

(c) For the exact value of ω_m, use eq (17.28)

$$\omega_m^2 = -a^2 + \sqrt{(\omega_p^2 + a^2)^2 - (2\sigma_p a)^2}$$

$$= -2.5\times10^5 + \sqrt{(1.00025\times10^8 + 2.5\times10^5)^2 - [2(500)(500)]^2}$$

$$= -2.5\times10^5 + \sqrt{1.0100\times10^{16} - 2.5\times10^{11}}$$

$$= -2.5\times10^5 + \sqrt{1.0100\times10^{16}}$$

$$= -2.5\times10^5 + 1.004988\times10^8$$

$$= 1.002488\times10^8$$

$$\omega_m = 10012.4 \text{ rad/s} \approx \omega_p = 10012.5 \text{ rad/s}$$

The maximum gain is

$$H_M = \frac{|K|}{2\sigma_p} = \frac{1000}{1000} = 1.00$$

(d) $B_\omega = 2\sigma_p = 1000$ rad/s

$$\omega_1 = \omega_m - \frac{1000}{2} = 10012.4 - 500 = 9512.4 \text{ rad/s}$$

$$\omega_2 = \omega_m + \frac{1000}{2} = 10012.4 + 500 = 10512.4 \text{ rad/s}$$

Chapter 17/ Problem 39

Fig P17.39

(a) Figure P17.39 is identical to Fig P17.38 with the exception that R_L in Fig P17.38 is R_p in Fig P17.39. The transfer function, developed in Problem 38 is displayed in the statement of Problem 38.

$$H(s) = Y(s) = \frac{\frac{1}{L}\left(s + \frac{1}{R_pC}\right)}{s^2 + \left(\frac{1}{R_pC} + \frac{R_s}{L}\right)s + \frac{1}{LC}\left(1 + \frac{R_s}{R_p}\right)}$$

With the circuit elements inserted

$$R_pC = 1600(0.00125) = 2$$

$$\frac{1}{R_pC} = 0.50$$

$$\frac{R_s}{L} = \frac{1}{0.5} = 2$$

$$\frac{1}{LC} = \frac{1}{0.5(0.00125)} = 1600$$

$$\frac{R_s}{R_p} = \frac{1}{1600} = 0.000625$$

$$\left(1 + \frac{R_s}{R_p}\right)\frac{1}{LC} = (1.000625)1600 = 1601$$

and the transfer function becomes

$$H(s) = \frac{2(s + 0.50)}{s^2 + 2.5s + 1601}$$

This is in the form

$$H(s) = \frac{K(s+a)}{s^2 + 2\sigma_p s + \omega_p^2}$$

Here

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{40.012}{2.5} = 16.005$$

This is high Q and

$$a = 0.5 << \omega_p = 40.0012$$

Equations (17.28) through (17.30) apply

17/39 Cont'd

$$\omega_M^2 = -a^2 + \sqrt{(\omega_p^2+a^2) - (2\sigma_p a)^2}$$

$$= -0.25 + \sqrt{(1601+0.25)^2 - [2(2.5)(0.5)]^2}$$

$$= -0.25 + \sqrt{2.564 \times 10^6 - 6.25}$$

$$= -0.25 + 1601.25 = 1600$$

$$\omega_M = 40\,\text{rad/s} \approx \omega_p$$

The maximum gain is

$$K = \frac{1/L}{2\sigma_p} = \frac{2}{2.5} = 0.80$$

(d) $B_\omega = 2\sigma_p = 2.5\,\text{rad/s}$

$$\omega_2 = 40 + \frac{B_\omega}{2} = 40 + 1.25 = 41.25\,\text{rad/s}$$

$$\omega_1 = 40 - \frac{B_\omega}{2} = 40 - 1.25 = 38.75\,\text{rad/s}$$

(e) With $\omega_0 \approx \omega_p \approx \omega_M$

$$Q_{cir} \approx \frac{\omega_0}{\frac{1}{R_pC} + \frac{R_s}{L}}$$

$$\frac{1}{Q_{cir}} \approx \frac{R_s}{\omega_0 L} + \frac{1}{R_p C \omega_0} = \frac{1}{Q_{coil}} + \frac{1}{Q_{cap}}$$

$$\approx \frac{Q_{cap}+Q_{coil}}{Q_{cap}Q_{coil}}$$

and finally

$$Q_{cir} \approx \frac{Q_{cap}Q_{coil}}{Q_{cap}+Q_{coil}}$$

Chapter 17/Problem 40 ①

Fig P17.40

(a)

$$H(s) = \frac{V_{out}(s)}{I_{IN}(s)} = Z(s) = \frac{1}{Y(s)}$$

$$Y(s) = \frac{1}{Ls+R_s} + Cs + \frac{1}{R_p}$$

$$= \frac{1}{Ls+R_s} + \frac{R_pCs+1}{R_p}$$

$$= \frac{R_pLCs^2 + (L+R_pR_sC)s + R_s + R_p}{R_p(Ls+R_s)}$$

$$Z(s) = \frac{\frac{1}{C}\left(s+\frac{R_s}{L}\right)}{s^2 + \left(\frac{1}{R_pC} + \frac{R_s}{L}\right)s + \frac{1}{LC}\left(1+\frac{R_s}{R_p}\right)}$$

With circuit elements inserted

$$\frac{R_s}{L} = \frac{2/3}{0.0005} = 1.333 \times 10^3$$

$$\frac{1}{R_pC} = \frac{10^6}{1200(1.25)} = 6.667\times10^2$$

$$\frac{R_s}{R_p} = \frac{2/3}{1200} = 5.556\times10^{-4}$$

$$\frac{1}{LC} = \frac{10^6}{5\times10^{-4}(1.25)} = 1.600\times10^9$$

Then

$$H(s) = \frac{8\times10^5(s+1.333\times10^3)}{s^2+2000s+1.60089\times10^9}$$

and this is in the form

$$H(s) = \frac{K(s+a)}{s^2+2\sigma_p+\omega_p^2}$$

17/40 Cont'd

(2)

(b) $Q_p = \frac{\omega_p}{2\sigma_p} = \frac{\sqrt{1.60089\times10^9}}{2000} = 20.01 > 10$

This is a high Q circuit and

$a = 1333 << \omega_p = 40011$

(c) The exact value of ω_m derives from eq (17.28)

$$\omega_m^2 = -a^2 + \sqrt{(\omega_p^2 + a^2)^2 - (2\sigma_p a)^2}$$

$$= -1.777\times10^6 + \sqrt{(1.60089\times10^9 + 1.777\times10^6)^2 - (2.667\times10^6)^2}$$

$$= -1.777\times10^6 + \sqrt{2.569\times10^{18} - 7.108\times10^{12}}$$

$$= -1.777\times10^6 + \sqrt{2.569\times10^{18}}$$

$$= -1.777\times10^6 + 1.603\times10^9$$

$$= 1.601\times10^9$$

$$\omega_m = 4.0011\times10^4 \text{ rad/s} \approx \omega_p = 4.0011\times10^4$$

$$(40011.10 \approx 40011.12)$$

Hence $\omega_m = 40{,}011$ rad/s and

$$H = \frac{K}{2\sigma_p} = \frac{8\times10^5}{2000} = 400\,\Omega$$

(d) $B_\omega \approx 2\sigma_p = 2000$ rad/s

$\omega_2 = \omega_m + \frac{B_\omega}{2} = 40{,}011 + 1000 = 41{,}011$ rad/s

$\omega_1 = \omega_m - \frac{B_\omega}{2} = 40{,}011 - 1000 = 39{,}011$ rad/s

17/40 Cont'd

$$Q_{cir} = Q_p = \frac{\frac{1}{LC}\sqrt{\left(1+\frac{R_p}{R_s}\right)}}{\left(\frac{R_s}{L} + \frac{1}{R_pC}\right)} \approx \frac{\omega_0}{\left(\frac{R_s}{L} + \frac{1}{R_pC}\right)}$$

$$\frac{1}{Q_{cir}} \approx \frac{\frac{R_s}{L} + \frac{1}{R_pC}}{\omega_0} = \frac{R_s}{L\omega_0} + \frac{1}{R_pC\omega_0}$$

$$= \frac{1}{Q_{COIL}} + \frac{1}{Q_{cap}} = \frac{Q_{COIL} + Q_{cap}}{Q_{COIL}Q_{cap}}$$

Thus

$$Q_{cir} = Q_p \approx \frac{Q_{coil}\,Q_{cap}}{Q_{coil} + Q_{cap}}$$

Chapter 17/Problem 41

Fig P17.41

(a)
$$Q = \frac{f_r}{B_f} = \frac{1600}{80} = 20 \quad \text{(high Q)}$$

(b)
$$Y(s) = Cs + \frac{1}{Ls+R} = \frac{LCs^2+RCs+1}{Ls+R} = \frac{C\left(s^2+\frac{R}{L}s+\frac{1}{LC}\right)}{s+R/L}$$

$$H(s) = \frac{V_{out}(s)}{I_{IN}(s)} = \frac{\frac{1}{C}\left(s+\frac{R}{L}\right)}{s^2+\frac{R}{L}s+\frac{1}{LC}}$$

This is in the form

$$H(s) = \frac{K(s+a)}{s^2+2\sigma_p+\omega_p^2}$$

(c) Because the circuit is high Q

$$\omega_p \approx \omega_m \approx \omega_0$$

$$\frac{1}{LC} = \omega_r^2$$

$$\frac{1}{LC} = (3200\pi)^2$$

$$L = \frac{1}{(3200\pi)^2 C}$$

and with $C = 1\times10^{-6}$ F

$$L = \frac{10^6}{(1.01026\times10^8)} = 9.89\times10^{-3} \quad (9.89\text{ mH})$$

$$B_\omega' = 2\sigma_p = \frac{R}{L} = 160\pi = 502.65$$

$$R = (502.65)(9.89\times10^{-3}) = 4.97\,\Omega$$

Chapter 17/Problem 42

Fig P17.42

(a) $H(S) = \frac{V_{out}}{V_{IN}}$

By voltage division

$$Y_p(s) = CS + \frac{1}{LS+R} = \frac{LCS^2+RCS+1}{LS+R}$$

$$Z_p(s) = \frac{1}{Y_p(s)} = \frac{LS+R}{LCS^2+RCS+1}$$

$$Z_T(s) = R_S + \frac{LS+R}{LCS^2+RCS+1} = \frac{R_SLCS^2+(RR_SC+L)S+R_S+R}{LCS^2+RCS+1}$$

$$H(S) = \frac{Z_p(s)}{Z_T(s)} = \frac{LS+R}{R_SLCS^2+(RR_SC+L)S+R_S+R} = \frac{\frac{1}{R_SC}\left(S+\frac{R}{L}\right)}{S^2+\left(\frac{R}{L}+\frac{1}{R_SC}\right)S+\left(1+\frac{R}{R_S}\right)\frac{1}{LC}}$$

(b) First insert the given element values

$$R_SC = \frac{5}{3} \qquad \frac{1}{LC} = 1$$

$$\frac{1}{R_SC} = \frac{3}{5} = 0.6 \qquad \frac{R}{R_S} = \frac{4/5}{5/3} = 0.48$$

$$\frac{R}{L} = 0.8 \qquad \frac{R}{L} + \frac{1}{R_SC} = 0.8+0.6 = 1.4$$

$$H(S) = \frac{0.6(S+0.8)}{S^2+1.4S+1.48}$$

(c)

$$W_0 = \frac{1}{\sqrt{LC}} = \frac{1}{1} = 1 \text{ rad/s}$$

(d) Consider only R, L and C and observe that the circuit is identical to the one in Example 17.3. Equation 17.4 gives

$$W_r = W_0\sqrt{1-\frac{CR^2}{L}} = 1\sqrt{1-\frac{1(0.8)^2}{1}}$$

$$= 1\sqrt{1-0.64} = 1\sqrt{0.36} = 0.60 \text{ rad/s}$$

Alternatively, a resonance for $Z_p(j\omega)$ will produce a resonance for the entire circuit. With $RC = 0.8$

$$Z_p(s) = \frac{s+0.8}{s^2+0.8s+1}$$

$$Z(j\omega) = \frac{0.8+j\omega}{1-\omega^2+j0.8\omega}\left[\frac{(1-\omega^2)-j0.8\omega}{(1-\omega^2)-j0.8\omega}\right]$$

$$= \frac{(0.8+j\omega)[(1-\omega^2)-j0.8\omega]}{(1-\omega^2)^2+0.64\omega^2}$$

Set $\mathrm{Im}[Z(j\omega)] = 0$

$$\omega(1-\omega^2) - 0.64\omega = 0$$

$$1-\omega^2 = 0.64$$

$$\omega^2 = 0.36$$

$$\omega = 0.60 \text{ rad/s}$$

(iii)

$$H(j\omega) = \frac{0.60(0.80+j\omega)}{1.48-\omega^2+j1.4\omega}$$

$$|H(j\omega)| = \frac{0.60\sqrt{\omega^2+0.64}}{\sqrt{(1.48-\omega^2)^2+1.96\omega^2}}$$

With $z = \omega^2$

$$|H(j\omega)|^2 = \frac{0.36(z+0.64)}{(1.48-z)^2+1.96z}$$

$$= \frac{0.36(z+0.64)}{z^2-z+2.1904}$$

To find z_{max} (or z_{min})

$$d\{|H(j\omega)|^2\} = \frac{0.36(z^2-z+2.1904)-0.36(z+0.64)(2z-1)}{z^2-z+2.1904} =$$

17/42 Cont'd

$$\therefore \left(z^2 - z + 2.1904\right) - \left(z + 0.64\right)\left(2z - 1\right) = 0$$

$$z^2 - z + 2.1904 = 0$$

Solving

$$\omega_r^2 = z = 1.1600$$

$$\omega_r = \sqrt{1.1600} = 1.077 \text{ rad/s}$$

(iv)

$$\omega_p = \sqrt{\left(1 + \frac{R}{R_s}\right)\frac{1}{LC}} = \sqrt{(1 + 0.48)} = \sqrt{1.48} = 1.2166 \text{ rad/s}$$

17.43

Everything fine except for ω_r

Text gets $\omega_r = 0.9602$ rad/s

We get $\omega_r = 0.9220$ rad/s

Chapter 17/Problem 43

(a) For a demonstration that

$$H(s) = \frac{\frac{1}{C}\left(s+\frac{R_s}{L}\right)}{s^2+\left(\frac{1}{R_pC}+\frac{R_s}{L}\right)s+\left(1+\frac{R_s}{R_p}\right)\frac{1}{LC}}$$

Fig P17.43

see the solution to Problem 32.

(b) With the given circuit elements

$$R_pC = 10 \qquad \frac{1}{LC} = 1$$

$$\frac{1}{R_pC} = 0.10 \qquad \frac{R_s}{R_p} = \frac{0.8}{10} = 0.08$$

$$\frac{R_s}{L} = 0.80 \qquad \frac{1}{R_pC}+\frac{R_s}{L} = 0.10+0.80 = 0.90$$

$$H(s) = \frac{s+0.80}{s^2+0.9s+1.08} = \frac{s+a}{s^2+2\sigma_p s+\omega_p^2}$$

$$\omega_0 = \frac{1}{LC} = 1 \text{ rad/s} \leftarrow$$

$$\omega_p = \sqrt{1.08} = 1.0392 \text{ rad/s} \leftarrow$$

$$\omega_d = \sqrt{\omega_p^2-\sigma_p^2} = \sqrt{1.08-(0.45)^2} = \sqrt{1.08-0.2025}$$

$$\omega_d = \sqrt{0.8775} = 0.9367 \text{ rad/s} \leftarrow$$

For ω_r observe that the circuit is resistive when the parallel portion of the circuit is at its ω_r. Using eq (17.4) gives

$$\omega_r = \omega_0\sqrt{1-\frac{CR_s^2}{L}} = 1\sqrt{1-\frac{1(0.8)^2}{1}}$$

$$= \sqrt{1-0.64} = \sqrt{0.36} = 0.60 \text{ rad/s}$$

17/43 Cont'd

$$H(j\omega) = \frac{0.80 + j\omega}{1.08 - \omega^2 + j0.9\omega}$$

$$|H(j\omega)| = \frac{\sqrt{\omega^2 + 0.64}}{\sqrt{(1.08 - \omega^2)^2 + 0.81\omega^2}}$$

With $z = \omega^2$

$$|H(j\omega)|^2 = \frac{z + 0.64}{z^2 - 2.16z + 1.1664 + 0.81z} = \frac{z + 0.64}{z^2 - 1.35z + 1.1664}$$

To find $|H(j\omega)|^2$ max or min, take

$$\frac{d\{|H(j\omega)|^2\}}{dz} = \frac{(z^2 - 1.35z + 1.1664)1 - (z + 0.64)(2z - 1.35)}{(z^2 - 1.35z + 1.6664)^2} = 0$$

$$z^2 + 1.28z - 2.0304 = 0$$

Solving

$$\omega_r^2 = z = 1.8441$$

$$\omega_r = 0.9220 \text{ rad/s}$$

Chapter 17/Problem 44

In the circuit in Fig P.17.43, the transfer function, developed in Problem 32 is

$$H(S) = \frac{\frac{1}{C}\left(S + \frac{R_s}{L}\right)}{S^2 + \left(\frac{1}{R_pC} + \frac{R_s}{L}\right)S + \left(1 + \frac{R_s}{R_p}\right)\frac{1}{LC}}$$

With the circuit element (without the value of C) given in Problem 17.43

$$H(S) = \frac{\frac{1}{C}(S + 0.80)}{S^2 + \left(\frac{0.1}{C} + 0.80\right)S + \frac{1.08}{C}}$$

Multiplication by C throughout gives

$$H(S) = \frac{S + 0.80}{CS^2 + (0.80C + 0.10)S + 1.08}$$

With $i_{IN}(t) = 2\cos t$, it is observed that

$$|I_{IN}| = 2A \quad \text{and} \quad \omega = 1 \text{ rad/s}$$

Thus

$$|V_{OUT}| = |H(j1)||I_{IN}| = 2|H(j1)|$$

With $\omega = 1$ rad/s

$$H(j1) = \frac{\sqrt{0.80 + 1}}{\sqrt{(1.08 - C)^2 + (0.80C + 0.10)^2}}$$

and

$$|H(j1)|^2 = \frac{1.64}{(1.08 - C)^2 + (0.80C + 0.10)^2}$$

$$= \frac{1}{C^2 - 1.2195C + 0.7113}$$

17/44 Cont'd

$|H(j1)|$ can be maximized by minimizing

$$P(C) = C^2 - 1.2195C + 0.7113$$

$$\frac{dP(C)}{dC} = 2C - 1.2195 = 0$$

$$2C = 1.2195$$

$$C = 0.6098 \text{ F}$$

17/45

If $R = 50\,\Omega$ $\quad 2\sigma_p = 500$

$$Q_p = \frac{1000}{500} = 2$$

This is <u>not</u> high Q_p

I made $R = 5\,\Omega$ so that

$$2\sigma_p = 50$$

and $Q_p = 20$

Chapter 17/Problem 45 ①

Fig P17.45

(a) By voltage division

$$H(s) = \frac{V_c(s)}{V_s(s)} = \frac{\frac{1}{Cs}}{Ls + R + \frac{1}{Cs}} = \frac{1}{LCs^2 + RCs + 1}$$

$$H(s) = \frac{1/LC}{s^2 + \frac{R}{L}s + 1/LC}$$

(b) With the given circuit elements inserted

$$\frac{R}{L} = \frac{5}{0.1} = 50$$

$$\frac{1}{LC} = \frac{10^6}{0.1(10)} = 10^6$$

$$H(s) = \frac{10^6}{s^2 + 50s + 10^6}$$

In the form

$$H(s) = \frac{K}{s^2 + 2\sigma_p s + \omega_p^2}$$

$$K = 10^6$$

$$2\sigma_p = 50$$

and

$$\omega_p^2 = 10^6$$

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{\sqrt{10^6}}{50} = \frac{1000}{50} = 20 > 10 \text{ (high } Q)$$

(c) By eq (17.34)

$$\omega_M = \omega_p\sqrt{1 - \frac{1}{2Q_p^2}} = 1000\sqrt{1 - \frac{1}{2(20)^2}} =$$

$$= 1000\sqrt{1 - 0.00125} = 1000\sqrt{0.99875}$$

$$= 1000(0.9994) = 999.4$$

$$\omega_M \approx \omega_p$$

$$H_m = \frac{|K|}{2\sigma_p} = \frac{10^6}{50} = 20{,}000$$

17/46 Cont'd

(d) $B_W = 2\sigma_p = 50$ rad/sec.

$\omega_2 = \omega_p + \sigma_p = 1000 + 25 = 1025$ rad/s

$\omega_1 = \omega_p - \sigma_p = 1000 - 25 = 975$ rad/s

Chapter 17/ Problem 46

(a) By current division

Fig P17.46

$$H(s) = \frac{I_L(s)}{I_{IN}(s)} = \frac{\frac{1}{LS}}{CS + \frac{1}{R} + \frac{1}{LS}} = \frac{\frac{1}{LS}}{\frac{RLCS^2 + LS + R}{RLS}}$$

$$H(s) = \frac{\frac{1}{RC}}{S^2 + \frac{1}{RC}S + \frac{1}{LC}}$$

which is in the form

$$H(s) = \frac{K}{s^2 + 2\sigma_p + \omega_p^2}$$

(b) With the network elements inserted

$$RC = 4000(10 \times 10^{-6}) = 0.04$$

$$\frac{1}{RC} = 25 = 2\sigma_p$$

$$\omega_p^2 = \frac{1}{LC} = \frac{10^6}{0.1(10)} = 10^6$$

$$\omega_p = 1000 \text{ rad/s}$$

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{1000}{25} = 40 > 10 \text{ (This is high Q)}$$

$$K = 10^6$$

(c) By eq (17.34)

$$\omega_M = \omega_p\sqrt{1 - \frac{1}{2(Q_p)^2}} = 1000\sqrt{1 - \frac{1}{3200}}$$

$$= 1000\sqrt{1 - 3.125 \times 10^{-4}} = 1000\sqrt{0.9969 \times 10^{-1}}$$

$$= 1000(0.9998) = 999.8$$

$$\omega_M \approx \omega_p$$

$$H_M = \frac{|K|}{2\sigma_p} = \frac{10^6}{25} = 40{,}000$$

(d)

$$BW = 2\sigma_p = 25 \text{ rad/s}$$

$$\omega_2 = \omega_p + \sigma_p = 1000 + 12.5 = 1012.5 \text{ rad/s}$$

$$\omega_1 = \omega_p - \sigma_p = 1000 - 12.5 = 987.5 \text{ rad/s}$$

Chapter 17 / Problem 41

$\boxed{\text{Fig P17.41}}$

(a) With the given circuit elements inserted,

$$R_1R_2C_1C_2 = (50{,}000)^2(0.2\times10^{-6})(0.5\times10^{-9})$$
$$= 2.500\times10^{-7}$$

$$\frac{1}{R_1R_2C_1C_2} = 4\times10^{6}$$

$$\frac{1}{R_1C_1} = \frac{10^6}{(0.2)(50{,}000)} = 100$$

$$\frac{1}{R_2C_1} = 100$$

$$\frac{1}{R_1C_1} + \frac{1}{R_2C_1} = 2(100) = 200$$

Hence

$$H(s) = \frac{4\times10^6}{s^2+200s+4\times10^6}$$

and in the form

$$H(s) = \frac{K}{s^2+2\sigma_p s+\omega_p^2}$$

Hence

$$K = 4\times10^6 \leftarrow$$
$$2\sigma_p = 200$$
$$\omega_p^2 = 4\times10^6$$
$$\omega_p = 2000 \leftarrow$$

(b)

$$Q_p = \frac{\omega_p}{2\sigma_p} = \frac{2000}{200} = 10 \leftarrow$$

(c) By eq (17.34)

$$\omega_m = \omega_p\sqrt{1-\frac{1}{2(Q_p)^2}} = 2000\sqrt{1-\frac{1}{200}} = 2000\sqrt{0.995}$$

$$\omega_m = 2000(0.9975) = 1995$$

$$H_m = \frac{|K|}{2\sigma_p} = \frac{4\times10^6}{200} = 20{,}000$$

17/47 Contd

(d)

$BW = 2\sigma_p = 200$ rad/s

$\omega_2 = \omega_p + \sigma_p = 1995 + 100 = 2095$ rad/s

$\omega_1 = \omega_p - \sigma_p = 1995 - 100 = 1895$ rad/s

Chapter 17/Problem 50

(a) By voltage division

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{R}{Ls + R + \frac{1}{Cs}} = \frac{\frac{R}{L}s}{s^2 + \frac{R}{L} + \frac{1}{LC}}$$

Fig P17.50

Using the given circuit elements

$$H(s) = \frac{0.1s}{s^2 + 0.1s + \frac{1}{4}}$$

(b) To obtain R = 50, make

$$K_m = \frac{50}{0.05} = 1000$$

$$K_f = \frac{1600\pi}{\frac{1}{\sqrt{LC}}} = \frac{3200\pi}{\frac{1}{2}} = 6400\pi$$

(c) New values, designated by subscript n

$$R_n = 50\,\Omega$$

$$L_n = \frac{K_m}{K_f}(0.5) = \frac{1000}{6400\pi}(0.5) = 0.0249\,H$$

$$C_n = \frac{1}{K_m K_f}C = \frac{8F}{6.4\times10^6\pi} = 0.3979\,\mu F$$

This make

$$H(s) = \frac{2010.6s}{s^2 + 2010.6s + 1.0106\times10^8}$$

Notice that the center frequency is

$$f_c = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = \frac{1}{2\pi}\sqrt{1.0106\times10^8} = 1600\,Hz$$

(d) With

$$H(s) = \frac{0.1s}{s^2+0.1s+0.25}$$

and pole-zero locations

$$z = 0$$

$$p_1, p_2 = -0.05 \pm j0.4975$$

the new pole locations will be

$$K_f(p_1, p_2) = 6400\pi(-0.05 \pm j0.4975)$$

$$= -1005.3 \pm j10002.7$$

Now check the poles of the new $H(s)$

$$H(s) = \frac{2010.6s}{s^2+2010.6s+1.0106\times10^8}$$

$$= \frac{2010.6s}{(s+1005.3+j10002.5)(s+1005.3-j10002.5)}$$

and notice that the new magnitude is

$$2010.6 = K_f(0.10)$$

$$= 0.10(6400\pi)$$

$$= 640\pi$$

$$= 2010.6$$

Chapter 17/Problem 51

(a) $$Z(s) = \frac{K}{(s-p_1)(s-p_2)} = \frac{K_m K}{\left(\frac{s}{K_f}-p_1\right)\left(\frac{s}{K_f}-p_2\right)} = \frac{K_m K_f^2 K}{(s-K_f p_1)(s-K_f p_2)}$$

The new pole locations are

$K_f p_1$ and $K_f p_2$

The new gain constant is

$K_m K_f^2 K$

The new impedance function is

$$Z(s) = \frac{K_m K_f^2 K}{(s-K_f p_1)(s-K_f p_2)}$$

(b) $$Z(s) = K\frac{s-z_1}{(s-p_1)(s-p_2)} = \frac{K_m K_f (s-K_f z_1)}{(s-K_f p_1)(s-K_f p_2)}$$

The new pole locations are

$K_f p_1$ and $K_f p_2$

The new zero location is

$K_f z_1$

The new gain constant is

$K_m K_f K$

The new impedance function is

$$Z(s) = \frac{K_m K_f (s-K_f z_1)}{(s-K_f p_1)(s-K_f p_2)}$$

17/51 Cont'd

(c)
$$Z(s) = K\frac{(s-z_1)(s-z_2)}{(s-p_1)(s-p_2)}$$

The new pole locations are

$K_f p_1$ and $K_f p_2$

The new zero locations are

$K_f z_1$ and $K_f z_2$

The new gain constant is

$K_m K$.

The new impedance function is

$$Z(s) = K_m K\frac{(s-K_f z_1)(s-K_f z_2)}{(s-K_f p_1)(s-K_f p_2)}$$

Chapter 17/Problem 52

(a) $$Y(s) = \frac{60}{(s+5)(s+6)}$$

$$K_f = 2000\pi$$
$$K_M = 20$$

New poles are at
$$p_1 = 10{,}000\pi \quad \text{and} \quad p_2 = 12{,}000\pi$$

The new gain constant is
$$\frac{K_f^2}{K_M}(60) = \frac{(2000\pi)^2}{20} = 120\pi^2 \times 10^5$$

The new admittance function is
$$Y(s) = \frac{120\pi^2 \times 10^5}{(s+10{,}000\pi)(s+12{,}000\pi)}$$

(b) $$Y(s) = 120\frac{s+1}{(s+5)(s+6)}$$

New poles are at
$$p_1 = 10{,}000\pi \quad \text{and} \quad p_2 = 12{,}000\pi$$

New zeros are at
$$z_1 = 2000\pi$$

The new gain constant is
$$\frac{K_f}{K_M}(120) = 1.2\pi \times 10^4$$

The new admittance function is
$$Y(s) = \frac{1.2\pi \times 10^4 (s+2000\pi)}{(s+10{,}000\pi)(s+12{,}000\pi)}$$

(c)

$$Y(s) = 120\frac{(s+2)(s+5)}{(s+4)(s+10)}$$

New poles are at

$p_1 = 8000\pi$ and $p_2 = 20{,}000\pi$

New zeroes are at

$z_1 = 4000\pi$ and $z_2 = 10{,}000\pi$

The new gain constant is

$$\frac{120}{K_m} = \frac{120}{20} = 6$$

The new admittance function is

$$Y(s) = 6\frac{(s+4000\pi)(s+10{,}000\pi)}{(s+8000\pi)(s+20{,}000\pi)}$$

(d)

$$Y(s) = \frac{s^2-4s+8}{s^2+4s+8} = \frac{(s+2+j2)(s+2-j2)}{(s-2+j2)(s-2-j2)}$$

New poles are at

$p_1 = +4000\pi - j4000\pi$ and $p_2 = 4000\pi + j4000\pi$

New zeroes are at

$z_1 = -4000\pi - j4000\pi$ and $z_2 = -4000\pi + j4000\pi$

The new gain constant is

$$\frac{1}{K_m} = \frac{1}{20}$$

The new admittance function is

$$Y(s) = \frac{1}{20}\left(\frac{s^2-4s+8}{s^2+4s+8}\right)$$

Chapter 17 / Problem 54

Because each $H(s)$ is a voltage ratio, the magnitude ratio, K_m, has no effect. With K_f as the frequency ratio

(a) $$H(s) = \frac{K_f^3 K}{(s - K_f p_1)(s - K_f p_2)(s - K_f p_3)}$$

(b) $$H(s) = \frac{K_f^2 K (s - K_f z_1)}{(s - K_f p_1)(s - K_f p_2)(s - K_f p_3)}$$

(c) $$H(s) = \frac{K_f K (s - K_f z_1)(s - K_f z_2)}{(s - K_f p_1)(s - K_f p_2)(s - K_f p_3)}$$