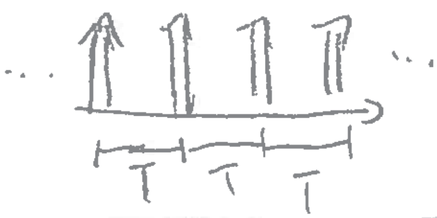
PS03

Mitchell Kwon

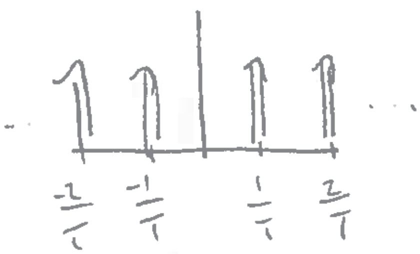
1e) $x(t)$

$X(\omega)$

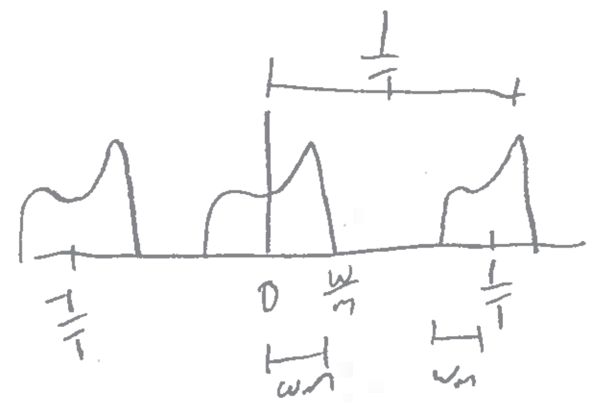
a) $p(t)$



b) $P(\omega)$



c) $X_p(\omega) = X(\omega) * P(\omega)$

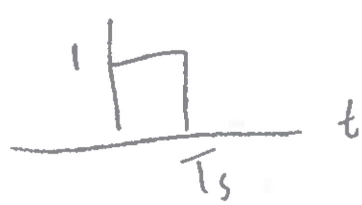


d) $\frac{1}{T} > 2 \cdot \omega_m$

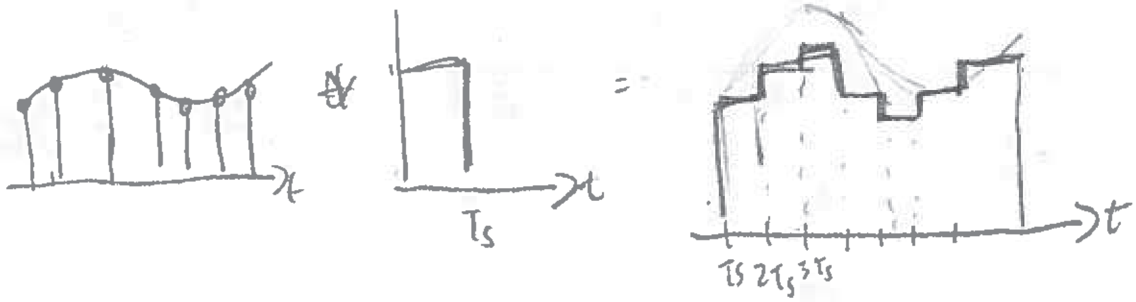
$$\boxed{2 \cdot T \cdot \omega_m < 1}$$

e) Apply LPF of $f_{cutoff} = \omega_m$

f) $z(t)$

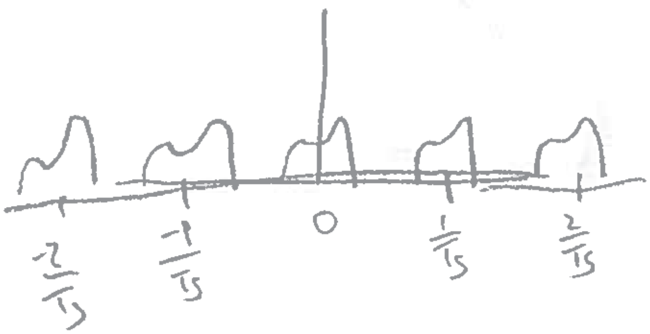


g) $x_p(t) * z(t) = x_z(t)$

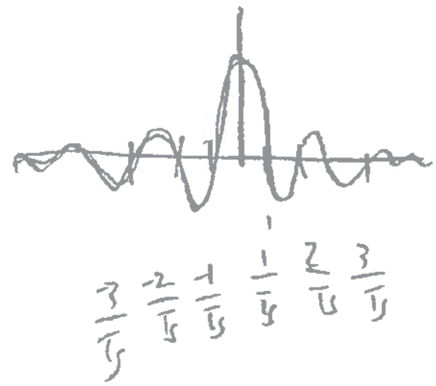


P. (b) $\bar{X}_z(\omega) = \bar{X}_p(\omega) \cdot Z(\omega)$

$X_p(\omega)$

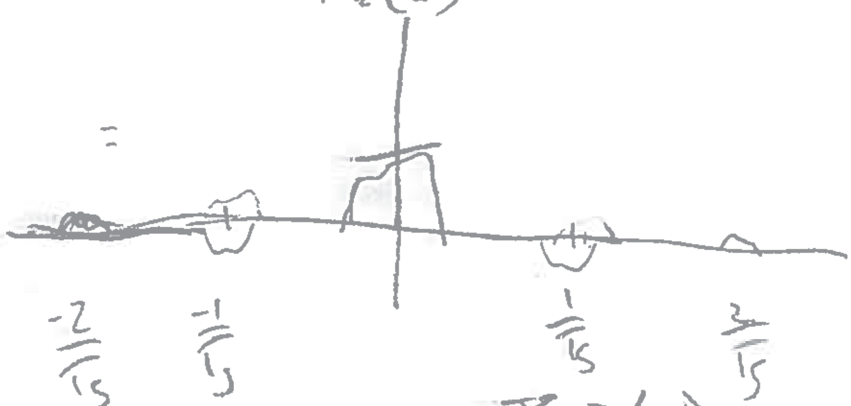


$\cdot$



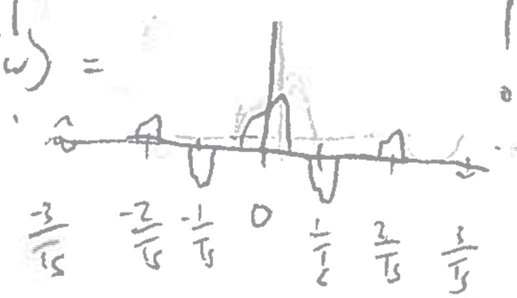
$X_z(\omega)$

=

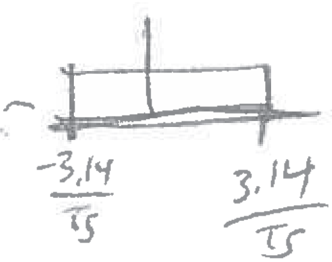


$\bar{X}z(\omega)$ $H(\omega)$

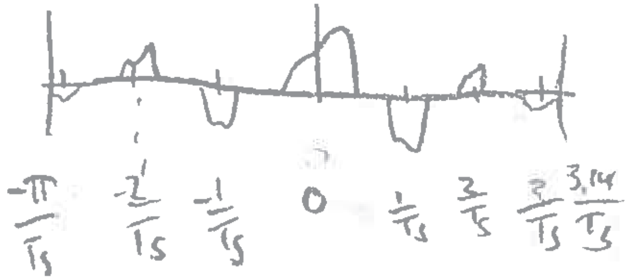
i) $\bar{X}(\omega) = X_z(\omega) H(\omega) =$



$\cdot$



$\bar{X}(\omega) =$



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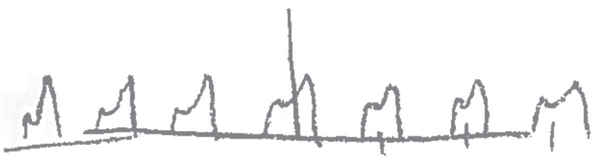
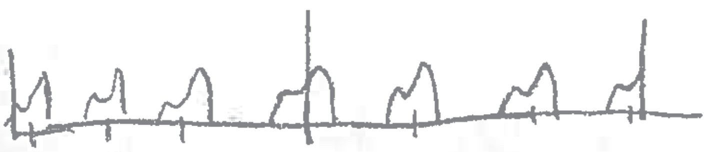
i) Continued

$\hat{X}(\omega) = X_p(\omega)\, H(\omega)$

$X_p(\omega)$



$\hat{X}(\omega)$



j) $\bar{X} = \hat{X}(\omega) \cdot \mathrm{sinc}(T_s\omega)$. Innermost is largest and outside harmonics are decreased by $\mathrm{sinc}(T_s\omega)$

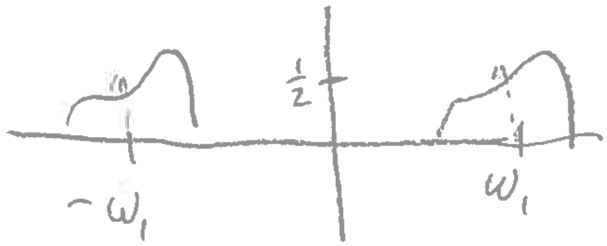
k. At $\omega = \frac{\pi}{T_s}$, $\bar{X}(\omega) = X_z(\omega) = X_p(\omega) \cdot Z(\omega) = X_p(\omega_n) \cdot Z(\omega_n)$

As $\omega = \frac{\pi}{T_s}$, $\hat{X}(\omega) = X_p(\omega) = X_p(\omega_n)$

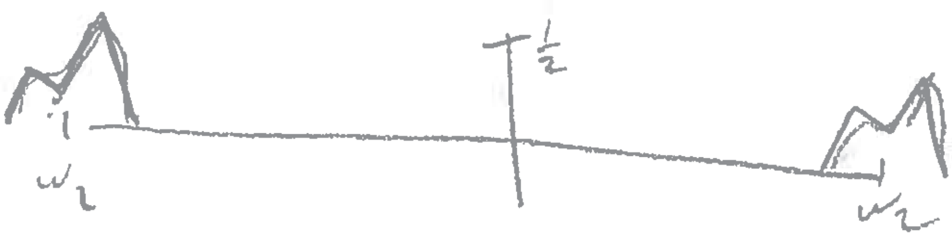
$$\therefore \frac{\bar{X}(\omega_n)}{\hat{X}(\omega_n)} = \frac{X_p(\omega_n) Z(\omega_n)}{X_p(\omega_n)} = \boxed{Z(\omega_n)}$$

2. a) $Y(\omega) = X_1(\omega) * \boxed{\cos(\omega_1 t)} + X_2(\omega) * \boxed{\cos(\omega_2 t)}$

$\frac{1}{2}(\delta(t \pm \omega_1))$ $\frac{1}{2}(\delta(t \pm \omega_2))$

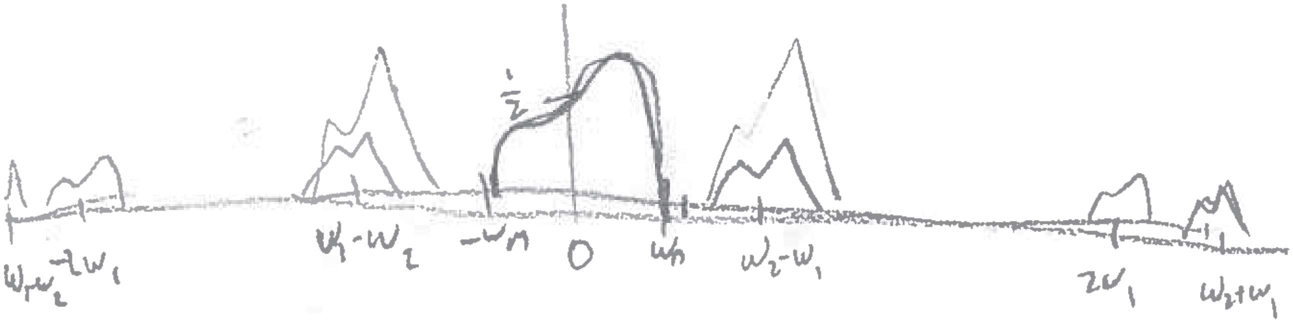


+

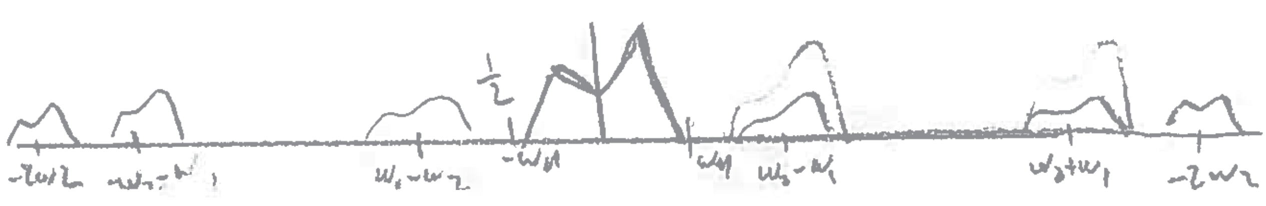


=

b) $y(t)\cos(\omega_1 t) \Rightarrow Y(\omega) * \left(\frac{1}{2}\delta(\omega \pm \omega_1)\right)$



$y(t)\cos(\omega_2 t) \Rightarrow Y(\omega) * \left(\frac{1}{2}\delta(\omega \pm \omega_2)\right)$



2. c) Recovering $x_1(t)$ from $y(t)$:

$x_1(t)\cos(\omega_1 t)$

LPF (cutoff $= \omega_M$)

$= \frac{1}{2} x_1(t)$

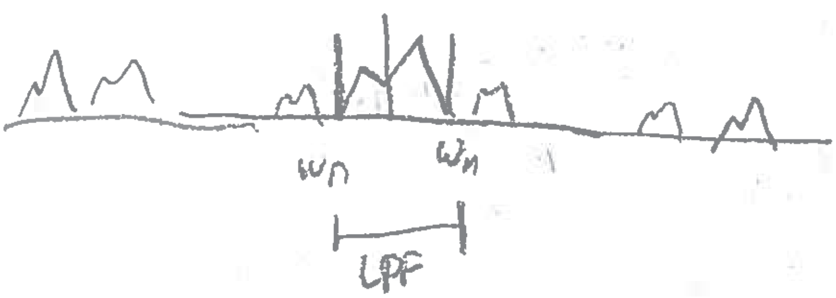
$$x_1(t) = \text{LPF}(y(t)\cos(\omega_1 t), \omega_M) \cdot 2$$

$$= \underline{2 \cdot \text{LPF}\left(y(t)\cos(\omega_1 t), \text{cutoff} = \omega_M\right)}$$

$x_2(t)$: Same process, but replace ω_1 with ω_2

$$\boxed{x_2 = 2 \cdot \text{LPF}\left(y(t)\cos(\omega_2 t), \text{cutoff} = \omega_M\right)}$$

$y(t)\cos(\omega_2 t) \Rightarrow$



$= \frac{1}{2} X_2(t)$

3. a) $V_{out} + V_L + V_R(t) = V_{in}(t)$ $\qquad V_L(t) = L\frac{di}{dt}$

$$V_{out} + L\frac{di}{dt} + Ri(t) = V_{in}(t)$$

$$V_{out} = \frac{Q}{C} \qquad V_L = L\,Q'' \qquad V_R = R\,Q'$$

$$V_L = LC(V_{out})'' \qquad V_R = RC(V_{out})'$$

a) $$\boxed{V_{out} + LC(V_{out})'' + RC(V_{out})' = V_{in}}$$

b) $$F(V_{out}) + (j\omega)^2 LC[F(V_{out})] + (j\omega)RC[F(V_{out})] = F(V_{in})$$

$$F(V_{out})(1 + j\omega RC - \omega^2 LC) = F(V_{in})$$

$$F(V_{out}) = \frac{F(V_{in})}{1 + j\omega RC - \omega^2 LC}$$

$$H(\omega) = \frac{1}{1 + j\omega RC - \omega^2 LC}$$

c) $$|H(\omega)| = \sqrt{R(H(\omega))^2 + I(H(\omega))^2}$$

$$\frac{1}{(1-\omega^2 LC) + \omega RC[j]}$$

$$R(H(\omega)) = \frac{1-\omega^2 RC}{(1-\omega^2 LC)^2 - (\omega RC)^2}$$

$$\frac{(1-\omega^2 LC) - \omega RCj}{(1-\omega^2 LC)^2 - (\omega RC)^2}$$

$$I(H(\omega)) = \frac{-\omega RC}{(1-\omega^2 LC)^2 - (\omega RC)^2}$$

$$\therefore |H(\omega)| = \frac{\sqrt{(1-\omega^2 RC)^2 + (\omega RC)^2}}{(1-\omega^2 LC)^2 - (\omega RC)^2}$$

$a = 1-\omega^2 RC$

$b = \omega RC$

$$\frac{\sqrt{a^2+b^2}}{a^2-b^2}$$

d) $$\frac{d(H(\omega))}{d\omega} = \cancel{\tfrac{1}{2}\left((1-\omega^2 RC)^2 + \omega^2 R^2 C^2\right)^{-\frac{1}{2}}}\big)($$

$$(a^2-b^2)\cdot \tfrac{1}{2}(a^2+b^2)^{-\frac{1}{2}}\big(2(1-\omega^2 RC)(2\omega RC) + 2R^2C^2\omega$$

Max when $\dfrac{d|H(\omega)|}{d\omega} = 0$

$$\frac{d\,\frac{a}{b}}{d\omega} = \frac{b\,da - a\,db}{b^2}$$

$$\frac{d|H(\omega)|}{d\omega} =$$

$b\,da = a\,db$

$$(a^2-b^2)\left[\tfrac{1}{2}(a^2+b^2)^{-\frac{1}{2}}\boxed{\left(2(a)(2\omega RC)\cancel{(RC)}+2b(RC)\right)^{a}}\right.$$

$$= (a^2+b^2)^{\frac{1}{2}}\boxed{\left[2a(2\omega RC)(RC) + 2b(RC)\right]}$$

$$\frac{a^2-b^2}{2} = a^2+b^2 \qquad a = 1-\omega^2 LC \qquad b = \omega RC$$

$$a^2-b^2 = 2a^2+2b^2 \qquad a^2 = 1-2\omega^2 LC + \omega^4 L^2C^2$$

$$0 = a^2+3b^2 \qquad b^2 = \omega^2R^2C^2$$

$$\overset{a}{\cancel{1}} - (\overset{b}{2LC + 3R^2C^2})\omega^2 + \overset{c}{(L^2C^2)}\omega^4 = 0$$

$$u = \omega^2 \qquad u = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$\frac{C}{2}\left[2L + 3R^2C \pm \sqrt{4L^2 + 6R^2CL - 4L^2 + 9R^4C^2}\right] = \frac{2LC + 3R^2C^2 \pm \sqrt{(2LC+3R^2C^2)^2 - 4L^2C^2}}{2}$$

$$\frac{C}{2}\left[2L + 3R^2C \pm R\sqrt{6CL + 9R^2C^2}\right] \qquad \frac{C}{2}\left[\frac{2L+3R^2C \pm \sqrt{(2L+3R^2C)^2 - 4L^2}}{2}\right]$$

$$\frac{d|H(\omega)|}{d\omega} = 0$$

$= \omega^2$

$$\boxed{\omega = \left[\frac{C}{2}\left[2L+3R^2C \pm R\sqrt{6CL+9R^2C^2}\right]\right]^{-\frac{1}{2}}}$$

Problem Set 8 - Mitchell Kwock - Problem 3e

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
```

In [2]:
```
def getRLC(w, r, l, c):
    '''
    Function returning the complex response of the system
    '''
    return 1.0/(1 + w * r * c * 1j - w * w * l * c)

def rlcHigh(r, l, c):
    '''
    Calculate location of the "Max".  Derivation found on homework
    '''
    front = c / 2.0
    mid = 2 * l + 3 * r * r * c
    back = r * (6 * c * l + 9 * r * r * c * c)
    u = (front * (mid - back))
    omega = u ** -0.5
    return omega
```

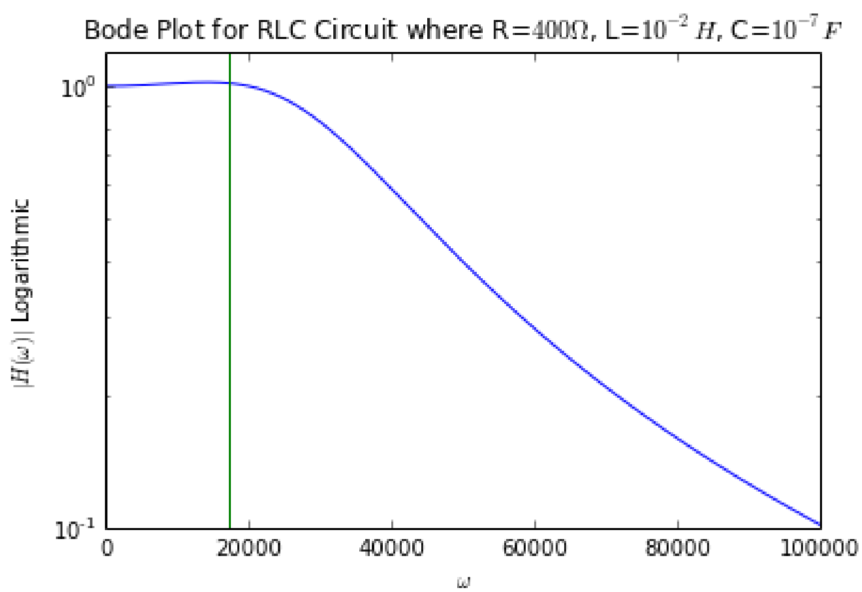
In [3]:

```
r = 400
l = 1e-2
c = 1e-7

omegas = np.linspace(0, 100000, 1001)
response = [np.abs(getRLC(w, r, l, c)) for w in omegas]
high = rlcHigh(r, l, c)

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.set_yscale('log')
plt.plot(omegas, response)
plt.plot([high, high], [1e-1, 1.2])
plt.ylim([1e-1, 1.2])
plt.title('Bode Plot for RLC Circuit where R=$400\Omega$, L=$10^{-2}H$, C=$1
0^{-7}F$')
plt.xlabel('$\omega$')
plt.ylabel('$|H(\omega)|$ Logarithmic')
```

Out[3]: <matplotlib.text.Text at 0xaa87c18>



In [4]:
```
r = 50
l = 1e-2
c = 1e-7

omegas = np.linspace(0, 100000, 1001)
response = [np.abs(getRLC(w, r, l, c)) for w in omegas]
high = rlcHigh(r, l, c)

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.set_yscale('log')
plt.plot(omegas, response)
plt.plot([high, high], [1e-1, 10])
plt.ylim([1e-1, 10])
plt.title('Bode Plot for RLC Circuit where R=$50\Omega$, L=$10^{-2}H$, C=$1
0^{-7}F$')
plt.xlabel('$\omega$')
plt.ylabel('$|H(\omega)|$ Logarithmic')
```

Out[4]: <matplotlib.text.Text at 0xb0b14e0>