1. State the significance of crystal filters in communication systems. (Nov/Dec 2012)

Crystal filter is most widely used to separate various channels in communication circuits such as telephone circuits.

Crystal filter is made up of Piezo electric crystal. The piezo electric quartz crystal have a very high Q, therefore it is possible to make very narrow band filters and filters in which attenuation rises very rapidly at cutoff.

2. Derive and draw the characteristics of m derived T section for high pass filter. (May/Jun 2013)

\[ Z'_1 = \frac{m}{j\omega C} \]

and

\[ Z'_2 = \frac{j\omega L}{m} + \frac{1}{j4m\omega C} \]

\[ e' = 1 + Z'_1 / 2Z'_2 + \sqrt{\left(Z'_1 / Z'_2\right)^2 + \left(Z'^2_1 / 4Z'^2_2\right)} \]

\[ Z'_1 = \frac{m}{j\omega C} \left( \frac{1}{\omega C} - \frac{2\omega C}{m} \right)^2 \]

\[ Z'_2 = \frac{j\omega L}{m} + \frac{1}{j4m\omega C} \left( 1 - \frac{(\omega / \omega_c)^2}{1 - (1 - m^2)(\omega_c / \omega)^2} \right) \]

Where, \( \omega_c = 1 / 2\sqrt{LC} \)

3. Draw a constant KT section band elimination filter and explain the operation with necessary design equations. (May/Jun 2013)

A band elimination filter is a network which attenuates frequencies between two cutoff frequencies \( f_1 \) and \( f_2 \) and passes all other frequencies. It can be thought of as a LPF in parallel with a high pass section, in which the cutoff frequency of the LPF is below that of high pass filter.
4. Design prototype T section band pass filter having cutoff frequency of 1KHz and 4KHz and impedance of 600 Ω. Find resonant frequency. (May/Jun 2013)
   \[ L_1 = \frac{R_K}{(\pi(f_2 - f_1))} = 63.66\text{mH} \]
   \[ C_1 = \frac{(f_2 - f_1)}{(4\pi R_K f_1 f_2)} = 0.099\ \mu\text{F} \]
   \[ L_2 = \frac{R_K(f_2 - f_1)}{4\pi f_2 f_1} = 35.8\ \text{mH} \]
   \[ C_2 = \frac{1}{\pi R_K(f_2 - f_1)} = 0.1768\ \mu\text{F} \]
   Resonant frequency, \( f_0 = \sqrt{f_1 f_2} = \sqrt{(4 \times 10^3 \times 1 \times 10^3)} = 2\text{KHz} \).

5. A constant k T-section high pass filter has a cutoff frequency of 10 KHz. The design impedance is 600 Ω. Determine the value of L. (Nov/Dec 2010)
   Given:
   \[ R_K = 600\ \text{ohm} \]
   \[ f_C = 10 \text{ KHz} \]
   \[ L = \frac{R_K}{4\pi f_c} = \frac{(600/4 \times \pi \times 10 \times 10^3)}{0.004771\text{H}} \]
   \[ L = 4.77\text{mH} \]

6. What are the advantages of m-derived filters? (Nov/Dec 2010)
   The advantages of m-derived filters are
   i) Attenuation rises near cutoff frequency \( f_C \) and its slope is adjustable by varying \( f_\infty \).
   ii) The characteristics impedance will be uniform in the pass band when m-derived half section having \( m = 0.6 \) is connected at the ends.
1. Explain the properties and characteristics impedance of symmetrical networks. (Nov/Dec 2012)
(i) \( I_0 \) in terms of \( I_{sc} (Z_{se}) \) and \( O.C. (Z_{oc}) \) Impedance.

\[
\begin{align*}
Z_{oc} - Z_{se} &= Z_{oc} \\
I_{oc} &= I_{sc} = Z_{oc} \\
I_{sc} &= \frac{I}{2} + \frac{Z_{se}}{2} \\
I_{se} &= I_{sc} = \frac{Z_{oc} - Z_{se}}{2} \\
Z_{ce} &= \frac{Z}{2} + \left( \frac{Z_{se}}{2} \right) \\
Z_{ce} &= \frac{Z}{2} + \frac{Z_{se}}{2} \\
\dot{Z}_{oc} \cdot \dot{Z}_{ce} &= \frac{Z_{oc}}{2} + \frac{Z_{ce}}{2} \\
\dot{Z}_{oc} \cdot \dot{Z}_{ce} &= \frac{Z_{oc}}{2} + \frac{Z_{ce}}{2} \\
Z_0 &= \sqrt{\dot{Z}_{oc} \cdot \dot{Z}_{ce}}.
\end{align*}
\]
Zo of a T network:

(i) Zo in terms of series & shunt arm impedance:

\[ Z_0 = 2Z_2 \left[ Z_1 + \frac{Z_3 Z_0}{Z_2 + Z_0} \right] \]

By the property of symmetrical power, the input impedance is:

\[ \frac{Z_0}{Z_0 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]

\[ Z_0 = \frac{Z_2}{Z_2 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]

\[ Z_0 = \frac{Z_2 \left[ Z_1 + Z_3 + Z_0 + \frac{Z_0 Z_2}{Z_2 + Z_0} \right]}{Z_0 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]

\[ Z_0 = \frac{Z_2 \left[ Z_1 + Z_3 + Z_0 + \frac{Z_0 Z_2}{Z_2 + Z_0} \right]}{Z_0 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]

\[ Z_0 = \frac{Z_2 \left[ Z_1 + Z_3 + Z_0 + \frac{Z_0 Z_2}{Z_2 + Z_0} \right]}{Z_0 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]

\[ Z_0 = \frac{Z_2 \left[ Z_1 + Z_3 + Z_0 + \frac{Z_0 Z_2}{Z_2 + Z_0} \right]}{Z_0 + \frac{Z_3 Z_0}{Z_2 + Z_0}} \]
2. Design T and π section low pass filter which has series inductance 80 mHz and shunt capacitance 0.022 µF. Find the cutoff frequency and design impedance. (Nov/Dec 2012)
3. What are the advantages of m derived filters? Design an m derived low pass filter (T and π section) having design resistance $R_0 = 500 \, \Omega$, cutoff frequency $f_C = 1500 \, \text{Hz}$ and infinite attenuation frequency $f_\infty = 2000 \, \text{Hz}$. (Nov/Dec 2012)

The advantages of m-derived filters are

i) Attenuation rises near cutoff frequency $f_C$ and its slope is adjustable by varying $f_\infty$.

ii) The characteristics impedance will be uniform in the pass band when m-derived half section having $m = 0.6$ is connected at the ends.

\[ C = \frac{1}{\pi f_C R_0} = \frac{1}{\pi \times 1500 \times 500} = 0.4244 \, \mu\text{F} \]

\[ m = \sqrt{1 - \left(\frac{f_C}{f_\infty}\right)^2} = \sqrt{1 - \left(\frac{1500}{2000}\right)^2} = 0.66143 \]

The components value of m-derived LPF,

\[
\begin{align*}
\frac{mL}{2} & = 35.088 \, \text{mH} & mL & = 70.177 \, \text{mH} \\
mC & = 0.28 \, \mu\text{F} & \frac{mC}{2} & = 0.14 \, \mu\text{F} \\
\left(\frac{1-m^2}{4m}\right)L & = 22.558 \, \text{mH} & \left(\frac{1-m^2}{4m}\right)C & = 0.09 \, \mu\text{F}
\end{align*}
\]
4. Design a m-derived T-section low pass filter having a cutoff frequency \( f_C \) of 5000 Hz and a design impedance of 600 ohms. The frequency of infinite attenuation is 1.25 \( f_C \).

\( \text{(Nov/Dec 2010)} \)

Given:

\[ f_C = 5000 \text{Hz}, \quad R_K = 600 \Omega, \quad f_e = 1.25 f_C \]

\[ L = R_K / \pi f_c = 600 / (\pi \times 5000) = 38.2 \text{ mH} \]

\[ C = 1 / R_K f_c = 1 / (\pi \times 5000 \times 600) = 1.106 \mu \text{F} \]

\[ m = \sqrt{1 - \left(\frac{f_c}{f_c} \right)^2} \]

\[ = \sqrt{1 - \left(\frac{f_c}{1.25 f_c} \right)^2} \]

\[ = \sqrt{1 - 0.8^2} = 0.6 \]

\[ mL/2 = 11.46 \text{ mH, mL} = 22.92 \text{ mH} \]

\[ mC = 0.063 \mu \text{F, mC/2 = 0.031 \mu \text{F}} \]

\[ (1 - m^2/4m)L = 10.18 \text{ mH, (1 - m^2/4m)C = 0.028 \mu \text{F}} \]
5. Draw and explain the operation of crystal filters. (Nov/Dec 2010)

Crystal filter is made up of Piezo electric crystal with very high Q. It acts as a very narrow band filter.
The crystal has \( R_S \), \( L_S \), \( C_S \) series in parallel with capacitance \( C_P \). The resonant frequency of series circuit is

\[
f_0 = \frac{1}{2\pi\sqrt{L_S C_S}}
\]

The resonant frequency of parallel circuit is

\[
f_A = f_0 \sqrt{1 + \left(\frac{C_S}{C_P}\right)}
\]

Filter gives maximum output at resonance and minimum at anti resonance.

6. Design a constant K T-section bandpass filter with a cutoff frequencies of 1 KHz and 4 KHz. The design impedance is 600 ohms. (Nov/Dec 2010)

Given:

- \( f_1 = 1 \text{ KHz} \), \( f_2 = 4 \text{ KHz} \), \( R_K = 600\Omega \)
- \( L_1 = R_K/\pi(f_2 - f_1) \)
- \( C_1 = (f_2 - f_1)/(4\pi R_K f_1 f_2) \)
- \( L_2 = R_K(f_2 - f_1)/(4\pi f_1 f_2) \)
- \( C_2 = 1/[\pi R_K (f_2 - f_1)] \)

Resonant frequency, \( f_0 = \sqrt{(f_1 f_2)} \)

\[ f_0 = \sqrt{4 \times 10^6} \]

\[ f_0 = 2 \text{ KHz}. \]
7. Draw a constant k T-section band elimination filter and the operation with necessary design equations. (Nov/Dec 2010)

A band elimination filter is a network which attenuates frequencies between two cutoff frequencies $f_1$ and $f_2$ and passes all other frequencies.

The band elimination filter is obtained by interchanging series and parallel tuned arms of the band pass filter.

For constant K type filter:

At cut-off frequencies:

\[
\begin{align*}
I_1 &= -4I_2 \\
I_1I_2 &= -4I_1^2 = \frac{Rk^2}{4} \\
I_2 &= \frac{-Rk^2}{4} \\
I_2 &= \pm j\frac{Rk^2}{2}.
\end{align*}
\]

If the filter is terminated with load $R = \Re k$,

then the lower cut-off freq:

\[
I_1 = \frac{1}{\sqrt{1 - \frac{(\omega_1\omega_2)}{\omega_1^2}}} = \frac{R}{I_2}.
\]
\[ 1 - L_2 C_2 \omega^2 = \frac{L}{2} C_2 \omega^2 \]
\[ -L_2 C_2 = \left( \frac{\omega}{\omega_0} \right)^2 - \frac{L}{2} C_2 \omega_0 \]

\[ f_1 = \frac{1}{\pi f_0} \frac{L}{C_2} \]
\[ f_0 = \frac{1}{\pi f_0} \frac{L}{C_2} \Rightarrow f_0 = \frac{1}{\pi f_0} \frac{L}{C_2} \]

\[ L_2 = \frac{1}{\omega^2} \]
\[ L_2 = \frac{1}{\omega^2} \]

\[ L_2 = \frac{L}{\omega^2} \]

\[ L_1 = \frac{L}{C_2} \Rightarrow L_1 = \frac{L}{C_2} \]

\[ L_2 C_2 = \frac{L^2}{C_1} = \frac{L^2}{C_1} \]

\[ C_1 = \frac{L_2}{R^2} \]
8. Derive the relevant equations of m-derived low pass filter and design m-derived T type low pass filter to work into load of 500 ohm with cutoff frequency at 4KHz and peak attenuation at 4.15 KHz. (Apr/May 2011)

For m-derived T-section of LPF

\[ m = \sqrt{1 - \left(\frac{f_c}{f_w}\right)^2} \]

\[ m = \sqrt{1 - \left(\frac{4000}{4150}\right)^2} = 0.266 \]

The actual values of components in series and shunt arms of the m-derived T-section of LPF is given by

\[ \frac{m\, L}{2} \]

where

\[ L = \frac{R_0}{\pi f_c} = \frac{500}{\pi \times 400} = 0.03978 = 39.78 \, \text{mH} \]

\[ C = \frac{1}{(\pi f_c) R_0} = \frac{1}{(\pi \times 4000) 500} \]

\[ = 1.591 \times 10^{-7} \, \text{F} = 0.1591 \, \mu\text{F} \]

\[ \frac{m\, L}{2} = \frac{(0.266)(39.78 \times 10^{-3})}{2} = 5.29074 \, \text{mH} \]

\[ m\, C = (0.266)(0.1591 \times 10^{-6}) \]
9. Explain the structure and application of crystal filter. Design a low pass filter with cutoff at 2600 Hz to match 550 ohm. Use one derived section with infinite attenuation at 2850 Hz. (Apr/May 2011)

Crystal filter is made up of Piezo electric crystal with very high Q. Its acts as a very narrow band filter.

The crystal has $R_s L_s C_s$ series in parallel with capacitance $C_p$. The resonant frequency of series circuit is

$$f_0 = \frac{1}{2\pi \sqrt{L_s C_s}}$$

The resonant frequency of parallel circuit is

$$f_A = f_0 \sqrt{1 + \left(\frac{C_s}{C_p}\right)}$$

Filter gives maximum output at resonance and minimum at anti resonance.
For m-derived LPF T section,

\[ m = \sqrt{1 - \left( \frac{f_c}{f_\infty} \right)^2} = \sqrt{1 - \left( \frac{2600}{2850} \right)^2} = 0.409 \]

\[ L = \frac{R_0}{\pi f_c} = \frac{550}{\pi \times 2600} \]

\[ = 0.0673 \text{ mH} \]

\[ C = \frac{1}{\left( \pi f_c \right) R_0} = \frac{1}{\pi \times 2600 \times 550} \]

\[ = 0.2225 \text{ \( \mu \)F} \]

\[ \frac{mL}{2} = \frac{(0.409)(67.3 \times 10^{-3})}{2} = 13.76 \text{ mH} \]

\[ mC = (0.409)(0.2225 \times 10^{-6}) \]

\[ = 0.0910 \text{ F} \]

\[ \left( \frac{1 - m^2}{4m} \right) L = \left[ \frac{1 - (0.409)^2}{4 \times (0.409)} \right] \times 67.3 \times 10^{-3} \]

\[ = 0.5089 \times 67.3 \times 10^{-3} = 34.25 \text{ mH} \]

Hence, m-derived T section LPF.