Electrical Circuits (2)

Lecture 4

Resonance Applications

(Filters)

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Applications of Resonance Circuits

FILTER NETWORKS

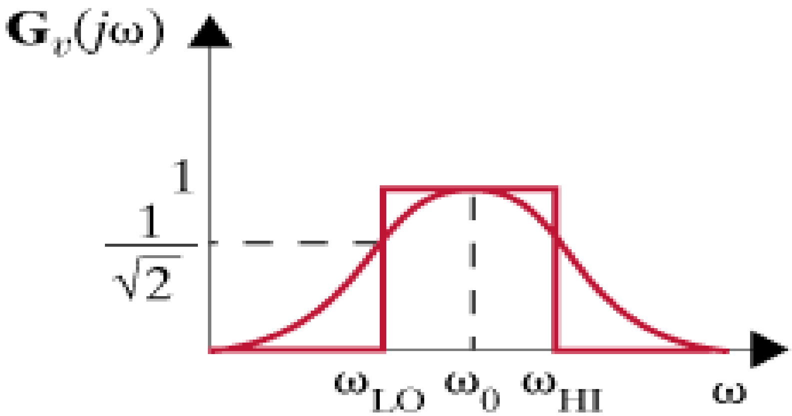
A **filter** is a circuit that is designed to pass signals with desired frequencies and reject or attenuate others.

- **The filter can be treated as a networks designed to have frequency selective behavior**
- **A filter can be used to limit the frequency spectrum of a signal to some specified band of frequencies.**
- **Filters are the circuits used in radio and TV receivers to allow us to select one desired signal out of a multitude of broadcast signals in the environment**

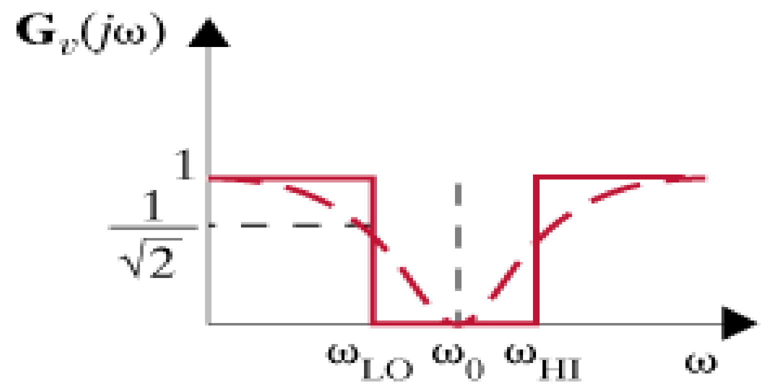
1. **Passive filter:** it consists of only passive elements R, L, and C.
2. **Active filter:** it consists of active elements (such as transistors and op amps) in addition to passive elements

Filter Networks

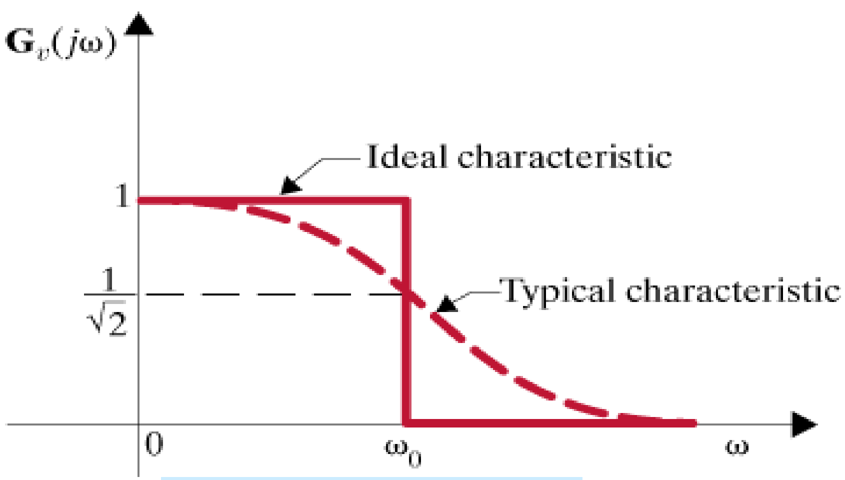
COMMON types of FILTERS



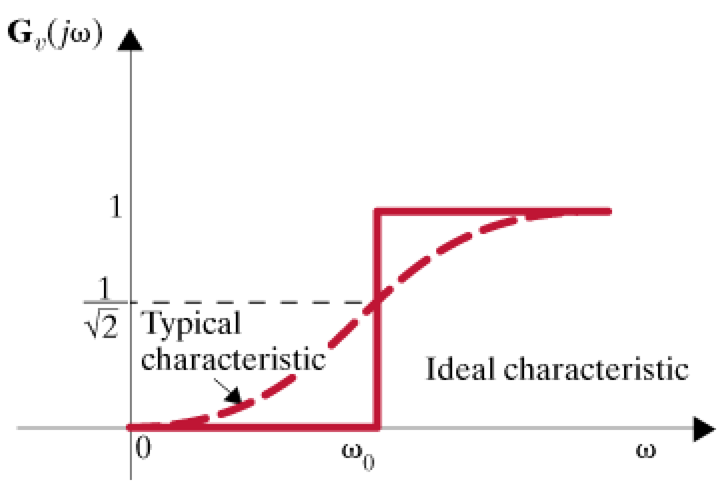
Band-pass filter



Band-reject filter



Low-pass filter



High-pass filter

Filter Networks

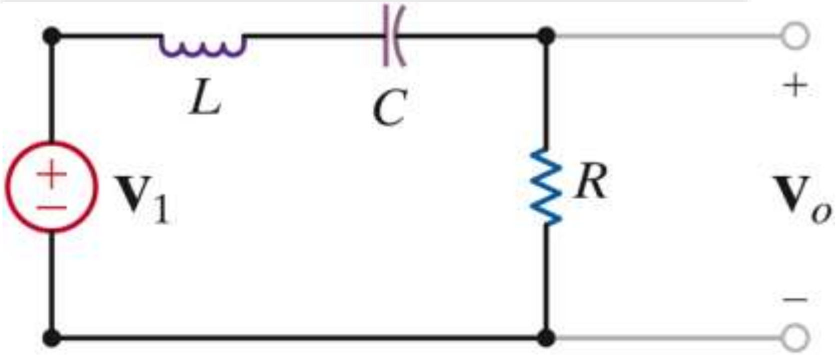
Important Table for determining the type of the filter from its Transfer function

Summary of the characteristics of ideal filters.

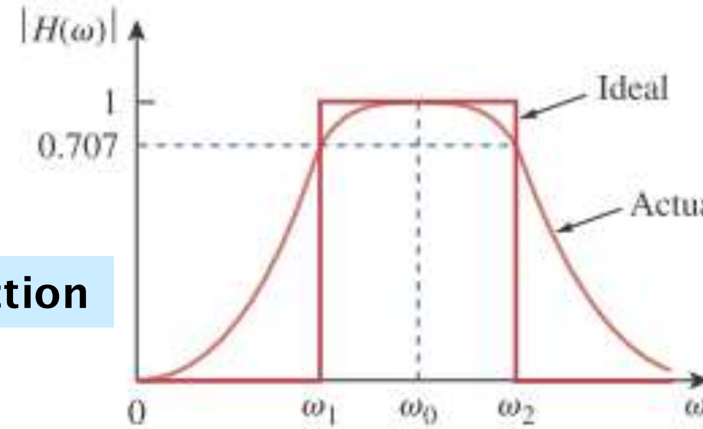
Type of Filter	$H(0)$	$H(\infty)$	$H(\omega_c)$ or $H(\omega_0)$
Lowpass	1	0	$1/\sqrt{2}$
Highpass	0	1	$1/\sqrt{2}$
Bandpass	0	0	1
Bandstop	1	1	0

Filter Networks

Simple Passive band-pass filter



The RLC series resonant circuit provides a bandpass filter when the output is taken off the resistor as shown in Fig.



$$H = \frac{V_0}{V_1} = \frac{R}{R + j\left(\omega L - \dfrac{1}{\omega C}\right)}$$

Transfer Function

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

$$\omega_{LO} = \frac{-(R/L) + \sqrt{(R/L)^2 + 4\omega_0^2}}{2}$$

$$H\left(\omega = \frac{1}{\sqrt{LC}}\right) = 1$$

$$H(\omega = 0) = H(\omega = \infty) = 0$$

$$\omega_{HI} = \frac{(R/L) + \sqrt{(R/L)^2 + 4\omega_0^2}}{2}$$

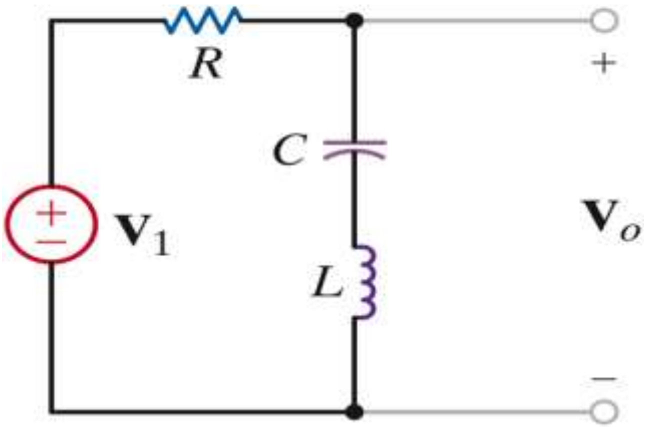
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$H(\omega_{LO}) = \frac{1}{\sqrt{2}} = M(\omega_{HI})$$

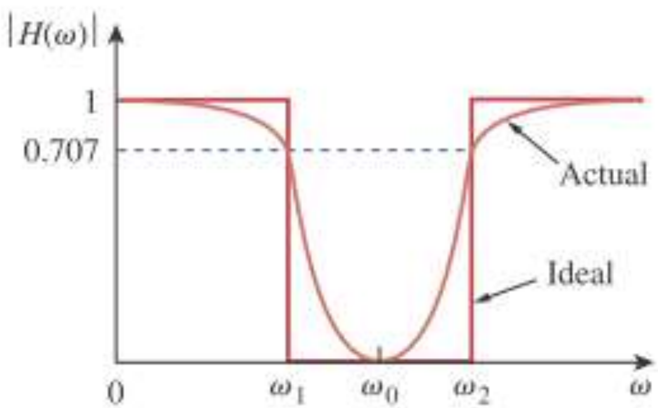
$$BW = \omega_{HI} - \omega_{LO} = \frac{R}{L}$$

Filter Networks

Simple Passive band-stop filter



- The RLC series resonant circuit provides a band-stop filter when the output is taken off the LC as shown in Fig.
- A filter that prevents a band of frequencies between two designated values
- It is also known as a band-stop, band-reject, or notch filter.



$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j(\omega L - 1/\omega C)}{R + j(\omega L - 1/\omega C)}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \Rightarrow j\left(\omega_0 L - \frac{1}{\omega_0 C}\right) = 0$$

at $\omega = 0$ the capacitor acts as open circuit $\Rightarrow V_0 = V_1$

at $\omega = \infty$ the inductor acts as open circuit $\Rightarrow V_0 = V_1$

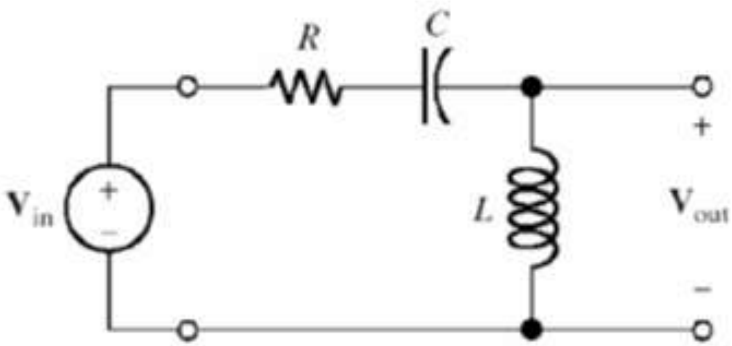
BW = Bandwidth of rejection

$$\mathbf{H}(0) = 1, \quad \mathbf{H}(\infty) = 1.$$

ω_1, ω_2 are determined as in the band - pass filter

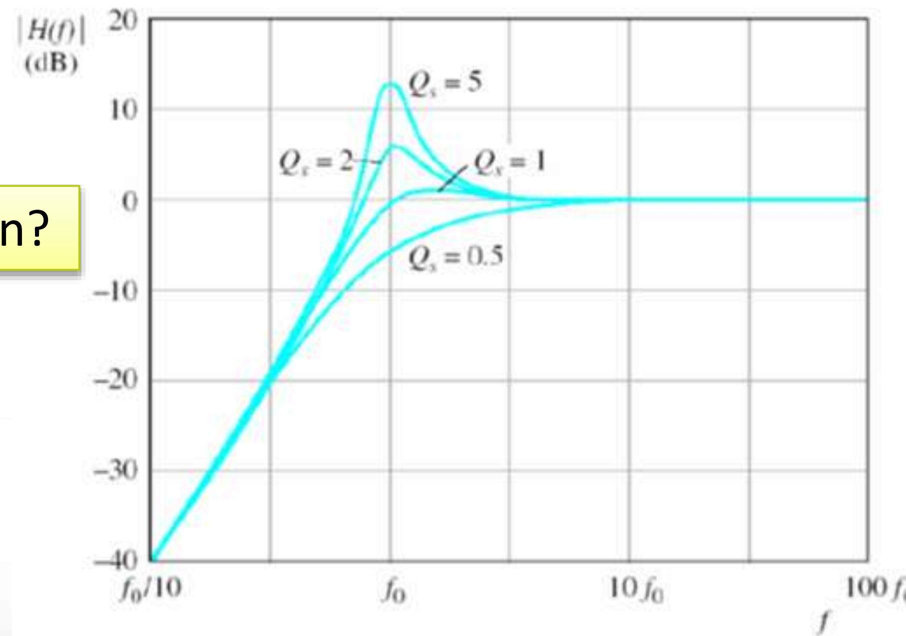
Filter Networks

High-Pass Filter



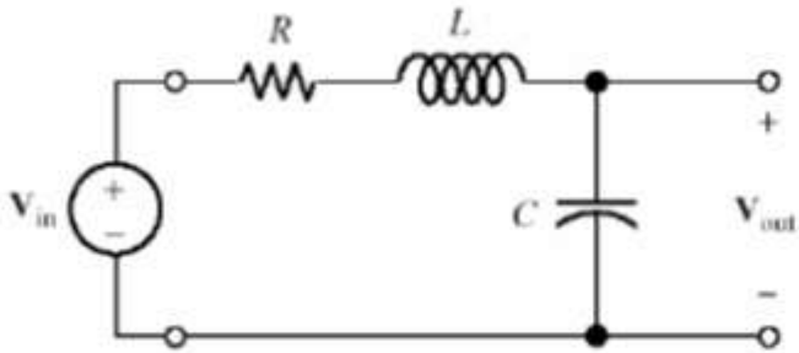
- At low frequency the capacitor is an open circuit (Vo = 0)
- At high frequency the capacitor is a short and the inductor is open (Vo = Vin)

Calculate/ Search for the transfer function?

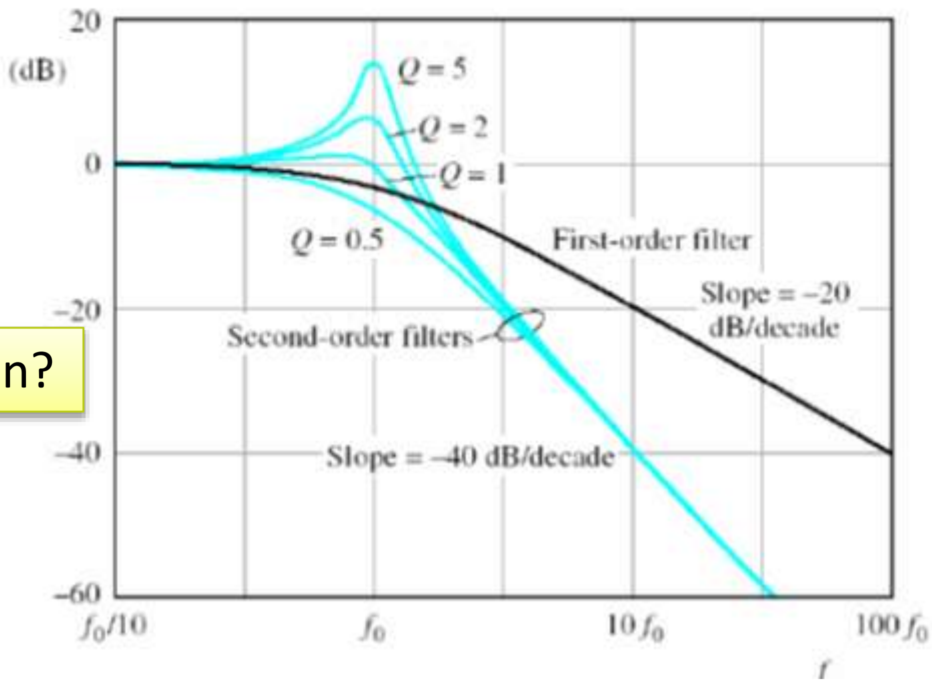


Filter Networks

Low-Pass Filter



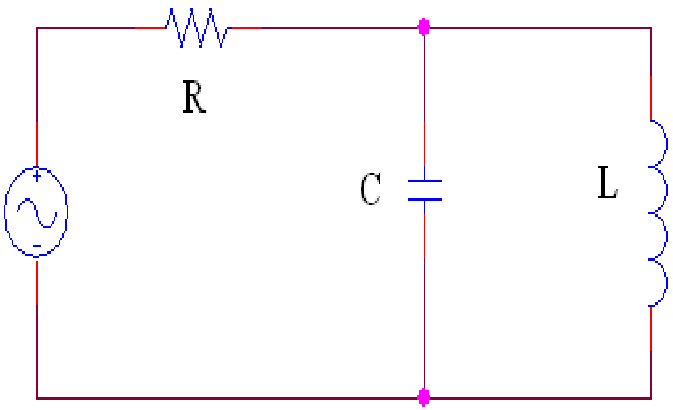
- At low frequency the capacitor is an open circuit (Vo = Vin)
- At high frequency the capacitor is a short and the inductor is open (Vo = 0)



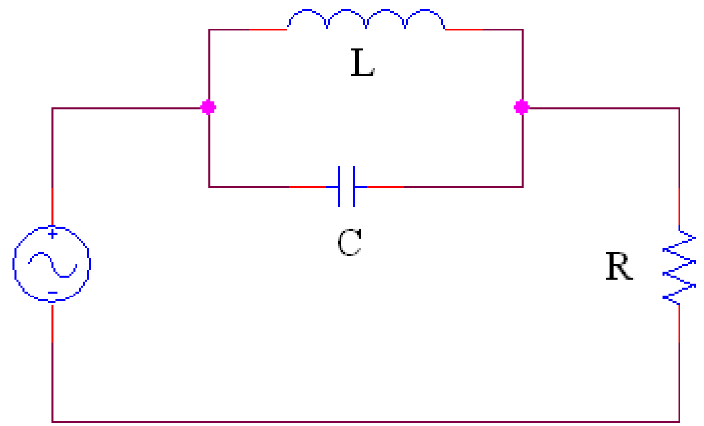
Calculate/ Search for the transfer function?

Filter Networks

Band-Pass Filter (Using Parallel Resonance Circuits)



Band-stop Filter (Using Parallel Resonance Circuits)



Calculate/ Search for the transfer function?

Order of the Filter

- All the previously described filtered are Second Order Filters because they contain two reactive elements (L and C)
- It is possible to create another type of filters using RC or RL only (First-order Filters) >>> not a complete series/parallel resonant circuit

Active Filters

Passive filters have several limitations:

1. **Cannot generate gains greater than one**
2. **Loading effect makes them difficult to interconnect**
3. **Use of inductance makes them difficult to handle**

- **Using operational amplifiers one can design all basic filters, and more, with only resistors and capacitors**

Thank you