Electric Circuits II

Frequency Selective Circuits (Filters)
Some Preliminaries

Lecture #35

The material to be covered in this lecture is as follows:

- Introduction to Filters
- The Main Four Types of Filter Circuits
- The Filter Transfer Function
- Magnitude Plot and Phase Angle Plot

After finishing this lecture you should be able to:

- Understand the Behavior of Filters
- Determine the

Introduction to Filters
Filter Types

- Filters Attenuate (Weaken) The Effect Of Any Input Signals With Frequencies Outside A Particular Frequency Band (Range)
- We Will Restrict Our Study Here To Sinusoidal Signals Only (Voltages)

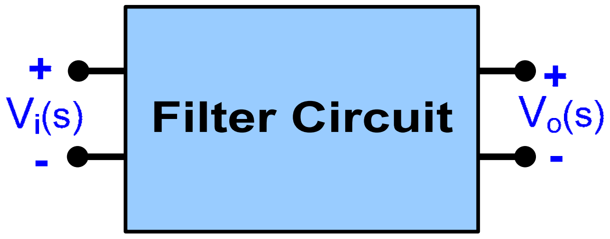

Fig. 7-1 Filter Transmission for Voltage Signal

- Identifying The Type Of Filter Is To Examine Its Frequency Response Plot
- There Are Four Major Categories Of Filters Shown In Fig. 7-2
    a. The Low-Pass Filter
    b. The High-Pass Filter
    c. The Band-Pass Filter
    d. The Band-Stop Or Band-Reject Filter

Filter Types (cont)

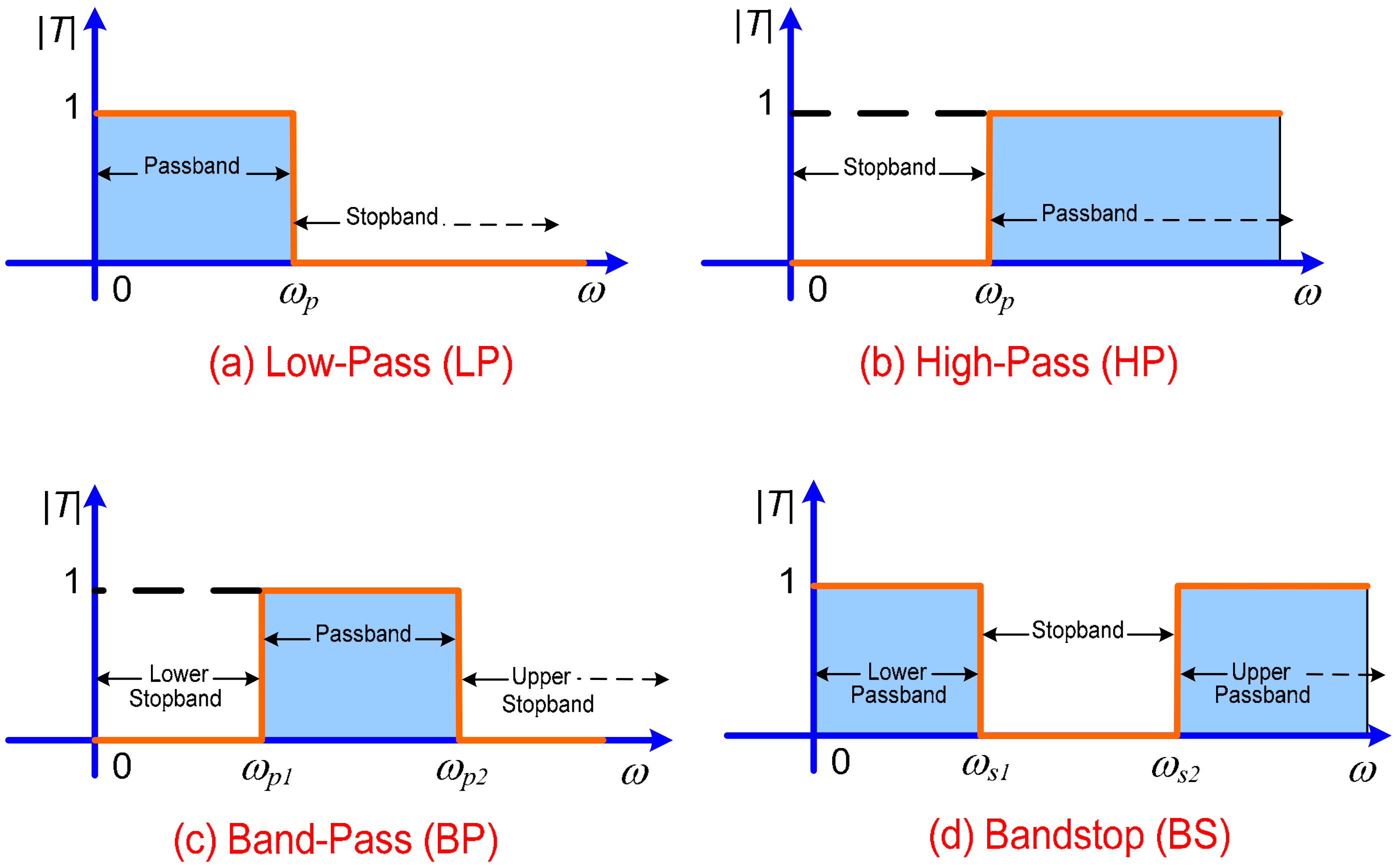

Fig.7-2 Ideal Frequency Response Plots of The Four Types of Filter Circuits

Frequency Response

- The Frequency Response Plot Has Two Parts
    - Magnitude Plot
    - Phase Angle Plot

- The Cutoff Frequency Separates the Passband from the Stopband
- The Signals Which are Passed from the Input to the Output Fall Within a Band of Frequencies Called the Passband
- Frequencies Not in a Circuit's Passband are in its Stopband
- Practical Filter Responses cannot Change its Characteristics from Passband to Stopband or vice versa in Zero Frequency. There should be some Transition Bands as well.

Filter Specifications

- The Transmission of a Low-pass Filter as shown in Fig. 7-3 is Specified by four Parameters:
    - The Passband edge, ω_p.
    - The maximum allowed variation in Passband Transmission, A_{max}
    - The Stopband edge, ω_s.
    - The minimum required Stopband Attenuation, A_{min}

Filter Specifications (cont)

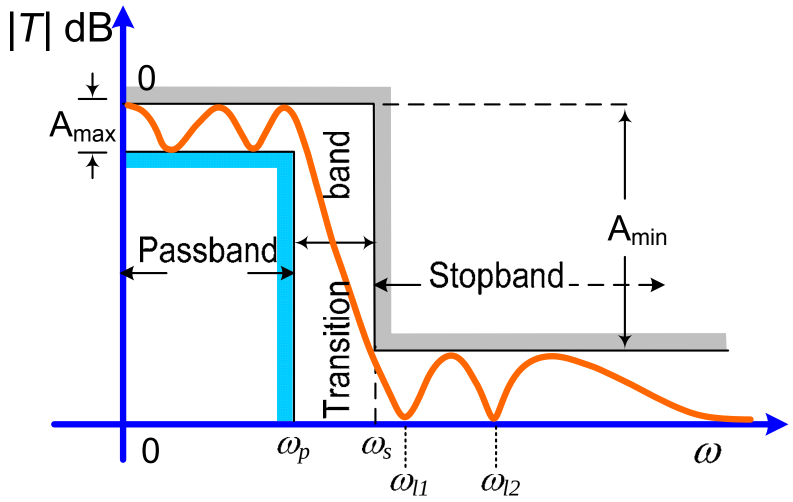

Fig.7-3 Specification of the transmission characteristics of a low-pass filter. The magnitude response of a filter that just meets specifications is also shown.

- Selectivity factor = ω_p / ω_s
- Tighter specification means closer to ideal characteristics and more complex and expensive filter design

Filter Specifications (cont)

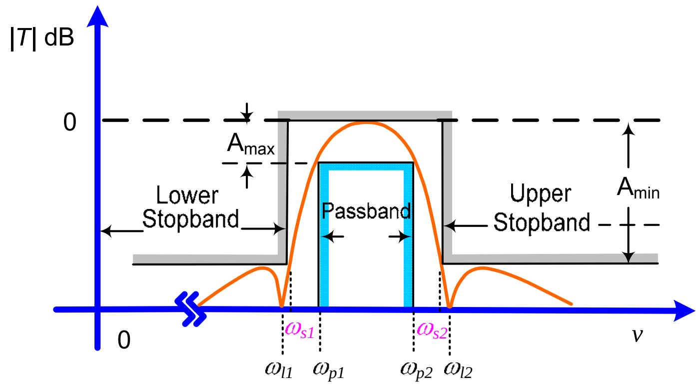

Fig.7-4 Transmission specification of a band-pass filter. The magnitude response of a filter that just meets specifications is also shown.

- The transmission of a band-pass filter as shown in Fig. 7-4 is specified by six parameters:
  - The Lower Passband edge, ω_{p1}.
  - The Higher Passband edge, ω_{p2}.
  - The maximum allowed variation in Passband Transmission, A_{max}.
  - The Lower Stopband edge, ω_{s1}.
  - The Higher Stopband edge, ω_{s2}.
  - The minimum required Stopband Attenuation, A_{min}.

Example 7.1

Consider the following circuit of Fig. 7-5:

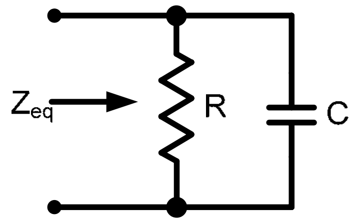

Fig. 7-5 Circuit For Frequency Response Example

$$Z_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{R\,\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} = \frac{R}{1 + j\omega RC} \qquad (7\text{-}1)$$

In polar form

$$\left|Z_{eq}\right| \angle \theta = \frac{R}{\sqrt{1+(\omega RC)^2}} \angle -\tan^{-1}\omega RC \qquad (7\text{-}2)$$

Since Z is complex the notation Z(jω) is often used. Both $|Z|$ and θ are function of ω.

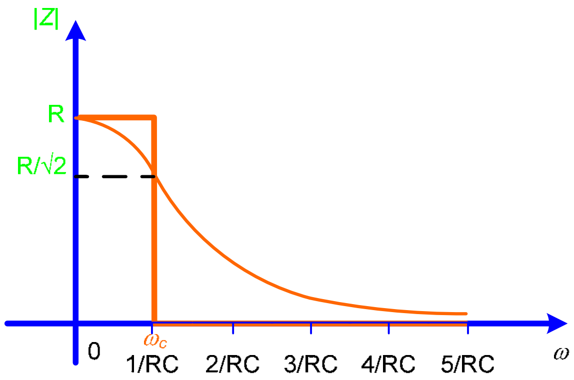

Fig. 7-6a Amplitude Response for Circuit in Fig. 7-5

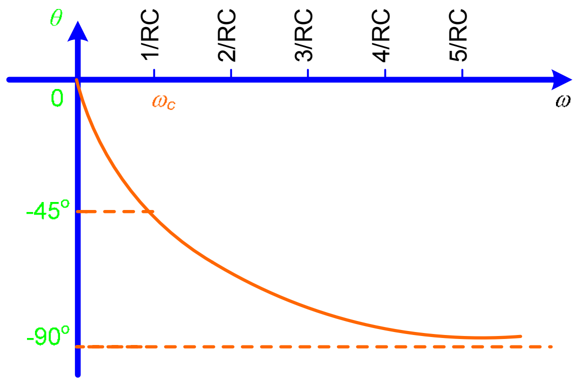

Fig. 7-6b Phase Response for Circuit in Fig. 7-5

Low-Pass Filter

Exploring Limiting Values (Cont)
Determining the Polarity of the Voltage and Current Ratios
Example 34-1

The state expressions for a) i_1, b) v_1, c) i_2, d) v_2

Fig.34-7 Circuit for Example 34-1

a)

$$\mathbf{V}_g = 2500\angle 0^\circ = (0.25 + j2)\mathbf{I}_1 + \mathbf{V}_1$$

and

$$\mathbf{V}_1 = 10\mathbf{V}_2 = 10\left[(0.2375 + j0.05)\mathbf{I}_2\right]$$

The Use of Ideal Transformer for Impedance Matching

Self Test:
The source