Laboratory #10: RF Filter Design and Simulation using Ansoft Designer

I. OBJECTIVES

Design filters and simulate the designs using Ansoft Designer SV. Methods for designing high-pass, and bandpass filters are used. Waveguide filters will be implemented and simulated with Ansoft Designer SV.

II. INTRODUCTION

In Lab Exercise #8, low-pass and high-pass filters were designed. The transfer functions werew then plotted using MatLAB. In this exercise, the filters designed are simulated using Ansoft Designer SV.

Low-pass filter design has been discussed in both class and in the accompanying laboratory. The transformation from the low-pass prototype to high-pass and bandpass filters will be used. Typically, filter specifications include the passband attenuation at the cutoff frequency and the stopband attenuation at the stopband frequency. Normalized values of the cutoff frequency ($\Omega = 1 = f / f_c$) and stopband frequency ($\Omega_s = f_s / f_c$) are used along with the nomograph for the particular type (Butterworth, Chebyshev, etc.) of prototype low-pass filter to determine required the order of the filter.

In the case of high-pass filters, the order of the filter is determined using the nomograph of the desired type (Butterworth, Chebyshev, etc.) of prototype low-pass filter with the normalized stopband frequency

$$\Omega_s = f_c / f_s \quad .$$

For bandpass filters, the order of the filter is determined using the nomograph of the desired type of prototype low-pass filter with the normalized stopband frequency equal to the ratios of bandwidths instead of frequencies, such that:

$$\frac{BW}{BW_c} = \frac{f}{f_c} \quad ,$$

Where BW = bandwidth at the required value of (stopband) attenuation
BW_c = specified passband bandwidth (3 dB for Butterworth) of the bandpass filter.

The frequency response of a bandpass filter exhibits geometric symmetry. The center frequency of a geometrically symmetric filter is given by,

$$f \;= \sqrt{f_h f_l}$$

Where f_h and f_l are the high and low frequencies (one above and one below the passband) having equal attenuation.

Two common low-pass LC filter configurations are shown in Figures 1 (a) and (b). Each "section" consists of an L-C pair, with each section corresponding to the order of the filter. Two section (or second order) filters are shown in Figure 1. Note that the values of the capacitors and inductors changes with varying input and output resistances. Tabulated "normalized" values for the inductors and capacitors for varying termination ratios are available to the design engineer. The component values in the tables are normalized with respect to the termination ratio and cutoff frequency. Generic representations of the *LC* low-pass filter are shown in Figure 2.

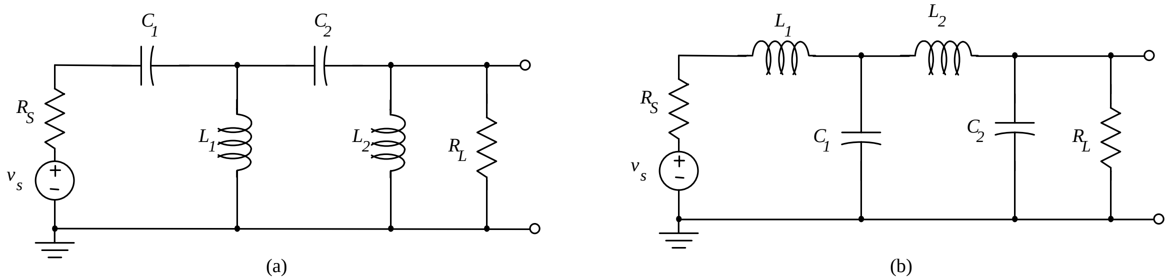


Figure 1. Two Ladder Network Configurations for *LC* Filters

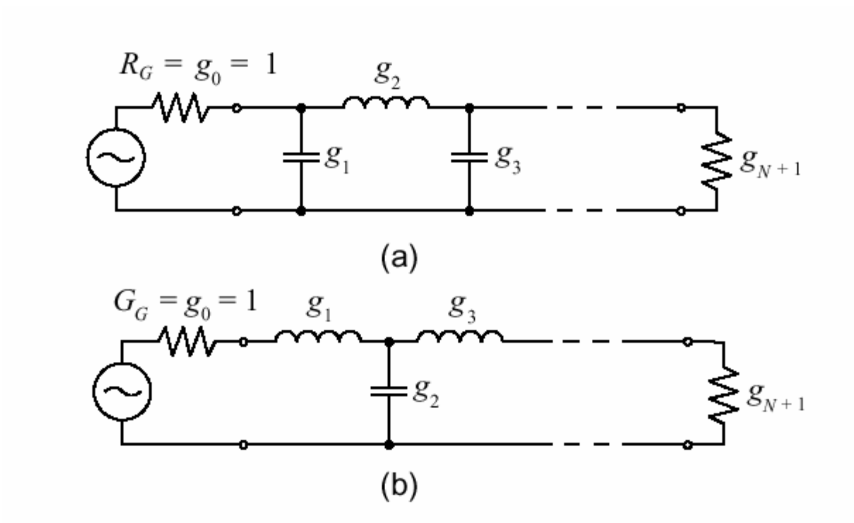
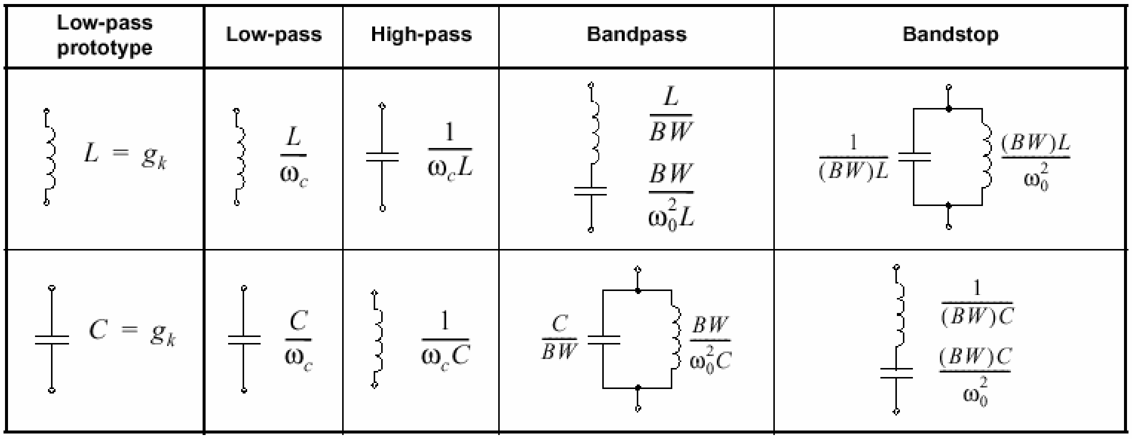


Figure 2. Two Generic Representations of Figure 1.

Normalized *L* and *C* component transformations are presented in tabular form in Table 5-5.

Table 5-5 Transformation between normalized low-pass filter and actual bandpass and bandstop filter ($BW = \omega_U - \omega_L$)



Low-pass prototype	Low-pass	High-pass	Bandpass	Bandstop
$L = g_k$	$\frac{L}{\omega_c}$	$\frac{1}{\omega_c L}$	$\frac{L}{BW}$, $\frac{BW}{\omega_0^2 L}$	$\frac{1}{(BW)L}$, $\frac{(BW)L}{\omega_0^2}$
$C = g_k$	$\frac{C}{\omega_c}$	$\frac{1}{\omega_c C}$	$\frac{C}{BW}$, $\frac{BW}{\omega_0^2 C}$	$\frac{1}{(BW)C}$, $\frac{(BW)C}{\omega_0^2}$

The normalized low-pass inductors and capacitors are:

$$C = \frac{C_n}{2\pi f_C R} \quad \text{and} \quad L = \frac{L_n R}{2\pi f_C} ,$$

where C_n is the normalized capacitor value,
L_n is the normalized inductor value,
C is the denormalized (actual) capacitor value,
L is the denormalized (actual) inductor value,
and R is the final load resistor.

The low-pass filter prototype elements are replaced with appropriate components or combination of components for high-pass, bandpass, and bandstop filters.

III. <u>PROCEDURE</u>

A. Hand analysis of discrete element filters

- Design a maximally flat low pass filter with cutoff frequency (-3 dB) of 35 MHz with a stopband of -40 dB at 105 MHz with equal 50 Ω generator and load resistances.
- Design a maximally flat high pass filter with cutoff frequency (-3 dB) of 105 MHz with a stopband of -40 dB at 35 MHz with equal 50 Ω generator and load resistances.
- Design a Chebyshev bandpass filter with 3 dB ripple with a bandwidth (-3dB) of 7 MHz and stopband bandwidth of 35 MHz at 40 dB attenuation with equal 50 Ω generator and load resistances.

B. Simulate the three filters in Part A using Ansoft Designer SV
C. Simulate the 7th order low-pass stub waveguide filter from the lecture using Designer SV
D. Design and simulate a stepped impedance 7th order low-pass filter from the lecture using Designer SV