

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 8 – FILTER NETWORKS

OBJECTIVES

In this lab session the student will investigate passive low-pass and high-pass RC filters.

MATERIALS/EQUIPMENT NEEDED

NI ELVIS Board

Resistors: (1) 600Ω

Capacitors: (1) 2.7nF, (1)6.6nF, (1) 26.7nF

INTRODUCTION

Filters are one of the most common elements in electronic circuits. They provide frequency selective amplification or attenuation of various electronic signals and noise. Every time you tune in a radio station, you are using at least 3 filters. The word “tune” means that you pass certain frequencies (the channel you want) and attenuate or reject other frequencies. A filter network can be either active or passive. An active filter requires an external source of power while a passive filter is simply an arrangement of circuit elements that will provide frequency selective attenuation. The three most common designations of filter type are the low-pass filter, the high-pass filter, and the band-pass filter. Frequency response curves for these types of filters are shown in Figures 8-1a, 8-1b, and 8-1c, respectively. Filters can be implemented by either analog or digital means and with various types of low and high frequency components. For example, in waveguide networks filters are constructed with quarter wavelength opens and shorts, magic T networks, etc. In addition to the basic filter types investigated in this laboratory, there are notch filters, comb filters, adaptive filters, statistically optimized filters, etc. Even a simple filter such as the band-pass can be implemented with a Butterworth, Gaussian, or Chebyshev transfer function. Each implementation will have certain advantages and disadvantages that must be evaluated for the particular application.

Transfer Function

A transfer function is a complex frequency dependent mathematical ratio of the filters output to input voltage. As a complex function it provides both the magnitude and phase of the output voltage relative to the input voltage. However, often in practice only the magnitude of the transfer function (referred to as the voltage gain) is considered. The frequency response curves in Figures 8-1a, 8-1b, and 8-1c show only the magnitude; and furthermore, these plots are of normalized gain rather than actual gain.

The normalized gain is defined as the ratio of actual gain to mid-band gain; i.e., $A_0 = A / A_{mid}$, where A_{mid} is the mid-band gain and is in fact the maximum gain of the filter in what is referred

to as the mid-band frequency range. Clearly, in the mid-band region $A/A_{mid} = 1$. The mathematical definition of the transfer function is

$$T(s) = \frac{V_o(s)}{V_i(s)}$$

The filter transmission is found by evaluating $T(s)$ for physical frequencies, $s = j\omega$, and can be expressed as:

$$T(j\omega) = |T(j\omega)| e^{j(\angle V_o(j\omega) - \angle V_i(j\omega))}$$

The phase relationship between the input and output voltage is an important parameter of the filter network and often is included with the gain plot. In the above transfer function the phase term is the exponential part.

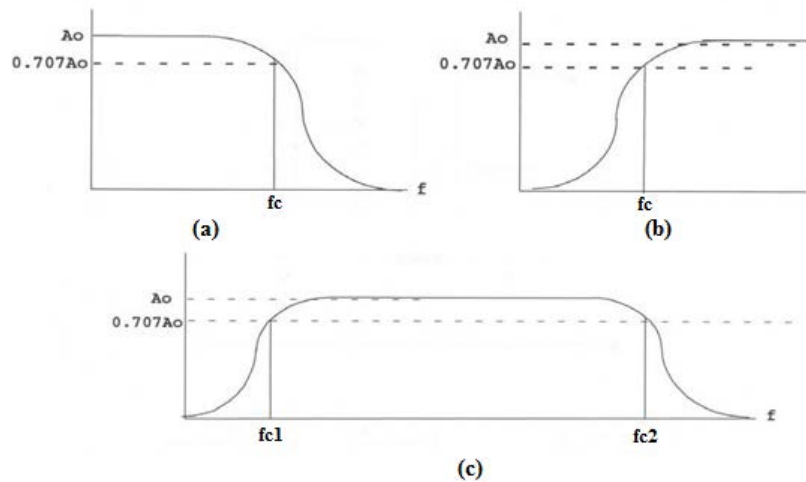


Figure 8-1 Frequency response of (a) low-pass, (b) high-pass, (c) band-pass.

Cut-off Frequency

The frequencies, f_c , are known as the half-power frequencies and also as the lower and upper break or cutoff frequencies. Additionally, they are known as the 3dB frequencies and are further identified as the frequencies where the output power is down to 0.5 of its mid-band value and the output voltage is down to 0.707 of its mid-band value. This can also be seen graphically as the point where the log-log representation is 3dB lower than the pass band.

Passive filter networks are made up of inductors, capacitors and resistors in various combinations and configurations. These networks can become quite complex in design depending on their desired application. Also, it should be stressed that the load on the output of the filter network can affect its frequency response and must therefore be considered as part of the network when determining the network bandwidth and attenuation curve.

PRELAB

1. Derive the voltage transfer functions for the networks in the following Figures 8-2 and 8-3.
2. Using MATLAB, obtain a plot of the voltage transfer function vs. frequency for the network in Figure 8-2. This should be done on a log-log scale. From the plot, identify the network as to whether it is low-pass, high-pass, or band-pass filter network and determine the break frequency (frequencies)
 - a. Assume $R= 600\Omega$ and $C=6.6\text{ nF}$.
 - b. Assume $R=600\ \Omega$ and $C=2.7\text{ nF}$.
3. Using MATLAB, obtain a plot of the voltage transfer function vs. frequency for the network in Figure 8-3. This should be done on a log-log scale. From the plot, identify the network as to whether it is low-pass, high-pass, or band-pass filter network and determine the break frequency (frequencies)
 - a. Assume $R=600\ \Omega$ and $C=26.5\text{ nF}$.
4. Repeat part 2 of the PreLab using PSPICE or Multisim.
5. Repeat part 3 of the PreLab using PSPICE or Multisim.

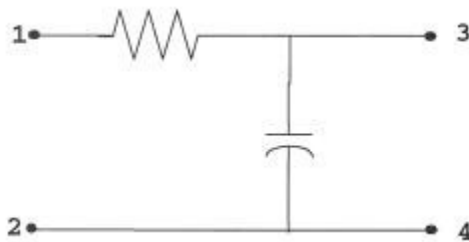


Figure 8-2 Low-pass configuration

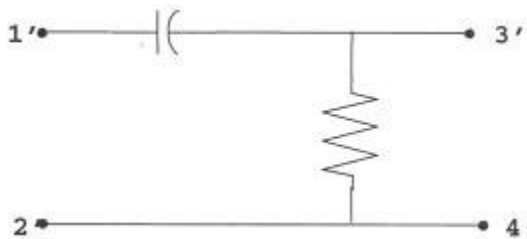


Figure 8-3 High-pass configuration

PROCEDURE

1. Connect the low-pass circuit shown in Figure 8-2 with the elements values specified in part 2a of the prelab.
2. In the NI ELVIS board connect both FGen and AI0+ to terminal 1 of the circuit. Then, connect AI0- to terminal 2.
3. Connect AI1+ to terminal 3 and connect AI1- to terminal 4 of the circuit.
4. Use the bode analyzer in ELVIS to implement a frequency sweep and obtain the bode plot. Record the cut-off frequency in Table 8-1.
 - a. Use a start frequency of one-tenth of the filter break frequency.
 - b. Use a stop frequency of ten times the filter break frequency.

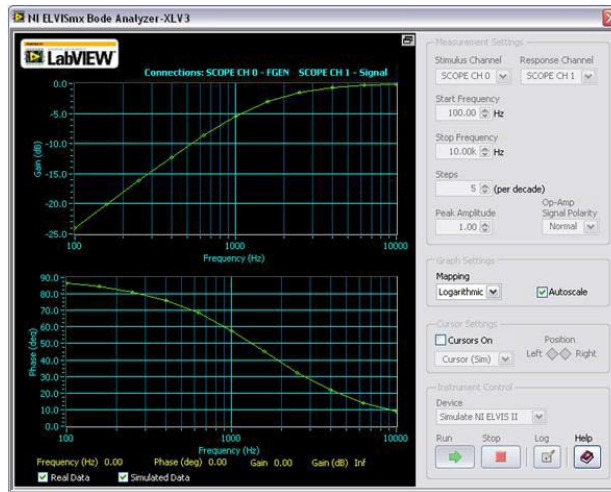


Figure 8-4 NI ELVIS Bode Analyzer

5. Connect the low-pass circuit shown in Figure 8-2 with the elements values specified in part 2b of the prelab. Repeat steps 2 to 4 of the lab procedure.
6. Connect the high-pass circuit shown in Figure 8-3 with the elements values specified in part 3 of the prelab. Repeat steps 2 to 4 of the lab procedure.

DATA/OBSERVATIONS

Table 8-1 Cut-off frequencies for the implemented filters

Procedure	Filter	Cut-off Frequency
1	Low-pass, $R=600\Omega$ & $C=6.6nF$	
3	Low-pass, $R=600\Omega$ & $C=2.7nF$	
4	High-pass, $R=600\Omega$ & $C=26.5nF$	

INSTRUCTOR'S INITIALS:

DATE:

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. Explain any differences between the experimental results and the calculated results.

Be sure to include all items from the post-lab exercise above in your written lab report.