UNIVERSITY OF MIAMI
Department of Electrical and Computer Engineering
EEN 203

Name: ____________________
Section: ____________________
Date: ____________________

EXPERIMENT 5

LOWPASS AND HIGHPASS FILTERS

Frequency Response of R-C circuits: Bode Diagrams

PURPOSE: The purpose of this experiment is to introduce the student to two practical frequency discriminating circuits: the *lowpass* and the *highpass* filters. The lowpass filter lets pass frequencies below a certain cutoff ω_C and rejects frequencies above it. The highpass filter performs the opposite task. The frequency band where signals pass through a filter is known as the *passband* and the region where they are attenuated or stopped is called the *stopband*. Since filters are not ideal, it takes a certain band for their gain to go from maximum to a level that can be considered negligible. This band is known as the *transition band*. Filters usually have relatively flat gains in the passband and decrease asymptotically at slopes of $\pm 20n$ dB/decade where n is the order of the filter. The frequency at which the gain is down by $\sqrt{2}$ from the maximum value is called the 3 dB point. For a lowpass filter, the 3 dB point is the same as the bandwidth. The bandwidth of a highpass filter is ideally infinite.

Equipment

1 Frequency Generator
1 DVM (Multimeter)
Resistors, Capacitors, and Inductors

Preliminary Work

a) Derive the exact equation for V_O/V_S for the circuit of Fig. 5.1 and find an expression for the cutoff frequency ω_C. Using semilog paper, plot the frequency response (magnitude *vs.* frequency) of the filter up to $10f_C$ using the specified component values. Plot the horizontal axis for frequency on a logarithmic scale and the vertical axis for magnitude $|V_O/V_S|$ (dB), on a linear scale.

b) Repeat part (a) for the circuit of Fig. 5.2.

Experimental Procedure

I. The LowPass Filter:

a) Set up the circuit shown in Fig. 5.1. Use R = 2.2 kΩ, C = 0.047 μF, and adjust the frequency generator's amplitude to 1 V_{rms}. Notice that the D.V.M. reading is in rms and must be used to get the proper reading.

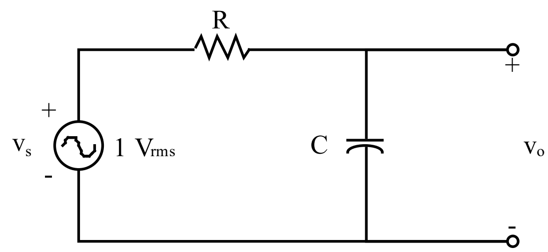

Figure 5.1 First order lowpass filter.

b) Vary the frequency of the signal generator according to the values given in Table 5.1. Record the output voltage, V_o. Make sure V_s is 1 V_{rms} before **each** reading.

f **(Hz)**	**V_o (V)**	**V_o/V_s (V)**	**$\|V_o/V_s\|$ (dB)**
100			
200			
300			
500			
700			
800			
900			
1 k			
1.5 k			
2 k			
3 k			
5 k			
7 k			
10 k			
20 k			
30 k			
50 k			
70 k			
100 k			

Table 5.1 Frequency Response data for circuit of Fig. 5.1.

c) Plot the graph of $|V_o/V_s|$ (dB) vs. f (Hz) on the **same** graph you obtained in your preliminary work.

d) From the graph, find the cutoff frequency, f_c of the filter. This is the 3 dB point.

$f_{c,\ experimental}$ = ____________

e) Calculate f_c from $\omega_c = \dfrac{1}{RC} = 2\pi f_c$.

$f_{c,\ calculated}$ = ____________

f) Calculate the % error.

% error f_c = ____________

II. The HighPass Filter:

a) Set up the circuit shown in Fig. 5.2. Choose R = 1 kΩ, L = 22 mH, and adjust the frequency generator's amplitude to 1 V_{rms}.

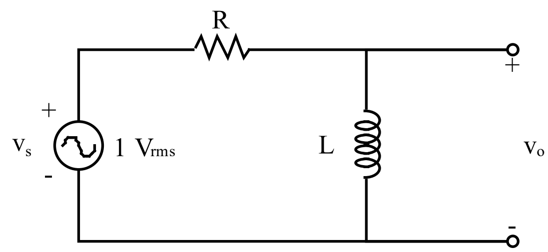

Figure 5.2 First order highpass filter.

b) Vary the frequency of the signal generator according to the values given in Table 5.2. Record the output voltage, V_o. Make sure V_s is 1 V_{rms} before **each** reading.

f **(Hz)**	**V_o (V)**	**V_o/V_s (V)**	**$\|V_o/V_s\|$ (dB)**
100			
200			
300			
500			
700			
800			
900			
1 k			
1.5 k			
2 k			
3 k			
5 k			
7 k			
10 k			
20 k			
30 k			
50 k			
70 k			
100 k			

Table 5.2 Frequency Response data for circuit of Fig. 5.2.

c) Plot the graph of $|V_o/V_s|$ (dB) vs. *f* (Hz) on the **same** graph you obtained in your preliminary work.

d) From the graph, find the cutoff frequency, f_c of the filter. This is the 3 dB point.

$f_{c,\ experimental} =$ ___________

e) Calculate f_c from $\omega_c = \frac{R}{L} = 2\pi f_c$.

$f_{c,\ calculated} =$ ___________

f) Calculate the % error.

% error $f_c =$ ___________

Discussion of Results

a) Find the slope of the Bode plots of each filter and calculate the errors as compared with the theoretical value of ±20 dB/decade.

b) Draw the circuit diagram of

(i) A simple lowpass filter (LPF) using an inductor and a resistor only.
(ii) A simple highpass filter (HPF) using a capacitor and a resistor only.

Indicate where the input and outputs are taken from.

c) Sketch the frequency response of a bandpass filter (BPF) and a bandstop filter (BSF).

d) Discuss the applications of filter circuits. Particularly in the following situations. Indicate the type of filter used in each case.

(i) Power supply smoothing.
(ii) DC blocking of audio inputs to speakers.
(iii) Radio tuning.
(iv) Cross-over networks in 3-way speaker systems.

e) Write a conclusion.