Lab 2 - Frequency Response of a Filter

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Objectives

This laboratory project has three objectives:

1. Compute the insertion loss of a filter.
2. To measure the insertion loss of a "real" filter.
3. To learn how to use the automated lab equipment.

Equipment

HP1116A Function Generator
HP34401 Multimeter
Oscilloscope
50 W termination
BNC T-connector
"Orange Filter"
PC running LabView

Background

Figure 1 shows a signal generator connected to a load resistor. The value of load resistance has been chosen for maximum power transfer. Figure 2 shows a filter inserted between the generator and the load.

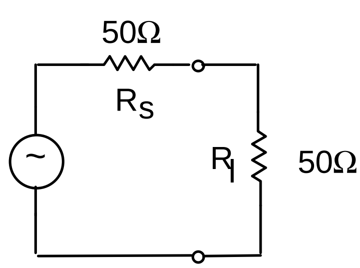

Figure 1. Signal generator connected to a load resistor.

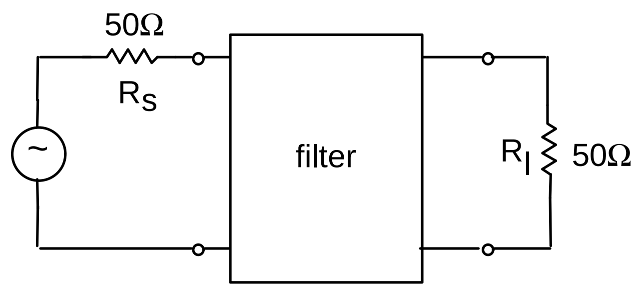

Figure 2. A filter inserted between the generator and the load.

The *insertion loss* of a filter is a measure of the power lost when the filter is inserted. It is defined as the ratio of power that the generator can deliver directly to a matched load to the power delivered to the same load when the filter is inserted between the generator and the load. Insertion loss is usually expressed in decibels according to the formula

$$\text{Insertion loss (dB)} = 10 \log \frac{P_{direct}}{P_{filter}}$$
$$= -10 \log \frac{P_{filter}}{P_{direct}}$$

The orange filters are designed to provide maximum power transfer to a 50 Ω load when the generator produces a sinusoidal signal having a frequency below about 3.5 kHz. It is intended that there be no power transferred to the load when the generator frequency is above about 3.5 kHz. The filters only approximate this ideal performance. In carrying out this experiment you will discover how well the filters achieve their design goal.

Figure 3 shows the circuit inside each of the orange boxes. Each box includes a 50 Ω load resistor which can be placed across the filter output by means of a switch. It is up to you to figure which position is which on the switch. As an alternative, the 50 Ω BNC termination can be used. The 50 Ω source resistance is an inherent part of the laboratory function generators.

Pre-lab

Before building or using a circuit you should have some idea what the circuit does. To this end, compute the insertion loss as a function of frequency for the circuit in Figure 3. Plot the insertion loss versus frequency for frequencies of 0 to 5 kHz. Record your computations in your lab notebook (you may use Maple, etc.)

Turn in a photocopy of your notebook during the lecture just before lab. Bring a couple of copies of your plot to lab. The data you take in lab will be placed on one of these plots.

Procedure

This laboratory project will be performed in the Advanced Circuits Laboratory, room B-105, using the desktop PCs and computer-controlled instrumentation.

1. Record in your laboratory notebook the number of your filter and the identifying number of each piece of laboratory equipment that you use. These numbers will come in handy if you have to return to the laboratory to gather additional data or to investigate suspicious results. Once you have characterized your filter, you may wish to use the same filter in future laboratory projects.

2. Use the HP1116A Function Generator to drive your filter. To determine the insertion loss, first put the 50 Ω termination directly on the output of the function generator. Set the voltage across the termination to a convenient value, say one volt peak. Then insert the filter between the function generator and the termination and measure the voltage again. Note that the filter input voltage is not measured! Use the HP34401 Multimeter to measure the termination voltages. Use an oscilloscope (either analog or digital!) to verify that the waveforms have an undistorted sinusoidal shape. Determine the frequency at which the insertion loss is 3 dB. Plot this on your pre-lab plot.

3. Measure the insertion loss at two additional frequencies, one below the 3 dB frequency and one above it. You will use these measurements to check the computer results obtained in the next step. Plot this on your pre-lab plot.

4. Refer to the section "Automated Insertion Loss Measurement" to learn how to use LabView to measure insertion loss. Measure the insertion loss of the orange filter over the range 100Hz and 4kHz, and will plot the results. **Make sure the plotted measurements agree with the measurements you made in the previous**

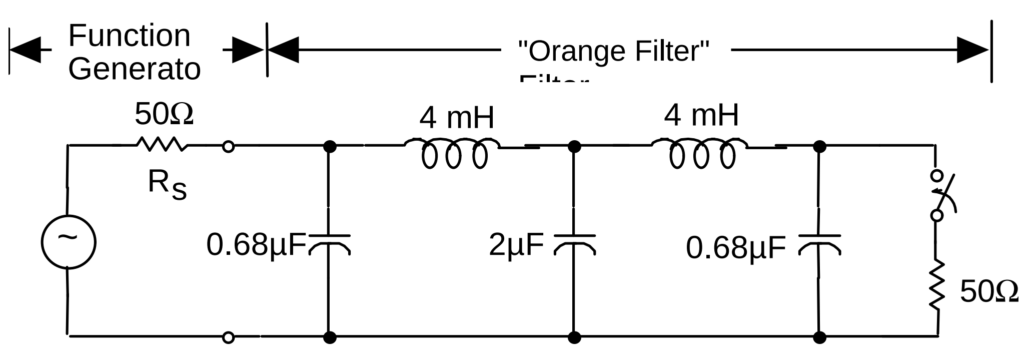

Figure 3. The "Orange" filter circuit

step. The insertion loss should be very small at low frequencies, and should rise smoothly as the frequency increases past 3.5 kHz.

Confirm that the data taken by the computer matches your previous measurements, and that it matches the plots made in the pre-lab.

Instructor Verification

5. The performance of a filter can depend on the proper termination being used. If the switch on the orange box is set to remove the 50 Ω resistor, then the filter will be terminated by the input resistance of the multimeter. (What is the value of this termination?) Measure insertion loss vs. frequency when the filter is terminated only by the multimeter (or multimeter and scope). Obtain a hard copy of your plot.

Report

A two page memo is required for this experiment. The memo should be carefully written, but as brief as possible.

Your memo should contain:

1. Graphs showing your measured and computed insertion loss as a function of frequency.

2. The graphs must be plotted in a way that will facilitate comparison of the results. (Hint: you can plot the Maple output *by hand* onto the Matlab output.)

3. Measured and hand computed data from steps 2 and 3. Tabulate the results for ease of reference. Plot data from sections 2 and 3 on your graphs.

4. An explanation of the graph of loss vs. frequency obtained in step 5. What would negative insertion loss imply physically? Is there another explanation you can propose?

Automated Insertion Loss Measurement

The following procedure describes how to use LabView to automatically control the function generator, to collect data from the multimeter, and to calculate the insertion loss [many thanks to Bruce Black for developing the LabView “InsertionLoss” virtual instrument code]:

1. In Windows, do Start -> Programs -> LabView

2. Choose “OpenVI” and select the InsertionLoss.llb file from the EC300 Novell class account (G:\ECE\EC300)

3. Select InsertionLoss.vi

4. Set up the parameters as needed (e.g., start frequency, stop frequency, etc.)

5. Click the arrow in the upper left corner to run the application.

6. You will be prompted to save the data once the application finishes its measurement. Use a file name with the extension “.dat”

7. Open the file in Matlab using “load ___.dat”

8. Do “whos” to see the variable that was created by the “load” command.

9. Make a correctly-labelled plot of insertionloss vs. frequency. Hint: the variable is a 2xN matrix. You can extract the c-th column of a matrix A using the syntax A(:,c).

Instructor Verification

Staple this page to the end of your Lab Memo.

Name: ______________________ Date: __________________________

Part 4	