Rose-Hulman Institute of Technology
Department of Electrical and Computer Engineering

EC 300 Signals and Systems | Fall 2000
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Frequency Response of a Filter

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Objectives

This laboratory project has three objectives:

1. To 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 and LabView.

Equipment

HP1116A Function Generator
HP34401 Digital Multimeter
Tektronix 22 Oscilloscope
50 Ω 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.

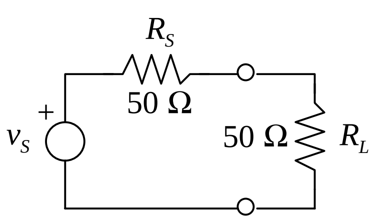

Figure 1: Signal Generator Connected to a Load Resistor

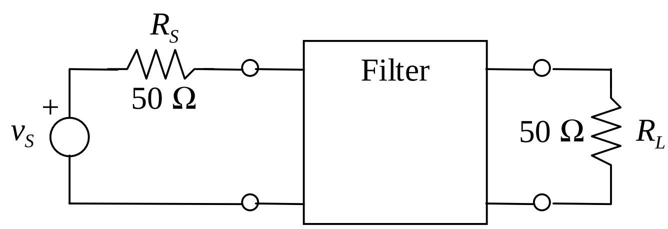

Figure 2: A Filter Inserted Between the Generator and the Load

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

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

The "Orange" filters are designed so that when one of them is inserted between a signal generator and a 50 Ω load there will be maximum power transfer to the load when the generator frequency is below about 3.5 kHz. There should 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 lab project you will discover how well the filters actually achieve their design goal.

Fig. 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. You can use an ohmmeter to help figure out which switch position enables the 50 Ω load. As an alternative, you can open the switch and use a 50 Ω BNC termination instead of the built-in resistor. The 50 Ω source resistance is an inherent part of the laboratory function generators.

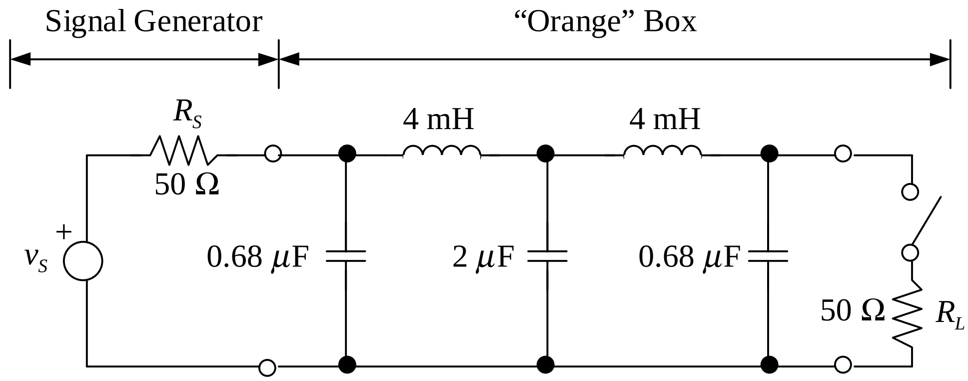

Figure 3: The "Orange" Filter Circuit

Pre-Lab

Before building or using a circuit it is good to have some idea what the circuit does. To this end, compute the insertion loss as a function of frequency for the circuit of Fig. 3 (with the 50 Ω load resistor included). Plot the insertion loss versus frequency (frequency on the horizontal axis) for frequencies from 0 to 5 kHz. Record your calculations and a plot of the insertion loss in your lab notebook. You may use Maple, MATLAB, Excel, or Mathcad. Computer printout should be taped in your notebook as shown in the Lab Manual handout. (Hint: LabView produces output that is easy to read into MATLAB or Excel. Using either of these will make is easy to add measured data to your pre-lab calculations in lab.)

Turn in a photocopy of the prelab section of your lab notebook at the start of the class before lab. When you use a computer to calculate the insertion loss, it is a good practice to save the file that generated the plot. You can then add your lab data and produce a graph showing both predicted and measured values.

Procedure

This laboratory project will be performed in the Circuits Laboratory, room D-115, using the desktop PCs and the 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 will probably 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. 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 Digital Multimeter to measure the termination voltages. Use an oscilloscope to verify that the waveforms have an undistorted sinusoidal shape. Determine the frequency at which the insertion loss is 3 dB. Compare the measured 3 dB frequency with the 3 dB frequency predicted by 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. Produce a new version of your pre-lab plot, and add the three measured insertion loss data points.
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 100 Hz to 4 kHz, and plot the results. **Make sure the LabView measurements agree with the measurements you made in the previous steps.** The insertion loss should be very small at low frequencies, and should rise smoothly as the frequency increases past 3.5 kHz. Add your LabView data to your plot so that the pre-lab data, the hand-measurements, and the automated measurements can be compared. Tape this plot in your lab notebook.
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 by the multimeter and oscilloscope). Obtain a hard copy of your plot and add it to your notebook.

Report

Write a paragraph in your lab notebook summarizing your findings. How well do your measurements agree with your pre-lab calculations? Can you quantify the difference? Also include an explanaton of the graph of insertion loss vs. frequency that you obtained in Step 5. What would negative insertion loss imply physically? Is there another explanation you can propose?

Hand in your lab notebook at the end of the lab period.

Automated Insertion Loss Measurement

The following procedure describes how to use LabView to automatically control the function generator, to collect data using the multimeter, and to calculate the insertion loss. In LabView a program is called a “virtual instrument.”

1. In Windows, do Start → Programs → LabView.
2. Choose “OpenVI” and select the InsertionLoss.llb file from the EC300 Novell class account (Saturn\CLASS\Ece\Ec300\Black\LabView).
3. Select InsertionLoss.vi
4. Set up the parameters as needed (e.g. start frequency, stop frequency).
5. Click the arrow in the upper left corner of the LabView window to run the application. You will be able to verify that the program is running by watching the numbers change on the panels of the function generator and multimeter.
6. When the program ends, you will be prompted to save the data. Save the data in your own Novell account, not on the computer hard disk. (It may not still be on the lab computer disk next time you need it.) Use any file name you like, but use the extension “.dat”.
7. Open the file in Matlab using “load *filename.dat*”.
8. Do “whos” to see the variable name that was created by the load command.
9. Make a correctly-labeled plot of insertion loss vs. frequency. The variable produced by the load command is a $2 \times N$ matrix. Frequency data are in the first row, and insertion loss data are in the second. You can extract row k from matrix A by using the syntax “x = A(k,:)”.
10. You can also import the data file into Excel. The data are delimited, with space as the delimiter. Just open the file in Excel and follow the instructions.