ELC 4383 RF/Microwave Circuits I
Laboratory 8: Lumped-Element Low-Pass Filter

Note: This lab procedure has been adapted from a procedure written by Dr. Larry Dunleavy and Dr. Tom Weller at the University of South Florida for the WAMI Laboratory. It has been modified for use at Baylor University.

Printed Name:_____

Lab Partner: _____

Please read the reminder on general policies and sign the statement below. Attach this page to your Post-Laboratory report.

General Policies for Completing Laboratory Assignments:

For each laboratory assignment you will also have to complete a Post-Laboratory report.   For this report, you are strongly encouraged to collaborate with classmates and discuss the results, but the descriptions and conclusions must be completed individually. You will be graded primarily on the quality of the technical content, not the quantity or style of presentation. Your reports should be neat, accurate and concise (the Summary portion must be less than one page). Laboratory reports are due the week following the laboratory experiment, unless notified otherwise, and should be turned in at the start of the laboratory period.   See the syllabus and/or in-class instructions for additional instructions regarding the report format.

This laboratory report represents my own work, completed according to the guidelines described above. I have not improperly used previous semester laboratory reports, or cheated in any other way.

Signed: _____

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Laboratory Assignment:

Overview

In this laboratory assignment, you will design, simulate, construct, and test a third-order maximally flat (Butterworth) low-pass filter. You will be given a cutoff frequency and will use the design methods used in class to find element values for your filter. You will then simulate and test the design.

Laboratory Procedure

A. Filter Design

Design a third-order, maximally flat (Butterworth) low-pass filter with the first element being an inductor (your design will be series L, shunt C, series L). Use the appropriate table in the Pozar text to find the prototype element values. Note that for N = 3 the two inductors will have the same value. You will be assigned a cutoff frequency of either 100 MHz, 250 MHz, or 500 MHz. List your design results below:

Cutoff Frequency (MHz)	Value of Inductors (nH)	Value of Capacitors (pF)

The exact values you have calculated may not be available. Choose the nearest inductor and capacitor values for your design. The available inductor and capacitor values are the following:

Inductors: 15 nH, 33 nH, 82 nH

Capacitors: 15 pF, 22 pF, 68 pF

List your component values to be used for fabrication below:

Inductor Value for Fabrication: _____ nH

Capacitor Value for Fabrication: _____ pF

B. Filter Assembly and Measurement

1. Assemble your filter using the provided microstrip board and the inductor and capacitor values achieved from your results in Part A. Solder the two series inductors and the shunt capacitor in place. Feed a short piece of wire through the via hole in the circuit board and solder one end to the ground plane and the other end to the grounding pad positioned at the output of the shunt capacitor. Attach an SMA connector at each of the ports. Do not solder the connectors in place as you will need to use these for future laboratory experiments. Use a DC multimeter to check for DC continuity across the inductors and from the output of the capacitor to the ground plane on the back of the board.

2. Change the start and stop frequencies of the VNA to 100 kHz to 3 GHz. Place a 10 dB attenuator at the end of the cable that is connected to Port 2 of the VNA. Keep this attenuator in place for both the calibration and your measurements. This will minimize errors caused by cable reflections.

3. Measure both S11 and S21. View both S11 and S21 on the display. Save the data as an .s2p file and provide a plot of the measured data in your report. Measure the 3-dB cutoff frequency of your filter:

Measured 3 dB Cutoff Frequency = _____ MHz

4. Repeat steps 2 and 3, this time performing the calibration and measuring only from the low-frequency end of the VNA to 3 times your cutoff frequency. This will ensure that you have enough data points in the filter pass-band to achieve a smooth plot.

C. Filter Simulation

1. Generate a circuit schematic in ADS that represents your lumped-element low-pass filter, and name the design **lpfckt.dsn**. Enter the values for the inductors and capacitors you have soldered into your own design (the component values you actually used). Place a copy of your schematic in your report.

2. Simulate your design to obtain two plots that contain both S11 and S21 in dB for the filter schematic. The first plot should cover the frequency range from 300 kHz to $3f_c$ (where f_c is the cutoff frequency), and the second plot should cover the frequency range from 300 kHz to 3 GHz. Obtain a hard copy of each plot to include in your laboratory report. You should run two separate simulations with 401 data points in each.

You probably notice some differences between the measured and simulated results at this point. It is very important to explain these differences. We will now increase the complexity of our simulations to try to pinpoint why these differences occur.

3. Construct the circuit schematic shown Figure 1 below and save the design as **lpfckt2.dsn**. This includes parasitic element models for both inductors and the capacitor (as examined in a previous lab session this semester) as well as the microstrip transmission line segments and junctions. The following table gives the element values for the different inductor and capacitor values that may be used for the experiment. Enter these values appropriately in the VAR block.
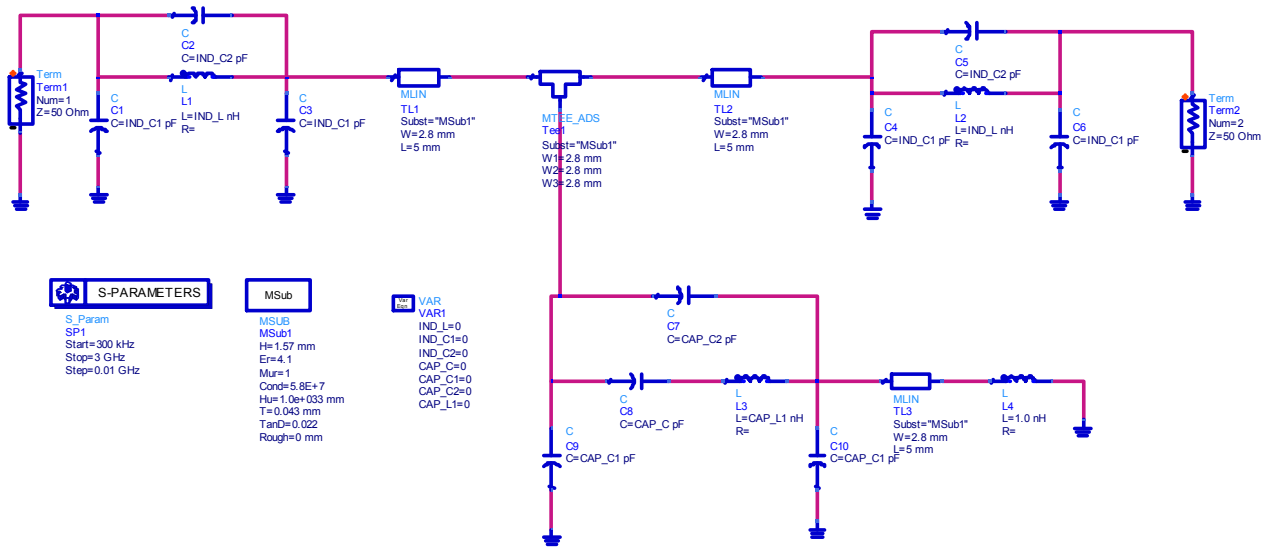
Figure 1: Complex low-pass filter schematic

	15 nH	**33 nH**	**82 nH**			**15 pF**	**22 pF**	**68 pF**
IND_L	15	33	82		**CAP_C**	15	22	68
IND_C1	0.04	0.04	0.04		**CAP_C1**	0.08	0.07	0.07
IND_C2	0.145	0.128	0.122		**CAP_C2**	0.03	0.02	0.05
					CAP_L1	1.25	1.25	1.25

Table 1: Low-Pass filter component values

4. Simulate the design and generate a plot that shows both S11 and S21 in dB for the lpfckt2 schematic from 300 kHz to 3 GHz.

5. Obtain a copy of the schematic with your values entered for all components.

6. Change the length of the MLIN element that represents the connection to ground (at the output of the shunt capacitor) to 0 mm. Re-simulate the circuit and obtain a copy of the plot for your report. Be prepared to discuss the significance of this transmission line section in your report.

Laboratory Report

Your laboratory report should contain the following:

1. A summary of the laboratory assignment.

2. The element values for your design and the specified cutoff frequency (if you include this lab write-up the results should be on one of the pages already).

3. The two measured data plots from the VNA.

4. A copy of your ideal (simple) low-pass filter schematic.

5. The two plots from ADS for the ideal filter schematic.

6. A copy of the more complex low-pass filter schematic that includes the parasitic and transmission line sections.

7. The plots from ADS that show the response of the modified filter schematic with the MLIN element below the capacitor set to have a length of 6 mm and 0 mm.

8. Discussion of Results answering the following questions:

    A. Compare the cutoff frequency of your ADS simulation results for the ideal filter (the one without parasitics) with your design cutoff frequency.

    B. Compare the measured filter response with the response predicted by the ideal ADS schematic.

    C. Compare the measured filter response and that predicted by the modified ADS schematic (the schematic including transmission line elements and parasitic models for the components).

    D. Based on your ADS modeling, what changes could you make to the filter design to improve its performance?