Project #2 – Resonance

Lab Objectives

1. To become familiar with the concept of parallel and series resonance
2. To design and analyze a parallel resonant circuit using ideal and non-ideal component models, determining the resonant frequency, loaded circuit Q and voltage gain.
3. To utilize the design tools necessary to create a printed circuit board (PCB) to implement multiple filters.

Pre-Laboratory Preparation

Prior to your laboratory meeting time, the following items need to be completed. As usual, the prelab quiz will be based on this preparation. It is VERY IMPORTANT that you review the posted information along with this entire lab handout BEFORE coming to lab.

The work we performed earlier this week (week 12, session 02) will be ***very helpful*** *to you in completing this prelab.*

Project Prelab Calculations and Simulation

1. Using an ideal inductor for L1, calculate the following for the circuit of Figure 1:
   a. fp, the resonant frequency in Hz
   b. Qp, the circuit Q
   c. BW, the circuit bandwidth in Hz
   d. Av = Vout/Vin at resonance (as a ratio)
   e. Av = Vout/Vin at resonance (in dB)
2. Using an ideal inductor for L1, simulate the circuit of Figure 1:
   a. Perform an AC Analysis (also called a **frequency sweep**) ranging from 500Hz to 5 MHz using at least 501 points/decade and a "Decibel" vertical scale (that is, voltage gain, Av in dB)
   b. View the output voltage and using the cursors, determine and label the following points:
      i. The resonant frequency, fp
      ii. The 3dB (cutoff) frequencies, (f1 and f2)
3. Using the simulation results from step 2, determine and record:
   a. fp, the resonant frequency in Hz
   b. Qp, the circuit Q
   c. BW, the circuit bandwidth in Hz
   d. Av = Vout/Vin at resonance (as a ratio)
   e. Av = Vout/Vin at resonance (in dB)
4. Repeat steps 1, 2 and 3 using an improved model for the inductor that includes the effect of series resistance. Use a Bourns 78F101J component and the specified DCR for this part as the series resistance. The appropriate data-sheet can be found at www.digikey.com
5. Place your calculations and simulation results from steps 1 through 4 above into appropriate data tables so that you can access this information quickly for the online prelab quiz. You will have 10 minutes to complete the prelab quiz at the start of lab. Leave room in your table to insert measured results and compare, similar to (some of the values have been left in these tables to help you check your work):

Ideal Circuit			% Error (sim as basis)
Parameter	Calculations	Simulation	Calculations
fp (Hz)	50.33E+3		
Qp	0.79	0.78	1.28
BW (Hz)			
Vo/Vin at fp	500.0E-3		
Vo/Vin at fp (in dB)		-6.02	

Non-Ideal Inductor Circuit				% Error (sim as basis)	
Parameter	Calculations	Simulation	Measurements	Calculations	Measurements
fp (Hz)		53.34E+3		-5.64	
Qp	0.72				
BW (Hz)		69.96E+3		0.33	
Vo/Vin at fp	454.0E-3				
Vo/Vin at fp (in dB)		-6.81			

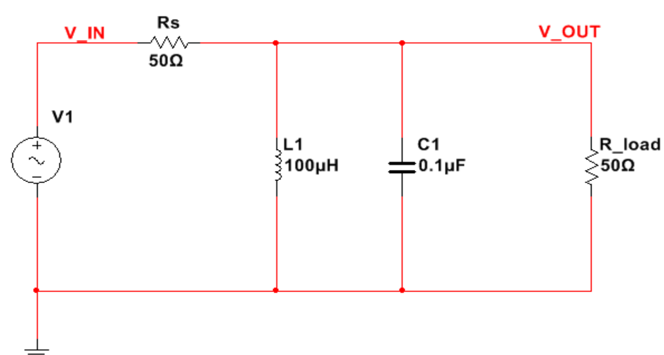

Figure 1 – Band-Pass Filter

Project #2 – Resonance

DC Circuits Lab Procedure

<u>PART 1 – PCB Design Using ExpressPCB (Project week 1 of 2)</u>

1. Design a PCB to implement the following 3 circuits
   a. <u>The circuit of Figure 1 (BPF)</u>
      i. The signal generator in 50-Ohm mode represents V_1 and Rs
      ii. Use a Bourns 78F101J inductor for L_1
      iii. Use lab components for C_1 and R_load
   b. <u>A series resonant circuit</u> (BRF) using the same component values as Figure 1 (including a 78F101J inductor)
   c. <u>A second parallel resonant circuit</u> (BPF) designed for Fr = 50 kHz (+/- 5%) using one inductor value and one capacitor value from the following list:

   C: 0.01uF, 0.022uF, 0.033uF, 0.047uF, 0.1uF, 0.22uF

   L (Bourns 78F Series): 0.82uH, 1uH, 3.3uH, 10uH, 22uH, 82uH, 220uH
2. Use the following constraints and guidelines:
   a. You will design a 3 "(in the x-direction) by 3.5 "(in the y-direction) double-sided pcb.
   b. The traces in your layout must all be horizontal, vertical or at 45 degree angles
   c. Signal Source – Voltage V_1 will be supplied by the laboratory function generator
   d. When connecting your components, keep in mind how you will measure the input and output voltages in lab.
3. Use the text tool to write your name, date, revision number, lab section, day and time on the board. Place text only on the silkscreen layer.
4. Prepare your design for printing and approval. Make sure your design fits within a 3" (x-direction) by 3.5" (y-direction) border with a 0.2" setback on all edges. To help facilitate this, set the yellow border per your instructor's direction and place an "index" mark at the upper-left corner of your design.
5. **<u>Get your instructor's signature</u>** for your individual PCB design by having them look at your completed work on the computer screen.
6. **You will populate a pre-designed board BEFORE coming to lab NEXT WEEK.** Make sure you purchase this board from Chris Brown or Ken Garland using Tiger-Bucks, it's $7.
7. **You will demonstrate** that your populated pre-designed board works next week at the start of lab.

Project #2 – Resonance

PART II – PCB Measurements (Week 2 of 2)

** You need to populate your board AHEAD OF TIME in order to complete this section of the project during project week 2 of 2. **

1. **Demonstrate to your instructor** that your individually populated PCB is functional and get a sign-off.
2. Using one of your team's PCBs, for the circuits described in PART 1.a (BPF) and in PART 1.b (BRF), using the function generator and oscilloscope, determine **the frequency response** over a frequency range of 500 Hz to 5 MHz, taking at least ***10 data points per decade***.
    a. You will need to keep track of the input and output voltage carefully for these measurements
    b. Take additional data-points as needed to accurately determine the resonant frequency and 3dB bandwidth for each circuit.
3. Plot **the measured frequency response** (Voltage gain in dB as a function of frequency in Hz) for these two circuits.
    a. Label each plot appropriately, including a title, and the x and y axes
    b. Carefully show and label the resonant frequency, the 3dB circuit bandwidth and the circuit's quality factor, Q in each case
4. For the circuit described in PART 1.c (another BPF) take measurements to determine the resonant frequency (in Hz), the voltage gain at that frequency (in dB), the circuit bandwidth (in Hz) and circuit Q.
    a. You do not need to take 10 data points per decade to determine this information. Plan on how you will get this information in a more timely fashion than you did in step 2.
5. Compare your results for the circuit of Figure 1 to your prelab calculations and simulations in an Excel data table including percent error calculations (see the example on page 1).
6. Have your data, plots and comparison table reviewed and signed-off by your instructor.

Post Lab Requirements:

Your team's submission package will be graded and returned with comments. **Submit ONLY the following (stapled together and in the following order):**

1) Your Project #2 cover sheet with signatures, one per team.

2) An Application Note (one per team) that instructs the reader how to:

I. Design a simple parallel resonant circuit (one L and one C) to provide a specified 3-dB bandwidth and center frequency given source and load impedances.
    a. Assume a lossless capacitor
    b. Assume an inductor with Q = 50

II. Estimate the voltage gain at resonance for this circuit

III. Determine the frequency response of the same circuit in lab using our equipment
    a. Be detailed enough in your description so that a 2nd-year RIT-ECTET student can follow your instructions
    b. Use information from your prelab/lab work as example(s) where appropriate to illustrate your points.

*** See the posted grading rubric to make sure you cover the critical topics ***

Project #2 – Resonance

Team Name and Lab Section:..

Team Members Present (printed)

First Name, Last Name	Role This Lab	PCB Layout (/10)	Working PCB (/10)

TEAM LABORATORY RESULTS GRADE

(all work done neatly, legible and properly organized, all signoffs in place, data and plots accurate and complete for circuits 1.a and 1.b, circuit of 1.c operation verified, comparison data table accurate and complete, no missing or extraneous information)

Lab Data	/10
Excel Plots and Data Table Comparison	/10
Application Note (see the grading rubric)	/40

Final Team Grade	**/60**