Laboratory 4: Transient Response of Second Order Circuits

*EE 11L – Circuits Laboratory I*

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*University of California, Los Angeles*

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LAB 1C

**1.0 OBJECTIVES**

The objective of this lab is to explore the natural and step response of second order capacitive and inductive circuits. In addition, this lab also analyzes the damping effects in second order circuits.

**2.0 THEORIES**

The differential equation of the series RLC circuit is:

(1)

Similarly, the differential equation of the parallel RLC circuit is:

(2)

The general solution to both equations above is the roots of the characteristic equation:  
 (3)

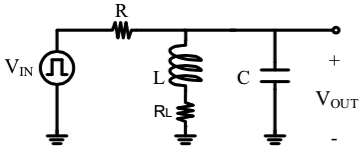
in which for a series RLC, and for a parallel RLC circuit. The resonant radian frequency is

For the damping part, we first define the damping coefficient as . If > 1, the response is overdamped with general solution of the form . If < 1, the response is an underdamped response with the general solution of the form If , the response is critically damped with general solution of the form .

**3.0 PROCEDURE**

3.1 Parallel RLC Circuit Response

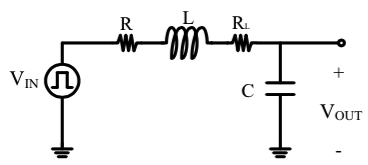
For this part of the experiment, we start by building the circuit in Figure 1 with a 1.2k resistor, 150mH inductor, and 0.22 capacitor. Then use the function generator to generate a square wave from 1V to 0V to analyze the response of the voltage Vout. Compare the theoretical and experimental results.



**Figure 1** – Parallel RLC circuit

3.2 Series RLC Circuit Response

Use a 3.3k resistor, 150mH, and 0.1 capacitor, build the series RLC circuit presented in Figure 2. Then as above, create a square wave with frequency of 100Hz from 1V to 0V and record the response of Vout. Use oscilloscope to view the input and output. Analyze the kind of damping involved and compare the theoretical result with the experimental one.



**Figure 2** – Series RLC circuit

3.3 Underdamped RLC Circuit Design

For this part we first change the value of the resistor in part 3.1 and acquire and underdamped response that over shoots the final value by approximately 0.25. Record the value of the resistor and the experimental value of the overshoot considering the internal resistance of the inductor and function generator. Then we design an underdamped system second-order circuit that has at least 4 visible peaks in oscillations. Record the experimental period and compare with the theoretical period.

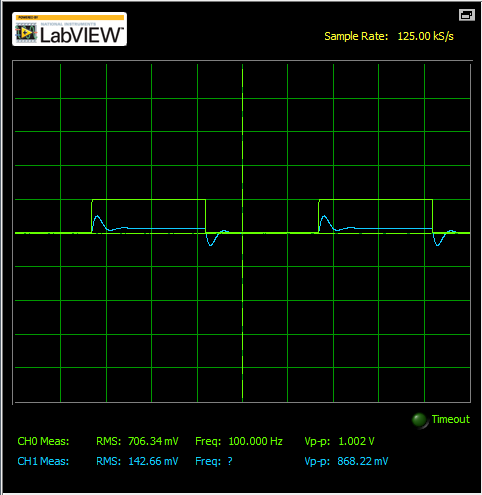
3.4 Critically Damped RLC Circuit

Replaced the resistor of the circuit in Figure 1 by a 10k potentialmeter. Adjust the potentialmeter until the system is critically damped. Record the output and measure the resistance of the potentialmeter.

**4.0 DATA, DATA ANALYSIS, AND ERROR ANALYSIS**

The data for each part of the experiment is presented below:

4.1 Parallel RLC Circuit Response



**Figure 3** – Vout of parallel RLC circuit

**Table 1**

|  |  |
| --- | --- |
| Variable | Voltage (mv) |
|  | 464.21  129.78 |

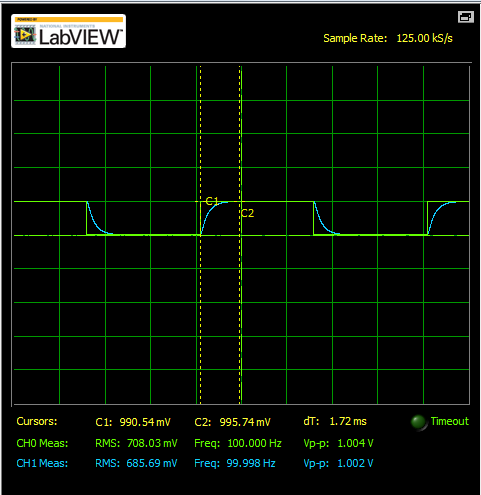
The Neper frequency and the resonant radian frequency we calculated with the theoretical values are 1894.0 rad/s and 5504.8 rad/s. Because , the system is an underdamped response with general solution of the form . Together with the initial conditions of the circuit that A and A. The coefficients are calculated as K1 = 0.119 and K2 = 0.689. As a result, the equation for Vout is: Vout = .

We can use the equation with the damping constant of to calculate the overshoot which is 0.316 for this part.

**DISCUSSION:**

The damping in this part is underdamped, same as the result we predicted.

4.2 Series RLC Circuit Response



**Figure 3** – Vout of series RLC circuit

We use the same method as in 4.1 to calculate the Vout. and . Since , the circuit is overdamped. The theoretical Vout is with the initial condition that i(0+) = 0A.

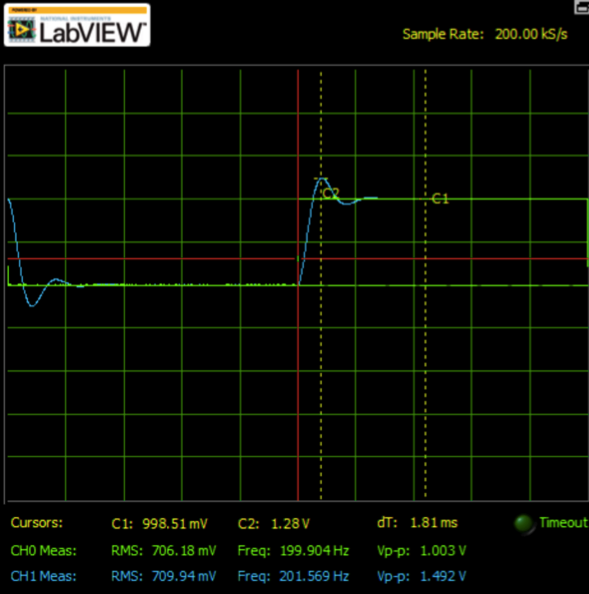
**DISCUSSION:**

The damping in this part is overdamped that the prediction and the experimental result matches.

4.3 Underdamped RLC Circuit Design

In order to acquire an overshoot of 0.25, we need to be 0.40. By applying the equation below with inductor’s internal resistance of 159, we can get the value of resistance to be 803. The internal resistance of the function generator is measured to be 5.

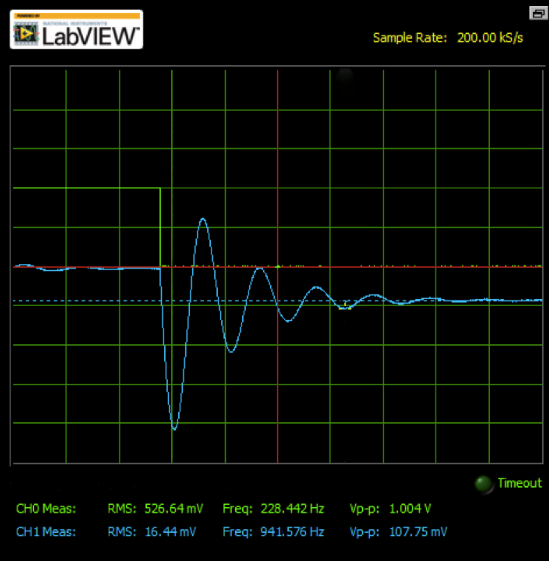
In convenient to set the resistance, we used the potentialmeter and set it to 785. Then we are able to generate the graph as Figure 4.



**Figure 4**

The peak voltage is 1.28V and the final voltage is 0.999V. The overshoot is then very close to 0.25.

Next, we chose a 10k resistor that and . With the initial conditions that and , we can get the voltage output to be represented by the equation . We can then calculate the period to be 1.14ms. The experimental period is measured to be 1.06ms by putting cursors on peaks.

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**Figure 5 –** visible peaks more than 4

**Table 2**

|  |  |  |
| --- | --- | --- |
| T theoretical (ms) | T experimental (ms) | Percentage of difference |
| 1.14 | 1.06 | 7.0% |

The percentage of difference is 7%, which can be caused by the differences between experimental and theoretical resistance, inductance and capacitance. This part of the experiment is successful.

Next, we removed the resistor and the circuit is supposed to be undamped. However，due to the internal resistance of the inductor, the response is still damped as shown in figure 6.



**Figure 6**

**DISCUSSION:**

1. The theoretical and experimental values have differences, which can be caused by the differences between real and expected resistance, inductance and capacitance.

2. A damped response caused by internal resistance of the inductor.

4.4 Critically Damped RLC Circuit

In this part of the experiment, when a circuit is critically damped, . The theoretical resistance for the circuit to be critically damped is approximately 448. The experimental value is 435. The percentage of difference is 2.9%. The minor difference indicates the validity of this part.

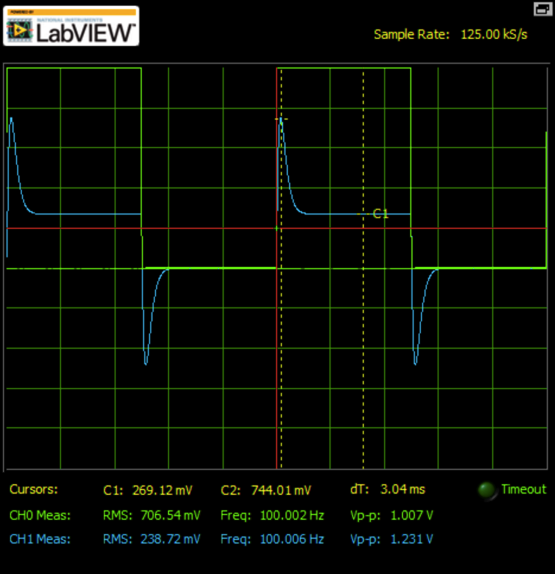


Figure 8 – Critically damped

**DISCUSSION:**

1. The experimental value and the theoretical value has a minor differences of 2.9% and this part of the experiment is successful.

2. If the resistance decreases, there will be oscillation since the circuit is underdamped. If the resistance increases, the response decays slower.

**5.0 CONCLUSION**

In this experiment, we build and study the RLC circuits in parallel and series. The underdamped, overdamped and critically damped circuits are built successfully that can show responses of the RLC circuit clearly. However, the internal resistance of the inductor cannot be ignored that it affects the precision of the experiment significantly. Also, the sample rate of myDAQ is low that it can causes errors. In general, this experimental is successful.

Lab Signature:

