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| **Course Number and Name:**  **ME 747** | |
| **Semester and Year:**  Fall 2017 | **Name of Lab Instructor:**  Alireza Ebadi |
| **Lab Section and Meeting Time:**  Section 2B, Tuesday 2-5 pm | **Report Type:**  Internal Group Report |
| **Title of Experiment:**  Time and Frequency Response of RC and RLC Circuits | |
| **Date Experiment Performed:**  9/19/17 | **Date Report Submitted:**  10/3/17 |
| **Names of Group Members:**  Zhangxi Feng  Simon Popecki  Reilly Webb | **Grader's Comments:** |
| **Grade:** |

Table of Contents

# Objectives

Frequency response analysis techniques were used to investigate the characteristics of an RC and RLC circuit. Breakpoint frequency, time constant, capacitance, inductance, and damping ratio were determined.

# Executive Summary

# Theory and Experimental Methods

**Theory**

Explain all equations, principles, and assumptions in both experiment and analysis. Show how raw data became manipulated to become results.

1. Step Response of a First Order System

Two methods were used to experimentally determine the time constant from the response data. The initial slope method locates τ by extrapolating the initial slope of the data. This slope is extended to the intersection with the steady-state voltage, and this point gives the time constant in seconds.

The second method is defined as follows

In short τ is the point where the output reaches 63.2% of the final steady state value.

Kirchhoff’s Voltage Loop law can be applied to the RC circuit, yielding the following equations

Solving for an equation relating and through

To solve for capacitance

The measured resistance for the RC circuit was

Multiple data points and methods were used to find τ, therefore the average calculated capacitance will be taken.

1. Frequency Response of a First Order System

To find the transfer function of the system, first take the Laplace transform of the differential equation.

Then rearrange to find

The time constant is related to the breakpoint frequency as follows

Experimentally the break frequency was found to be 250 Hz. With a measured resistance , calculated capacitance is

1. Step Response of a Second Order System

The RLC circuit can be modeled using a 2nd order differential equation. Using Kirchhoff’s Voltage Loop law,

With the equivalent voltage output relating the equations

The damping ratio can then be found from the raw data using the log decrement method on any two successive peaks

where is the amplitude at time , is the period, and is the number of positive successive peaks. The undamped natural frequency can then be found as follows

and can then be found with the following equations derived from the general form of the system’s differential equation

1. Frequency Response of a Second Order System

The transfer function of the system can be derived by taking the Laplace transform of the differential equation

The damping ratio and undamped natural frequency were then determined from a bode plot of the transfer function, where max peak is in dB and correlates to this peak location.

and can be found using the same equations as before, **EquationNumber**

3. Frequency Response Using LabView

The time constant and capacitance was found from the 1st order LabView results using a bode plot and the following relationships

The damping ratio for the 2nd order system was found using the same max peak equation, **EquationNumber**. The natural frequency also correlates to the location of this peak.

and can be found using the same equations as before, **EquationNumber**

**Experimental Methods**

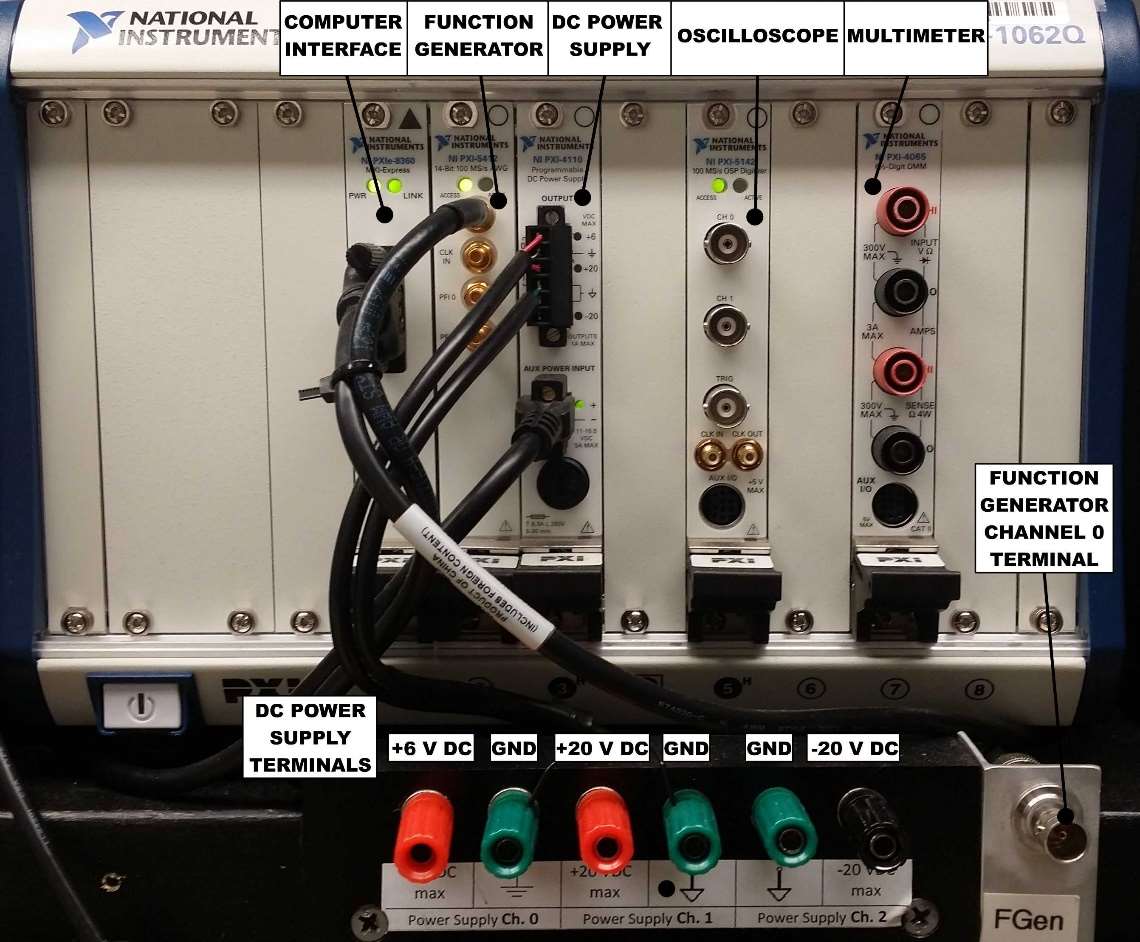
1. First Order System

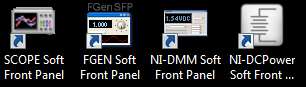
**A first order RC circuit was set up as shown in FigureNumber. A T-junction BNC connector was used to connect a function generator to both a digital scope and the circuit input, ei(t).**

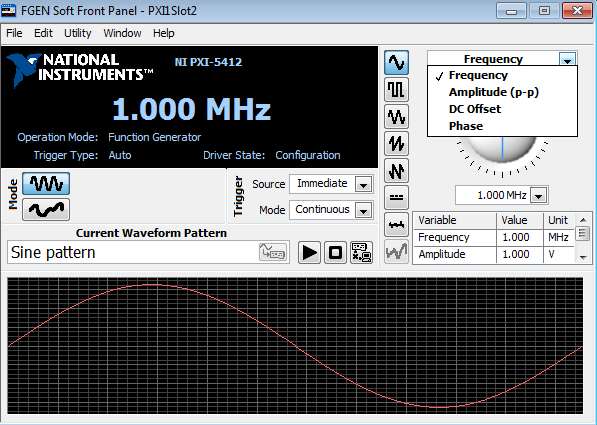


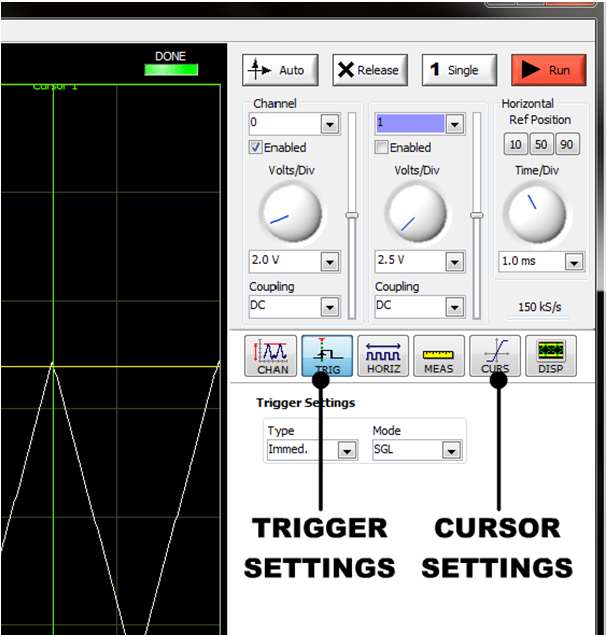
**The resistance, R (14.1 Ω), was measured using a digital multimeter. A square wave with an amplitude of 2 volts was sent through the circuit and the input and output curves were recorded using a digital oscilloscope.**

**Images taken from Lab 0**









**Next a 4 volt DC offset was applied so that the square wave amplitude is from -3.0 V to +5.0 V, and the step response was recorded and compared.**

**The function generator was then set to a sin wave with a 2 volt amplitude and no dc offset. The output amplitude and phase delay was recorded using the scope cursor for a range of input frequencies. These input frequencies ranged from 10-10000 Hz, with a higher density of points near the break frequency (250 Hz).**

2. Second Order System

**A second order RLC circuit was set up as shown in FigureNumber. A T-junction BNC connector was used to connect a function generator to both a digital scope and the circuit input, ei(t).**

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**The resistance, R (20 kΩ), was measured using a digital multimeter. A square wave with an amplitude of 2 volts was sent through the circuit input, and the input and output curves were recorded for a complete step response.**

**A 4 volt DC offset was applied so that the square wave amplitude is from -3.0 V to +5.0 V, and once again the input and output curves for a full step response were recorded using the scope.**

**The function generator was then set to sinusoidal input with an amplitude of 2 V and no DC offset. The break frequency (317 Hz) was estimated by sweeping the frequency of the sin wave from 10 Hz to 10 kHz. The output amplitude and phase shift was recorded for input frequencies of 1/20, 1/4, 1/2, 3/2, 2 and 4 times the break frequency.**

3. Frequency Response Using LabView

**LabView was used as an alternative method for determining the frequency response for both systems. ADD REFERENCE TO EXPLANATION ON BROADBAND NOISE OR CROSS POWER SPECTRAL DENSITY.**

**ADD SCREENSHOTS OF LABVIEW? Maybe just reference the procedure by M.H. deLeon instead of regurgitating these instructions.**

**The following procedure was performed on both the RC and RLC circuits.**

**The filter input was connected to the NI DAQ output terminals. Connect the RC circuit output to scope Ch.1 and the input to scope Ch. 0.**

**Select the “Data View” tab, then press the “Run” button. Once the curve has converged, hit the “Stop” button. Export the bode plot and use the zoom tools in LV-SE to estimate the break frequencies.**



# Results and Discussion

Summarize your results in a topic sentence. Relate results to Objective. This is the place for graphs, tables and figures. Explain the results of the experiment. Comment on the shapes of the curves, compare obtained results with expected results, give possible reasons for discrepancies. Answer all questions and solve any problems presented in the instructions. Tell why things happened, not only that they did happen. Experimental error should be discussed here. Calculations and formulas are not presented in this section. Avoid space consuming zeros.

**OUTLINE**

1.1

a.)

|  |  |  |
| --- | --- | --- |
| Method | Tau Adjusted (s)\* | Calculated Capacitance (nF) |
| Output 1 Initial Slope | 6.68155e-4 | 60.19 |
| Output 1 63.2% | 6.54000e-4 | 58.92 |
| Output 2 Initial Slope | 6.35428e-4 | 57.25 |
| Output 2 63.2% | 6.52000e-4 | 58.74 |
| Average |  | 58.77 |

\*Adjusted Tau is the value found taking into account that the data did not start at time = 0.

The average of these calculations is

**EXPLAIN THE DIFFERENCES BETWEEN TAU VALUES**



The only noticeable difference between the initial step response and the offset step response is the actual voltage offset. The curve shape was unaffected. The time constant will not change from a DC offset.

1.2

The system Bode plot would be unaffected by a dc offset. The Bode a plot will remain the same for a circuit regardless of input.



**still need to calculate the experimental time constant and resulting cap value here (c), then compare to value found in 1.1**

# Conclusions

# References

# Appendices

1. **Data Tables**
2. **Sample Calculations**
3. **Equipment List**
4. **Raw Data Sheets**
5. **Lab Instructions**