

Resonant Frequency and Q Factor in a Parallel RLC Circuit

by John Boswell

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Electrical and Electronic Principles – ACDA4006

Resonant Frequency and Q Factor in a Parallel RLC Circuit

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Declaration

The work of this report was completed under the supervision of Dr S. Mosey. I declare that this report is the product of my own work and is not being submitted for any other degree etc.



Abstract

A parallel RLC circuit will have a resonant frequency which will be determined by the values of the components used and the voltage supplied. This report explains some of the background information relevant to resonant frequency and Q factor in the RLC circuit. It also describes a laboratory experiment carried out using both computer simulation software and physical components to measure the point at which resonant frequency is reached. A short analysis of the experiment results concludes that a resonant frequency can be measured and there is a noticeable difference between a circuit simulated on computer software and a circuit built using physical components.



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1. Introduction

An electronic circuit with a resistor, inductor and capacitor arranged in a parallel formation is known as a parallel RLC circuit. The 'R' is the symbol for a resistor, the 'L' is the symbol for an inductor and the 'C' is the symbol for a capacitor. This group of components, which can also be arranged in series, is commonly found in many different types of electronic devices.

Frequency, measured in Hertz, can be described as the number of cycles completed in one second and Resonant Frequency is the frequency at which a resonant condition occurs [1]. Resonance, the term for this resonant condition, is achieved when the impedance of the circuit is maximum, the current is minimum and ideally equal to zero. The phase angle is also zero. To quote Horowitz and Hill,

"Impedance is the "generalised resistance"; inductors and capacitors have reactance (they are "reactive"); resistors have "resistance" (they are "resistive"). In other words, impedance = resistance + reactance." [2]

The phase of a sine wave is an angular measurement which specifies the position of that wave in relation to a reference point [1]. Sin waves can either 'lead' or 'lag' when compared to another wave and 'phase angle' is the measure of the difference between the two waveforms. For a parallel resonant circuit, the frequency at which resonance occurs is determined by the following formula [1].

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$

This resonant frequency occurs at a specific point. In a parallel RLC circuit, that point is when the inductive reactance (XL) is equal to the capacitive reactance (XC). The 'Q' or 'quality' factor is the accuracy of the point at which resonance occurs.

The purpose of the experiment described in this report was to find the resonant frequency of a RLC circuit and look at the 'Q' factor of that frequency. The report will also describe the differences found between the computer simulated circuit and the circuit constructed using physical components. This description can be found in the discussion and conclusion sections of this report.

2. Method

The experiment carried out was divided into two separate parts. Part one consisted of a computer based simulation of the RLC parallel circuit using the Proteus VSM Simulation computer software package. Part two consisted of a practical experiment, constructing the RLC parallel circuit using physical components mounted onto a piece of circuit board and connected to a digital oscilloscope. Both the computer simulation and the practical experiment produced a table of results which will be explained fully in the results chapter of this report.

2.1 Computer Simulation

Proteus has evolved into one of the most cost effective, fully featured EDA packages on the market. With current sales in over 50 countries spanning the globe, Labcenter Electronics Ltd. the company behind the software program is continuously expanding both its product portfolio and its customer base [3].

The simulation was carried out in the electronics laboratory over a period of two hours. The RLC circuit was built as per the experiment brief and the components were placed in the circuit in the following positions (see figure 1).

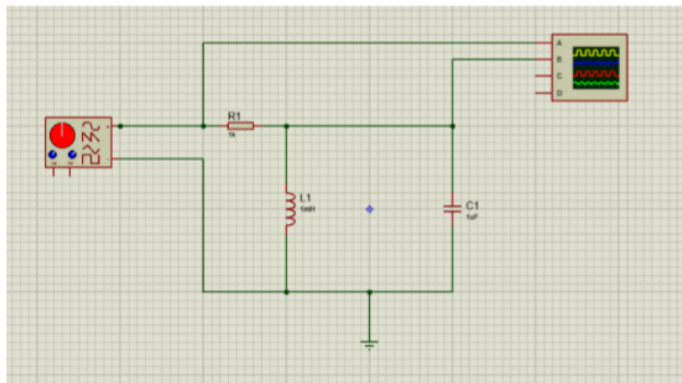


Figure 1

The signal generator output was set to 4 Volts (peak to peak measurement) at a frequency of 100Hz. The resistance value of the resistor in the circuit was 1k Ohms, the inductance value of the inductor was 1mH and the capacitance value of the capacitor was 1uF.

When the circuit was complete and the components checked for accuracy, the simulation was run using Proteus VSM Simulation.

A total of twenty nine readings of peak voltage across the capacity and the inductor were taken at a range of frequencies from 100Hz to 20kHz.

The frequency was set using the signal generator and the readings were taken using the simulation oscilloscope. Both of these simulated devices were built in to the Proteus software (see figure 2 and figure 3.)

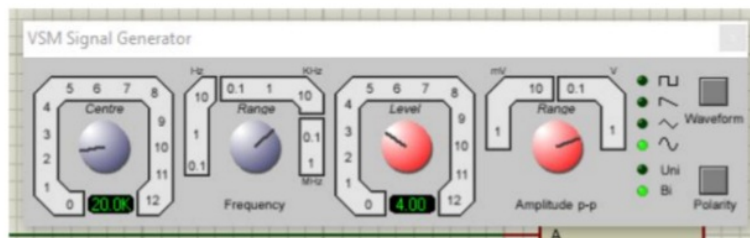


Figure 2

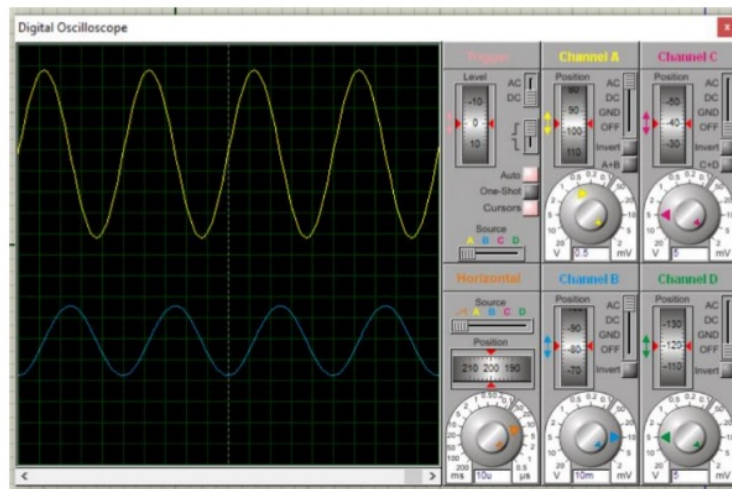


Figure 3

2.2 Practical Experiment

The practical experiment was carried out in the electronics laboratory over a period of two hours.

The signal generator output was set to 4 Volts (peak to peak measurement) at a frequency of 100Hz. The resistance value of the resistor in the circuit was 1k Ohms, the inductance value of the inductor was 1mH and the capacitance value of the capacitor was 1uF.

When the circuit had been built and the physical components checked, the experiment was carried out (see figure 4).

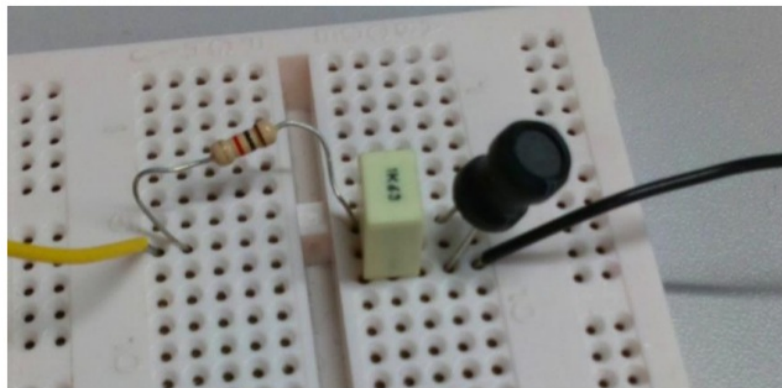


Figure 4

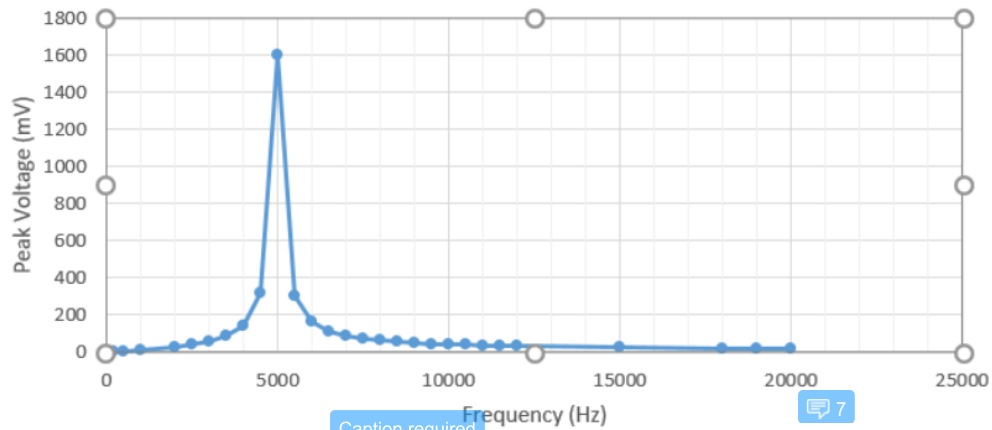
A total of twenty nine readings of peak voltage across the capacitor and the inductor were taken at a range of frequencies from 100Hz to 20kHz.

The frequency was set using the signal generator and the readings were taken using a Picoscope Multi Signal oscilloscope, connected to a desktop computer.

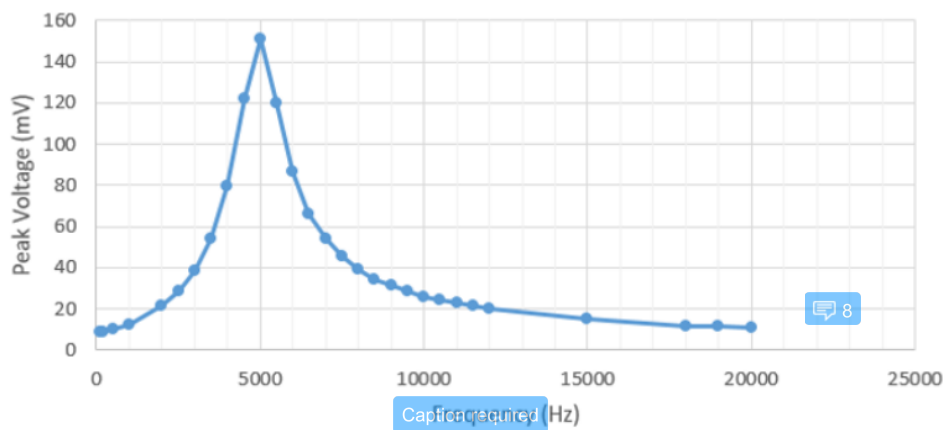
3. Results

The two graphs below show the results from both experiments. The tables of exact readings taken can be found in the data sheet documents, appendix A and appendix B at the end of this report.

Graph of capacitor / inductor voltage vs frequency
(Computer Simulation)



Graph of capacitor / inductor voltage vs frequency
(Practical Experiment)



4. Discussion

The results from the experiment show that there is a clear resonant frequency in a RLC circuit. This frequency is at 5000Hz in the two circuits tested but due to readings only being taken at 4500, 5000 and 5500 Hz, this isn't an accurate measure of the exact resonant frequency, it is a guide as to where it is approximately. Further, more specific readings taken between 5000Hz and 5500Hz would help to find the exact resonant frequency.

Basic electronic principles theory and mathematics can be used to calculate the exact resonant frequency. Using the formula below the theoretical resonant frequency can be calculated.

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$

Caption required

This basic theory combined with further practical experiments could achieve an exact measure of resonant frequency.

The theoretical Q Factor for the circuits can be calculated using the formula below.

$$Q = \frac{f_r}{f_U - f_L}$$

Caption required



The two graphs show that there is a sharp peak at the resonant frequency indicating a high Q factor for the two circuits. They also show that the peak is sharper on the computer simulated circuit compared to the circuit constructed using physical components. This is most likely to be due to the computer simulation using pre-determined figures and values. The physical components will all have slight differences with regards to performance and amount of physical resistance. These factors which will be present in any physical component, in any physical circuit will have an effect on the readings taken.

Further experiments comparing different circuits using both computer simulation and physical components could investigate this difference in more detail.

5. Conclusions

This experiment has shown that it is possible to measure the approximate resonant frequency of a parallel RLC circuit using both an electronics computer software simulation and a circuit constructed using physical components. It has also shown that there are important factors regarding accuracy that would need to be considered when using either method in the future. Finally, it has shown that it would be possible to calculate the exact theoretical resonant frequency and its Q factor using basic theory.

6. References

- [1] D. M. B. Thomas L. Floyd, Electronics Fundamentals: Circuits, Devices and Applications, Pearson, 2010 (Eighth Edition).
- [2] W. H. Paul Horowitz, The Art of Electronics, Cambridge University Press, 1987.
- [3] Unknown, "Labcenter Electronics - About Labcenter," 2019. [Online]. Available: www.Labcenter.com. [Accessed 31 December 2019].



Appendix A

Raw data collected from computer simulation (taken from Microsoft Excel spreadsheet)

Data from Proteus Circuit - 11/11/19									
Frequency (Hz)		Vin			V		VLC		
100		2V	-2V		0.0013V		1.30mV	-1.30mV	
200		2V	-2V		0.0026V		2.60mV	-2.60mV	
500		2V	-2V		0.0064V		6.40mV	-6.40mV	
1000		2V	-2V		0.0133V		13.30mV	-13.30mV	
2000		2V	-2V		0.0305V		30.50mV	-30.50mV	
2500		2V	-2V		0.0425V		42.50mV	-42.50mV	
3000		2V	-2V		0.06V		60mV	-60mV	
3500		2V	-2V		0.089V		89mV	-89mV	
4000		2V	-2V		0.145V		145mV	-145mV	
4500		2V	-2V		0.32V		320mV	-320mV	
5000		2V	-2V		1.6V		1.60V	-1.60V	
5500		2V	-2V		0.3V		300mV	-300mV	
6000		2V	-2V		0.165V		165mV	-165mV	
6500		2V	-2V		0.115V		115mV	-115mV	
7000		2V	-2V		0.089V		89mV	-89mV	
7500		2V	-2V		0.074V		74mV	-74mV	
8000		2V	-2V		0.064V		64mV	-64mV	
8500		2V	-2V		0.056V		56mV	-56mV	
9000		2V	-2V		0.05V		50mV	-50mV	
9500		2V	-2V		0.0455V		45.50mV	-45.50mV	
10,000		2V	-2V		0.0415V		41.50mV	-41.50mV	
10,500		2V	-2V		0.06V		40mV	-40mV	
11,000		2V	-2V		0.0375V		37.5mV	-37.5mV	
11,500		2V	-2V		0.035V		35mV	-35mV	
12,000		2V	-2V		0.033V		33mV	-33mV	
15,000		2V	-2V		0.0245V		24.5mV	-24.5mV	
18,000		2V	-2V		0.02V		20mV	-20mV	
19,000		2V	-2V		0.0185V		18.50mV	-18.50mV	
20,000		2V	-2V		0.0175V		17.5mV	-17.5mV	

Appendix B

Raw data collected from practical experiment (taken from Microsoft Excel spreadsheet).

Data From Breadboard Circuit - 12/11/19						
Frequency (Hz)	Vin		VLC			
100	1.244V	-1.244V	9.143mV	-8.675mV		
200	1.244V	-1.244V	9.143mV	-8.675mV		
500	1.244V	-1.244V	10.08mV	-9.89mV		
1000	1.244V	-1.244V	12.64mV	-12.54mV		
2000	1.244V	-1.244V	21.48mV	-21.34mV		
2500	1.244V	-1.244V	28.84mV	-28.37mV		
3000	1.244V	-1.244V	38.68mV	-38.69mV		
3500	1.245V	-1.261V	53.95mV	-53.96mV		
4000	1.263V	-1.262V	79.43mV	-80.23mV		
4500	1.281V	-1.281V	121.7mV	-119.8mV		
5000	1.3V	-1.3V	151.2mV	-149.5mV		
5500	1.281V	-1.262V	119.8mV	-119.5mV		
6000	1.253V	-1.262V	86.8mV	-86.24mV		
6500	1.244V	-1.244V	66.15mV	-66.34mV		
7000	1.244V	-1.244mV	53.95mV	-53.96mV		
7500	1.244V	-1.244V	45.34mV	-44.78mV		
8000	1.244V	-1.244mV	39.15mV	-38.69mV		
8500	1.244V	-1.244V	34.47mV	-34.47mV		
9000	1.244V	-1.244V	31.18mV	-31.14mV		
9500	1.244V	-1.244V	28.44mV	-28.07mV		
10,000	1.244V	-1.244V	26.02mV	-25.56mV		
10,500	1.244V	-1.244V	24.15mV	-23.68mV		
11,000	1.244V	-1.244V	22.67mV	-22.27mV		
11,500	1.244V	-1.244V	21.34mV	-20.87mV		
12,000	1.244V	-1.244V	19.93mV	-19.53mV		
15,000	1.244V	-1.244V	15.22mV	-14.33mV		
18,000	1.244V	-1.244V	11.98mV	-11.96mV		
19,000	1.244V	-1.244V	11.51mV	-11.18mV		
20,000	1.244V	-1.244V	11.02mV	-10.55mV		

Resonant Frequency and Q Factor in a Parallel RLC Circuit

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

57 / 100

PAGE 1

PAGE 2



Comment 1

You do not need to include a declaration for assignment work

PAGE 3



Comment 2

Nice abstract, it would have been nice to see a little more detail about what you did and some more results.

PAGE 4

PAGE 5



Comment 3

any resonant circuit



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 6



Comment 4

Not sure this is needed. This experiment could have been done with any simulation software.



Comment 5

A caption should also tell the reader what is in the picture.

PAGE 7

PAGE 8



Comment 6

Your method reads like a step by step guide. All you need to do is say WHAT you did, you don't need to say HOW.

This is all you really needed:

"The circuit was connected as shown in Figure 1. The input and capacitor voltages were measured at a range of frequencies, and plotted. The -3dB bandwidth was estimated from the graphs and Q-factor calculated using Equation 1. The process was repeated for both the practical and simulated circuits."

You should try to be as concise as possible.

PAGE 9



Comment 7

This should have been plotted on a logarithmic X-axis



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 8

This should have been plotted on a logarithmic x-axis



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 10

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 9

The graphs in figure 2 and figure 3.....



Comment 10

Good, it would have been better if you had supported this statement with a reference or more simulation work.

PAGE 11



Comment 11

More references should have been used.

PAGE 12

PAGE 13

JOHN
BOSWELL

56.50

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



"References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.

2.4

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is accurate with a good understanding of the field of study.

17.4

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and

15

situations without guidance. Needs to use evidence to support the argument. Valid conclusions and recommendations, where relevant

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.

18.6

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

3.1