

Resonance

by Joshua H

Submission date: 03-Apr-2025 10:18PM (UTC+0100)

Submission ID: 254727849

File name: 59371_Joshua_H_Resonance_658780_1559180448.docx (574.03K)

Word count: 2036

Character count: 11065

Resonance

L4 –Electrical and Electronic Principles– ACDA4021

Electrical & Electronic Engineering Degree Apprenticeship

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Abstract

This report explores how parallel RCL circuit's function and possible problems with using simulation software to model them. Parallel RLC circuits are made of a resistor in series, with an inductor and a capacitor which are then connected in parallel. The report will show the key differences between the outputs of a real-world RLC circuit and a simulated circuit. Namely being the large disparity in quality-factor value, in this case, it denotes the selectiveness of a frequency response, as well as, the difference in attenuation for both. A key part of RCL circuitry is the phenomenon known as resonance which is due to the interactions between the reactances of both inductor and capacitor resulting in a purely resistive circuit. The analysis is based on simulations in Proteus 8 and a breadboard circuit set up to be able to observe the phenomenon, including the effects of parasitic elements and component tolerances. Results from these experiments show an attenuation of -18.9 dB for the breadboard circuit and an attenuation approaching 0 for the simulated. This report shows clearly that whilst simulations are a valuable tool for circuit design, they lack the real-world conditions needed for accurate predictions and performance.

Introduction

Parallel RLC circuits consist of three main elements, a resistor, an inductor, and a capacitor. A key feature of this circuit is that when driven at a specific frequency to the components the reactive properties of the inductor and capacitor will cancel each other out because their currents are 180 degrees out of phase resulting in a purely resistive circuit. When connected to a voltage source the RLC circuit will store energy within the magnetic field of the inductor and the electric field of the capacitor. The energy in this system will be transferred back and forth between the two stores resulting in an oscillatory response, and the cancellation of currents as the capacitor lags 90 degrees behind and the inductor 90 degrees ahead of supply. Parasitics such as the winding in the inductors coil and wires used in the circuit will have their resistance which will affect the efficiency of the system. [1,2,8]

These circuits are used in many electronic devices, in band-pass filters found in radios allow specific frequencies through whilst preventing others, as oscillators where their passing of charge between the inductor and capacitor can be utilised. [3,4]

The scope of this report is to explain this phenomenon and show how the theory works in practice, this will be achieved using the simulation software Proteus 8 and by using components to show any differences between a perfect system and a real-world system. By knowing the properties of the components, the behavior of an RLC circuit can be estimated.

Reactance is a component's opposition to the change in direction of current, it is specific to AC circuitry and is a key parameter in the impedance function. Impedance in the case of the RLC circuit describes the circuit's total resistance, this value will affect the total useful bandwidth when attenuation is at -3dB. Reactance is a

components opposition to the change in direction of current, it is specific to AC circuitry and is a key parameter in the impedance function. Impedance in the case of the RLC circuit describes the circuits total resistance, this value with effect the total useful bandwidth when attenuation is at -3dB.

$$X_c = \frac{1}{2\pi fC} \quad X_l = 2\pi fL$$

- X_c being the capacitive reactance, X_l being the inductive reactance
 - f being the frequency
 - C being the capacitance of the capacitor
 - L being the inductance of the coil

As shown by the formula, the reactance of a capacitor is inversely proportional to its capacitance and to the frequency of current applied to it. In a purely capacitive circuit, the capacitive reactance leads supply by 90 degrees of phase. The inductor is the opposite; it is directly proportional to its inductance and to the frequency of current applied to it. In a purely inductive circuit, the inductive reactance lags supply by 90 degrees. It's due to these properties that we observe the main feature of an RLC circuit, resonance. [6,7]

$$X_l = X_c$$

Resonance is the state in which the reactance of both the inductor and capacitor are equal. The resonant frequency is the frequency in which the circuit is resonant. At resonance in an RLC circuit the reactance, being 180 degrees apart in phase, cancels each other out leading to the resistor being the only component to have an effect on the circuit impedance. [6,7]

$$Z = R + jX$$

Impedance is the combined opposition of the change in alternating current, it takes resistance and reactance as an imaginary number. Reactance can be seen as imaginary as both reactance equations can be substituted into equations using imaginary numbers. As j being the $\sqrt{-1}$ ω being the frequency in radians ($2\pi f$)

$$X_c = \frac{1}{j\omega C} \quad \text{and} \quad X_l = j\omega L$$

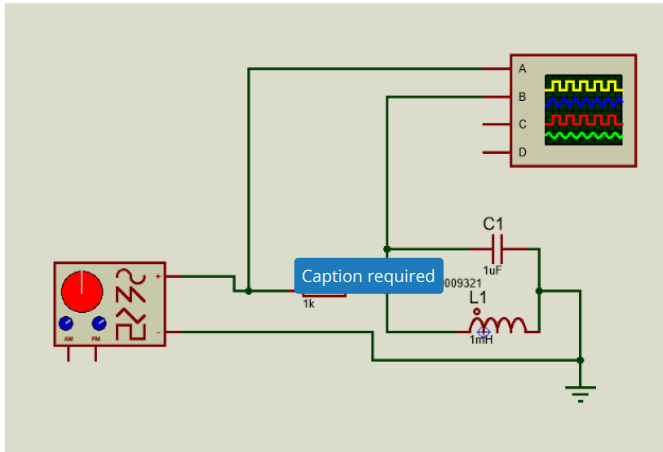
Q factor or quality factor is the ratio of a resonator's frequency to its bandwidth, it is a useful measure in determining how selective a circuit is at specific frequencies. [5]

$$Q = \frac{f_c}{B_w}$$

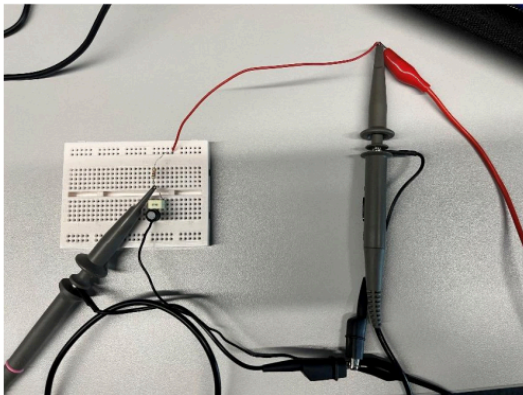
$$\text{where } B_w = f_h - f_l \text{ and } f_c = f_l + \frac{B_w}{2}$$

- f_c being the midpoint frequency, f_l being the lowest frequency and f_h being the highest frequency at -3dB
- B_w being the bandwidth

Simulation Setups



The simulation was created in proteus mirroring the specification, the wave generator was set at two volts, peak to peak, and a voltage probe (R1(2)) was placed in between the resistor, inductor, and capacitor. The oscilloscope recorded the wave at the source and then after the resistor in between the inductor and capacitor. Then using a tool within proteus a frequency response curve was able to be generated using the voltage measured in R1(2). Data from this graph was then used in Microsoft Excel so that it could be manipulated further.



For the breadboard set-up a 1000 ohm resistor was connected in series with a 1 mH inductor and a 1 μ F capacitor, these components were connected in parallel as



following the circuit diagram above. These components were checked using an LCR meter, as shown in Figure 3 below, this showed that whilst the components were not exact, they were within good enough tolerance for use in the circuit. An oscilloscope probe was placed in between the resistor and the two other components to measure the change in voltage across the circuit. Another probe was placed on the input signal to allow for attenuation calculations to be made using the equation below as well as insuring that the inputted signal was accurate.

$$A = 20 \times \log_{10} \frac{V_{out}}{V_{in}}$$

Caption required

Citation Needed

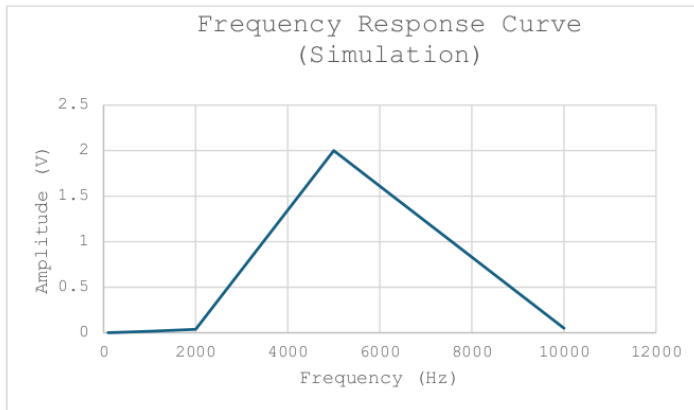


Figure 3: The inductor under test to find the components values

Results

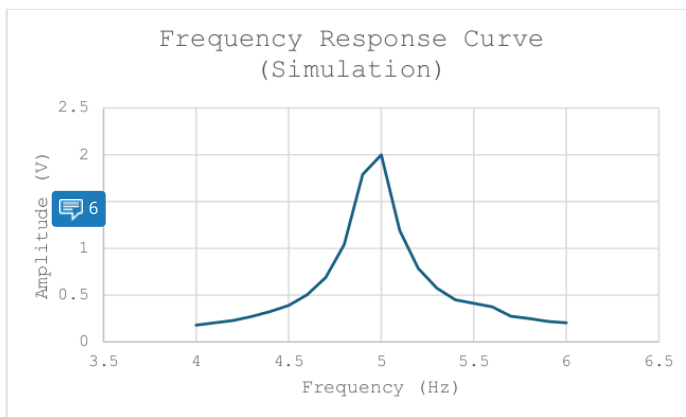


Graph 1:



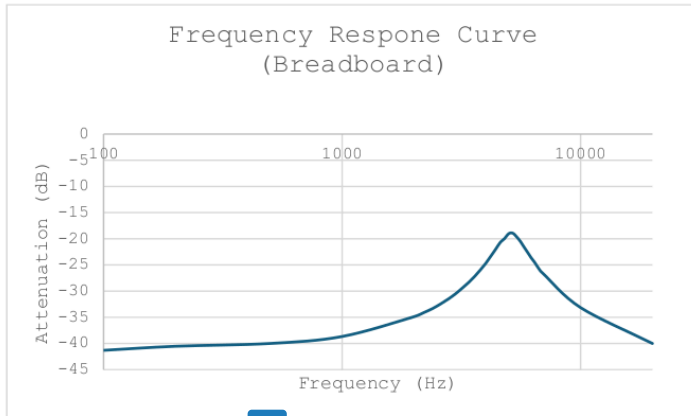
Graph 1 shows the initial readings taken in proteus to find the point of resonance. This graph shows the peak in the region of 4000 to 6000 Hertz, peaking at a maximum amplitude of 2 volts peak to peak.

Graph 2:



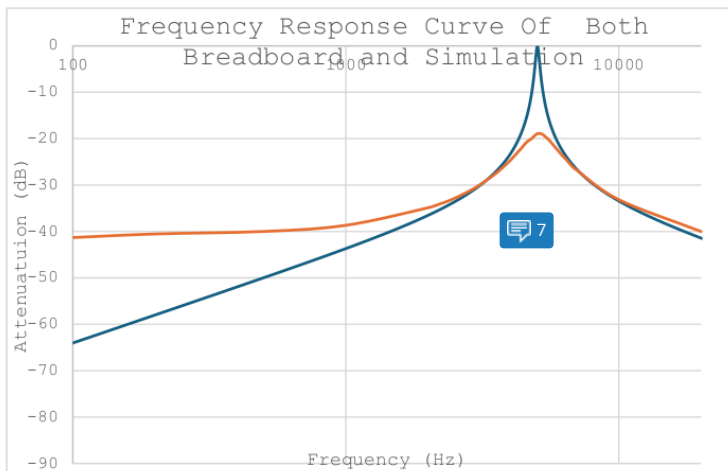
Graph 2 shows the second set of readings taken at a higher resolution. Readings were taken from 4000Hz to 6000Hz at 100Hz intervals. Findings show a peak at 5000Hz with a maximum amplitude of 2 volts.

Graph 3:



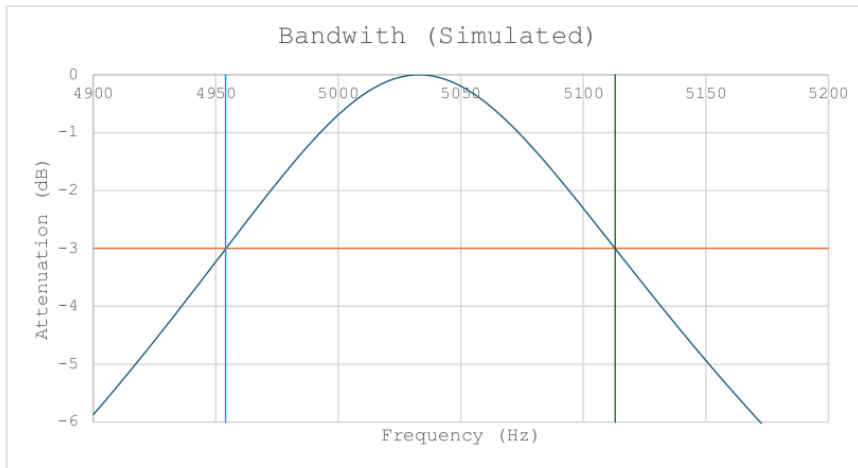
Graph 3 shows the set of readings taken on a breadboard. Readings were taken from 100Hz to 20,000Hz at 200Hz intervals. Findings show a peak at 5200Hz with an amplitude of 2.26 volts.

Graph 4:



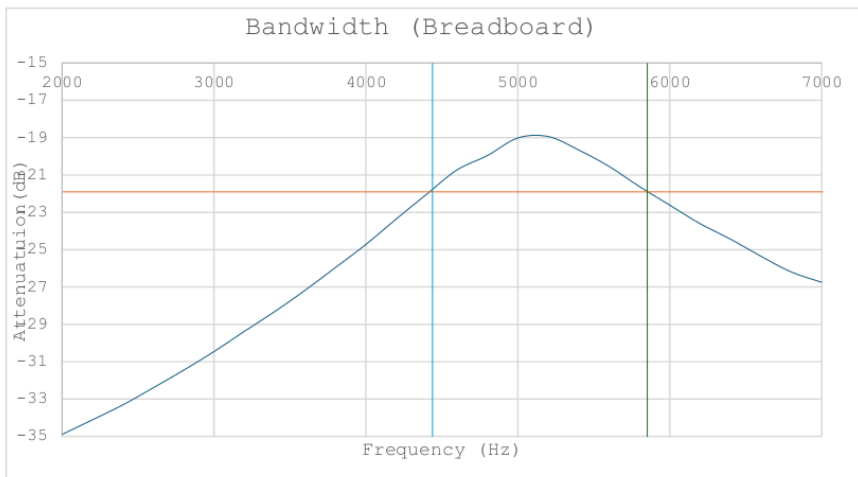
Graph 4 shows the comparison of simulated and breadboarded results. The blue series represents simulated results and the orange breadboarded results. These results are in dB's shows and whilst the breadboard's maximum attenuation is -18.938 the simulated is -0.298. Further, the minimum attenuation in the simulated circuit is -64.033 dB and the breadboard minimum is -41.31 dB

Graph 5:



Graph 5 shows the bandwidth the simulated circuit would have at -3dB. Starting at 4954Hz and ending at 5113Hz. With a midpoint of 5035Hz and a total bandwidth of 159Hz. When calculated with the formula shown in the introduction the resulting Q factor would be 31.6667

Graph 6:



Graph 6 shows the bandwidth the breadboarded circuit would have at -3dB. Starting at 4438Hz and ending at 5852Hz. With a midpoint of 5200Hz and a total bandwidth of 1414Hz. When calculated with the formula shown in the introduction the resulting Q factor would be 3.6755

Discussion

Graph 1 shows the initial readings taken; this was done to find the general frequency the circuit resonated at. Once this frequency range was determined a more focused scan of frequencies could be done to determine at which exact frequency the circuit began resonating. This was done by taking a 100 Hz interval from 4000 Hz to 6000 Hz, as shown in Graph 2. The same process was applied to the breadboard circuit using the range found within the initial readings. Graph 3 shows a slight difference between Graphs 1 and 2 in the resonant frequency as well as a smaller Q characterized by a shallower peak. Further readings of both breadboard and simulated circuits were taken to provide a greater resolution thus allowing for a more accurate response curve and Q factor which would then help determine possible reasons as to why there was a difference.

From Graph 4 onwards data converted from voltage to attenuation. Attenuation is the loss of aspects within an input signal generally characterised as a loss of strength. Frequency Response curves that use attenuation allow viewers to better understand where a signal's strength is best for

Graph 4 shows the large variation between simulation and real-world components. Both start to peak at around the 4800 Hz and fall at 7000 Hz with the simulated peaking at 5035 Hz and the breadboard peaking at 5200. However, the Q factor of the simulated circuit was ten times that of the breadboard. This could be possible due to the differences in component values. Rearranging the equations set out in the introduction and using the values recorded by the LCR we can calculate what the frequency and Q factor should be given the different values.

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(1.008 \cdot 10^{-6}) \cdot (0.986 \cdot 10^{-3})}}$$
$$\therefore f = 5048$$

Caption required

$$Q = \frac{1}{0.986} \cdot \sqrt{\frac{(0.986 \cdot 10^{-3})}{1.008 \cdot 10^{-6}}}$$
$$\therefore Q = 31.72$$

These results obviously don't match the breadboarded results and more closely mirror the simulation, this could be due to a multitude of reasons however it is most likely parasitics. Parasitics are unintended aspects of all electronics, wires connecting components inherently have resistance, as well as coils in inductors. Fields can be generated unintentionally and whilst small will have an effect on the current inside a circuit. Furthermore, components too close together may inadvertently create a small capacitive charge across each other. Breadboards are

also notoriously poor for sensitive circuits due to their composition. Finally, when temperature increases, so does the resistance of components this then by Ohm's law affects voltage and current. These factors all affect how a circuit in the real world functions. When compared to a simulated circuit where all the components are treated as being perfect differences are bound to be observed.

Conclusion

In conclusion, the differences between a simulated circuit and a real-world circuit are clear, with the simulated Missing Units attenuation approaching to near 0 Missing Units and the real-world circuit only reaching -18.9 as well as the Q-factor being ten times that of the real in the simulated, this is most probably due to the effects of parasitics as well as differing component values. However, this does show that simulations are still valid to use as a tool to create RLC circuitry, as long as the user understands that the output of the simulations is most likely impossible in a real-world scenario.

References

[1]

Ref Qual

M. Mulko, "Parallel RLC Circuits: What Are They and How Do They Work?," *interestingengineering.com*, Sep. 24, 2021.

<https://interestingengineering.com/science/parallel-rlc-circuits-what-are-they-and-how-do-they-work>

[2]

Wikipedia Contributors, "LC circuit," *Wikipedia*, Mar. 08, 2025.

https://en.wikipedia.org/wiki/LC_circuit#Operation

[3]

Wikipedia Contributors, "Band-pass filter," *Wikipedia*, Apr. 18, 2019.

https://en.wikipedia.org/wiki/Band-pass_filter

[4]

"Electronic filter," *Wikipedia*, Apr. 07, 2020.

https://en.wikipedia.org/wiki/Electronic_filter

[5]

Wikipedia Contributors, "Q factor," *Wikipedia*, Apr. 21, 2019.

https://en.wikipedia.org/wiki/Q_factor

[6]

electronics tutorials, "Parallel RLC Circuit and RLC Parallel Circuit Analysis," *Basic Electronics Tutorials*, Jun. 25, 2013. <https://www.electronicstutorials.ws/accircuits/parallel-circuit.html>

[7]

Electronics Tutorials, "Parallel Resonance and Parallel RLC Resonant Circuit," *Basic Electronics Tutorials*, Oct. 15, 2018. <https://www.electronicstutorials.ws/accircuits/parallel-resonance.html>

[8]

Electronics tutorials, "Series Resonance in a Series RLC Resonant Circuit," *Basic Electronics Tutorials*, Jun. 04, 2018. <https://www.electronicstutorials.ws/accircuits/series-resonance.html>

[9]

S. Mugo, "Understanding Attenuation in Signal Transmission," *Eepower.com*, Oct. 26, 2022. <https://eepower.com/technical-articles/understanding-attenuation-in-signal-transmission/#>

Resonance

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

66/100

PAGE 1

PAGE 2



Comment 1

Good abstract, although a little deep on the theory for an abstract. I was also expecting something about the Q factors of the circuits and how they compare.



Comment 2

energy. - Charge relates to an electric field which the inductor does not have.

PAGE 3

QM

Citation Needed

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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 3

the current in the capacitor leads the supply voltage by 90 degrees

QM

Caption required

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PAGE 5



Comment 4

as shown in figure XX

Caption your images, tables, equations etc. and refer to them by their captions in your text.

QM

Caption required

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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

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Comment 5

Try not to have a heading as the last thing on a page

PAGE 6



Comment 6

This should be in dB, not Volts

PAGE 7

QM

Sp.

Spelling error



Comment 7

Nice graph, although the heading should not encroach into the plot area

PAGE 8

PAGE 9



Comment 8

They also remove the effect of differences in input voltage allowing a direct comparison between the losses shown by two different circuits regardless of input voltage

QM

Caption required

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Comment 9

Why is it obvious?



Comment 10

Another simulation would prove it. Adding a small resistance in series with [only] the inductor would show the effect you have observed in the practical circuit. This could easily be done in another simulation.



Comment 11

This is doubtful at the frequencies we were using.

PAGE 10

QM

Missing Units

What units is this in?

You should always include the units for all quantities you describe in your text. Some quantities have more than one unit. Frequency, for example, can be measured in Hertz (Hz) or radians per sec (rad/s).

Make it clear for your reader and remove any ambiguity.

QM

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Make it clear for your reader and remove any ambiguity.

QM

Ref Qual

GRADING FORM: SMU GENERIC_SMOSEY

JOSHUA H

65.63

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Exceptional engagement with an extensive range of relevant and credible literature. Reliance on inappropriate sources, and/or indiscriminate use of sources. Consistently accurate application of referencing. Some omissions or minor errors.

3.13

KNOWLEDGE & UNDERSTANDING

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



Excellent knowledge and understanding of the basic underlying concepts and principles of the subject.

21

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.



Sound evaluation of the underlying concepts and principles. Can interpret qualitative and

quantitative data accurately. Ability to devise arguments using evidence to make mostly appropriate and valid judgements. You should look to use evidence to support your arguments.

18

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of taught, basic methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Excellent evidence of different approaches to problem-solving in particular contexts and proposes appropriate solutions.

21

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.



Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed. Demonstrates the skills for employment requiring the exercise of some personal responsibility, with some areas of strength and some of minor weakness. You communicate complex technical concepts clearly and concisely, making them accessible to both technical and non-technical audiences.

2.5