

Electrical and Electronics Resonance Lab Report

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Abstract

This experiment investigated how a parallel RLC circuit responds to different frequencies using both simulation software and real laboratory components. The circuit contained a resistor, capacitor and inductor connected to an AC signal generator set to 2 V peak-to-peak. The frequency was changed from 100 Hz to 20 kHz while the voltage across the inductor and capacitor was measured. The results were used to calculate the attenuation of the circuit and produce a graph of attenuation against frequency. From the graph, the resonant frequency and Q factor of the circuit were found and compared with theoretical values. The experiment showed that the circuit produced a maximum output voltage at resonance, which occurred close to the theoretical resonant frequency.

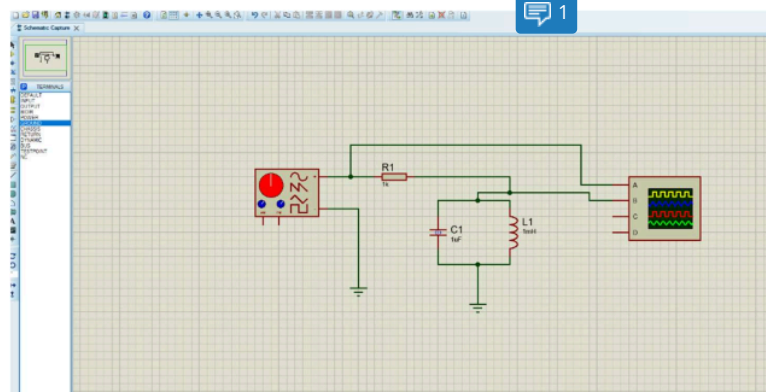
Introduction

RLC circuits are electrical circuits that contain a resistor (R), inductor (L), and capacitor (C), also known as a resonance circuit [1]. These circuits are commonly used in electronic systems because they can respond differently to different signal frequencies [2]. One important behaviour of an RLC circuit is resonance, which occurs when the inductive reactance and capacitive reactance become equal. At this point, the circuit produces its maximum amplitude at a particular frequency known as the resonant frequency [3].

Parallel resonance circuits are widely used in applications such as radio tuning circuits, filters, oscillators, and communication systems [4]. The behaviour of a resonant circuit can be analysed by measuring how the output voltage changes as the input frequency changes.

The test circuit forms a parallel resonance circuit as the capacitor and inductor are connected in parallel, as shown in figure 1. Resonance occurs when the inductive reactance (X_L) and capacitive reactance (X_C) are equal in magnitude. At this point, the inductive current (I_L) and capacitive current (I_C) are equal and opposite, causing them to cancel each other out. As a result, the overall current in the circuit is in phase with the supply voltage (V), and the parallel RLC circuit behaves as though it has a very high impedance. This causes the circuit to produce its maximum voltage response at the resonant frequency [3] [2] [5].

Figure 1 - Resonate Circuit



Due to this behaviour, a parallel resonant circuit is often known as a rejector circuit because it opposes the flow of current from the source at the resonant frequency. The voltage response of the circuit follows a similar shape to the impedance curve, reaching a peak at resonance and decreasing as the operating frequency moves away from the resonant frequency [5].

The resonant frequency of a parallel RLC circuit can be calculated using the equation:

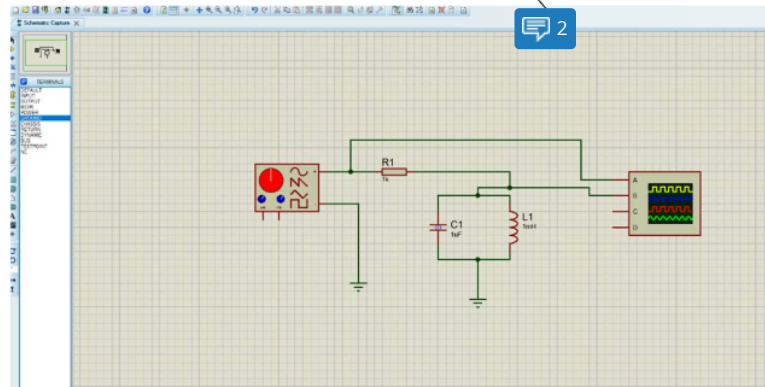
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Another important property of resonant circuits is the quality factor, or Q factor. The Q factor describes how sharp or selective the resonance is. A high Q factor means the circuit has a narrow bandwidth and stronger resonance peak, while a low Q factor means the response is broader, as defined by $BW = \Delta f = \frac{f_r}{Q}$ or $BW = f_2 - f_1$ [5].

Simulation Setups

The circuit used in this experiment was a parallel RLC resonant circuit consisting of a resistor, inductor, and capacitor connected to an AC signal source, built using Proteus simulation software. The circuit contained a 1 kΩ resistor connected in series with a parallel LC branch made up of a 1 mH inductor and a 1 μF capacitor. An AC sine wave of 2 V peak-to-peak was supplied by a signal generator, while the frequency was varied between 100 Hz and 20 kHz to investigate the frequency response of the circuit. As seen in Figure 1.

Figure 2 - Resonate Circuit



Voltage measurements were taken across the inductor and capacitor branch at different frequencies in order to observe the resonant behaviour of the circuit. Near the resonant frequency, additional measurements were recorded to accurately determine the peak voltage and half-power frequencies required for calculating the bandwidth and Q factor. The circuit was first analysed using Proteus simulation software, using the below parameters in table 1, before constructing a breadboard and testing using physical laboratory components for comparison with theoretical and simulated results.

Table 1 - Simulation Parameters

Parameter	Value
Input Voltage	2V peak to peak
Frequency Range	100Hz – 20 kHz
Resistor	1 kΩ
Inductor	1 mH
Capacitor	1 μF

Simulation Results

The theoretical resonant frequency of the parallel RLC circuit was calculated using the standard resonance equation:

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

where L is the inductance and C is the capacitance of the circuit. The component values used in the experiment were substituted into the equation to determine the expected resonant frequency before measurements were taken. Using the component values of $L = 1 \text{ mH}$ and $C = 1 \mu\text{F}$, the theoretical resonant frequency of the circuit was calculated to be approximately 5.03 kHz. This value represents the frequency at which the inductive and capacitive reactances are equal, causing resonance to occur in the circuit.

The simulation circuit was tested once the signal generator was set to 2 Vpk-pk at 100Hz. The results from this simulation can be seen below in Table 2.

Table 2 - Simulation Results

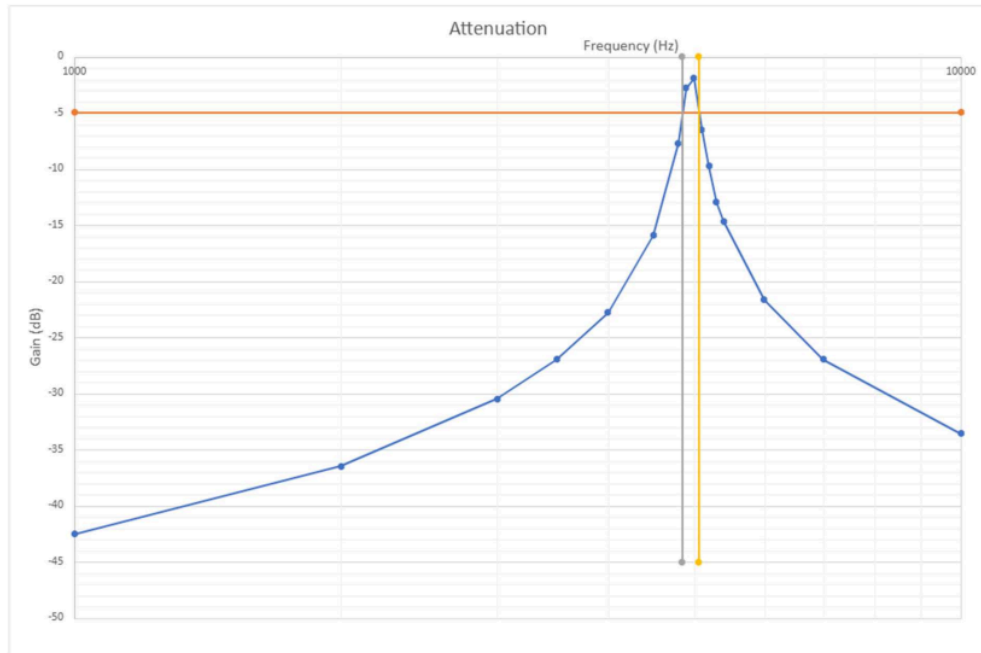
Frequency	Vin	Vout	Gain db
100	2	0	
500	2	0	
1000	2	0.015	42.49877473
2000	2	0.03	36.47817482
3000	2	0.06	30.45757491
3500	2	0.09	26.93574972
4000	2	0.145	22.79323987
4500	2	0.32	15.91760035
4800	2	0.825	7.691520942
4900	2	1.45	2.793239869
5000	2	1.6	-1.93820026
5100	2	0.95	6.466127808
5200	2	0.65	-9.76233278
5300	2	0.45	12.95634964
5400	2	0.37	14.65656543
6000	2	0.165	21.67092103
7000	2	0.09	26.93574972
10000	2	0.042	33.55561411
20000	2	0.0165	41.67092103

The attenuation of the circuit was calculated from the measured voltage values using the following equation:

$$A = 20\log_{10} \left(\frac{V_L}{V_{in}} \right)$$

where A represents the attenuation in decibels (dB), V_L is the measured peak-to-peak voltage across the inductor branch, and V_{in} is the input peak-to-peak voltage supplied by the signal generator. These calculated values were then used to plot the frequency response of the circuit, as seen in figure 2.

3 - Attenuation Graph



From the graph and measured results, the maximum output voltage occurred at approximately 5000 Hz, where the output voltage reached 1.6 V and the gain was closest to 0 dB. This indicates that the resonant frequency of the circuit was:

$$f_r \approx 5.0 \text{ kHz}$$

The theoretical resonant frequency was found to be:

$$f_r \approx 5.03 \text{ kHz}$$

This is very close to the measured resonant frequency of 5000 Hz, giving a difference of approximately, 33Hz. The percentage error is therefore:

$$\frac{33}{5033} \times 100 \approx 0.66\%$$

This shows that the experimental results closely matched the theoretical prediction.

The Q factor was determined from the bandwidth of the resonance curve using:

$$Q = \frac{f_r}{BW}$$

The maximum output voltage was:

$$V_{max} = 1.6 \text{ V}$$

Half of the maximum voltage is:

$$\frac{1.6}{2} = 0.8 \text{ V}$$

From the results table, the lower half-amplitude frequency occurred at approximately 4800 Hz ($V_{out} \approx 0.825 \text{ V}$) and the upper half-amplitude frequency occurred at approximately 5150 Hz (estimated between 5100 Hz and 5200 Hz)

Therefore, the bandwidth was approximately:

$$\begin{aligned} BW &= 5150 - 4800 \\ BW &\approx 350 \text{ Hz} \end{aligned}$$

The experimental Q factor was therefore:

$$\begin{aligned} Q &= \frac{5000}{350} \\ Q &\approx 14.3 \end{aligned}$$

The theoretical Q factor for the circuit can be estimated using:

$$Q = R \sqrt{\frac{C}{L}}$$

Next, substituting the component values into the equation as shown below,

$$\begin{aligned} Q &= 1000 \sqrt{\frac{1 \times 10^{-6}}{0.001}} \\ Q &\approx 31.6 \end{aligned}$$

The simulated Q factor obtained from the graph was lower than the theoretical value predicted by basic circuit theory.

Discussion

The results obtained from the simulation showed the expected behaviour of a parallel RLC resonant circuit. As the input frequency increased from 100 Hz, the output voltage across the LC branch gradually increased until a maximum value was reached at approximately 5 kHz. Beyond this point, the output voltage decreased again as the frequency continued to rise. This produced the characteristic resonant response curve expected from a parallel resonant circuit.

The resonant frequency determined from the graph was approximately 5000 Hz, which was very close to the theoretical resonant frequency of 5033 Hz calculated using:

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

The small difference between the theoretical and simulated values resulted in a percentage error of approximately 0.66%, showing strong agreement between theory and simulation. This close agreement indicates that the circuit behaved largely as expected under resonant conditions.

One noticeable feature of the results was the sharp increase in output voltage near the resonant frequency. At lower and higher frequencies, the gain remained significantly negative, indicating low output voltage across the LC branch. However, near resonance the gain rapidly increased, reaching a maximum value of approximately -1.94 dB at 5 kHz. This occurred because the inductive reactance and capacitive reactance became equal in magnitude at resonance, causing the reactive currents to cancel each other out. As a result, the circuit exhibited maximum impedance and produced the largest voltage response.

The graph also showed that the response curve became narrower around resonance, which is characteristic of a resonant circuit with a relatively high Q factor. Using the half-power frequencies obtained from the graph, the bandwidth was estimated using the following equation:

$$BW = f_2 - f_1$$

$$BW = 5150 - 4800$$

$$BW \approx 350\text{Hz}$$

Which was then used to calculate a Q factor of approximately 14.3. Although this demonstrated a clear resonant peak, the value was lower than the theoretical Q factor. This difference may have been caused by the limited number of measurement points taken around the resonant region and the estimation of the half-power frequencies directly from the graph. In addition, simulation software may include small non-ideal

characteristics within component models, preventing the circuit from behaving as a perfectly ideal resonant circuit [6].

Another noticeable trend was the symmetry of the response around the resonant frequency. The output voltage increased rapidly as the circuit approached resonance and decreased in a similar manner once the frequency moved above resonance. This behaviour is typical of parallel resonant circuits and demonstrates how the circuit selectively responds to frequencies close to resonance while rejecting frequencies further away.

Overall, the results closely followed theoretical expectations and successfully demonstrated the resonant behaviour, bandwidth characteristics, and frequency selectivity of a parallel RLC circuit.

Breadboard

Following the completion of the simulation, the circuit was intended to be constructed on a breadboard using physical components in order to investigate the behaviour of the parallel RLC circuit under real operating conditions. However, due to time limitations during the experiment process, the practical stage was not completed.

If the practical experiment had been carried out successfully, it would be expected that the overall shape of the frequency response curve would remain similar to the simulated results, with a clear resonant peak occurring close to the theoretical resonant frequency of approximately 5 kHz. The output voltage across the LC branch would still be expected to increase near resonance before decreasing at frequencies above and below the resonant point.

However, some differences between the simulated and practical results would likely have been observed. In a real circuit, components are non-ideal and contain parasitic properties such as internal resistance within the inductor, stray capacitance, and additional resistance from breadboard connections and wiring. These components have a high impact on performance and efficiency and will likely behave very differently when operating at higher and lower frequencies [7]. These factors would likely reduce the sharpness of the resonant peak, resulting in a lower Q factor and a slightly wider bandwidth compared to the simulation. Small shifts in the resonant frequency may also occur due to component tolerances, as real inductors and capacitors rarely match their stated values exactly [3]. In practical circuits, energy losses caused by resistive effects and imperfect component behaviour can dampen the resonant response and reduce the maximum output voltage observed at resonance [8]. Breadboard layouts and connecting wires may also introduce additional parasitic inductance and capacitance, which can slightly alter the measured frequency response of the circuit [9].

Despite these expected differences, the practical experiment would still be expected to demonstrate the same overall resonant behaviour observed in the simulation, confirming the theoretical principles of parallel resonance.

Conclusion

In this experiment, the resonant behaviour of a parallel RLC circuit was successfully investigated using circuit simulation software. The frequency response of the circuit was analysed by varying the input frequency from 100 Hz to 20 kHz while measuring the output voltage across the LC branch. From these measurements, the attenuation, resonant frequency, bandwidth, and Q factor of the circuit were determined and compared with theoretical predictions.

The results demonstrated the expected characteristics of a parallel resonant circuit. As the input frequency approached resonance, the output voltage increased significantly and reached a maximum value at approximately 5 kHz. Beyond this frequency, the output voltage decreased again, producing the characteristic resonant response curve. The resonant frequency obtained from the simulation was found to be approximately 5000 Hz, which closely matched the theoretical value of 5033 Hz calculated using the standard resonance equation. The small percentage error of approximately 0.66% indicated strong agreement between theoretical and simulated results.

The bandwidth of the circuit was determined from the half-power frequencies and used to calculate a Q factor of approximately 14.3. The response curve showed a relatively sharp resonance peak, demonstrating the frequency selectivity of the circuit. Although the calculated Q factor was lower than the theoretical value, the simulation still accurately demonstrated the overall resonant behaviour expected from a parallel RLC circuit.

The experiment also highlighted the relationship between resonance, impedance, and voltage response in parallel resonant circuits. At resonance, the inductive and capacitive reactance's became equal, causing the reactive currents to cancel each other and resulting in maximum impedance and minimum supply current. This behaviour confirmed the theory discussed within the report and demonstrated why parallel resonant circuits are often referred to as rejector circuits.

Although the practical breadboard construction was not completed during the experiment process, the expected practical results were considered and compared with the simulation. It was concluded that a real circuit would likely produce a similar resonant response but with a slightly lower Q factor and small shifts in resonant frequency due to component tolerances, parasitic effects, and additional resistance within physical components and wiring.

Overall, the experiment successfully achieved its aim of investigating resonance within a parallel RLC circuit and demonstrated close agreement between simulation results and theoretical circuit analysis.

References

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Electrical and Electronics Resonance Lab Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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Comment 1

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GRADING FORM: EEP

MATHEW GEORGE

58.70

ENGAGEMENT WITH LITERATURE

Marks for engagement with literature skills will be gained through the use of information collected from appropriate reference material embedded in mainly the introduction, but also in the discussion and conclusion sections of your report. This reference material should be used to explain concepts and to support arguments in the discussion of your results.



Engagement with a wide range of literature. Good use of range of relevant references, including textbooks and technical sources on RLC circuits, resonance, circuit theory and parasitic effects. The literature is strongest in the introduction, but it should be used more directly in the discussion to support claims about bandwidth, Q factor and practical circuit losses. The sources were integrated more critically into the analysis rather than mainly used for background explanation.

3.2

KNOWLEDGE AND UNDERSTANDING

Marks for knowledge and understanding skills will be given for the accuracy of your description of the concepts and principles of resonance and how this relates to the experimental setup used.



Excellent knowledge and understanding are demonstrated through a good understanding of parallel RLC resonance. The explanation of maximum impedance, reactive current cancellation, and frequency selectivity is relevant and mostly accurate for a parallel resonant circuit. The theoretical resonant frequency of approximately 5.03 kHz is correctly identified and linked to the simulation results.

24

COGNITIVE AND INTELLECTUAL

Marks for cognitive and intellectual skills will be given for the quality and validity of your interpretation of the experimental results gathered. You should consider the differences between the simulated and experimental and explain possible causes for them.



The report demonstrates a good evaluation of the underlying concepts and principles, providing a clear interpretation of the simulated results and comparing the resonant frequency with the theoretical value. The calculated percentage error of approximately 0.66% is a strong analytical feature, demonstrating effective numerical comparison. However, the half-power method requires clearer explanation, and the absence of practical data limits the comparison between simulated and experimental results.

16

PRACTICAL SKILLS

Marks for practical skills will be given for your use of the available tools, models and techniques to explain your results and their relationship to the theory of the concepts.

12



The report demonstrates an adequate awareness and generally appropriate application of simulation methods and tools, with the Proteus simulation setup described clearly. The simulation results include suitable frequency measurements around the resonance point, helping to identify the peak response accurately. However, the practical breadboard stage was not completed, which is a significant limitation as the assignment requires physical measurements and comparison with simulation results. While the report discusses expected real-world effects, this does not fully compensate for the absence of practical data, oscilloscope readings, experimental tables, and a practical graph.

TRANSFERABLE SKILLS FOR LIFE

Marks for transferable skills for life and professional practice will be given for the structure, coherence, presentation and overall quality of your report.

3.5



The report exhibits a high level of structure and coherence, with well-organised sections including a contents page, table of figures, abstract, introduction, simulation setup, results, discussion, breadboard implementation, conclusion, and references. The presentation is clear and contributes to a strong overall quality. However,

some formatting issues remain, including repeated figure numbering and missing equation formatting. The conclusion is detailed, but it should more clearly acknowledge that the practical experiment was not completed rather than implying that all project objectives were fully achieved.