

Aaron Bell Electronic Principles assignment

by Aaron Bell

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ACDA4006- Electronic Principles

Level 6 Embedded Electronics Apprenticeship

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1.0 Abstract

This report investigates RLC circuit networks, their potential applications and details results from the modelling and bread boarding of an example circuit.

Proteus circuit simulator was used to initially design the network, from which measurements were taken and graphed. Followed by a practical bread boarding of the same circuit, using components rated to identical values, the same voltage applied to the circuit as the simulation. The results of the bread board are measured by hand using an oscilloscope and graphed in a similar fashion, calculations to find the Q factor of each experiment were then done.

The resulting calculations show that the circuit simulator far exceeded the  1 e of Q factor when compared to the bread board, with Proteus resulting in a value of 458 and the bread board having a value of 4.39. This suggest some inherent problems of the circuit simulators inability to account for factors such as internal resistance, tolerances of components and phenomena such as parasitic capacitance.

These findings are significant and highlight that while Proteus is an extremely useful tool, that actual circuit performance may differ. Therefore recommending that both tests are carried out before moving ahead in the circuit design and production process.



2.0 Introduction

This report seeks to identify the composition and use of RLC circuits in real world applications, whilst also investigating a simple RLC circuit in a simulation program and the same circuit built on a breadboard. This will allow for comparison between the simulation results and results obtained from practical experimentation with the circuit. Before detailing this experiment, some background knowledge on RLC circuits will be discussed.

RLC circuits are given their name from the fact they contain a Resistor (R), Inductor (L) and Capacitor (C) connected within the same circuit, these components can be connected in either series or parallel. The actual placement of these common components can greatly change both the behaviour and the practical applications of the circuit, however this report only looks directly at circuits where the inductor and capacitor are placed in parallel with each other, since that is the circuit that was simulated and built.

Whilst we only simulate and build one particular circuit topology, discussing the applications of these components is useful to understand their purpose. By combining resistors with capacitors it is possible to make frequency dependent voltage dividers. [1] This fact allows for the characteristics of an RC circuit to filter either upper or lower frequencies (Also known as high-pass and low-pass filters), however when capacitors are combined with inductors it allows for a much better filter and the addition of using a "resonant circuit" to create what is known as a band-pass filter [2], passing through a selected or "tuned" part of the frequency domain whilst filtering everything else either side of it. The application of this may be recognisable from the tuning of a car radio, often this is achieved by making the capacitor and/or inductor variable, allowing the person using the circuit to change the exact part of the frequency domain being passed through the circuit.

The above only refers to one type of filter, the use of Inductors and Capacitors together can also be used to deliver the opposite effect, known as a "Band-stop" filter, where a very low impedance shorts out the signal, dropping it across a resistor and preventing its passage on to the load [3]. The exact effect of the circuit differs greatly by its design, hence understanding the orientation of these components is a critical stepping stone to designing and building tuned circuits in the future. The exact frequency response of an RLC circuit can be visualised with calculations that include bandwidth, upper and lower frequencies and -3dB points [4]. These findings are then used to find the ratio of reactance or stored energy to resistance or consumed energy [5], better known as Q or Quality Factor.

The reason why these circuits produce the results that they do is due to the reactance these circuit networks have due to the inductance from the inductor and capacitance from the capacitor, when these two reactances are combined they produce resonance, which is an important concept underpinning the design and application of filtering circuits.

3.0 Simulation Setups

In the simulation a simple RLC circuit was designed consisting of a resistor with a value of 1K ohms, an inductor with a value of 1uH and a capacitor with a value of 1mF, with the inductor and capacitor being in parallel with each other, supplied with a voltage of +2V_{in} from the positive and provided with a ground reference of 0V to create a closed circuit.

The simulation was then adjusted at intervals, so that multiple measurements could be taken of the V_{out} across a wide range of frequencies, these measurements were then used in the formula $Gain(dB) = 20 \log_{10} \left(\frac{V_{out}}{V_{in}} \right)$ to find the gain of the circuit at the values. The circuit diagram from the simulator is shown in Figure 1, alongside the simulated oscilloscope and signal generator in Figure 2.

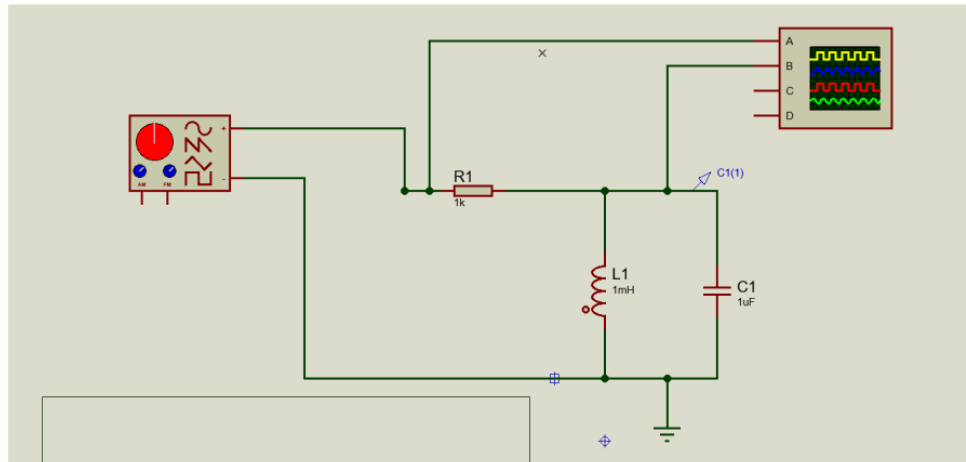


Figure 1 - Diagram of the RLC circuit being tested in Proteus circuit simulator

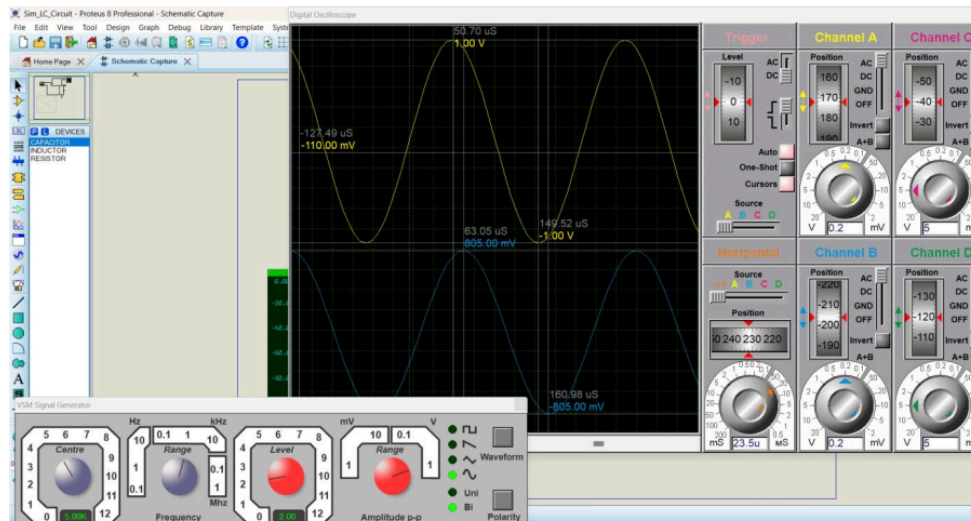


Figure 2 - The simulation Oscilloscope and Signal Generator

After these circuits had been simulated in Proteus, the example circuit was then replicated on a breadboard in order to compare the simulated results to those of an actual circuit with physical components. The test setup for the breadboard used components with stated values that were identical to those in the simulation, in identical orientation being supplied with an identical V_{in} value. Whilst there are nuances to be discussed, they shall be saved for later sections.

The test setup for the breadboard circuit are show in Figure 3 and 4.

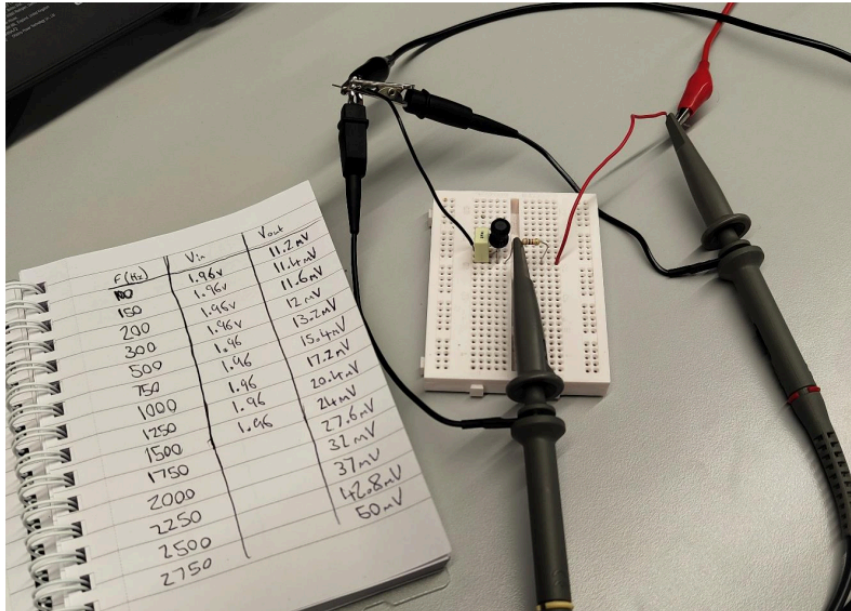


Figure 3 - The breadboard (right) with probes attached and values being recorded (left)

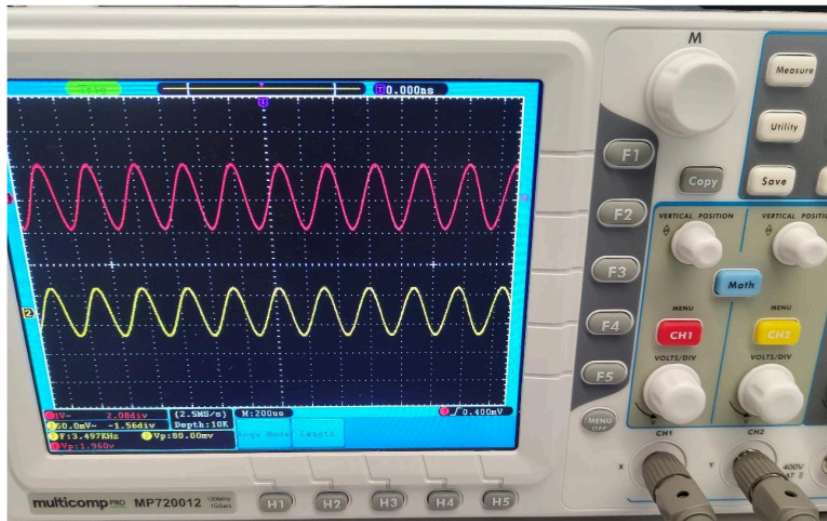


Figure 4 - The Oscilloscope being used for recording the values

Shown in figure 3 is the breadboard setup used for testing with a red wire representing the positive and black wire representing the negative. Oscilloscope probes were then connected directly to the red wire to measure V_{in} and to the side of the resistor closest to the negative terminal, effectively acting as a wire in order to capture measurements of V_{out} .

Once these measurements were acquired, Microsoft Excel was used to build a graph of Gain over Frequency and estimate the position of the 3dB points in the circuits frequency response. From the 3dB points, Q-Factor can be found.

$$\text{Bandwidth (Hz)} = \text{Upper} - \text{Lower};$$

Citation Needed

Caption required

where upper and lower represent frequency value in Hz of the 3dB points

After calculating the bandwidth, f_c can be estimated by finding the value with the highest gain value.

Finally the Quality factor can be found with the following calculation,

$$Q_{factor} = \frac{f_c}{\text{Bandwidth}}$$

Caption required Citation Needed

Contraction

It is worth acknowledging that the values recorded aren't a perfect match, as more values were able to be exported directly from the circuit simulation compared to the manual changing of the signal generator when testing the breadboard circuit.

The results from these simulations shall be discussed in the next section.

4.0 Results and Discussion

The results from these experiments differ significantly, with the Q factor for the simulated graph being a value of 458 (3 s.f.) implying something has gone horribly wrong either with the simulation or the calculation in the frequency response graph, because a Q-factor this high would imply an impossibly low resistance. However for the breadboard circuit, the Q factor was a value of 4.39 (3 s.f.). The appearance of this becomes quite clear when looking at the graphs in Figures 5, 6 and 7.

With Figure 5 representing the data collected manually from the breadboard, there is a significant difference in the linearity of the gain before reaching the resonant frequency. Whilst there is a difference in the maximum and minimum of X axes, this is due to the simulated result in Figure 6 not matching up with reality and the results outside those bounds can be neglected as a product of simulation. However one comparison is that the graphs appear to decline with a similar curve after the resonant frequency, but this is noticeably more gradual in the breadboard results.

Q-factor itself is represented by the peaks and orange lines, in crude terminology, the greater the gradient of the peak the greater the Q-factor, hence there must be also be a link between Q-factor and a derivative of the function, but that's outside the scope of this report.

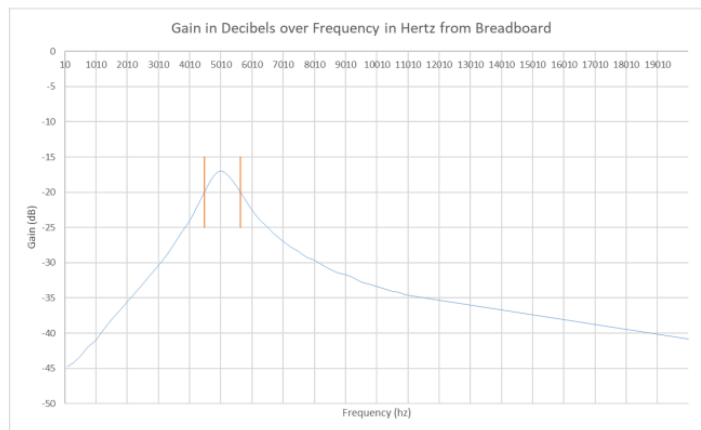


Figure 5 - Graph of Gain over Frequency from Breadboard, orange represents 3dB points

The results from the breadboard behave as expected, but very different from the simulation. A potential area of difference here is that physical manufactured components will have tolerances, these tolerances result in uniquely different components, whether by the batch they are produced or by individual differences in the silicon they are manufactured from. For example, the measurements for the components used in the breadboard were measured and found to be:

Component	Simulation Measurement	Actual Value
Inductor	1mH	1.05mH
Capacitor	1 μ F	0.991 μ F
Resistor	1000 Ω	981 Ω

Table 1 - Table of simulation measurements vs physical components

Table 1 shows the discrepancies between simulation components and the actual value of the components used in the breadboard, within their tolerance limits. It is also worth noting that the simulation assumed no internal resistance, whereas all real components will have some degree of internal resistance, even if it's negligible.

Figures 6 and 7 (below) show graphs of the results from Proteus, demonstrating that the simulation had a much smaller bandwidth on the 3dB points. By using this bandwidth in the calculations, it results in a Q factor that implies a theoretical resistance that is impossibly low.

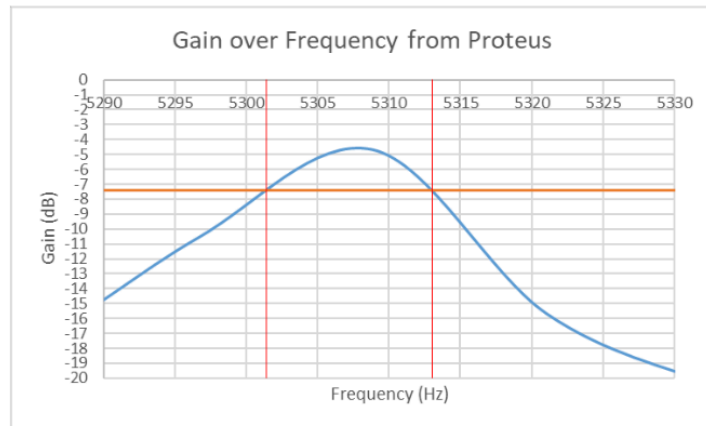


Figure 6 – Graph showing the frequency response from Proteus, red lines represent the 3dB points

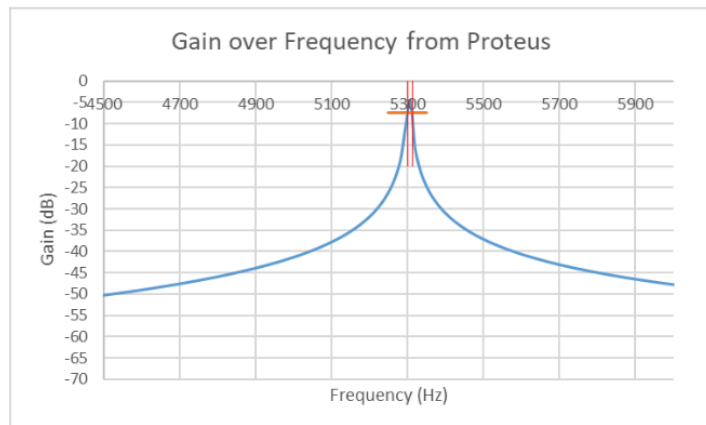


Figure 7 – Wider span of the graph from Proteus Frequency Response

Considering the bandwidth over which these circuits allow, they would be considered a very small band pass filter, with the breadboard circuit measurements showing a bandwidth of roughly 1.1 kHz, which while small for some circuits such as radio transmitters, might have applications elsewhere.

It is worth noting, whilst not discussed here, calculations may also take place in the complex domain. With phasor diagrams also being a tool to the visualisation of the practical results of such a circuit.

5.0 Conclusion

This report sought to investigate the potential applications and design of RLC circuits, whilst also looking at circuit simulation software versus practical bread boarding.

It was discovered that there is a large discrepancy between simulated results and actual results, with the simulation results having a significantly larger Q factor than the physical bread board. Some potential reasons for this are stated as:

- Simulator components are perfect, simulated as exact values. When measuring the actual components with a meter, it was discovered that there were small differences between the values that could impact the results.
- The components in the simulator do not account for internal resistances. All components have some value of internal resistance, along with other characteristics such as parasitic capacitance, which are not modelled in the circuit simulator.

The Q factor in this case, represents how large the gradient is leading to and from the resonant frequency, with different Q factors being required for different results. The individual Q factor of a circuit may even be tuned to perform across a certain range for particular applications.

The report highlighted the key issues that need to be considered when using a circuit simulator, whilst also explaining part of the theory and maths behind resonant circuits.

References

- [1] W. H. Paul Horowitz, "RC Highpass filters," in *The Art of Electronics, 3rd Edition*, Cambridge University Press, 2015, p. 48.
- [2] W. H. Paul Horowitz, "Resonant Circuits," in *The Art of Electronics, 3rd Edition*, Cambridge University Press, 2015, pp. 52-53.
- [3] "All About Circuits," [Online]. Available: <https://www.allaboutcircuits.com/textbook/alternating-current/chpt-8/resonant-filters/>. [Accessed 13 March 2025].
- [4] "Series Resonance Circuit," Electronics Tutorials, [Online]. Available: <https://www.electronics-tutorials.ws/accircuits/series-resonance.html>. [Accessed 14 March 2025].
- [5] P. S. a. S. Monk, "2.30.2 Q (Quality Factor) and Bandwidth," in *Practical Electronics for Inventors*, Mc Graw Hill Education, 2016, p. 193.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

63/100

PAGE 1

PAGE 2

PAGE 3



Comment 1

This seems a little high. Should this be 45.8 and not 458?



Comment 2

Good abstract

PAGE 4

PAGE 5

QM

Sep. Eqn.

Separate Equations:

Equations should be given their own line and caption to allow you to discuss them in your text. You should also identify and describe each of the variables in the equation.

PAGE 6

PAGE 7

QM

Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:
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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....

QM

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QM

Contraction

In formal academic writing, you should avoid using contractions like "aren't" "can't" "don't" etc. instead you should use the full form of the words. "Are not" "Can not", "Do not".

PAGE 8



Comment 3

Without seeing your workings out, it is difficult to see where you have had this from. It seems very high to me. I was expecting it to be closer to about 35 for the simulated circuit.



Comment 4

I don't think there is any silicon in these components. Silicon is only found in semiconductors



Comment 5

Even a small resistance for the inductor or capacitor would not be negligible - this would eat away at the energy transferred between the components, reducing the Q factor and dampening the response.

PAGE 9



Comment 6

Your analysis seems a bit thin. You have not shown the values you have used to calculate the Q factor.

Putting both sets of data on one graph would allow you to compare them more easily - giving you more to talk about.

Another simulation could have proven your theories about the internal resistance of the components. You could also have used the measured component values in this simulation to see how close to reality you could make it.

PAGE 10



Comment 7

...They could be if you added them into the simulation.

PAGE 11

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

GRADING FORM: SMU GENERIC_SMOSEY

AARON BELL

63.40

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Consistently accurate application of referencing. Some omissions or minor errors.

2.9

KNOWLEDGE & UNDERSTANDING

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



Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding.

19.5

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.



Good evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data, with minor errors. An emerging ability to use evidence to support the argument. Mostly valid arguments and logical judgements.

16.5

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.



Work is coherent, very fluent and is presented professionally. Demonstrates excellent skills for employment requiring the exercise of some personal responsibility with an appetite for further development. You communicate complex technical concepts clearly and concisely, making them accessible to both technical and non-technical audiences.

3.5