

GD EE Principles assignment

by Gabriel Dunning

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Electronic Principles Assignment

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L4 – Electrical and Electronic Principles

ACDA4006

Electrical & Electronic Engineering Degree
Apprenticeship

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Abstract:

The following report details the undertaking and results of a lab based exercise that involved the simulation and construction of an RLC circuit which then had frequency response measurements taken from both sim and real circuit. These frequency response measurements were then used to calculate the upper and lower frequency bands, and then the bandwidth and Q factor of both circuits. It was ultimately found that the simulated circuit had a narrower bandwidth and higher Q factor than the real circuit, though this was determined to be caused at least in part ¹ to the simulation software simulating an ideal component, which led to certain factors like inherent component resistance not being taken into account.

Introduction:

The circuit used in this lab exercise is commonly referred to as an RLC circuit, the name RLC stands for the three main constituent parts of the circuit, being a resistor (R), an inductor (L) and a capacitor (C) connected in series. This circuit is being investigated for this exercise because of the properties it has when AC signals of varying frequencies are put into it. This is due to both the inductor and capacitor having a reactance (named Inductive reactance and capacitive reactance respectively).

When the frequency of the input AC signal is increased, this causes the Inductive reactance to increase linearly along with it, however, when this frequency change is applied to the capacitor, the capacitive reactance decreased as the frequency increases, though as a curve rather than linearly like the inductive reactance. If these are both plotted on the same graph, the frequency where both plots overlap is the resonant frequency of the circuit. This is the frequency at which the resonant and capacitive reactances are both of equal magnitude, but opposite signs. This then results in the two reactances cancelling each other out [1]. This property means that at this frequency, the impedance is at a minimum [2] [3].

These properties mean that the RLC circuit has a wide variety of real-world uses as the circuit's resonant frequency can be used to "pass" signals at that frequency whilst minimising those at other frequencies, an example of this is in a radio receiver as changing the capacitor value will change the resonant frequency of the circuit and enable you to tune in to a different channel (Frequency) [4]. This circuit can also be re-arranged to have the opposite effect, by connecting the components in parallel rather than in series, the resonant frequency instead becomes the point at which the impedance is at a maximum rather than a minimum. This circuit setup can be used to block signals at the resonance frequency whilst "passing" signals at other frequencies

The rest of this report will consist of a recap of how the lab exercise was performed, giving details such as, equipment used and equations used for calculations where necessary. It will also present the results gained from both simulation and measurement phases of the exercise as well as discuss what these results mean, and why they are what they are.



Lab Exercise:

The lab exercise was started by looking at the RLC circuit presented in the assignment brief and re-creating it in Proteus whilst setting it up to be simulated by including an oscilloscope connected to the input and output of the circuit and an AC waveform generator connected to the input and generating a sine wave. The values of the constituent components in the circuit were a 1K Ω resistor a 1 μ F capacitor and a 1mH Inductor. The Test setup can be seen in the figure below.

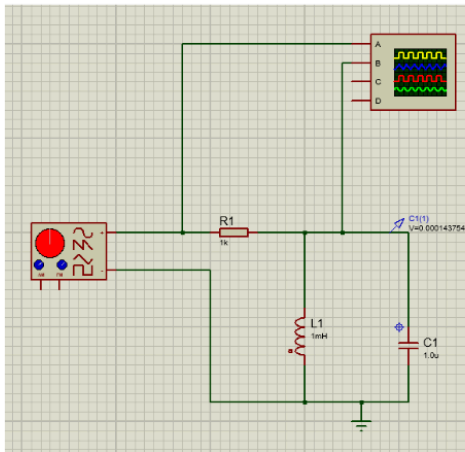


Figure 1: Proteus simulation of the RLC circuit

After this a set of test parameters were chosen, these parameters were, an input wave amplitude of 500mVpk (1Vpp) and for the measurements to be taken at logarithmic intervals from 100Hz to 100KHz, the parameter that was actually being measured would be the amplitude of wave at the output of the circuit. A calculation would then be performed in order to more easily plot the data gathered on a graph. The aforementioned calculation was used in order to convert the difference in amplitude between input and output waves into a value in dB, which was done using the equation $20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$.

After the simulation measurements were recorded, a real version of the circuit was built on breadboard in the workshop. After construction, the real circuit was connected to both a waveform generator and an oscilloscope and the exact same set of measurements that were taken with the simulated circuit, were taken with the real one. And formatted in a graph the same as the simulated circuit.

Results:

Below are the table of results for the simulated and measured results as well as the accompanying graph.

Simulated			
Freq (Hz)	Vin (mVp)	Vout (Vp)	Gain (dB)
100	500	0.000302	-124.3792612
200	500	0.000655	-117.6490063
300	500	0.000958	-114.3528153
400	500	0.00126	-111.9719892
500	500	0.00161	-109.8428826
600	500	0.00192	-108.3133755
700	500	0.00227	-106.8588829
800	500	0.00262	-105.6133743
900	500	0.00297	-104.5242711
1000	500	0.00333	-103.5305154
2000	500	0.00763	-96.32890933
3000	500	0.015	-90.45757491
4000	500	0.0365	-82.7335428
5000	500	0.4	-61.93820026
6000	500	0.04125	-81.67092103
7000	500	0.0225	-86.93574972
8000	500	0.01625	-89.76233278
9000	500	0.0125	-92.04119983
10000	500	0.01	-93.97940009
20000	500	0.00425	-101.4116215
30000	500	0.00275	-105.1927462
40000	500	0.002	-107.9588002
50000	500	0.0016	-109.8970004
60000	500	0.0013	-111.700533
70000	500	0.00115	-112.7654433
80000	500	0.001	-113.9794001
90000	500	0.00085	-115.3910216
100000	500	0.0008	-115.9176003

Table 1: A table showing the simulated circuit results

Measured Results			
Freq (Hz)	Vin (mVp)	Vout (Vp)	Gain (dB)
100	500	0.00472	-100.501
200	500	0.00444	-101.032
300	500	0.00428	-101.351

400	500	0.0048	-100.355
500	500	0.00476	-100.427
600	500	0.00464	-100.649
700	500	0.0053	-99.4939
800	500	0.0055	-99.1721
900	500	0.006	-98.4164
1000	500	0.0065	-97.7211
2000	500	0.01	-93.9794
3000	500	0.016	-89.897
4000	500	0.032	-83.8764
5000	500	0.066	-77.5885
6000	500	0.036	-82.8534
7000	500	0.023	-86.7448
8000	500	0.017	-89.3704
9000	500	0.014	-91.0568
10000	500	0.012	-92.3958
20000	500	0.006	-98.4164
30000	500	0.0048	-100.355
40000	500	0.004	-101.938
50000	500	0.0036	-102.853
60000	500	0.0032	-103.876
70000	500	0.003	-104.437
80000	500	0.00292	-104.672
90000	500	0.0026	-105.68
100000	500	0.00232	-106.67

Table 2: A table showing the real circuit results

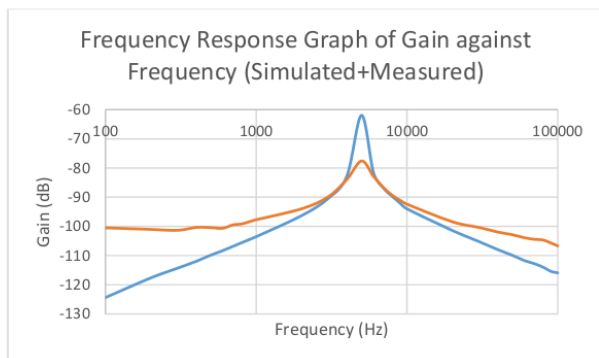


Figure 2: Graph showing gain against frequency for simulated and real results.

After this, the two graphs were separated in order to aid in the calculation of their bandwidth. This was done by taking the highest value of the measurement set and measuring the two points on the graph that intersect with the 70.7% point of that value. Since the values on the graph were plotted in dB rather than mV, an alternative method was used, this involved finding the points on the graph that intersect with the highest graph value but with 3dB subtracted. After this had been done, the

frequency of these two points were recorded as both the lower and upper frequency bounds of the circuit.

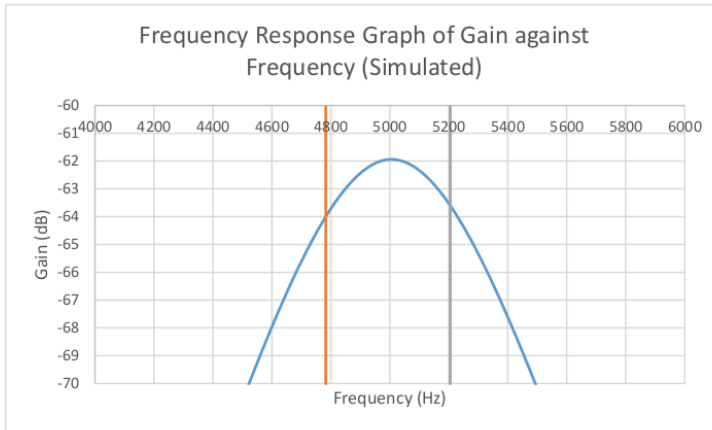


Figure 3: Graph showing the frequency response for the simulated results, used to calculate bandwidth.

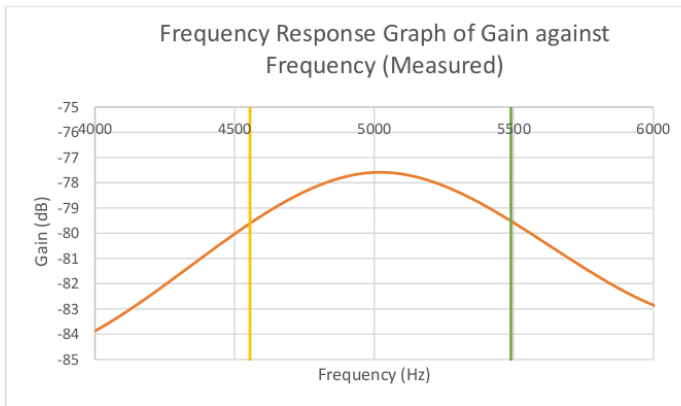


Figure 4: A graph showing the frequency response of the real circuit, used to calculate bandwidth.

By using these upper and lower frequency bounds, other details about the frequency response of the circuit could be calculated, the first of these was the bandwidth of the circuit. This was calculated by subtracting the lower frequency bound from the upper frequency bound. This gave a total bandwidth of 422Hz for the simulated circuit and 935Hz for the real circuit. After this, the exact centre frequency of the circuit could be calculated by taking the upper frequency bound and adding half the bandwidth to it. For the simulated results the centre frequency was 4994Hz and for the real circuit, the centre frequency was 5022Hz. Once the centre frequency of the circuits had been calculated one final set of calculations could be performed. These calculations were to work out the "Q Factor" of the two circuits. This was done by dividing the centre frequency of the circuit by its

bandwidth. The Q factor of the simulated circuit was 11.83, whilst the Q factor for the real circuit was 5.37.



Discussion:

As both sets of graphs show, the gain increases steadily from 100Hz to around 4KHz from which point it drastically increases until it peaks at around 5KHz, the gain then heavily decreases until approximately 6KHz where it then continues to decrease but at a much slower rate where it reaches a level close to where it started at 100KHz. What these graphs show, is that the theory described in the introduction is in full effect within this RLC circuit. From the calculations in the previous section, it can be surmised that the resonant frequency is 5022Hz for the real circuit, before which, we see the gain slowly increasing due to the inductive reactance increasing as well as the capacitive reactance decreasing due to the steady increase in frequency. This then changes at the resonant frequency as both the inductive and capacitive reactance are of an equal magnitude but opposite sign, therefore effectively cancelling each other out and reaching a minimum impedance at 5022KHz [1] [5]. After this point, as the frequency continues to increase past the resonant frequency, the inductive reactance continues to increase whilst the capacitive reactance continues to decrease, resulting in them no longer cancelling each other out and for the impedance to start increasing between the resonant frequency and 100 KHz.

In the previous calculations, the Q factor of the real circuit was calculated to be 5.37 and the Q factor of the simulated circuit was 11.83, this means that compared to each other, the simulated circuit has a narrower bandwidth as indicated by its higher Q factor and thus would be preferred in certain application such as in radios due to having a higher “selectivity” [6]. The difference in measured results between the simulated and real circuits could be caused by a variety of factors, the most likely of which is that when a circuit is tested in circuit sim software like Proteus or other software packages, the components used are often taken as “Ideal” components, meaning that, within the bounds of the simulation, the component works perfectly. An example of this would be that a 100K Ω resistor in a piece of simulation software is always 100K Ω , whereas in reality, the existence of tolerances means that a 100K Ω resistor could be anywhere from 5% – 10% either side of 100K Ω depending on the listed tolerance of the resistor, this same principle can also be applied to most components. Another reason why the results between the simulation and real circuit are different is that the simulation software doesn’t take certain factors into account when simulating the circuit. An example that’s likely applicable in this instance is that the simulation doesn’t take into account the fact that other components have their own inherent resistance, the simulation of the circuit adds no resistive properties to components like the inductor because it’s supposed to be an ideal component, however, when the inductor used in the real circuit was probed for resistance, a value of 71 Ω was recorded. To mitigate issues such as this in future, resistors representing the inherent resistance of certain components could be included in the circuit simulation to provide a more accurate approximation of a real circuit.

Conclusion:

In this experiment, it has been determined that the Q factor of the real circuit is 5.37, this means that the circuit has a moderate degree of selectivity. It has also been found that the bandwidth of the real circuit is 935Hz and that both the aforementioned values differ from the simulated model of the circuit and it has been surmised that these differences in measurements stem from the simulation software not being truly representative of a circuit in reality as it neglects to account for

factors such as the inherent resistance of non-resistor components like the inductor. It has also been concluded that this issue can be mitigated by measuring the inherent resistance of components in the circuit and adding these to the simulation via separate resistors that mimic the various component resistances in the circuit.

References:

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Ref Qual
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[Accessed 04 04 2025].

GD EE Principles assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

67 /100

PAGE 1

PAGE 2

PAGE 3



Comment 1

Good abstract, although you should quantify your results here also.

The simulated circuit had a Q factor of XX, while the practical circuit had a Q factor of only YY.



Comment 2

Do you mean "... inductive and capacitive reactances ..."?



Misplaced apos.

Misplaced apostrophe:

An apostrophe can function to indicate a possessive when accompanied by an -s ("the book that belongs to Roy" = "Roy's book"). For words that already have an -s at the end, just adding the apostrophe will do ("the team belonging to the boys" = "the boys' team"). Certain exceptions to this rule apply, and possessive personal pronouns ("like ours," "yours," "hers," "his," "its") are possessive already and therefore do not take an apostrophe. It is always wrong to use a possessive apostrophe to simply make a word plural.



Comment 3

Only in a series circuit.

In a parallel circuit, the impedance of the capacitor and inductor in parallel tends to infinity (in theory) but in practice it is just very high.

PAGE 4



Comment 4

Good introduction, but I think it was missing some maths to explain X_c and X_L , and maybe a graph.

Nice link to the rest of the report



Comment 5

You shouldn't start a sentence with "And", it is supposed to join sections of a sentence together.

PAGE 5



Comment 6

For the gain in dB, it looks as though you have not got Vin and Vout in the same units. I think you have Vin in volts, not millivolts as shown in the table.

$$20 \times \log(0.000302 / 0.5) = -64.38 \text{ dB}$$

$$20 \times \log(0.000302 / 500) = -124.38 \text{ dB}$$

PAGE 6



Comment 7

Nice graph, although it should have a legend showing which colour is which data.

PAGE 7



Comment 8

I feel this paragraph could benefit from an equation for Q factor.



Comment 9

You could have measured this

PAGE 8



Comment 10

Good

PAGE 9



Comment 11

A second simulation could have been done to prove this.



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.



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GRADING FORM: SMU GENERIC_SMOSEY

GABRIEL DUNNING

66.56

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Engagement with an extensive range of literature. 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.

3.56

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.

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.



Work is accurate, coherent, fluent, well-structured and organised. Demonstrates very good skills for employment requiring the exercise of some personal responsibility, with just occasional minor weakness. You communicate complex technical concepts clearly and concisely, making them accessible to both technical and non-technical audiences.

3