

ELECTRONIC & ELECTRONIC PRINCIPLES ASSIGNMENT

by George Welham

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ELECTRONIC & ELECTRONIC PRINCIPLES ASSIGNMENT

ACDA4006

George Welham
2410225@uwtsd.ac.uk

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Abstract

This assignment discusses the behaviour and analysis of an RLC circuit. Theoretical formulas to calculate the resonant frequency are provided. The circuit will also be explored. This report includes a simulation using Proteus, real-world measurements, and a comparison, which finds that component tolerances and internal resistances must be considered to accurately calculate the resonant frequency and Q factor.

Introduction

Resistor, inductor, and capacitor circuits (RLC) are used in a wide range of alternating current (AC) applications. RLC circuits can function as filters or in tuning circuits found in audio or radio frequency equipment. RLC circuits can be constructed in a variety of configurations to achieve different functions based on the resonance caused by the capacitor and inductor.

This report will show an RLC circuit being simulated and measured, which performs as a bandpass filter. Alternatively, by changing the connections of the resistor, inductor, and capacitor, the same components can be used to create other filters, such as low-pass and high-pass filters.

The example RLC circuit utilises a parallel LC circuit, also known as a tank circuit, to generate the resonant frequency. If the capacitor is initially charged, as it begins to discharge, current passes through the inductor, creating an electromagnetic field that stores energy transferred from the current. Once the capacitor's energy is discharged, the current decreases. This causes the magnetic field around the inductor to collapse, transferring energy back into electrical current, which re-charges the capacitor. This cycle then repeats. In an ideal LC circuit, there is no resistance in the wires, the inductor, or the capacitor, so the energy would continue to be transferred between the capacitor and the magnetic field generated by the inductor. This would cause a stable oscillation.

Unlike in theoretical calculations, in practical applications, resistance is present in components and wires. Over time, the resistance transfers the energy into heat using Ohm's law; this energy is not transferred back into the circuit, so the total energy is reduced. This causes the oscillation to be damped, resulting in a reduction of the current flow over time.

The resonant frequency of the LC circuit can be theoretically calculated by using:

$$f_0 = 1/2\pi\sqrt{LC}$$

Using the simulated values seen in Figure 1 and the example circuit, the resonant frequency can be calculated as follows:

$$f = 1/2\pi\sqrt{(1 \times 10^{-6})(1 \times 10^{-3})}$$

Therefore;

$$f = 5032.9 \text{ Hz}$$

The second metric vital to filters is the Q factor, which represents the sharpness and shape of the peak. In some applications, the Q factor must be as high as possible to pass only a narrowband signal. This can be achieved by decreasing the resistance, either in the wires or the inductor and capacitor. Opposite this, a resistor can be added to reduce the Q factor and, therefore, flatten the peak. [3, p. 54]

The Q factor can be calculated from known values by:

$$Q = \omega RC$$

Citation Needed

Where;

$$\omega = 1/\sqrt{LC}$$

Caption required

For the values in Figure 1;

$$\omega = 31623 \text{ rad/s}$$

$$Q = (31623)(1000)(1 \times 10^{-6})$$

$$Q = 31.623$$

Caption required

This Q factor is higher than the simulated measured value discussed later on page 6; however, this theoretical calculation does not account for resistance within the capacitor or inductor. Practically, the Q factor can also be used to determine the bandwidth of the circuit. This can be achieved by using; [4]

$$BW = f_0/Q$$

Caption required

Citation Needed

An application of the RLC circuit, as seen in the brief's example circuit, could be used as a Bandpass filter. A bandpass filter uses the resonant frequency generated by the LC network and the shape of the peak, determined by the resistance of the circuit, to filter all but selected frequencies. A Bandpass filter like this may be used for an application to attenuate unwanted spurious transmission. By changing the connections of the resistor, inductor, and capacitor, the same components can be used to create other filters, such as low-pass and high-pass filters.

Additionally, changing the values of the inductor and capacitor will change the resonant frequency. For a lower resonant frequency, the inductance can be increased or the capacitance decreased. Conversely, to increase the resonant frequency, the inductance must decrease, or the capacitance must increase.

Simulation method

The circuit was simulated in Proteus 8 Professional using generic components.

Figure 1 shows the values of components used in the circuit.

Component	Value
C1	1uF
R1	1K Ohms
L1	1mH

Figure 1 RLC component value

The circuit was designed as seen in Figure 2. R1(1) is an AC input set to 1V peak to peak. This remains the same during testing. On the right of Figure 2 is the frequency response graph. This is set as R1(1) as a reference for the frequency. R1(2) is a voltage probe; this is the data corresponding to the Y axis on the graph.

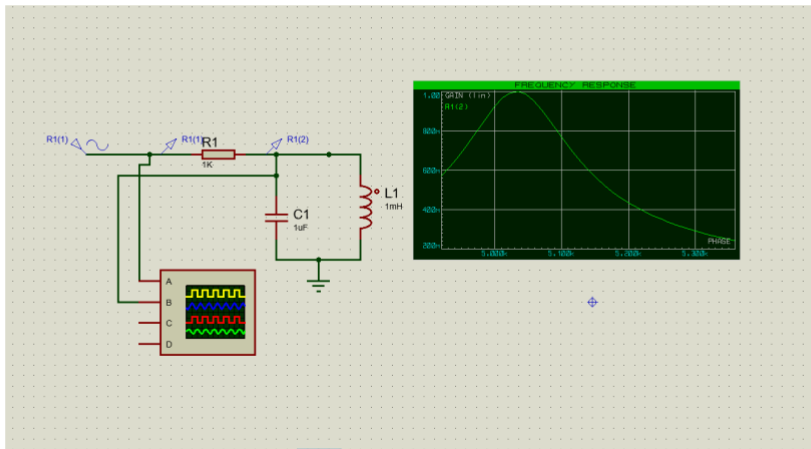


Figure 2 Cropped Screen of Resistor, Capacitor and Inductor circuit in Proteus

Additional measurements were made around the resonant frequency to increase precision. The data from the simulation was then exported to an appropriate application like Microsoft Excel.

The gain of the circuit can be calculated using the equation:

$$Gain = 20 * LOG_{10}(V_{out}/V_{in})$$

Caption required Citation Needed

Simulated Results

Frequency (Hz)	Vin (mV Pk)	Vout (mV pk)	Simulated Gain (dB)
100	500	0.3	-64.4
200	500	0.65	-57.7
300	500	0.9	-54.9
500	500	1.5	-50.5
1000	500	3	-44.4
2000	500	7.63	-36.3
3000	500	15	-30.5
4000	500	36	-22.9
4700	500	137.5	-11.2
4900	500	360	-2.9
4950	500	430	-1.3
5000	500	405	-1.8
5032	500	345	-3.2
5100	500	240	-6.4
5300	500	115	-12.8
6000	500	41	-21.7
8000	500	16	-29.9
10000	500	10	-34.0
20000	500	4	-41.9
30000	500	2.5	-46.0
50000	500	1.5	-50.5
100000	500	1	-54.0

Figure 3 Simulation result of RCL circuit



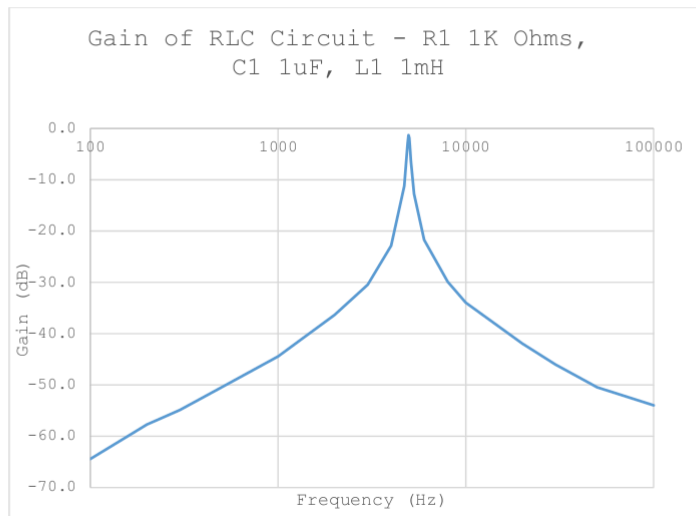


Figure 4 Graph of simulated RLC attenuation

Using the data found in Figure 3, the resonant frequency of the RLC circuit is 4950 Hz. The Q-factor of the circuit can be found using the equation:

$$Q = f_0 / \Delta f_{3dB}$$

Where f is the resonant frequency of the simulation, 4950 Hz, divided by the width at the -3 dB points.

The Q factor for this simulation is calculated as 26.

Figure 4 illustrates that all frequencies outside of the bandwidth at the resonant frequency would be attenuated. For example, if this filter were used before a speaker, the power of all other frequencies would be attenuated and reduced, leaving the frequencies close to the resonant frequency the loudest.

Breadboard Measurements

The values of components selected for practical testing were the same as those found in Figure 1. However, physical components have a manufacturing tolerance. Therefore, components were measured using an LCR meter to determine their true value. The resistance of the inductor was also measured.

Component	Value
C1	1.041uF
R1	1K Ohms
L1	1.00mH
L1 (resistance)	7.1 Ohms

Figure 5 Measured component values

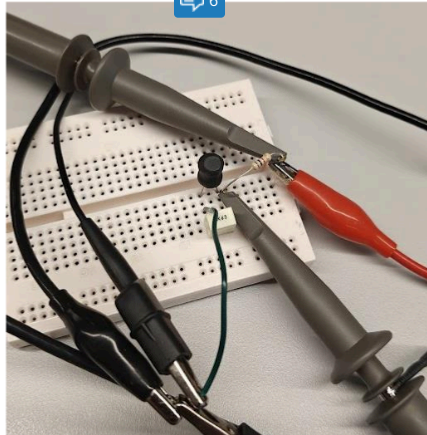


Figure 6 Picture of RLC circuit being measured

The voltage of the circuit was measured using a multichannel oscilloscope. Channel 1 was connected to the input source, a signal generator which was set to a 2V peak-to-peak sine wave. Channel 2 was connected to the output of the circuit. The Frequency of the signal generator was increased with additional measurements around the calculated resonant frequency.

Frequency (Hz)	Vin (mV)	Vout (mV)	Measured Gain (dB)
100	1940	16	-41.6736
200	1940	16	-41.6736
300	1940	16.8	-41.2498
500	1940	16.8	-41.2498
1000	1940	21.2	-39.2293
2000	1940	34.8	-34.9244
3000	1940	60	-30.193
4000	1940	119.2	-24.2305
4200	1940	140	-22.8335

4250	1940	148	-22.3508
4300	1940	152	-22.1192
4700	1960	204	-19.6525
4800	1960	212	-19.3184
4900	1960	220	-18.9967
4950	1960	220	-18.9967
5000	1960	220	-18.9967
5032	1940	220	-18.9076
5100	1960	220	-18.9967
5200	1940	216	-19.067
5300	1960	204	-19.6525
5800	1940	153.6	-22.0282
5870	1940	147.2	-22.3979
5900	1940	144.8	-22.5407
6000	1960	136.8	-23.1234
8000	1920	62.6	-29.7345
10000	1920	41.6	-33.2842
20000	1920	16.94	-41.0878
30000	1920	11.28	-44.6198
50000	1920	7.2	-48.5194
100000	1960	4	-53.8039

Figure 7 Measured RLC results



The measured results in Figure 7, in comparison to the simulated results in Figure 3, perform differently. This can be seen in Figure 8.

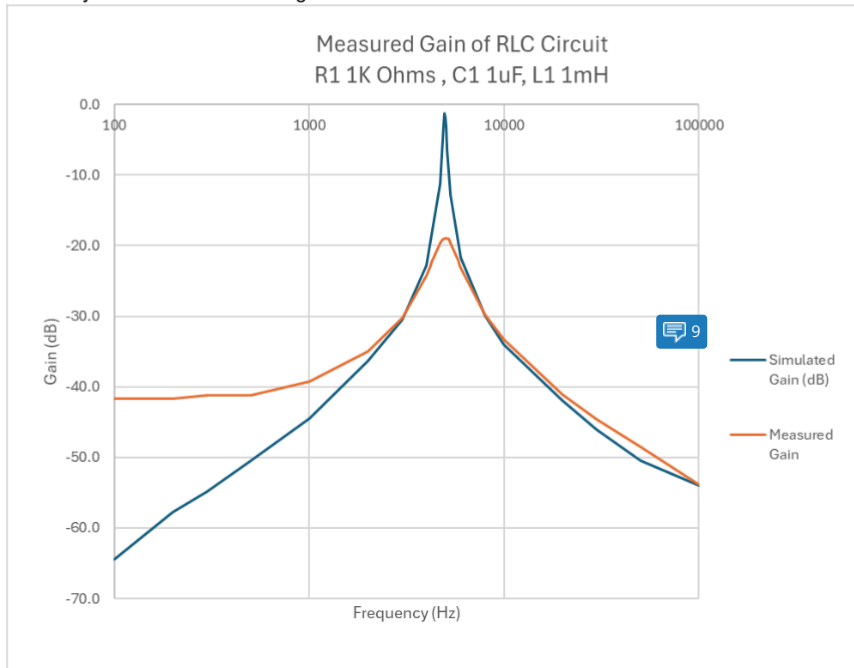


Figure 8 Simulated and measured gain compared

Comparison

Firstly, the peak gain at the resonant frequency for the measured gain does not exceed -18.9 dB, resulting in a high loss of the signal at the resonant frequency. Compared to the simulated gain, performing well at -1.3 dB, close to the resonant frequency.

Secondly, the physical circuits' resonant frequency matches the calculated theoretical value. Whereas the simulated gain is measured 60Hz lower than the theoretical calculations. This could be a result of an error within the simulation or the method used to record it. However, it was repeatable.

Thirdly, the Q factor of the practical circuit is less than that of the simulated and the theoretical. The practical circuit Q factor is 3.3, significantly lower than the simulated value of 26. This is due to the components having a resistance that damps the circuit and transfers the energy into heat, as well as the high loss at the resonant frequency.

This test shows the importance of measuring practical circuits as well as using theory and simulation, as results may vary depending on a variety of factors including the internal resistance of components and wires. Using the measured values of the components. The circuit can be re-simulated to give increased accuracy.

Using the measured values of the components and the internal resistance of the inductor, the simulation could be updated to more accurately reflect the performance of the circuit.

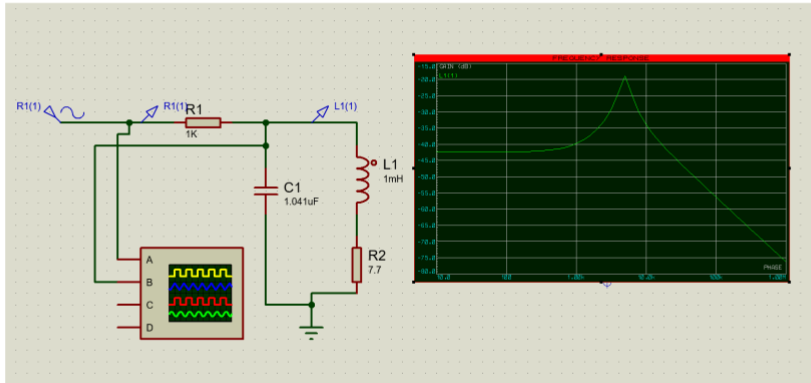


Figure 9 Simulation in Proteus Professional with updated component values

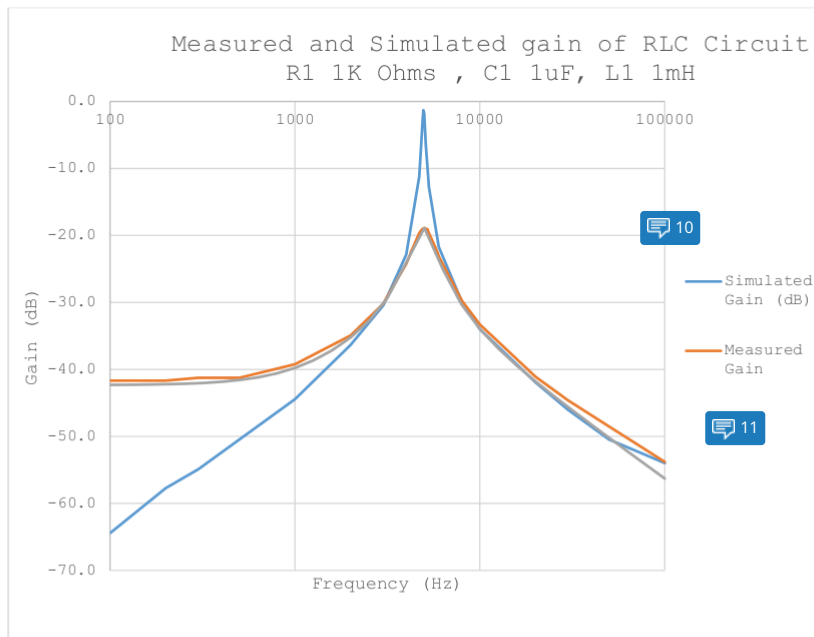


Figure 10 Comparison of simulated, measured and re-simulated gain

The grey line on the graph shows the resimulated data, which follows the trend of the measured gain. This shows that the original simulation did not consider the resistance of the

inductor and therefore caused the simulation to unrealistically perform better than what would be achievable practically.

Conclusion

RLC, LC, and resonant circuits are essential to understand when designing mixed-signal or AC circuits. In this report, it has been determined that the frequency and Q factor have a direct relation with the values of the components. And, in the example circuit, a bandpass filter with a centre frequency of 5032 Hz can be generated. Additionally, the report includes how to calculate, simulate and test these circuits, which reduces the likelihood of faults caused by miscalculation or errors when considering tolerances or component resistances.

Bibliography

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ELECTRONIC & ELECTRONIC PRINCIPLES ASSIGNMENT

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

79/100

PAGE 1

PAGE 2

PAGE 3

QM

Abstract - results

Good abstract, although you should include a statement of your results.



Comment 1

This should be before the full stop if it is referencing the sentence that reads "RLC circuits can function or radio frequency equipment". If it belongs to the next sentence, then it should be at the end of that sentence before the full stop.



Comment 2

Good

QM

Citation Needed

Cite Source:

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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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**Comment 3**

Table 1

**Comment 4**

Circuit diagram showing connection of resistor, capacitor and inductor

QM

Sp.

Spelling error

QM

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PAGE 6



Comment 5

Table 2.....

PAGE 7

PAGE 8



Comment 6

Table 3....



Comment 7

Is this needless detail?

PAGE 9



Comment 8

Table 4

PAGE 10



Comment 9

Nice graph

PAGE 11



Comment 10

excellent



Comment 11

The legend does not show what the grey data series represents

PAGE 12



Comment 12

Excellent work.

PAGE 13

GEORGE WELHAM

78.85

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Engagement with an appropriate range of literature, including sources retrieved independently. You have used relevant and credible sources. Consistently accurate application of referencing. Some omissions or minor errors.

3.35

KNOWLEDGE & UNDERSTANDING

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



Exceptional, detailed knowledge and understanding of the basic underlying concepts and principles

24

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.



Exceptional evaluation of the underlying concepts and principles based evidence. Outstanding interpretation of qualitative and quantitative data. Exceptional ability to devise arguments using evidence and make wholly appropriate and valid judgements.

25.5

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.

22.5

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