

Sam Parker Electronics Assignment

by Samuel Dylan Parker

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ACDA4006 Electrical and Electronic Principles
Assignment

Sam Parker

1. Abstract

An LC circuit was simulated in a perfect environment (Proteus) and then built using real components. The output voltage was measured against the frequency, and the resonant frequency was established. The Q factor for both the real and simulated results was also calculated. The results showed that the correct theoretical trend was followed, but that the simulated environment overestimates the output voltage due to missing out the internal resistance of components.

2. Introduction

The circuit in question is something known as an LC circuit, and is formed when a inductor and capacitor are connected in series or in parallel. The example that has been covered in this exercise is the parallel LC circuit, shown in figure 1 below. The purpose of this assignment was to build a parallel LC circuit both in a simulated state (e.g. proteus) and then compare measured results with a circuit made using real components. LC circuits show the phenomenon of resonance when the reactance of both the capacitor and inductor are equal ($X_L = X_C$). At resonance the current and voltage will be in phase, the impedance is at its maximum, and the current is at its minimum point [1]. The peak height of the voltage is controlled by the input voltage, and the values of any resistors included before the LC part of the circuit.

A common practical use of this type of circuit is known as a tank circuit which are often used in radio transmitters and receivers. These circuits require a capacitor and inductor and work by changing the resonant frequency of the circuit, to tune into different radio stations. When the circuit is at the resonant frequency, it will only allow that frequency to be 'heard', meaning that the other frequencies will be filtered out and so you only hear the station that you have tuned into. Another practical use comes from power factor correction.

Power factor works by correcting a lagging power factor, caused by the inductor/resistor part of the circuit by adding a capacitor in parallel. This capacitor draws a current, known as a leading current that cancels out the reactive component going through the resistor and inductor. If the capacitor draws the correct amount of current and balances out the reactive component, then the supply current would be perfectly in phase with the resultant current. This would help reduce wasted energy by controlling the reactive power consumption. In a home scenario, this would result in savings on energy bills [2].

LC circuits can also behave as oscillators. This occurs when the capacitor discharges, causing the current to drop to zero and a new current to be induced of the collapsing magnetic field of the inductor. This drives a new current onto the capacitor causing the polarity to change. If the capacitor discharges again, but in the other direction then this cycle will repeat itself and the current will keep momentarily changing direction, known as oscillation. When there is resistance in the circuit, it will dampen out the oscillation [3].

The theory behind LC circuits is governed by reactance (X) and impedance (Z) of the circuit. Both the inductor and capacitor have a reactance, and in an ideal world

contribute no resistance (this is not the case in real life but will be discussed later). The current and voltage in an LC circuit still obey Ohm's law, but this time can be expressed as $V = IZ$. As stated, Z is the impedance of the circuit and is given by the equation below.

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad [4]$$

The rest of this report will outline the experimental procedure that has been used, a results section for the data that was obtained, followed by a discussion section analysing and interpreting the results. This will be followed up by a conclusion setting out the technical findings of the report.

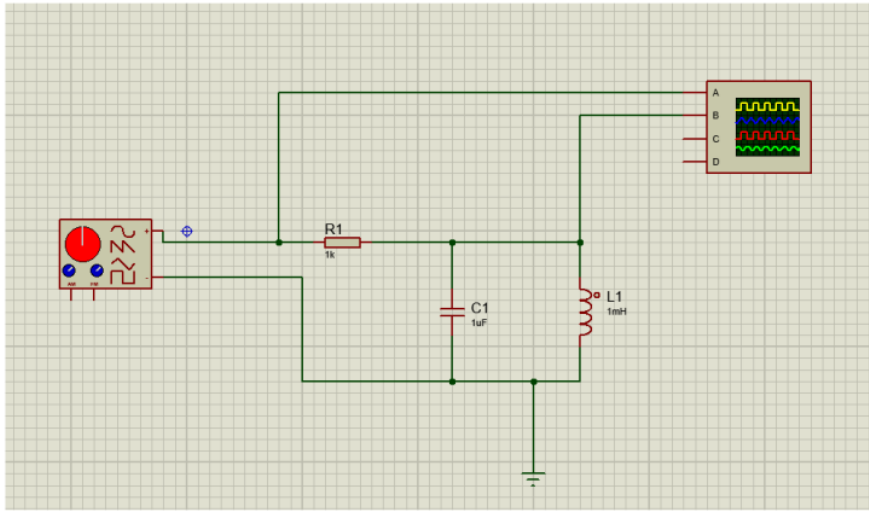


Figure 1 - Parallel RLC Circuit

3. Simulation Steps

To start, the RLC circuit (figure 1) was simulated in Proteus. The oscilloscope was setup to measure the voltage (V_{out}) across the resistor and inductor/capacitor, while the signal generator was set to 100Hz with a voltage of 2 V_{pk-pk}. The frequency was the variable that was changed, and it was measured in increments that got smaller the as the resonance frequency of 5032.9121 was approached. Values ranged from 100hz – 20000hz. The resonant frequency was calculated via equation 1 shown below, where C is the value of the capacitor in farads, and L is the value of the inductor in Henrys. The values used for the parts were 1k Ohms for the resistor, 1μF for the capacitor and 1mH for the inductor.

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} \quad [5]$$

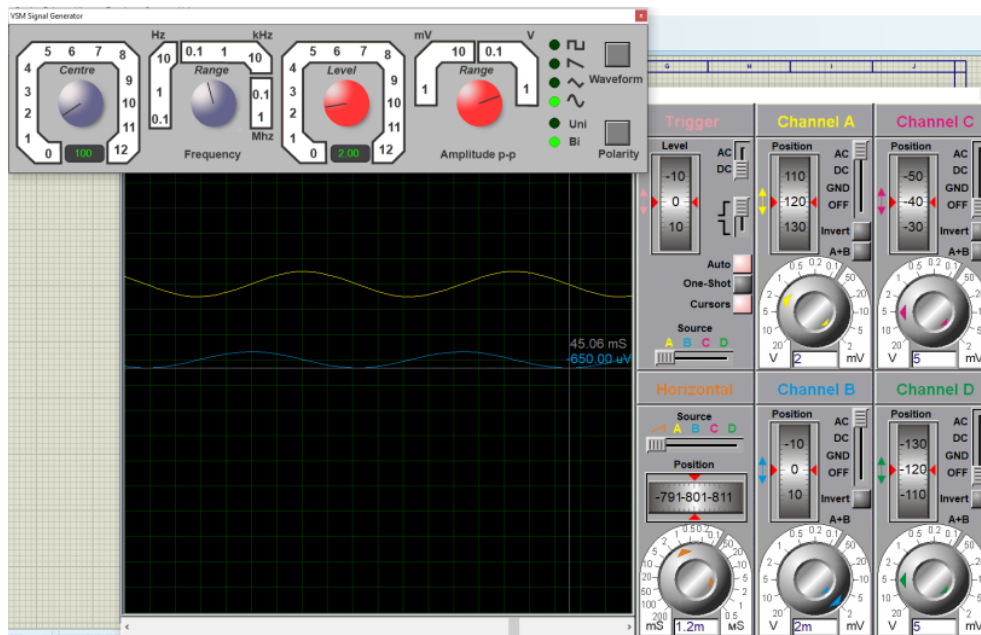


Figure 2 - Waveform at 100Hz

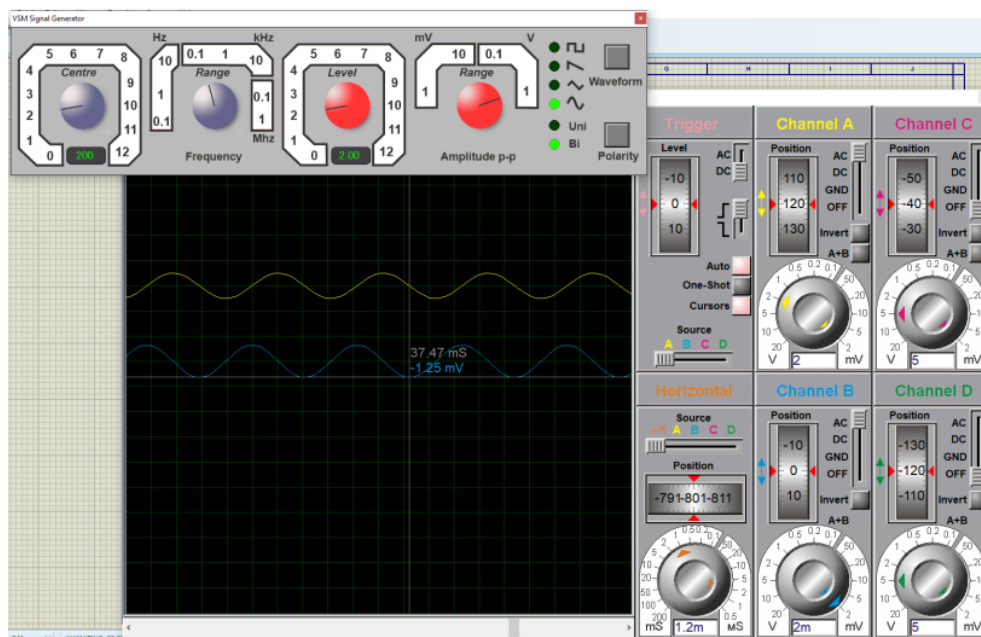


Figure 3 - Waveform at 200Hz

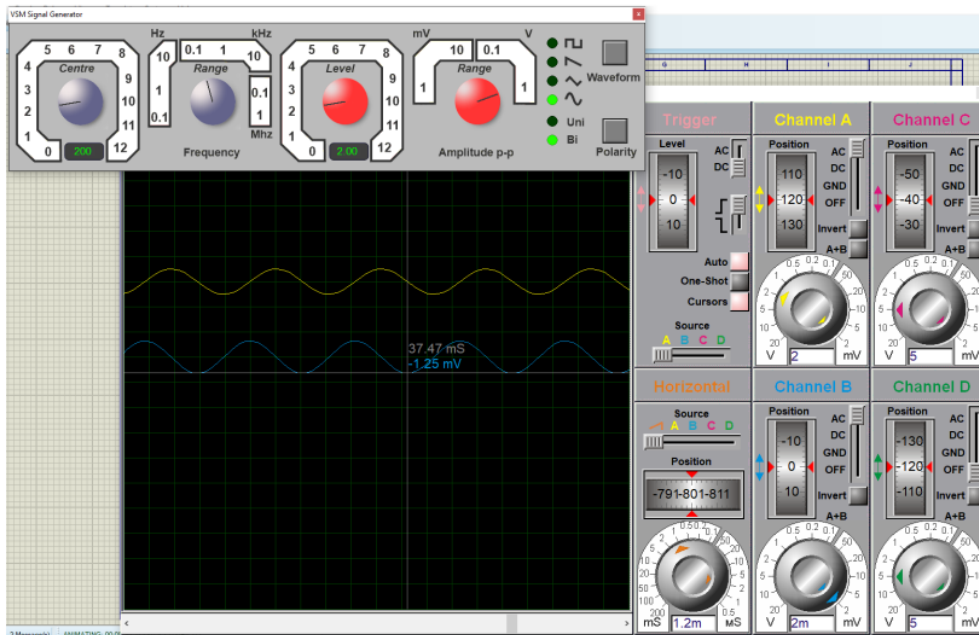


Figure 4 - Waveform at 10000Hz

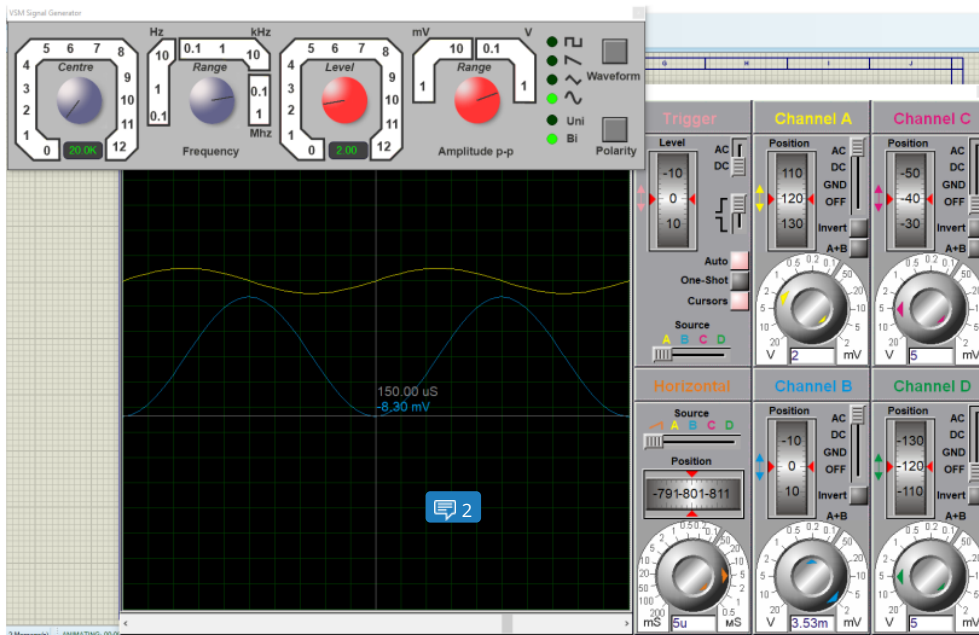


Figure 5 - Waveform at 20000Hz

Figures 2-5 show how the signal generator frequency was altered, and then how the peak – peak output voltage was measured. The cross hair was set at the max positive or negative point of the waveform created from channel B (the output voltage across the resistor and inductor/capacitor). To determine the peak amplitude (and so the total voltage) the value obtained from centring the crosshairs was doubled.

Next, the circuit was made with real components on a breadboard, as shown below in figure 6. The components used were designated to have the same values as in Proteus, those being a resistor of 1000Ω , an inductor of 1mH and a capacitor of $1\mu\text{F}$. An oscilloscope was connected which again measured the voltage across the resistor and inductor/capacitor. The breadboard was connected to a power supply that was capable of altering the frequency and the input voltage was again set at 2V peak-peak. Figure 7 shows an example of the oscilloscope reading at as close as possible to the resonant frequency. It also shows the signal generator displaying the frequency that is being supplied. The frequencies for which the voltage was measured was kept as similar as possible to those used in the simulation Proteus ensuring that the results were comparable. The oscilloscope shows the peak-peak voltage and so the value does not need to be doubled like when Proteus was used. To adjust the frequency of the supply generator switches were used to set the increment, and the knob was turned to adjust the number of Hz up or down.

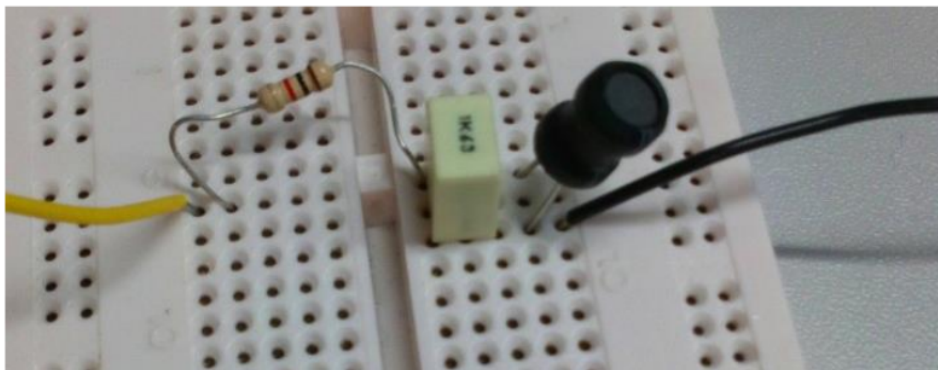


Figure 6 - RLC Breadboard Circuit

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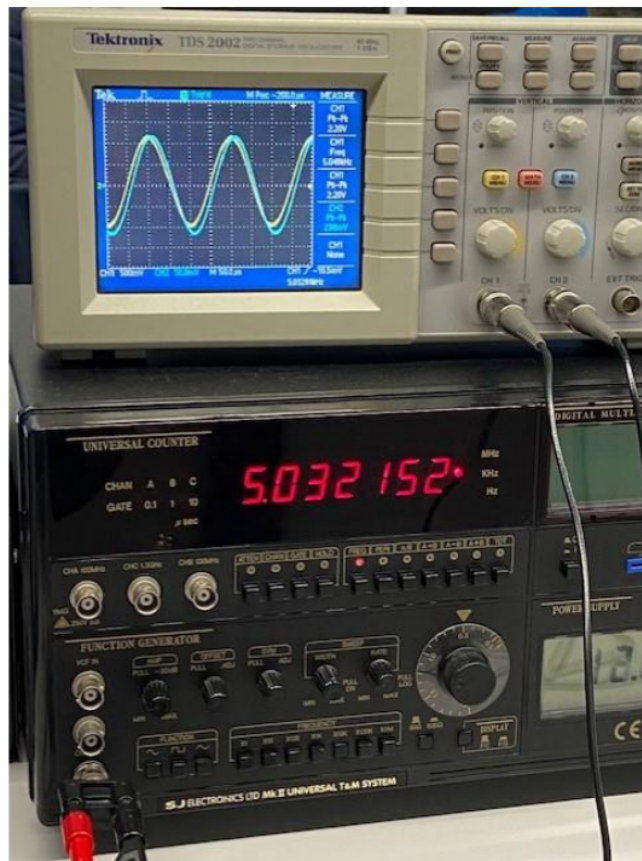


Figure 7 - Real circuit at resonance

4. Results

A log graph of frequency vs V_{out} was plotted for each experiment (the Proteus simulation and physical circuit). From each graph the bandwidth was by taking 70.7% of the peak voltage, and then finding both the frequencies that meet the value, then finding the difference between. The Q factor was then calculated by dividing the resonant frequency by the bandwidth.

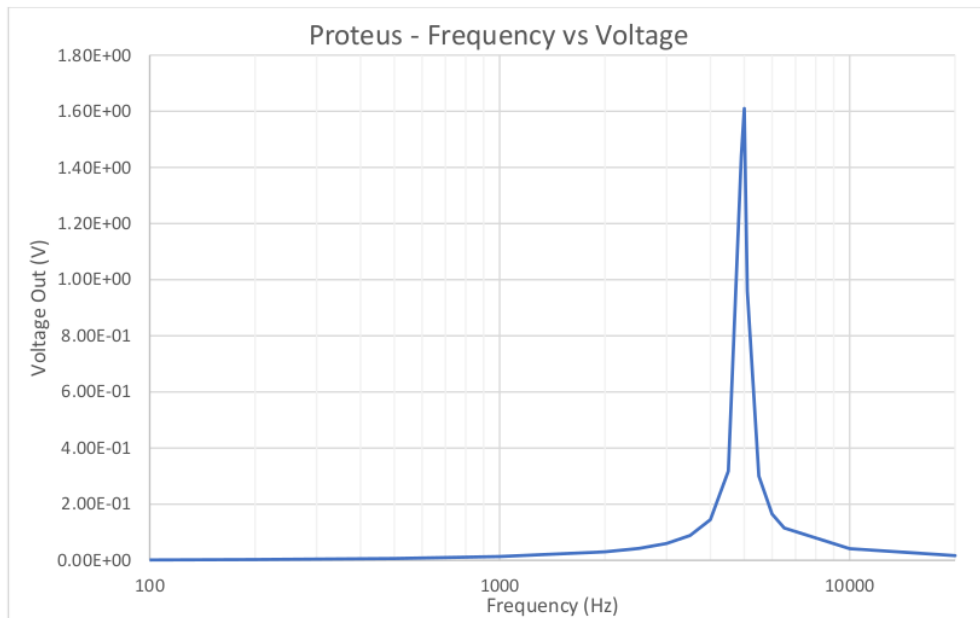


Figure 8 - Proteus Frequency vs Voltage

Figure 8 above shows how the voltage changes with the frequency. As is clear, the voltage spikes sharply at the resonant frequency. Since we already know that the impedance is at its maximum when the circuit is at resonance, and in a parallel RLC circuit the voltage will have the same shape as total impedance, this is the result that should be expected [6].

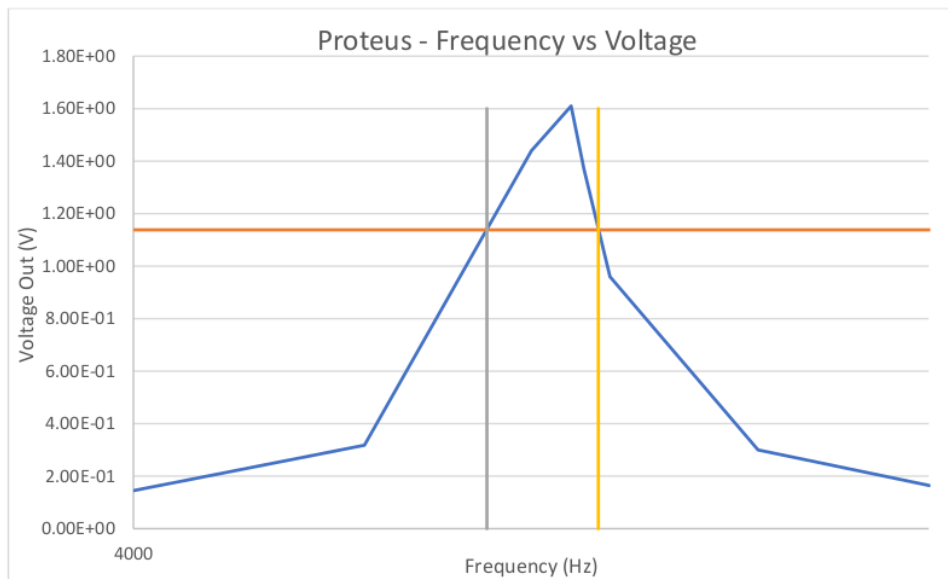


Figure 9 Proteus Q Factor Calculation

Figure 9 shows how the bandwidth and Q factor were calculated. The horizontal line represents 70.07% of the peak voltage, and the 2 vertical lines show the frequencies at which the horizontal line is met. The left hand vertical line had a value of 4790Hz and the right hand one had a value of 5070Hz making the bandwidth 280Hz. The previously mentioned resonant frequency divided by the bandwidth gave a value of 17.97 for the Q factor of the Proteus experiment.

Next, the same process was repeated for the results obtained via the real circuit. Figure 10 below shows the frequency vs the voltage across the resistor and capacitor/inductor. As you can see, it has followed the same shape as for the perfect simulation in Proteus. This indicates that the real circuit is behaving as the theory suggests and is resonating at approximately the correct frequency. The V_{out} is significantly lower than for the Proteus circuit, for which an explanation will be provided in the discussion section.

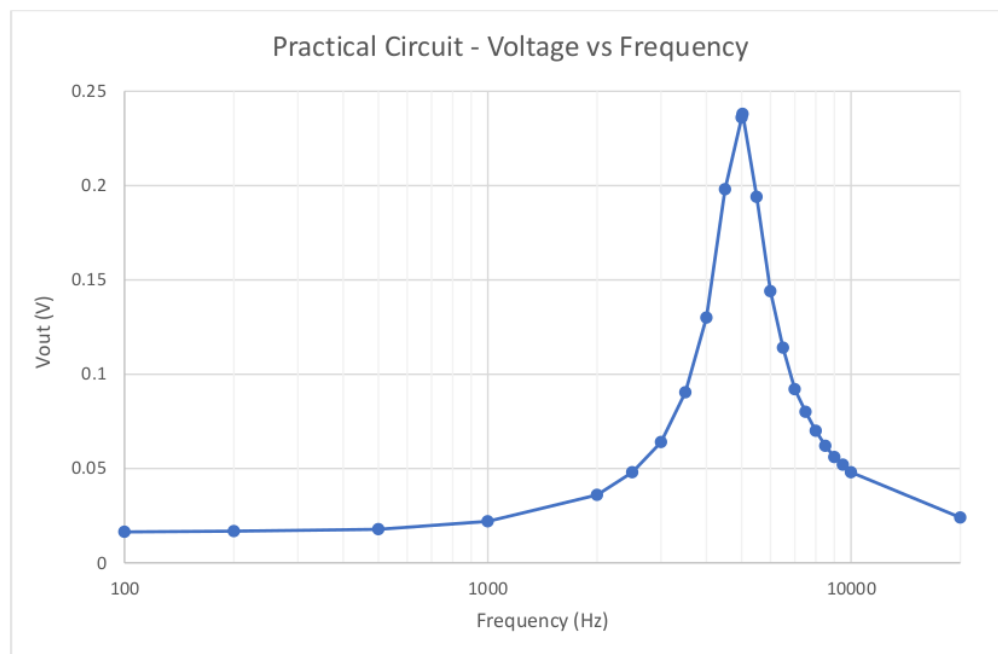


Figure 10 - Real circuit frequency vs voltage

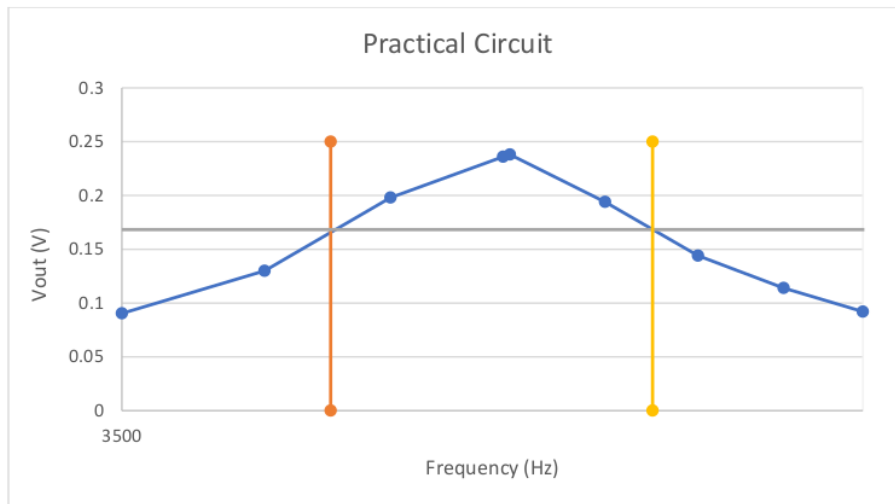


Figure 11 - Real circuit Q Calculation

Figure 11 shows the same technique for finding the Q factor of the real circuit. The left-hand vertical line in this case crosses at 4255Hz, and the right hand at 5750Hz. This means that the bandwidth for the real circuit is 1495Hz, thus making the Q factor 3.367. Clearly the Q factor for the practical circuit was much lower than that from Proteus, meaning that peak is much less sharp. Another observation from the practical circuit that has varied from the circuit in Proteus is the fact that the voltage being put into the circuit increased in real life, whereas it remained constant in Proteus. A graph showing this has been included as figure 12. As the frequency approached the resonant frequency, the voltage in reached its peak value, and then began to fall off as the frequency increased beyond the resonant frequency. It should be noted that the input voltage was not being changed on the signal generator, and instead has arisen due to the nature of the circuit.

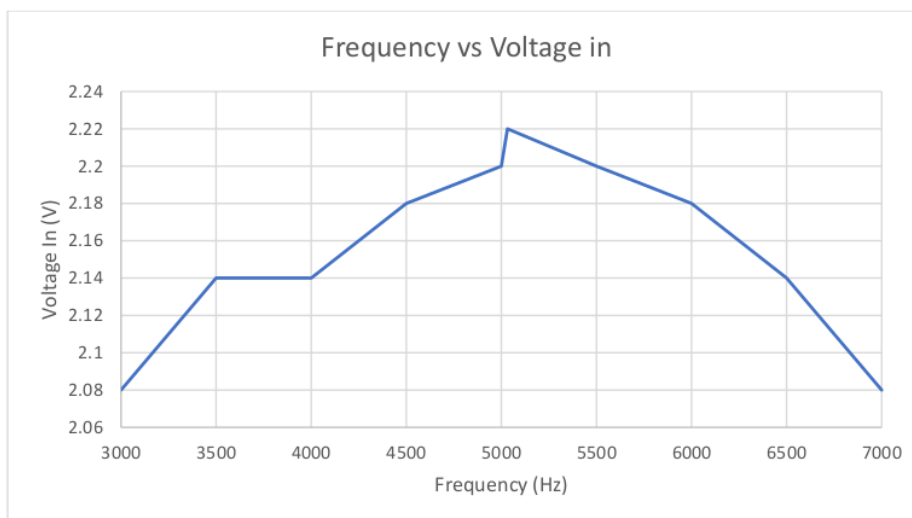


Figure 12 - Frequency vs Voltage In - Real Circuit

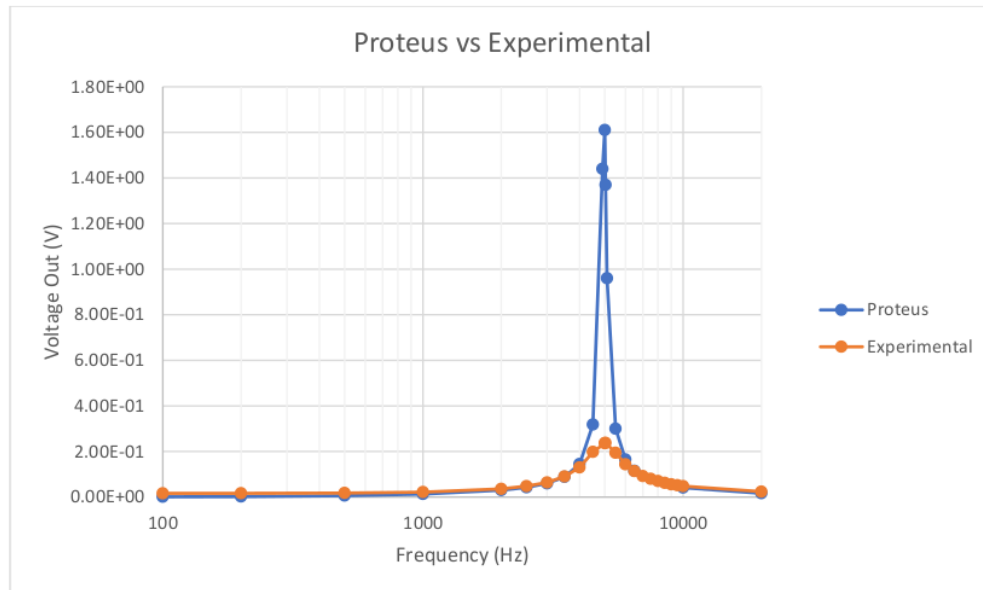


Figure 13 - Proteus vs Practical

Figure 13 above shows the data generated from Proteus on the same graph as the values obtained from the experimental procedure. This graph has made it far easier to visualise the significant difference between the two circuits. Clearly, the example in Proteus is generating a much higher output voltage than the real circuit, and the peak is much sharper which is reflected by the Q factor values.

5. Discussion

The results show that there is a clear disparity between the real world, and the Proteus simulation environment. In the real world, the output voltage is significantly lower than the model predicts. As Proteus is a perfect simulation, the components used will have no in-built internal resistance, and the internal resistance of the power supply will not be taken into account unless specific resistive components are added. For example, in Proteus it has been assumed that the parts are ideal, and have no internal resistance and so meaning that the imaginary part (the reactance, X) of the impedance (Z) is equal to zero [7]. In reality, the components will have some internal resistance causing the output voltage to drop. To account for this, the simulation was re-ran with the measured values of the resistor, inductor and capacitor, as well as their respective resistance. The resistor, $R1$ was changed to 979Ω , the inductor was changed to 0.994mH and a resistor of 7.32Ω was added to represent the internal resistance of the inductor. Finally, the capacitor was

assigned a capacitance of $1.064\mu\text{F}$. The internal resistance of the power supply was also included, which was 50Ω , shown by R3 in figure 14.

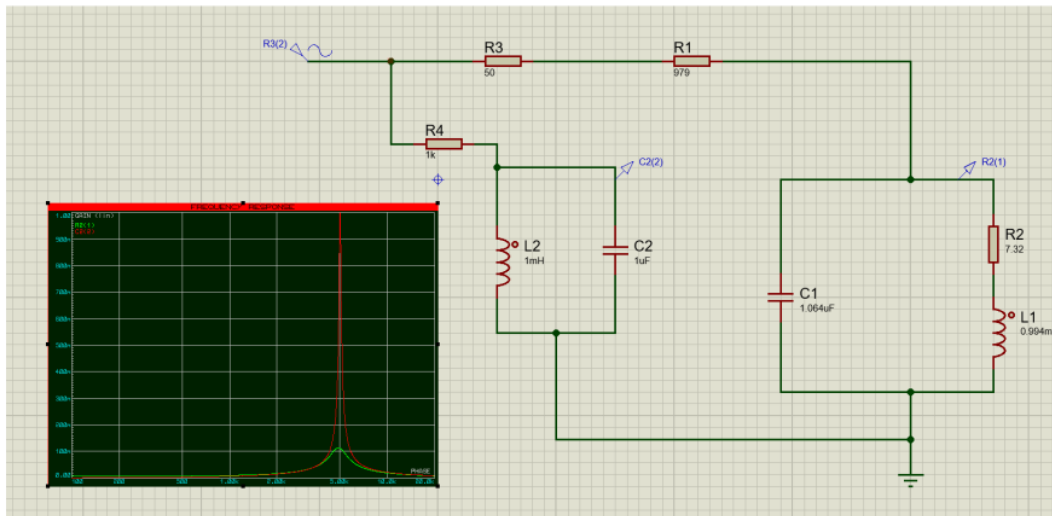


Figure 14 - Circuit with Ideal and Internal Resistance

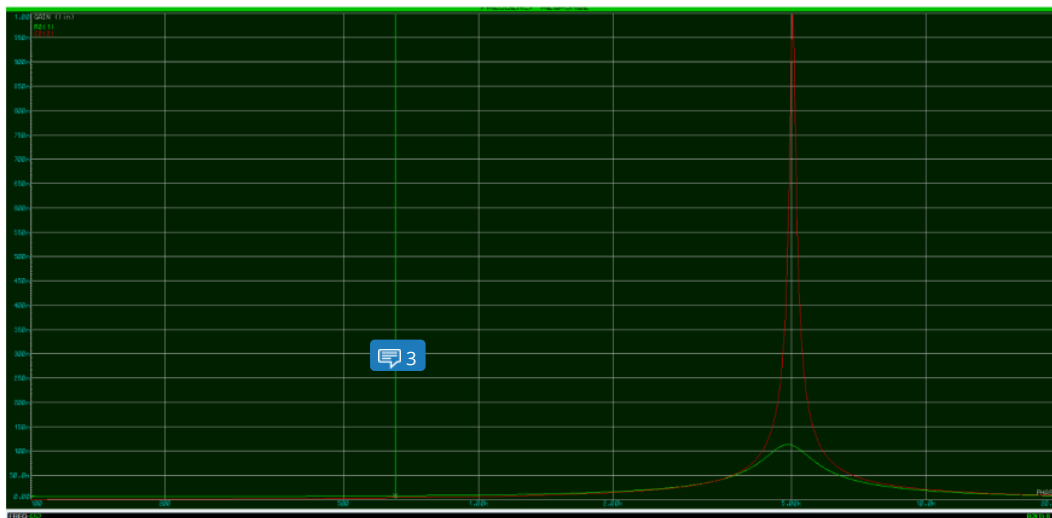


Figure 15 - Internal Resistance vs Ideal

Figure 14 shows both the original Proteus circuit and a new circuit which takes into account the internal resistance and uses the measured values for the components used in the practical. The voltage was then taken across the resistor and capacitor/inductor for both circuits, and figure 15 shows the graph of frequency vs voltage. The red line depicts the original Proteus circuit, whereas the green line shows the new circuit voltage when

considering the internal resistance. Clearly, when the internal resistance has been taken into account, the results generated are much more representative of those found in real life. When adding the internal resistance, you change the components from being ideal into a real one. This means that there will be a real value for the resistance for both the inductor and capacitor, and not just the imaginary part that occurs in an ideal world. This can be shown by the equation below. In an ideal scenario, $R = 0$, but adding the internal resistance changes this.

$$Z = R + jX \text{ [8]}$$

This additional resistance also explains why the Q-factor is much lower for the real circuit. It is often the case that a 'Q-spoiling' resistor is added to a parallel LC circuit to deliberately reduce the sharpness of the peak at the resonant frequency, and so reducing the Q factor. Clearly then, the additional resistance reduces the Q factor which explains why when there is the added internal resistance, the Q factor is much lower [9].

In addition to the inductor and capacitor resistances being inaccurate in the original simulation on Proteus, the value for the resistor, R_1 will also be an overestimate. This was shown as the measured value for the resistor was 979Ω , not the 1000Ω that was originally used. This discrepancy was caused by the fact that real resistors have something called a tolerance. A tolerance is a percentage value given to the resistor by the manufacturer that provides the allowance of Ω either side of the stated value.

6. Conclusions

In this experiment it has been determined that LC circuits display resonance at a particular frequency. When the simulation is ran in a perfect environment (e.g. Proteus), the output voltage across the resistor and the capacitor/inductor is significantly higher than the value you would expect to see when building the circuit from real components at resonance. This is due to the fact that the internal resistance of the components in question, as well as the power supply is not being accounted for if you simply put the 'vanilla' components in on Proteus. It has been shown that it is possible to get a better representation in Proteus when these extra factors are added onto the simulation parameters. Overall, the real experiment follows the correct trend that the model predicts thus showing that resonance does occur in an LC circuit.

Colloquialism

References

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- [2] M. Brown, Power Sources and Supplies, Newnes, 2007.
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- [7] P. Horowitz and W. Hill, The Art of Electronics 3rd Edition, New York: Cambridge University Press, 2015.
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- [9] A. Simon, "TEACHING RLC PARALLEL CIRCUITS IN HIGH-SCHOOL PHYSICS CLASS," vol. 8, no. 4, pp. 33-45, 2015.

Sam Parker Electronics Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

70/100

PAGE 1

PAGE 2

PAGE 3



Comment 1

All variables can be changed.

Do you mean independent variable?

PAGE 4

PAGE 5



Comment 2

Are these figures really needed?

PAGE 6



Citation Needed

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PAGE 7

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PAGE 9



Comment 3

Axis labels are not clear



Comment 4

Too informal.



Comment 5

Tolerance is not something specific to resistors, it is used throughout science, engineering and manufacturing.



Colloquialism

You should not use colloquialisms in formal writing.



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.



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

SAMUEL DYLAN PARKER

69.90

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.

3.4

KNOWLEDGE & UNDERSTANDING

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

-  Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.

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, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity and significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions

20.4

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with extensive use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.

21.6

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.



Can communicate professionally and, confidently in a suitable format. Work is coherent, very fluent and is presented professionally.

3.5