

JT1810310 E&EPASS

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Comparison of Theoretical Computational and Practical Series RLC Circuits with Respect to Resonance.

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Executive Summary:

A demonstration of understanding the basic underlying concepts of electrical and electronic principal theory in relation to resonance, Q factor and basic RLC circuits. A theoretical exploration, a computational simulated navigation and practical exercise of the same RLC circuit was undertaken to source comparative data. Analysis of this data was exercised and concluded that Q factor, losses and resistance are the overriding parameters within an RLC circuit that can alter the effective bandwidth in which a series resonant circuit can operate.



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1 INTRODUCTION

1.1 Objective

The objective of this report was to demonstrate an understanding of the basic underlying concepts of electrical and electronic principal theory in relation to resonance, Q factor and basic RLC circuits. The activity undertaken was that of a theoretical exploration, a computational simulated navigation and practical exercise of the same RLC circuit. Analysis of this data was undertaken and conclusions were made.

1.2 Theory

1.2.1 Resonance

Resonance in respect of a series "RLC" circuit was defined as the point at which reactance of both the inductor and capacitor are of equal proportion; given that inductive reactance (X_L) is 180 degrees out of phase from capacitive reactance (X_C) the effect is that one would subtract from the other leaving a minimal series impedance signal remaining. Parameters that affect resonance are resistance, capacitance and inductance: this being the case a frequency of resonance in a series RLC circuit will change or can be 'honed' using different circuit components over a period of time. Measured values may change due to circuit degradation and should be aptly investigated at regular intervals. Resonance can be defined by the formula: [1,2,3,4]

$$F_r = [X_C = X_L] = \frac{1}{2\pi\sqrt{LC}}$$

Where L was inductance measured in Henry's (H) C was capacitance measured in Farads (F) and X was reactance measured in Ohms (Ω).

Understanding of the importance of resonance was taken from its application; series resonant RLC circuits often are used to 'tune' electronic circuits for instance AC mains/ noise filters specifically High pass filters, radios television tuning circuits and communications. To simplify in terms of a television or radio each 'channel' works on a different resonant frequency containing its own bandwidth this meaning that within set parameters i.e. bandwidth a signal will be received. Caution should be applied with the application of an RLC resonant circuit as error can result in noise, signal distortion and damage to components due to current being highest at resonance. [1, 2, 3, 4]

1.2.2 Series RLC circuit.

A series RLC circuit is comprised of a resistor (R) Inductor (L) and Capacitor (C) connected in series connected to an AC signal generator. **Figure 1** demonstrates one of the applications of a series RLC circuit; a High pass filter. This image does not demonstrate a power source only an in/out point where it would connect to a circuit. [1]

1.2.3 AC Theory

To adequately understand resonance, it was important to explore all of the subordinate theory that ultimately attains resonance.

- 1.2.3.1 Resistance and reactance in terms of electricity: electric current flowing along a conductor is opposed by electrical resistance this resistivity is usually attributed to material parameters in conjunction with temperature. With an alternating current in addition to resistance (electrical resistivity) there is reactance which acts as a resistive force to oppose the flow of electrons. Both Reactance (X) and Resistance (R) are measured in ohms. The definition of reactance can be summarised as:

"Reactance is the opposition of change of flow of current within a circuit." [1]

Reactance is only apparent in **dc** circuits when there is deviation from steady flow for instance when a switch is operated. [1, 5, 6]

Ohms Law:

"The current through a conductor is directly proportional to the voltage across it." [1]

$$I = \frac{V}{R}$$

Given that R in an AC circuit is not a 'pure' resistor it is assumed that impedance would take its place in that it is essentially a summation of resistivity in the circuit and so becomes:

$$I = \frac{V}{Z}$$

- 1.2.3.2 Reactance in an AC circuit is directly relative to inductive and capacitive components and so reactance can be defined as inductive reactance (X_L) or capacitive reactance (X_C).

- 1.2.3.3 Inductive reactance is essentially a property drawn from the alternating magnetic field created by and shrouding a wire or coil of wire traversing an alternating current. This alternating field will affect the voltage and current that can flow through that part of the circuit. The inductor stores electrical energy and is designed to oppose sudden changes in current, as the magnetic field changes it creates a **voltage which is in resistance** to the original voltage referred to as back EMF. This back EMF causes the voltage drop seen across inductors in an AC circuit. Inductive reactance retains a linear relationship to frequency, it is a measure of this **resistivity** in proportion of 2π to frequency and inductance. [1, 5, 6]

$$X_L = 2\pi fL$$

- 1.2.3.4 Capacitive reactance is caused by when alternating current is passed through a component with two conductive plates separated by a dielectric material such as; a capacitor. A capacitor essentially works in opposite to an insulator in that it causes the alternating voltage to lag behind the current. The **resistivity** of capacitive reactance unlike inductive capacitance retains an inversely proportional relationship to frequency meaning it emanates in a descending curve decreasing in magnitude as frequency increases and can be described as a reciprocal measure in proportion of 2π to frequency and capacitance. [1, 5, 6]

$$X_C = \frac{1}{2\pi fC}$$

- 1.2.3.5 Inductive and capacitive circuits is a definition used to describe an RLC circuit an inductive and capacitive circuit retains particular parameters discussed above that affirm resonance. In respect of a series RLC circuit there is necessity to take into account phase in order to adequately assess the level of reactance at a given frequency within the AC cycle. With theoretically 'pure' inductors and capacitors there is a provision of a 180 degree phase shift from each other further endorsing the two equations embracing a reciprocal affiliation. In order to ascertain a measure of total reactance (X_T) it is necessary to implement the equation. [1, 5, 6]

$$X_T = X_L - X_C$$

- 1.2.3.6 Impedance is the term used to annotate the total resistance to electron flow within a circuit. Resistance and reactance are 90° apart graphically; in order to attain Impedance by graphical methods this can be executed by way of evaluating the length of the hypotenuse; its length representing the amount of impedance (Z), measured in ohms. To summarise: Impedance is a Pythagoras type summation of resistance and reactance. [1, 6]

$$|Z| = \sqrt{R^2 + X^2}$$

- 1.2.3.7 Phase difference in terms of an AC circuit for continuous waveforms entails that both the voltage and current act independently. Given that purely capacitive circuits have voltage that is led by current to the amount of 90 degrees and purely inductive circuits have current that leads the voltage by 90 degrees; Current can lag or lead the voltage dependant on the ratio of inductance or capacitance respectively. [1]

- 1.2.3.8 Q factor on occasion referred to as 'Quality' Factor in relation to series RLC circuits is the ratio of power stored within a circuit over power dissipated from a circuit. Similar to its mechanical counterparts Q factor retains no unit of measurement and is greater than 1. Graphically speaking a higher Q factor is identified by narrower bandwidth, and in addition denotes reduced losses within the circuit. Practically speaking the ratio Q factor can be summarised as the supply voltage divisible by the resonant voltage across the inductor and capacitor with respect to ground. Current peaks at resonance and impedance at is at its minimum. Given Q factors relative to resonant frequency and bandwidth; Q will change relative to resistances with in the circuit. [1, 5, 6, 7]

$$Q \text{ Factor} = \frac{f_{\text{Resonance}}}{\text{Bandwidth}}$$

- 1.2.3.9 Relevance of equivalent circuits: In a theoretical sense, a purely inductive circuit exists; as does a purely capacitive circuit. Reality however negates theoretical ideology; even within stated capabilities of theoretical components due to the construct, there is additional parameters that may affect the circuitry such as inductance of resistors, resistance of inductors and equivalent series resistance of capacitors. To define this **Figure 2** demonstrates the RLC circuit laid out with equivalent circuits which has given guidance as to what to measure in addition to the stated values given in **2.1**. [1]

1.2.3.10 Bandwidth can be defined as the divergence between the two 'half power' frequencies Identified by 0.707 of the amplitude change of the curve or 70.7% or -3dB. Normally this measurement would be taken from current as a measure of maximum current however a more generic approach was taken to understand bandwidth from the total change in amplitude of the voltage of the circuit relative to inductance and capacitance. The graphical intersections between the half power and voltage curve can be identified as low band frequency f_l and high band frequency f_h . In order to ascertain Bandwidth (BW) graphically the points of intersect must be identified then a simple calculation must be made

$$BW = f_h - f_l$$

Bandwidth can also be identified as a ratio of resonant frequency and the Q factor in that

$$BW = \frac{f_{Resonance}}{Q Factor}$$

2 EXPERIMENT DESCRIPTION

2.1 Practical apparatus

- 2.1.1 Breadboard.
[Figure 3]
- 2.1.2 Signal generator.
[Figure 4]
- 2.1.3 Oscilloscope.
[Figure 5]
- 2.1.4 Resistor.
stated value - 3.3 Ω Measured resistance - 2.89 Ω Measured Inductance - 13.7 μH
[Figure 6]
- 2.1.5 Inductor.
stated value - 1 mH Measured inductance - 0.977 mH Series Resistance - 2.89 Ω
[Figure 7]
- 2.1.6 Capacitor.
stated value - 1 μF measured capacitance - 1.013 μF ESR @ 1 kHz - 5.09189×10^{-5}
ESR @ 10 kHz - 7.63784×10^{-4}
[Figure 8]

2.2 Computational experimental layout

- 2.2.1 The set-up of the RLC circuit for assessment denoted by **Figure 9** in this document: Contained was a signal generator set to 4V and frequency was initiated at 100Hz but varied throughout the experiment. Attached to this in series was a 3.3Ω resistor, 1mH inductor and $1\mu\text{F}$ capacitor leading to ground. To this, measurements were taken by way of an oscilloscope with channel A recording the supply voltage positioned between the resistor and the signal generator; channel B was connected between the resistor and the inductor to attain the voltage over the inductor and capacitor with respect to ground these results have been tabulated in **Table 1**.

$$(V_L + V_C)$$

- 2.2.2 The suitable simulation software used was Labcenter Electronics; Proteus v.8 Professional.
- 2.2.3 All components unless stated were generic forms of their identity i.e. generic resistor et al.

2.3 Practical experimental layout

- 2.3.1 The listed practical apparatus was applied as demonstrated in **Figure 10** laid out in the same format detailed in **2.2.1** in order to attain the voltage over the inductor and capacitor with respect to ground $(V_L + V_C)$. Once the circuit had been assembled and connected to the equipment, a series of measurements were taken as discussed in **3.3.1** shown in **Table 2** at increments with a closely spaced range close to the suspected point of resonance.
- 2.3.2 Assurance of continuity of components into the breadboard was attained in order to ensure correct operation of the circuit. Losses through connections or additional resistance from wires were not taken into account for the purpose of this report. In addition, a visual inspection of the supply voltage was made to instil confidence within these results at each measurement.
- 2.3.3 Requirement would normally entail a planning document be filled out prior to this experiment but was surpassed due to the minimal number of components.

3 EXPERIMENTAL DATA

3.1 Theoretical

- 3.1.1 Calculations made from given values. [1]

The values collated here were used in conjunction with basic theory to give provide an estimated range in which practical and computational results should be.

$$\begin{aligned}L &= 1\text{mH} = 1 \times 10^{-3} \\C &= 1\mu\text{F} = 1 \times 10^{-6} \\R &= 3.3\Omega\end{aligned}$$

$$F_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(1 \times 10^{-3})(1 \times 10^{-6})}}$$

$$F_r = 5032.921$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{3.3} \sqrt{\frac{1 \times 10^{-3}}{1 \times 10^{-6}}}$$

$$Q = 9.583$$

$$BW = \frac{F_r}{Q} = \frac{5032.921}{9.583}$$

$$BW = 525.192 \text{ Hz}$$

3.1.2 Calculations made from measured values [1]

The values collated here were used in conjunction with basic theory to give provide an estimated range in which practical and computational results should be.

$$\sum L = 0.977 \text{ mH} = 0.977 \times 10^{-3}$$

$$\sum C = 1.013 \mu\text{F} = 1.013 \times 10^{-6}$$

$$\sum R = 2.89 \times 2.89 = 5.78$$

$$F_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.977 \times 10^{-3})(1.013 \times 10^{-6})}}$$

$$F_r = 5059.04$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{5.78} \sqrt{\frac{1 \times 10^{-3}}{1 \times 10^{-6}}}$$

$$Q = 5.471$$

$$BW = \frac{F_r}{Q} = \frac{5059.04}{5.471}$$

$$BW = 924.689 \text{ Hz}$$

3.1.3 Note:

Due to the minimal sizing ESR values were taken as negligible and so discounted from any theoretical calculations.

3.2 Computational

3.2.1 Results were obtained by interrogation of graphical data as seen in **Figure 11** sourced from **Table 1**.

3.2.2 The method of interrogation for resonant frequency involved the identification of the lowest 'dip' in the graph. From AC theory (**section 1.2.3**) this is the point wherein $X_C = X_L$. This graphical point was attained by an approximation taken between points as the graphical representation was not able to be interrogated through the Microsoft office software used for this task hence, retains a hint of ambiguity and approximation.

$$F_r = 5000 \text{ Hz}$$

3.2.3 The bandwidth was identified by way of graphical methods stated in **1.2.3.10**.

$$BW = 325Hz$$

3.2.4 Q factor was attained by way of identifying the point of resonance graphically then completing theoretical calculations as per **3.1.2**. with amended values and transposed formula.

$$BW = \frac{F_r}{Q} \therefore Q = \frac{F_r}{BW}$$

$$Q = \frac{5000}{325}$$

$$Q = 15.3846$$

3.3 Practical

3.3.1 Results were obtained by interrogation of graphical data as seen in **Figure 12** sourced from **Table 2**.

3.3.2 The method of interrogation for resonant frequency in the practical experiment results was as per **3.2.2** again identification of the lowest 'dip' in the graph wherein $X_C = X_L$ was attained by an approximation taken between points as the graphical representation was not able to be interrogated through the Microsoft office software used for this task.

$$F_r = 4900Hz$$

3.3.3 The bandwidth was identified by way of graphical methods stated in **1.2.3.10**.

$$BW = 3050Hz$$

3.3.4 Q factor was attained by way of identifying the point of resonance graphically then completing theoretical calculations as per **3.2.4**. with amended values.

$$Q = 1.6066$$

4 ANALYSIS

4.1 Comparison

4.1.1 Stated and measured values

The purpose of this comparison is to understand the practical limitations of the engineering practice used within the manufacture of electronic components. The term used to define these limitations with respect to the components themselves is 'Tolerance'. Unlike theoretical and computer simulations the real world has variables beyond control; best practice means controls can be implemented in order to hone variance from specification yet the ability to create a component with pure or perfect properties is not possible. Tolerances are implemented in order to allow an acceptable bandwidth in which components can operate with only negligible change to any of the variables. **2.1**. shows

the additional changes that can occur due to tolerance which in turn affect the results shown in **3.1.1.** and **3.1.2.** showing just a small variation at components level can directly and massively effect the output of a circuit with respect to its resonance bandwidth and Q factor

4.1.2 Theoretical calculation and computational experiment

Adequate assessment should be taken of the theoretical calculation and its computational counterpart in order to attain confidence into the software output and quantify any resultants achieved in **3.2.** For full understanding of this comparison it is necessary to ensure where possible the same methodology is used to attain each type of experiments results. For this comparison the methodology to complete this exercise was exhaustive and so was not undertaken meaning relevant assumptions were made for instance, the point of resonance is clear on the computational experiment and so it can be assumed that the level of ambiguity in the attainment of for instance, bandwidth as an example is not apparent and so can be assumed to be relevant data. The value of resonant frequency in both theoretical and computational executions deviate by a value of less than 60Hz and so assumption can be made that this resultant is biased due to uncertainty of measurement though data interpretation.

4.1.3 Computational experiment and practical experiment

The comparison of both computational and practical experiments requires an in depth and exploratory assessment comparison. Firstly, as can be seen through assessment **4.1.1.** using stated values of components will only provide a marginal insight into the expected trend that was to be subjectively stated by the software. Essentially the input into the software must equate to the realistic input to the circuit to attain a realistic output for frequency of resonance. There was a need to then assess computational with stated resistive values shown in **Figure 13** against the practical experiment

Using the results from **3.3.** to reference the practical experiment and the methodology from **3.2.**, **Figure 14** and **Table 3** to attain results

$$F_r = 5000Hz$$

$$BW = 225Hz$$

$$Q = 22.2222$$

From these results that give a more realistic out turn from the circuit it was seen that Q factor is prominent in the implication of any circuit as the resonant frequency retains a maximum deviation on 100Hz

4.1.4 Additional computational modelling

Using a 12v RLC circuit to assess whether voltage would affect the shape of the graphical results **Figure 15**, **Table 4**:

$$F_r = 5000Hz$$

$$BW = 300Hz$$

$$Q = 16.6666$$

These results proved within additional Voltage did not overtly affect point of resonance where a high Q Factor is assumed i.e. simulated.

To quantify this statement, it is necessary to assess all the graphical representations against one another as shown in **Figure 16** with further interrogation around the most commonly stated points of resonance ($5\text{kHz} \pm 500\text{Hz}$) as shown in **Figure 17** both figures are relative to **Table 5**.

As can be seen Resonance seems to fall near to the point of 5kHz regardless of voltage and only seems to fluctuate in respect to resistance and Q factor.

4.1.5 NOTE:

"Respect the data" [1] in essence no relevant data has been omitted or honed during the execution of this report and its subordinate activities.

4.2 Error

During any experimental activity there is a margin of error that needs to be accounted for during interpretation of results; stated in section 4 is potential error sources that have not been addressed through the report and perhaps could affect data stated and evaluated throughout this report

4.2.1 Margins of error through calculation by way of rounding

4.2.2 Error due to the resolution of graphs and/or oscilloscope readings and picking the wrong point with the added potential of noise

4.2.3 Tolerances of electrical components in that there is not a pure component in reality i.e. the requirement to account for equivalent circuits.

4.2.4 The losses due to additional resistance in wires not accounted for through any of the calculations

4.2.5 Practical frequency values were $\pm 50\text{Hz}$ due to difficulty using the signal generator

4.3 Review and learning initiative

To assess this report and all its subordinate activity it is required to make recommendations based on the delivery of what can be altered to potentially produce a better experiment.

4.3.1 Creation of a highly tolerance circuit, use higher quality components within the practical experiment, honing of the circuit: keep all wires/tracks as short as practicable to reduce interference and noise.

4.3.2 A full exploration into potential losses within the circuit considering all connections and reverse modelling a circuit to ascertain all points of loss inclusive of those associated with measuring equipment.

5 CONCLUSION

To conclude this report, it is necessary to revisit the objective of the report:

Resonance in a Series RLC Circuit has three main parameters that define one another in a ratio type format.

Q factor, Bandwidth and resonant frequency are all proportionate to one another yet from reviewing this report the overlying parameters that affect change are associated with resistance and electronic losses. Greater losses within a series RLC equate to a resultant which appears outside the circuitries designed purpose in a mechanical sense this could be represented to a bucket of Newtonian fluid with a hole in the base. To ensure a highly tuned circuit (low bandwidth), set at the appropriate channel (point of resonance); a circuits Q factor must be of a larger value essentially with minimal loss. This can be simulated using appropriate simulation software but ultimately requires due diligence of practical experimentation to ascertain where losses occur and how to effectively combat them.

6 FIGURES AND TABLES

6.1 Figures

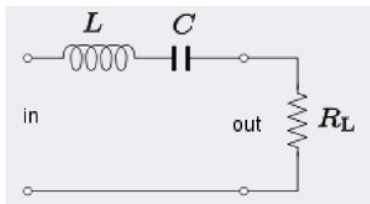


FIGURE 1 - High Pass filter circuit [9]

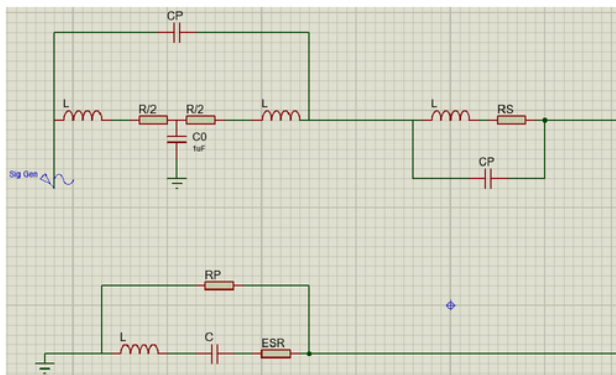


FIGURE 2 - Equivalent circuit diagram of an RLC circuit diagram



FIGURE 3 – Breadboard [10]



FIGURE 4 - Signal generator

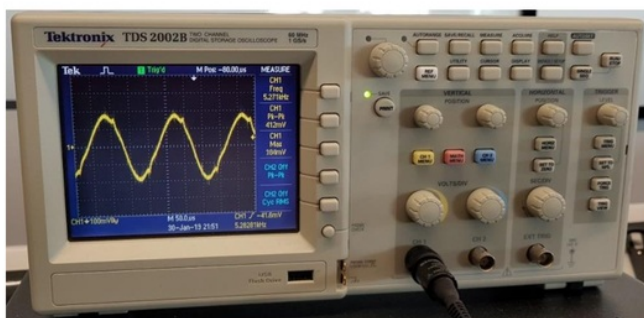


FIGURE 5 - Oscilloscope



FIGURE 6 – Resistor



FIGURE 7 – Inductor

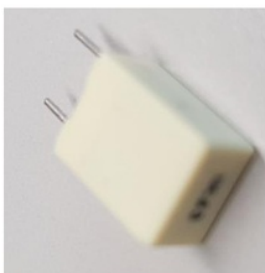


FIGURE 8 - Capacitor

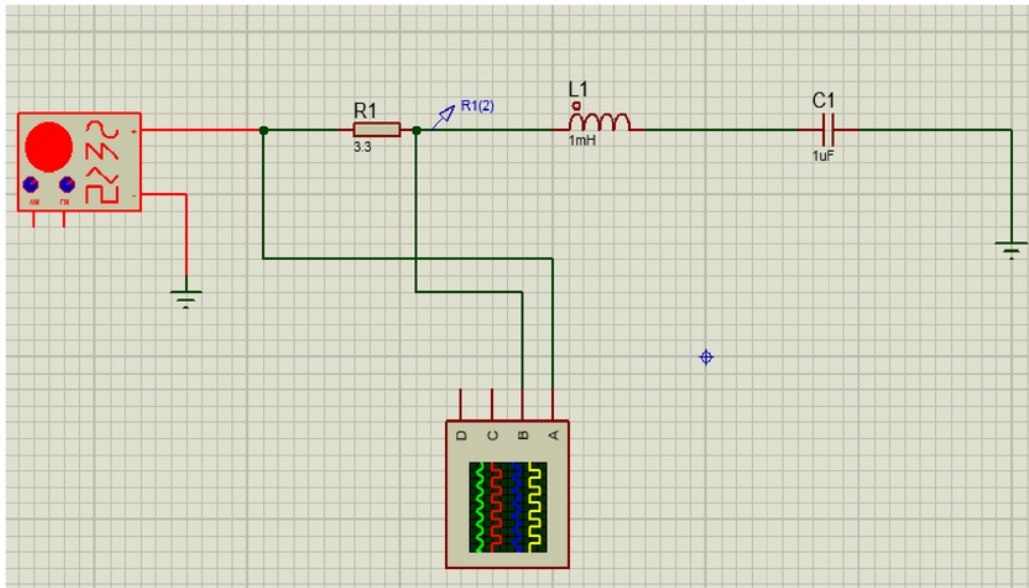


FIGURE 9 - Computational Set-up

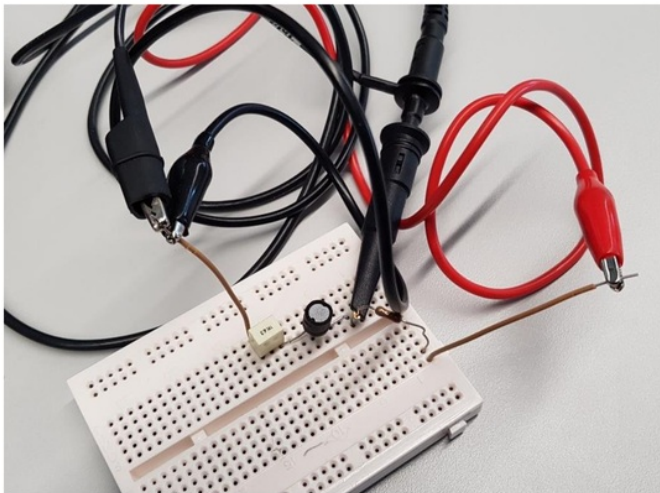


FIGURE 10 - Practical Set-up

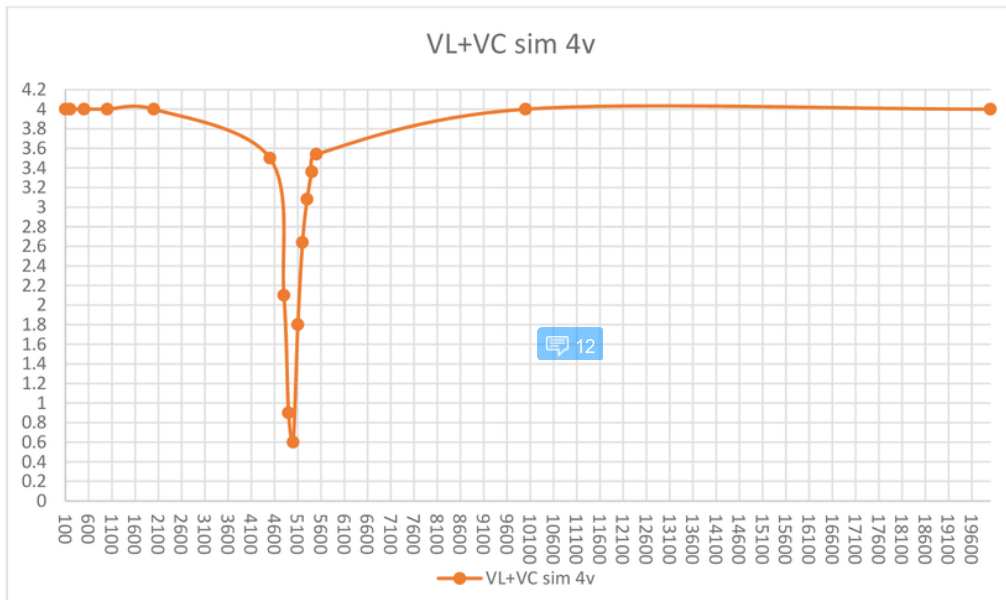


FIGURE 11 - Computational results graph (Table 1)

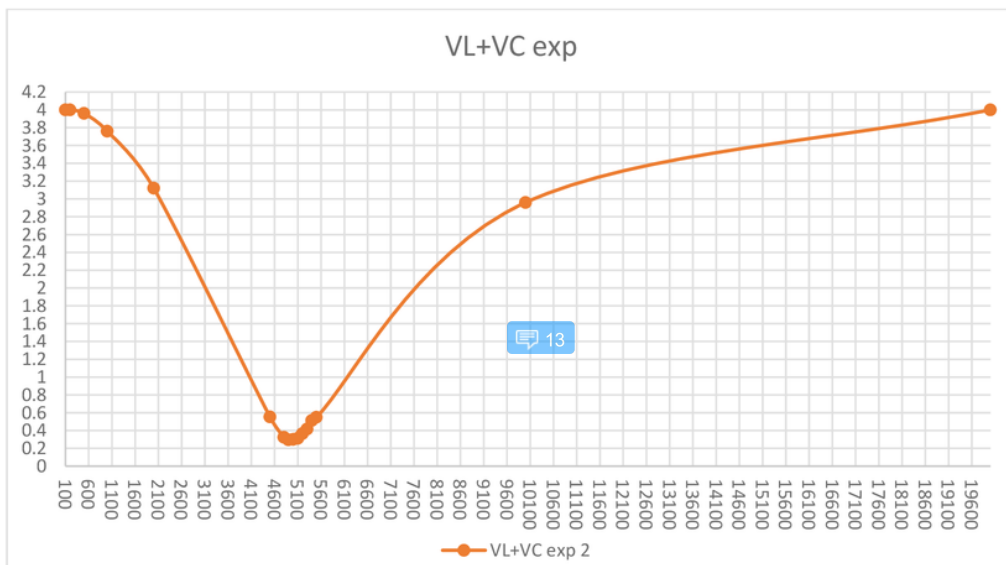


FIGURE 12 - Practical results graph (Table 2)

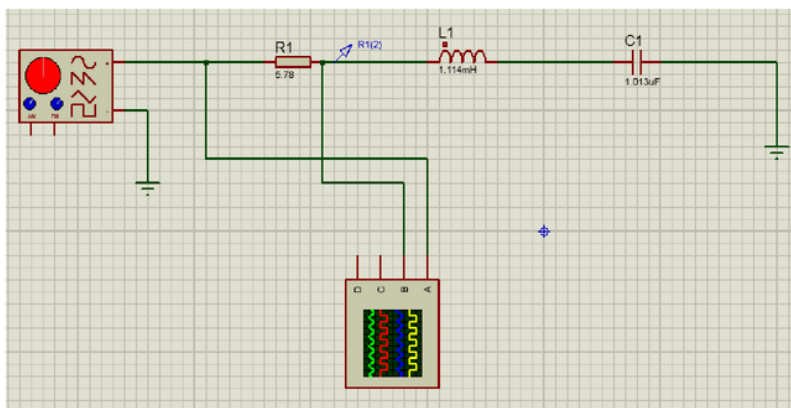


FIGURE 13 - Computational set-up measured values

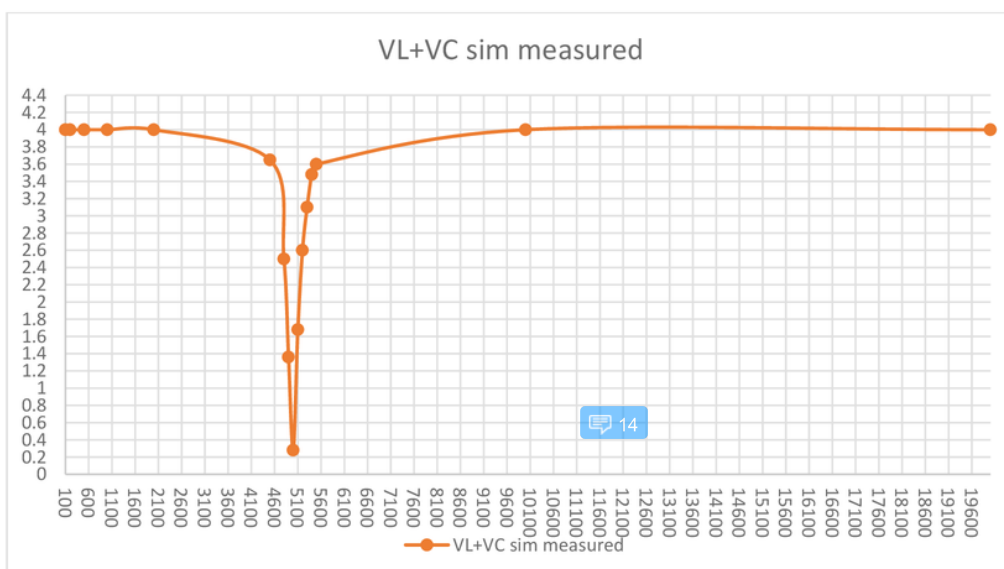


FIGURE 14 - Computational measured values results graph (Table 3)

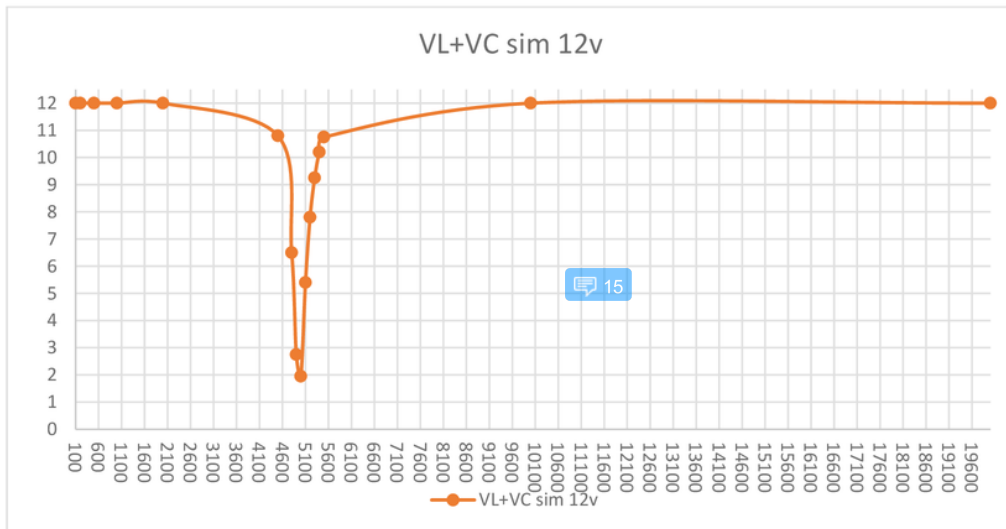


FIGURE 15 -12v Computational results graph (Table 4)

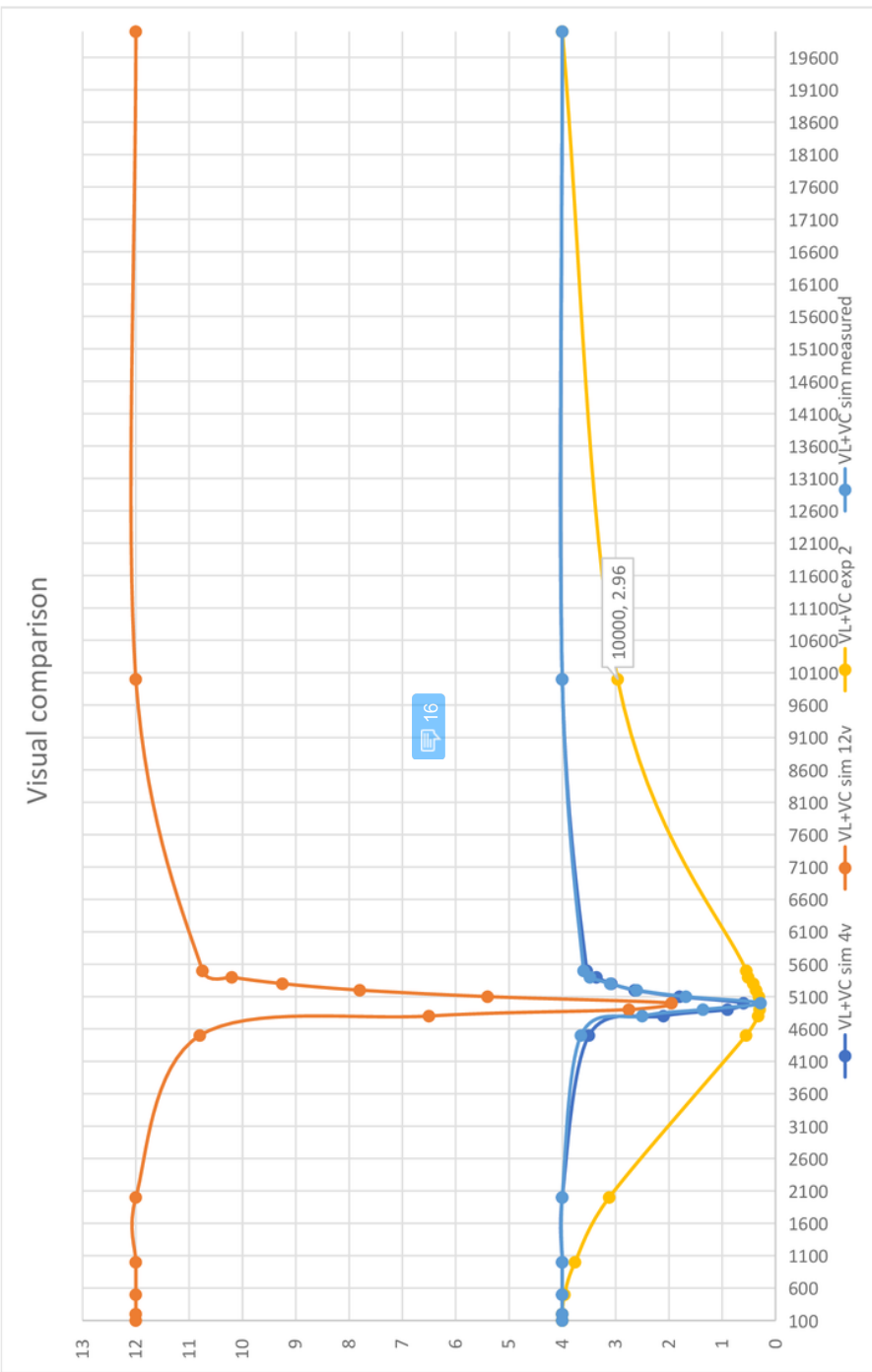


FIGURE 16 - Comparative graph

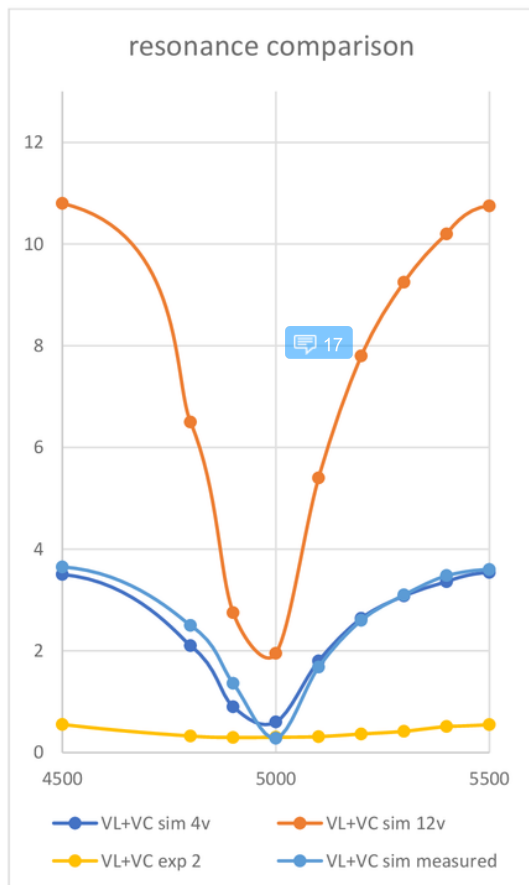


FIGURE 17 - Resonance comparison

6.2 Tables

TABLE 1 – Computational with stated values

Freq	Vsupply	VL+VC sim 4v
100	4	4
200	4	4
500	4	4
1000	4	4
2000	4	4
4500	4	3.5
4800	4	2.1
4900	4	0.9
5000	4	0.6
5100	4	1.8
5200	4	2.64
5300	4	3.08
5400	4	3.36
5500	4	3.54
10000	4	4
20000	4	4

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TABLE 2 - Practical

Freq	Vsupply	VL+VC exp
100	4	4
200	4	4
500	4	3.96
1000	4	3.76
2000	4	3.12
4500	4	0.552
4800	4	0.324
4900	4	0.296
5000	4	0.3
5100	4	0.312
5200	4	0.364
5300	4	0.416
5400	4	0.512
5500	4	0.548
10000	4	2.96
20000	4	4

TABLE 3 - Computational with measured values

Freq	Vsupply	VL+VC sim measured
100	4	4
200	4	4
500	4	4
1000	4	4
2000	4	4
4500	4	3.65
4800	4	2.5
4900	4	1.36
5000	4	0.28
5100	4	1.68
5200	4	2.6
5300	4	3.1
5400	4	3.48
5500	4	3.6
10000	4	4
20000	4	4

TABLE 4 - 12V Computational stated values

Freq	Vsupply	VL+VC sim 12v
100	12	12
200	12	12
500	12	12
1000	12	12
2000	12	12
4500	12	10.8
4800	12	6.5
4900	12	2.75
5000	12	1.95
5100	12	5.4
5200	12	7.8
5300	12	9.25
5400	12	10.2
5500	12	10.75
10000	12	12
20000	12	12

TABLE 5 - Comparative table

Freq	VL+VC sim 4v	VL+VC sim 12v	VL+VC exp	VL+VC sim measured
100	4	12	4	4
200	4	12	4	4
500	4	12	3.96	4
1000	4	12	3.76	4
2000	4	12	3.12	4
4500	3.5	10.8	0.552	3.65
4800	2.1	6.5	0.324	2.5
4900	0.9	2.75	0.296	1.36
5000	0.6	1.95	0.3	0.28
5100	1.8	5.4	0.312	1.68
5200	2.64	7.8	0.364	2.6
5300	3.08	9.25	0.416	3.1
5400	3.36	10.2	0.512	3.48
5500	3.54	10.75	0.548	3.6
10000	4	12	2.96	4
20000	4	12	4	4

7 REFERENCES

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FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

PAGE 1



Comment 1

You should include a summary of results here too.

PAGE 2

PAGE 3



Comment 2

impedance is not a signal.



Comment 3

Do not need to capitalise "inductor" or "capacitor" as they are not proper nouns or the start of a sentence.



Comment 4

pertains to?

PAGE 4



Comment 5

ac circuits



Comment 6

voltage which is in opposition to the original voltage.



Comment 7

reactance



Comment 8

reactance

PAGE 5



Comment 9

Not always

PAGE 6

PAGE 7

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PAGE 12



Comment 10

circuit's



Comment 11

Please embed figures in text where they are discussed. Putting them at the end causes the reader to constantly flip pages to find the relevant figure.

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Comment 12

Nice graph, but where are your axis labels and why is the X axis not logarithmic?



Comment 13

See comments on 1st graph

PAGE 17



Comment 14

see comments on 1st graph

PAGE 18



Comment 15

See comments on 1st graph

PAGE 19



Comment 16

See comments on 1st graph.

Also consider making the lines thinner - this will tidy up the area around resonance. At the moment it looks a bit messy.

PAGE 20



Comment 17

axis labels?

PAGE 21



Comment 18

You don't need tables of values if you are including a graph, it is far easier to identify trends in data on a graph than it is in a table.

PAGE 22

PAGE 23



Comment 19

principles

PAGE 24

JORDAN TIMBERLAKE

67.70

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied

3.75

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.

23.4

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 & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions.

18.6

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, tools and techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.

19.2

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 effectively in a suitable format, but may have minor errors. Mostly coherent work and is in a suitable structure. You should place figures on the same page as the text discussing them and you should also remember to label the axis of your graphs.

2.75