

2022429 - Final Report

by Stan Joseph Collins

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Resonance Assignment

Electrical & Electronic Principles

ACDA4006

Stan Collins

2022429

17/11/2021

1. **Abstract**

This report aims to assess the differences between simulating and practically building a circuit when viewing the circuit response. A parallel RLC circuit was simulated in Proteus 8, a simulation software, then built in person on a breadboard. The voltage across the capacitor and inductor was recorded across various frequencies, to find the resonant frequency in both. When compared, the simulation produced values a degree of magnitude higher than the experiment. The report concludes this is due to the unaccounted for resistance in the circuit, and another simulation agrees with this hypothesis. As such, the simulation can be trusted to produce accurate values, but only when adjusted to reflect real world component values.

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3. Introduction

The purpose of the assignment is to model the following circuit both practically and in a software simulator, assessing the differences between them. Resonant circuits such as this can be used as a tuning amplifier, amplifying a specific frequency based on the internal components. Most other components will themselves contain some fractional resistance, inductance and capacitance, making this circuit reflective of potentially any component with the right internal values [1].

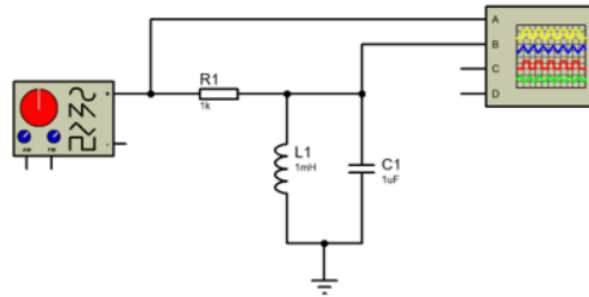


Figure 1: A parallel RLC circuit

While simulations can provide good estimates for circuit outputs and behaviour, this report aims to examine the discrepancies between real world and simulated results in this case. The voltage across the inductor and capacitor will be recorded at various intervals in the simulation and practically, then compared to find any inconsistencies between the two to assess how accurate the simulation's predictions are.

4. Theory

For an ideal circuit, at resonance, the voltage over the capacitor and inductor should be close to, but not equal to, the input voltage. The impedance reaches its maximum value, equal to the resistance of the resistor, resulting in a circuit condition of very low current and an output voltage functionally equal to the input [2]. A graphical depiction of the impedance at the resonant frequency can be seen in figure 2. While the V_{out} may get very close or equal to the V_{in} in theory and simulations, the restrictions of real world components mean that a gain of 1 cannot be achieved without the help of high gain amplifiers [1].

The theoretical resonant frequency (f_r) can be calculated using the following formula, where L is the inductance, and C is the capacitance:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

While likely getting close to the practical value, it is estimated that this theoretical resonant frequency will differ slightly from the one observed in the experiment, due to real world components having tolerances.

Additionally, the bandwidth for both circuits will be calculated, as well as their Q factor. The Q factor is a representation of how damped the system is, with higher Q factors reflecting a less damped system [2]. The Bandwidth (BW) for each circuit will be obtained graphically in this case, rather than using theoretical values to calculate Q factor.

$$Q = \frac{f_r}{BW}$$

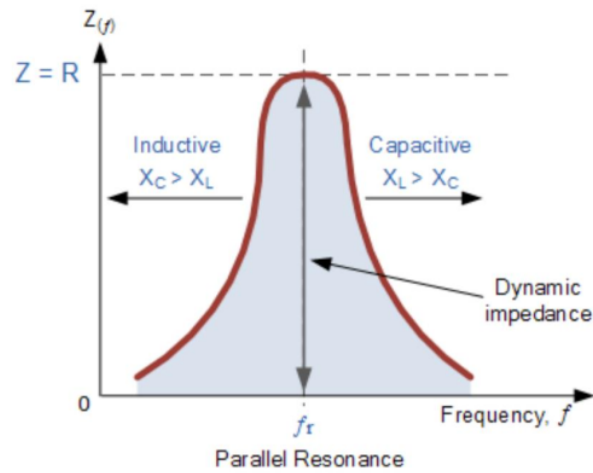


Figure 2: A plot of Impedance against frequency for a parallel RLC circuit [3].

5. Methodology

5.1. Proteus

To model the circuit performance, a copy of the circuit was created in Proteus 8, a software simulator [4]. The final modelled circuit can be seen in figure 3. Component parts for the resistor, inductor and capacitor were selected from the Proteus library, then had their values altered to the desired values. An input AC voltage of 2V peak to peak was selected using the signal generator.

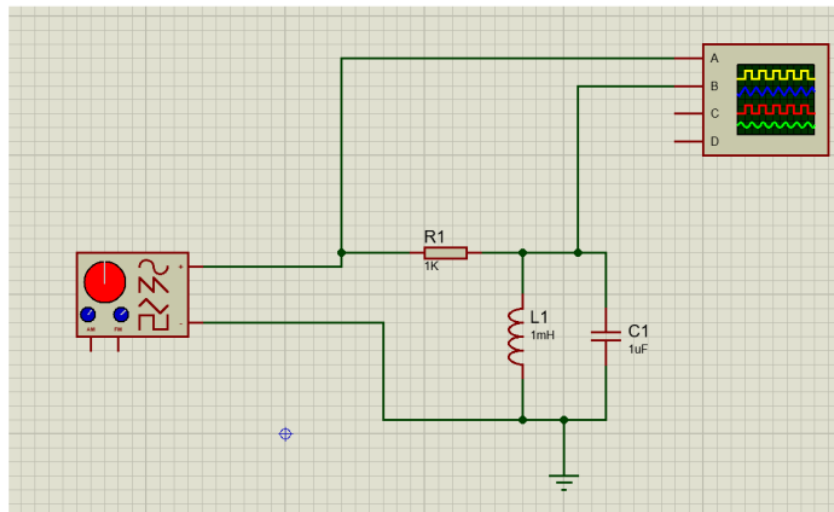


Figure 3: The modelled circuit in Proteus 8

When running, the signal generator was used to change the frequency of the supply voltage, ranging from 100Hz to 20,000Hz in a logarithmic system of intervals. Using the equation in section 4, the theoretical resonant frequency was calculated to be 5032.92121 Hz.

To model the response at the resonant frequency, a sine wave AC generator was added to the model at the input set to the specific frequency. Once the resonant frequency was roughly identified, more readings were taken around the peak to better define its shape on any plots.

The values for V_{in} and V_{out} were read off the oscilloscope, using the mouse to find the peak to peak voltage at each frequency, as seen in figure 4.

After the actual values for the components were measured in the experiment (see Table 1), another circuit was built with those values, in order to directly compare the response of the system within the Proteus simulation.

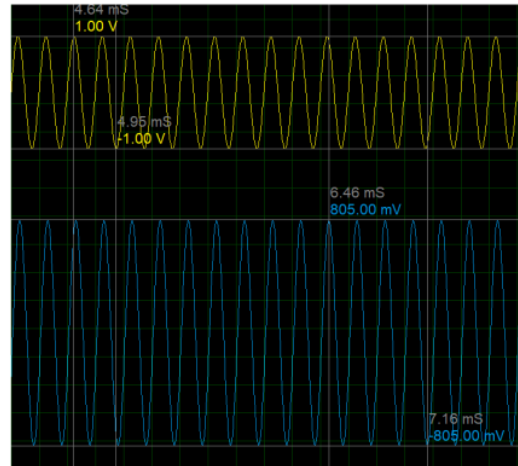


Figure 4: An example of an oscilloscope display, with the peak voltages for V_{in} (yellow) and V_{out} (blue)

5.2. Practical experiment

Once results had been collected from the software, the circuit was recreated using physical components, such as in figure 5. While the components were selected to reflect the values used in Proteus, when measured their values were recorded as seen in table 1. Proteus also assumes an ideal power source, whereas in experimental conditions the power source was taken to be at around 50Ω internal resistance.

Table 1: Simulated vs Real values for the components

	Proteus	Real - Resistance	Real - Capacitance	Real - Inductance
Resistor	1 K Ω	979 Ω		
Capacitor	1 μ F		1.064 μ F	
Inductor	1 mH	7.32 Ω		0.994 mH

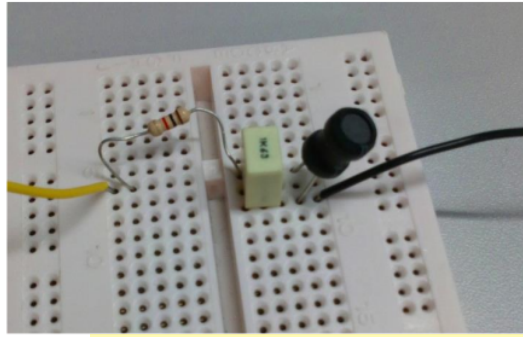


Figure 5: Photo of an example of the experimental set-up

Citation Needed

5 Due to the slightly awkward process of selecting specific frequencies to any degree of accuracy using the oscilloscope, many of the frequencies are close to the values selected during the simulation, but not the exact same. While this makes direct comparison at the exact frequency of resonance impossible, enough readings were taken around the peak to accurately model the peak for a wider comparison to the simulated plot.

6 Another slight inconvenience was the signal quality obtained from the circuit. Despite multiple component changes and resets, the output signal remained 'fuzzy', noticeably more so than the input signal. While this didn't impact reading the value off the oscilloscope, as this was done using a function of the oscilloscope itself, it may have impacted the oscilloscope's reading of the peaks of the plot.

5.3. Q Factor

Once values had been recorded for both circuits, they were plotted in order to compare results, but also to calculate the bandwidth of the circuit. This was done by plotting additional lines onto the graph, first for the '70.7%' points of the graph, then lines for where that line intercepted the resonant circuit curve. The exact plots used to calculate the bandwidth can be found in Appendix 1.

This process was done graphically and by eye rather than coding an intercept point, so the values could be open to interpretation. To address this, the graph was zoomed in when reading off it, and as such any differences in results if done again would be minimal, and would not change enough to effect the overall analysis.

6. Results

6.1. Output Voltage

When comparing the simulated output voltage and the experimental values, a very large difference can be observed. While either side of the peak the voltage remains very low in both cases, approaching the peak results from the Proteus simulation become a degree of magnitude higher than those obtained practically. Interestingly, despite using ideal components, the Proteus simulated results did not match the theoretical resonant frequency, instead reaching resonance at 5000Hz, as seen in table 2.

Table 2: Results from the simulated circuit and the experimental process

Practical			Proteus		
Frequency (Hz)	Vin (V)	Vout (V)	Frequency (Hz)	Vin (V)	Vout (V)
100.9	2	3.40E-02	100	2	1.30E-03
200.2	2	3.60E-02	200	2	2.60E-03
503.6	2	3.12E-02	500	2	6.40E-03
1005.387	2	3.36E-02	100	2	1.33E-02
2005.66	2	4.64E-02	2000	2	3.04E-02
2495.12	2	5.52E-02	2500	2	4.25E-02
2997.41	2	7.20E-02	3000	2	6.03E-02
3998.92	2.04	1.40E-01	4000	2	1.45E-01
4506.56	2.04	1.96E-01	4500	2	3.18E-01
4899.14	2.06	2.34E-01	4900	2	1.44E+00
5000.53	2.06	2.36E-01	5000	2	1.60E+00
5033.93	2.04	2.40E-01	5032.92121	2	1.37E+00
5100.35	2.04	2.34E-01	5100	2	9.60E-01
5500.39	2.04	2.00E-01	5500	2	3.00E-01
6007.85	2.04	1.54E-01	6000	2	1.65E-01
7995.16	2.04	8.20E-02	8000	2	6.35E-02
10009.33	2.02	5.80E-02	10000	2	4.15E-02
20000	2.02	3.60E-02	20000	2	1.67E-02

When plotted together, the difference seen easily be seen, with the Proteus simulation producing a much higher, sharper peak when compared to the practical results. The output voltage of the simulation gets close to the input voltage of 2 V at resonance with 1.6 V, whereas the experimental results remain much lower, peaking at only 0.24 V.

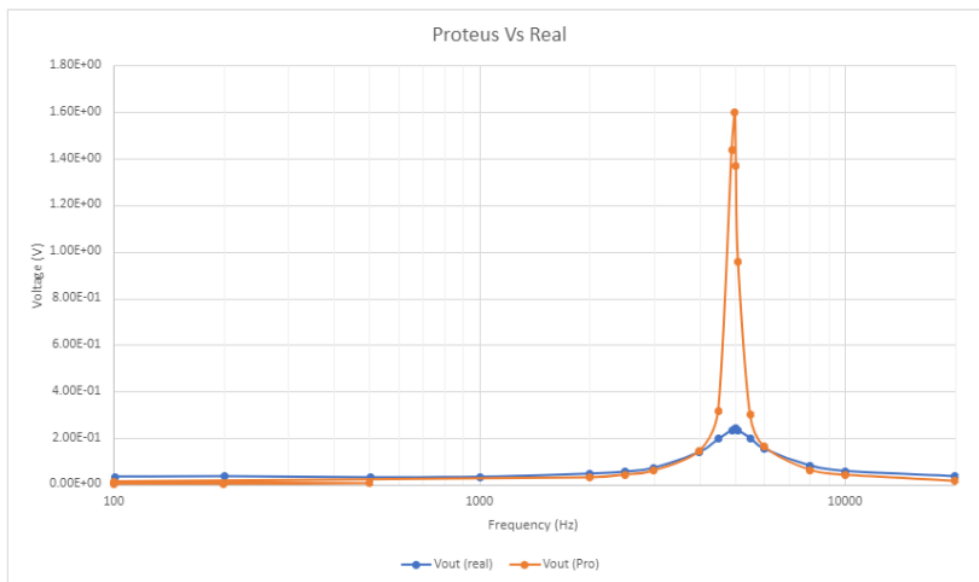


Figure 6: Plot of the simulated output voltage vs the experimental results

Simulating the measured real world values of the components rather than the ideal values changes the results drastically, as seen in figure 7, producing values much closer to the values obtained from the practical experiment.

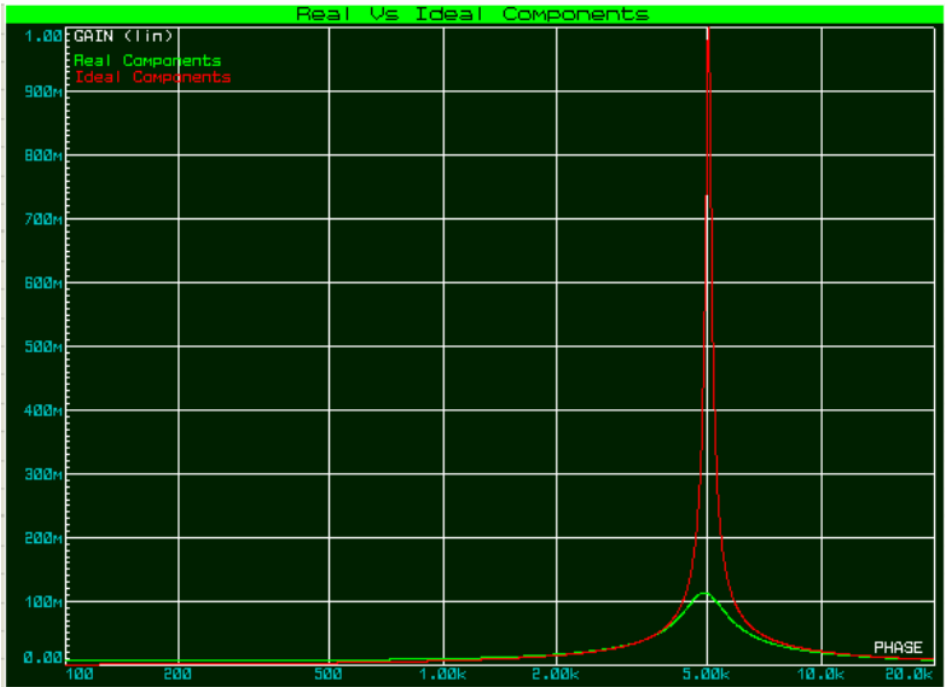


Figure 7: Plot of the simulated ideal components output vs ‘real’ simulated components output

6.2. Q

As expected, the Proteus values for Q factor are much higher than the practical values. This is unsurprising, as the simulated circuit is ideal, so there is no internal resistance from the power supply or inductor like the real world components. As such, the real world circuit was much more damped, resulting in a much lower resonant peak, and a much lower Q factor. Even with the large discrepancies between Q factors, both values are above 0.5, and as such would both represent ‘undamped’ systems [5].

Table 3: The calculation of bandwidth and Q factor

	Proteus	Practical
FL (Hz)	4800	4280
FH (Hz)	5050	5780
BW (Hz)	250	1500
Q factor	20.1317	3.35595

The higher Q value for the Proteus simulation came with a smaller bandwidth, just 250Hz compared to 1500Hz. In the context of an amplifier, this would mean the circuit would only amplify a much more specific range of frequencies, useful if you were looking for a specific signal at a known specific frequency, reducing the noise from other signals at adjacent frequencies or background noise, such as phase noise from an oscillator [6].

7. Analysis

As demonstrated throughout this report, there are large differences between the Proteus simulation and that of the practical set up. Firstly, there are the discrepancies between component values. Real world components have degrees of accuracy, whereas Proteus uses ideal parts. As Table 1 shows, while these differences can appear only small, when simulated they produce very different results.

Another factor to consider are the internal resistances of the additional components of the circuits.

7 The power supply used will have its own internal resistance [7], which was only estimated here to be 50 Ω , as will the wires and probes used by the oscilloscope.

Additionally, when looking at the equivalent circuits for each component [1], it is clear that, however small, there are values of capacitance and inductance from the resistor that have not been taken into account, as well as inductance from the capacitor and capacitance from the inductor. It is worth mentioning that while these values are likely so small as to barely effect results, they are still missing from the simulation [1].

The few issues mentioned in the methodology section on the practical experiment are still valid concerns that could have affected the specific readings at each frequency, but would not have caused the large discrepancy between results. While potentially masking the signals read by the oscilloscope, the noise would not have reduced the gain for the system [8]. This can be seen in the simulated circuit with the real world component values, where the gain was still much lower, without any if the issues raised in the practical experiment.

In a parallel RLC circuit at resonance, the inductance is at its peak, being equal to the resistance of the resistor [2]. As such, it is only the resistance that affects the height of the Vout peak. It is therefore a logically conclusion that all the above unaccounted for additional resistances would be the cause of the large drop in gain, a viewpoint supported by the adjusted simulation results.

Similarly, the difference in Q factor can be explained by the difference in resistance between the two circuits. Just introducing the internal resistance of the power supply and the inductor caused a huge change in gain between the two simulated circuits.

Less simple to explain is the difference in resonant frequencies between the simulated and practical results. As seen in Table 2, the simulated circuit peaked at 5000 Hz, rather than the calculated 5032.92121 Hz. While the equivalent circuit's resistance, capacitance and inductance for each component could partially explain the difference, that should effect the practical components, not the simulation. These values would also be so small as to not affect the resonant frequency [1]. As the difference between resonant frequencies is only 32.9 Hz, it should not impact any of the other analysis, but it is a discrepancy that currently has no explanation.

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8. Conclusion

When comparing the ideal simulation to the practical experiment and 'real world' simulation, the differences are clear to see. A degree of magnitude difference between results illustrates how simulations cannot be trusted to accurately reflect real world behaviour of a circuit without first having more accurate reading put into place. Once the values were changed to better represent the circuit being used in the experiment, results were much more similar, although the adjusted simulation and the experimental values were never directly compared.

That said, the initial simulation still behaved similarly to the experimental set up, reaching resonance at roughly the same frequency, so can be trusted to illustrate rough patterns in response from a circuit when operating in ideal conditions. As long as the restrictions of the simulation are understood and accounted for, it will produce results similar to experimental values.

9. References

- [1] Texas Instruments, "Understanding Basic Analog Passive Devices," Texas Instruments, 1999.
- [2] M. Wang, Understandable Electric Circuits - Key Concepts, Institution of Engineering and Technology, 2019.
- [3] Electronics Tutorials, "Parallel Resonance Circuit," Electronics Tutorials, [Online]. Available: www.electronics-tutorials.ws/accircuits/parallel-resonance.html. [Accessed 20 November 2021].
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- [6] K. Chang, "Q-factor," in *Encyclopedia of RF and Microwave Engineering, Volumes 1 - 6*, John Wiley & Sons, 2005.
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- [8] M. Prudenziati, "5.4.3 - Electronic Noise," in *Thick Film Sensors*, Elsevier, 1994, p. 93.

10. Appendix

10.1. Q Factor Graphically calculations

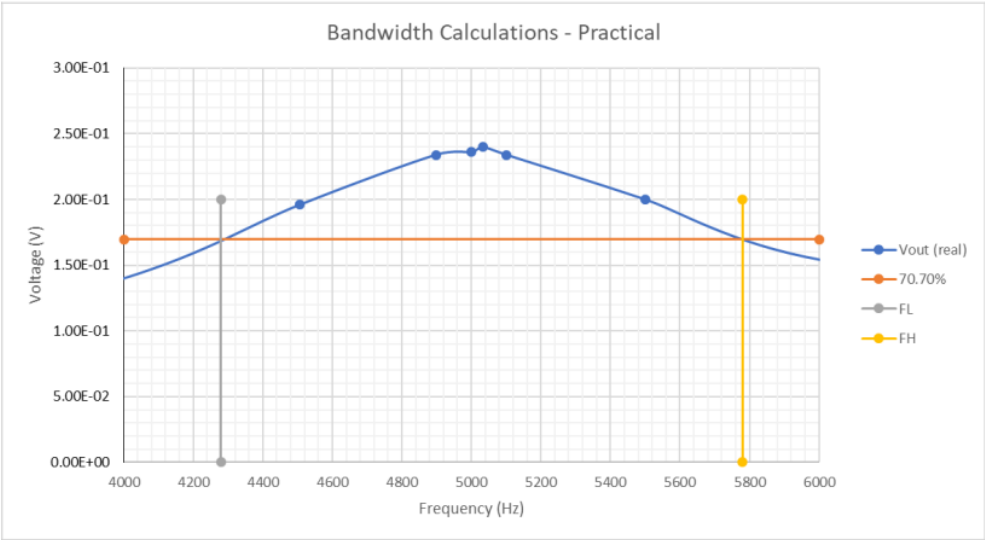


Figure X: Bandwidth calculations for the experimental values

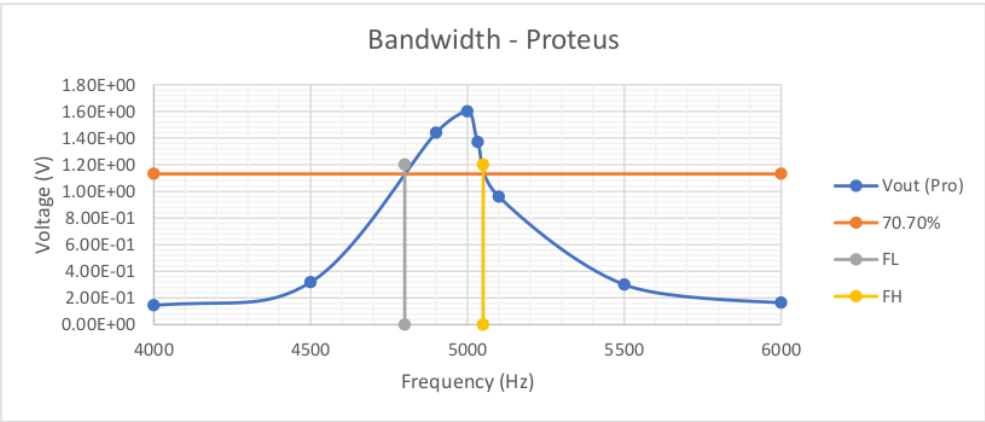


Figure X: Bandwidth calculations for the Proteus simulation

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

70 / 100

PAGE 1

PAGE 2



Comment 1

in?



Comment 2

But what about numerical results? These should be included in an abstract.

PAGE 3



Comment 3

intervals of what? time? frequency?

PAGE 4



Comment 4

Impedance

PAGE 5

PAGE 6



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Comment 5

You didn't use the oscilloscope to select the frequency - you used it to *measure* the frequency. It was selected using a function generator.



Comment 6

Could have been the oscilloscope probe

PAGE 7

PAGE 8

PAGE 9



Comment 7

Signal generator



Comment 8

logical conclusion



Comment 9

This would be between the theoretical resonant frequency and the resonant frequency of a practical circuit using the components I measured, these would not necessarily be the same values for the components you were using. This data was only included as a guide that the component values are subject to a tolerance. A few calculations based on component tolerance could have got you to a range of resonant frequencies which would allow you to determine if this is an acceptable value or not.

PAGE 10



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.

PAGE 11

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

3.55

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.

21.3

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

20.4

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

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of methods, materials, tools and/or techniques.

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.



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

3.75