

ACDA4006 assignment

by Christopher Peacock

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Abstract

This report details the method, results and a discussion of both a simulated and an experimental R-L-C circuit. The results of the simulated circuit show that there is a clear and sharp drop in the voltage in the circuit between 4700Hz and 5200Hz. The experimental circuit also showed a drop in the voltage between 2200Hz and 12000Hz, however the drop is more gradual over a larger bandwidth. The Q factor for the simulated circuit was calculated as 9.58 from the components and 9.9 from the graph of the results. For the experimental circuit the Q factor was calculated as 10.74 from the actual component values and as 0.72 from the graph of the results. The differences between the Q factor values calculated from the components are due to the real components being constructed to a tolerance, therefore having difference values to that stated. The difference in the Q factor calculated from the graph of results for both of the circuits is because the simulated circuit doesn't take into account the additional resistance within the circuit in the experimental circuit. The additional resistance comes from multiple sources in the circuit: the signal generator, the resistance of the capacitor, resistance of the inductor and the resistance of the wires within the circuit. The resistance of the signal generator is the primary source of additional resistance.



Introduction

This report details the results and conclusions into an investigation between the differences in voltages at different frequencies within a simulated and an experimental R-L-C circuit. From the results on both the simulated and the experimental circuits the bandwidth at which the voltage drop occurs was determined allowing the resonant frequency of the circuit to be determined. The Q factor of each circuit was calculated by using both the resistance, capacitance and inductance values of the components and from the results taken from graph of the results.

R-L-C circuits are circuits which contain a resistor, inductor and capacitor. If the voltage is in phase with the current the circuit is resonant. An R-L-C circuit resonates by the cycle of stored energy accompanied by the energy dissipating due to the resistance. The inductor stores energy in its magnetic field which it then transfers to the electric field of the capacitor and is subsequently transferred back to the magnetic field. This process is then repeated. A circuit is said to be at resonance when the impedance of the inductor and the impedance of the capacitor are equal [1, pp. 391-94].

Resonance is a phenomenon which is used within radio, television and communications. This is because it allows small parts of a frequency spectrum to be singled out and amplified separately from the rest of the spectrum [1, p. 391].

Q factor is an abbreviation for quality factor and indicates the energy losses within a circuit. For an electrical resonant circuit this relates to the resistance in a circuit which damps it. A low Q factor in a circuit shows that it has been damped while a high Q factor is undamped. Low Q factor circuits have a wide bandwidth while high Q factor circuits have a narrow band [1, p. 391] [2].

Units of measurement

Resistance – Ohms (Ω)

Inductance – Henries (H)

Capacitance – Farads (F)

Voltage – Volts (V)

Frequency – Hertz (Hz)

Theory

Resonant frequency

From component values

Where [3]:

- X_L = Impedance of the inductor
- X_C = Impedance of the capacitor
- f = Resonant frequency
- L = Inductance
- C = Capacitance

$$X_L = X_C$$
$$X_L = 2\pi fL$$

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

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

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

From bandwidth

The bandwidth is calculated using the graph of the results. The bandwidth is measured between the 70.7% amplitude points on the graph [1, p. 399]. For both the simulated and experimental circuits the 70.7% point is at 2.82V.

Where:

- BW = Bandwidth
- F = Frequency
- f_h = High frequency band edge
- f_l = Low frequency band edge
- f_c = Resonant frequency

$$BW = \Delta f = f_h - f_l$$

$$f_l = f_c - \frac{1}{2}BW$$

Q factor

Where [1]:

- f = Frequency
- L = Inductance
- R = Resistance
- f_c = Resonant frequency.
- BW = Bandwidth

$$Q \text{ factor} = \frac{2\pi fL}{R}$$

$$Q \text{ factor} = \frac{f_c}{BW}$$

Method

Simulation

A simulated circuit was constructed on a computer based electronic circuit board design software simulator, Proteus 8 professional. The circuit was an RLC circuit constructed in series with an AC signal generator and an oscilloscope, with the oscilloscope set to record the voltage over the inductor and capacitor (V_{L+C}). The values of the resistor, capacitor and inductor were set to the values given in the tasking (Figure 1):

- Resistor: 3.3Ω
- Inductor: 1mH
- Capacitor: $1\mu\text{F}$

The signal generator was used to generate a constant voltage of 4V and a varying frequency. Measurements were taken of the voltage over the inductor and capacitor (V_{L+C}) at a range of frequencies between 100Hz and 20000Hz . When the voltage (V_{L+C}) started to drop and subsequently rise, measurements were taken at a closer frequency intervals to allow the drop to be more closely mapped.

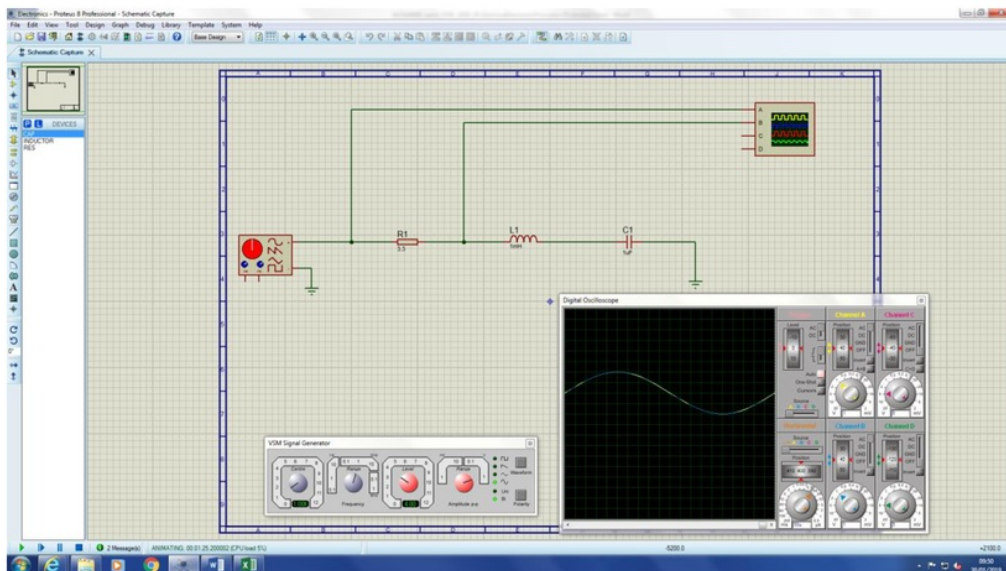


Figure 1: Proteus overview of the circuit

Experimental

An RLC circuit was constructed in series on a breadboard (Figure 2) with a signal generator and an oscilloscope (Figure 3). The oscilloscope was set to record the voltage over the inductor and capacitor (V_{L+C}). The stated values of the components were the same as the simulated circuit. The measured values of the components were as follows [4]:

- Resistor: 2.89Ω
- Inductor: 0.977 mH
- Capacitor: $1.013\mu\text{F}$

The signal generator was used to generate a constant voltage of 4V and a varying frequency. Measurements were taken of the voltage over the inductor and capacitor (V_{L+C}) at a range of frequencies between 100Hz and 20000Hz.

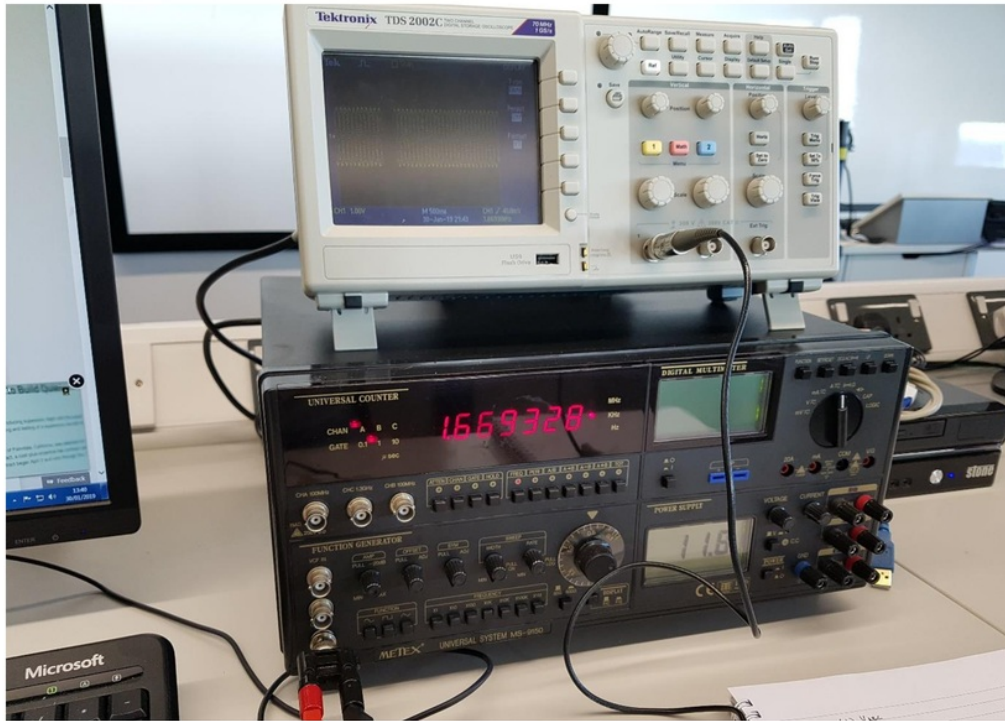


Figure 2: Set up of the signal generator and oscilloscope

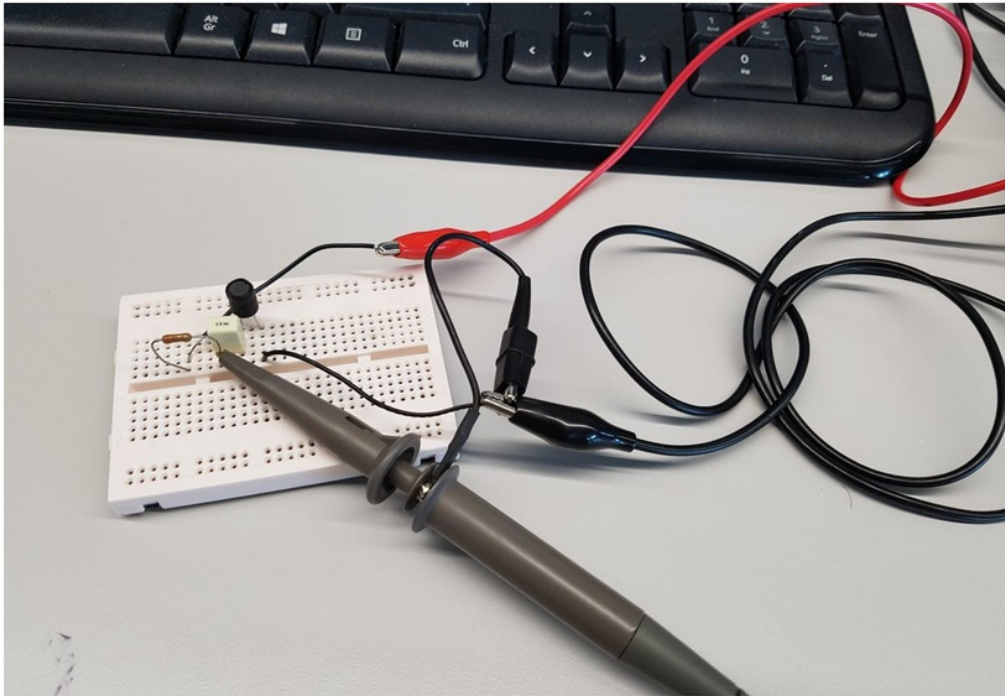


Figure 3: Breadboard showing experimental circuit

Results

The results which were obtained for both the simulated and experimental circuits are detailed in the Annex to this report.

Simulation

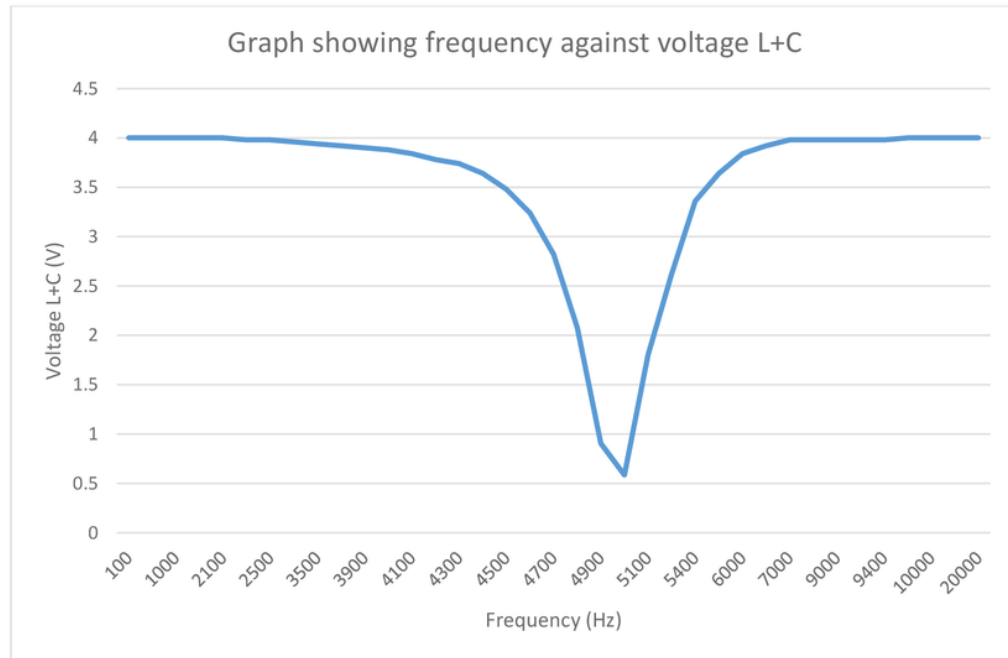


Figure 4: Graph of the simulated circuit

The graph above (Figure 4) shows the frequency against the L+C voltage for the simulated circuit.

Resonant frequency

From the components

The resonant frequency for the simulated circuit can be calculated using the following formula and values [5].

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

- L = 1mH
- C = 1μF

The resonant frequency of the simulated circuit is 5032.92Hz (to two decimal places)

From the graph

The resonant frequency for the simulated circuit can be calculated using the following formula and values [5]. The values of f_h and f_l are derived from the graph.

$$BW = \Delta f = f_h - f_l$$

$$f_l = f_c - \frac{1}{2}BW$$

- $f_h = 5200\text{Hz}$
- $f_l = 4700\text{Hz}$
- $BW = 500\text{Hz}$

The resonant frequency calculated from the graph is 4950Hz.

Q Factor

From the components

The Q factor for the simulated circuit can be calculated using the following formula and values [1].

$$Q\ factor = \frac{2\pi fL}{R}$$

- $L = 1\text{mH}$
- $R = 3.3\Omega$
- $f = 5032.92\text{Hz}$

The Q factor of the simulated circuit is 9.58 (to two decimal places).

From the graph

The Q factor for the simulated circuit can be calculated using the following formula and values [1].

$$Q\ factor = \frac{f_c}{BW}$$

- $BW = 500\text{Hz}$
- $f_c = 4950\text{Hz}$

The Q factor for the simulated circuit is 9.90 (to two decimal places).

Experimental

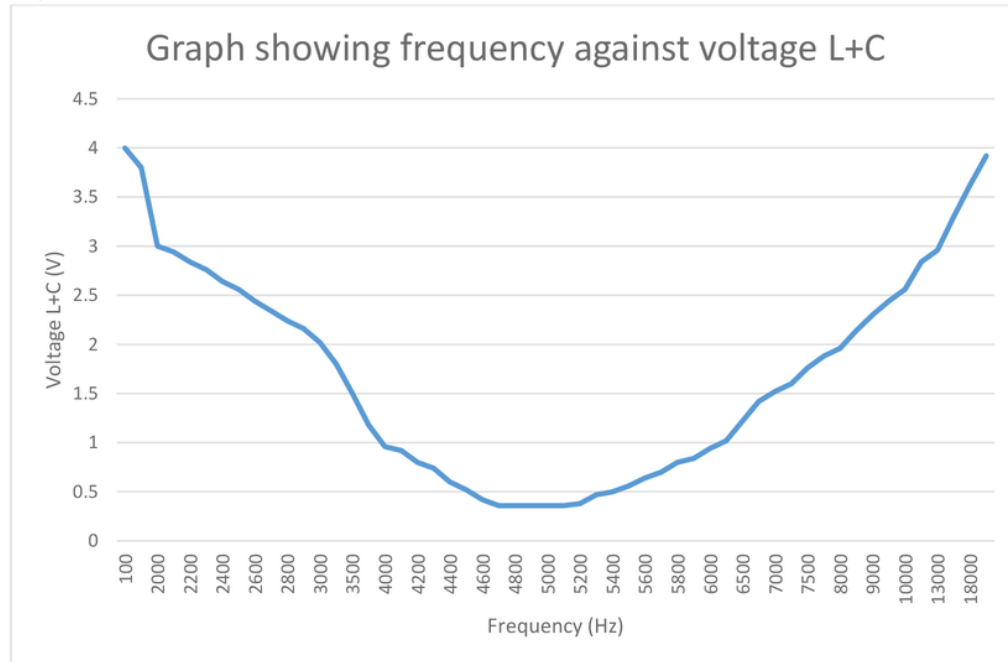


Figure 5: Graph of the experimental circuit

The graph above (Figure 5) shows the frequency against the L+C voltage for the experimental circuit.

Resonant frequency

From the component values

The resonant frequency for the experimental circuit can be calculated using the following formula and values [5].

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

- L = 0.977mH
- C = 1.013μF

The resonant frequency of the experimental circuit is 5059.04Hz (to two decimal places)

From the graph

The resonant frequency for the experimental circuit can be calculated using the following formula and values [5]. The values of fh and fl are derived from the graph.

$$BW = \Delta f = fh - fl$$

$$fl = fc - \frac{1}{2}BW$$

- fh = 12000Hz
- fl = 2200Hz

- BW = 9800Hz



The resonant frequency calculated from the graph is 7100Hz.

Q Factor

From the component values

The Q factor for the experimental circuit can be calculated using the following formula and values [1].

$$Q \text{ factor} = \frac{2\pi fL}{R}$$

- L = 0.977mH
- R = 2.89Ω
- f = 5059.04Hz

The Q factor of the experimental circuit is 10.74 (to two decimal places).

From the graph

The Q factor for the experimental circuit can be calculated using the following formula and values [1].

$$Q \text{ factor} = \frac{f_c}{BW}$$

- BW = 9800Hz
- f_c = 7100Hz

The Q factor for the experimental circuit is 0.72 (to two decimal places).

Discussion

Looking at the two sets of results for both the simulated and experimental circuits they both show a drop in the voltage in the circuits from 4V to around 0.5V. For the simulated circuit there is a clear drop over a short frequency range which contrasts to a more gradual drop in the experimental circuit. The bandwidth of the resonant frequency for the simulated circuit is narrow at 500Hz whilst the bandwidth for the experimental circuit is considerably higher at 9800Hz.  3

The resonant frequency for the simulated circuit is was calculated from the stated component values at 5032.92Hz (to two decimal places). The resonant frequency from the results on the simulated circuit was calculated as 4950Hz. A difference of 82.92Hz. The resonant frequency for the experimental circuit is was calculated from the actual component values at 5059.04Hz (to two decimal places). The resonant frequency from the results on the experimental circuit was calculated as 7100Hz. A difference of 2040.96Hz.

The Q factor for the simulated circuit is calculated as 9.58 from the stated component values and 9.90 from results on the graph. For the experimental circuit the Q factor is 10.74 from actual component values and 0.72 from the graph.

The differences between the stated values of the components as used in the simulated circuit and the actual values for the components used in the experimental circuit are due to the differences in the tolerances. As a result of the manufacturing processes and quality of the materials used all of the components which were used have been manufactured with different tolerances. These differences will impact on the stated resistance, capacitance or inductance of each of the components and as a result the resonant frequency and Q factor of the experimental circuit compared to the simulated circuit.

The capacitor and the inductor within the experimental circuit also have a resistance value [6, pp. 44-45]. Within the simulated circuit the capacitor and inductor do not have any resistance. This results in the overall resistance of the simulated circuit being less than that in the experimental circuit. The actual resistance of the inductor is 2.89Ω which is equal to the actual value of the resistance of the resistor. As this increases the resistance it damps the circuit, reducing the Q factor. The resistance of the capacitor also increases the resistance of the circuit and is dependent on the frequency of the input signal [1]. It is calculated by the following formula.

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

The resistance of the signal generator has a significant impact on the results on the experimental circuit. The signal generator used in the experimental circuit has an internal resistance of 50Ω . When the resistance of the signal generator and the inductor is added to the circuit it gives a Q factor of 0.56 (to two decimal places) which is close to the figure derived from the values obtained in the experimental circuit.  4

The resistance of the wires used in the experimental circuit was not taken into account when calculating the resistance of the circuit. Although this will not make a significant difference to the resistance of the circuit it will increase it. The increase in the resistance will impact, however limited, the Q factor within the circuit. Other imperfections within the circuit can cause increases in resistance within the experimental circuit. These include the following: Corrosion of connectors within the signal generator and the breadboard; imperfect and damaged connections within the

breadboard; the age and previous use of the resistor, capacitor or the inductor and other imperfections within the circuit.

At the resonant frequency the voltages over the inductor (V_L) and the capacitor (V_C) must be equal in their value and opposite, therefore cancelling each other out. This results in the L+C voltage being 0V [5]. Neither the simulated or experimental circuits produced results which demonstrated this. This is because of the tolerances and construction of the components within the circuit and the construction of the circuit.



Conclusions:

The differences between the resonant frequencies and Q factors of the simulated and experimental circuits are a result of several factors. These include such factors as: the tolerances of the components; the resistances of different components not being factored into the simulated model; the construction of the components and the circuit. The differences in the tolerances of the components in the experimental circuit to those in the simulation has less of an impact on the Q factor than the resistance of the components and the signal generator.

Recommendations:

For future testing using components with less tolerance would reduce the variance of the values for the resistance, capacitance and inductance.

In order to improve the accuracy of the simulated circuit the circuit a number of things could be modified. The simulated circuit used generic components with the values inputted manually. Using the specific resistor, inductor and capacitor which were used in the experimental circuit, including adding the resistance of the capacitor and inductor, would reduce the differences between the two circuits. Inputting the resistance of the signal generator into the simulated circuit would allow a more accurate simulated circuit to be constructed.

References

- [1] B. J, Electrical Circuit Theory and Technology 4th Edition, London: Routledge, 2012.
- [2] [Online]. Available: https://www.electronics-notes.com/articles/basic_concepts/q-quality-factor/basics-tutorial-formula.php. [Accessed 13th February 2019].
- [3] "Electronics tutorials series circuits," [Online]. Available: <https://www.electronics-tutorials.ws/accircuits/series-circuit.html>. [Accessed 14th February 2019].
- [4] S. Mosey, "UWTSD Moodle," [Online]. Available: <https://moodle.uwtsd.ac.uk/mod/page/view.php?id=152419>. [Accessed 6th February 2019].
- [5] "Electronics tutorials series resonance," [Online]. Available: <https://www.electronics-tutorials.ws/accircuits/series-resonance.html>. [Accessed 14th February 2019].
- [6] P. & H. W. Horowitz, The Art of Electronics 3rd Edition, New York: Cambridge University Press, 2015.
- [7] [Online]. Available: <https://radio-electronics.com/info//formulae/q-quality-factor/basics-tutorial.php>. [Accessed 4th February 2019].

Annex

Results for the simulation

Frequency (Hz)	Voltage _(L+C) (V)	Frequency (Hz)	Voltage _(L+C) (V)
100	4.00	4800	2.08
500	4.00	4900	0.90
1000	4.00	5000	0.58
2000	4.00	5100	1.80
2100	4.00	5200	2.62
2200	3.98	5400	3.36
2500	3.98	5600	3.64
3000	3.96	6000	3.84
3500	3.94	6500	3.92
3800	3.92	7000	3.98
3900	3.90	8000	3.98
4000	3.88	9000	3.98
4100	3.84	9200	3.98
4200	3.78	9400	3.98
4300	3.74	9700	4.00
4400	3.64	10000	4.00
4500	3.48	15000	4.00
4600	3.24	20000	4.00
4700	2.82		

Results for the experiment

Frequency (Hz)	Voltage L+C (V)	Frequency (Hz)	Voltage L+C (V)
100	4.00	5100	0.36
1000	3.80	5200	0.38
2000	3.00	5300	0.47
2100	2.94	5400	0.50
2200	2.84	5500	0.56
2300	2.76	5600	0.64
2400	2.64	5700	0.70
2500	2.56	5800	0.80
2600	2.44	5900	0.84
2700	2.34	6000	0.94
2800	2.24	6200	1.02
2900	2.16	6500	1.22
3000	2.02	6800	1.42
3200	1.80	7000	1.52
3500	1.50	7200	1.60
3800	1.18	7500	1.76
4000	0.96	7800	1.88
4100	0.92	8000	1.96
4200	0.80	8500	2.14
4300	0.74	9000	2.30
4400	0.60	9500	2.44
4500	0.52	10000	2.56
4600	0.42	12000	2.84
4700	0.36	13000	2.96
4800	0.36	15000	3.30
4900	0.36	18000	3.62
5000	0.36	20000	3.92

ACDA4006 assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

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PAGE 2



Comment 1

Good abstract. It contains all the information required and draws the reader into your paper.

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Comment 2

You cannot determine resonant frequency in this way as the slope of the curve is different either side of resonance meaning the resonant frequency is not in the geometric centre of the bandwidth.

To find the resonant frequency from the graph you simply find the lowest point and read its frequency.

**Comment 3**

Mixed tenses. Should this be "is" or "was"?

**Comment 4**

Not so much the wires used, but more the connections at either end of the wires.

**Comment 5**

Possibly due to the inaccuracies in setting the frequency produced by the signal generators (software limited to 100Hz steps and hardware realistically limited to a couple of Hertz if not more.)

GRADING FORM: SMU GENERIC_SMOSEY

CHRISTOPHER PEACOCK

62.00

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

3.25

good use of referencing conventions, consistently applied.

KNOWLEDGE & UNDERSTANDING

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



Knowledge is extensive. Exhibits understanding of the breadth and depth of the concepts involved.

20.4

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.



Evidence of some logical, analytical thinking and synthesis. Can analyse abstract data. Ability to use evidence to support the argument. Minor errors in part of the analysis. Valid conclusions and recommendations.

17.7

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods and techniques. Good appreciation of the context of the application, with some use of examples, where relevant.

17.4

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 well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

3.25