

Jacob Smith Assignment

by Jake Ian Smith

Submission date: 08-Dec-2021 07:48PM (UTC+0000)

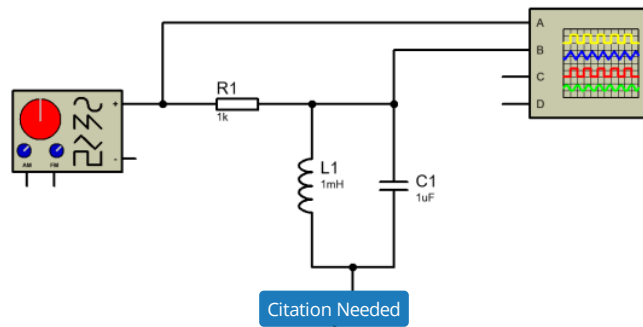
Submission ID: 165455129

File name: 27246_Jake_Ian_Smith_Jacob_Smith_Assignment_387569_694492269.pdf (447.47K)

Word count: 2680

Character count: 12094

Electrical & Electronic principles assignment 1
ACDA4006
Jacob Smith



- **Abstract**

The task was to first simulate the circuit in Figure 1 within a virtual simulator, for this experiment Proteus was chosen to be the simulator to be used. The same circuit would then be replicated with a breadboard and appropriate electronic components. This was done to compare and demonstrate the differences between a virtual and real-life example. Although the results were similar there were some noticeable differences.

- **Introduction**

For this simulation we used a simple circuit using a sine wave generator, a resistor, an inductor and a capacitor, with an oscilloscope connected in parallel. This type of circuit can commonly be found in radio circuit constructions in a part of the circuit known as a tank circuit. A tank circuit is found on both receiver and transmitter side of the circuits, where its role is to connect the amplifier to the antenna allowing the circuit to transmit to space. It also works on the receiving side of the radio by converting the received signal to the appropriate frequency [1]

The theory behind these two simulations is to demonstrate the differences between a virtual simulation and a real-life example. By building a circuit in a simulation programme like Proteus you can model and test certain parameters to find the desired output. For example, you can easily change the values of the resistors, capacitors or inductors and see immediately the effect this would have on the circuit's output. By doing everything in a virtual simulation first you can avoid expensive testing and fine tune the circuit before a physical replication is made.

In the rest of this report, you will be able to see a virtual representation of the circuit found in Figure 1 with also a real-world example being tested in the exact same way. The results will then be plotted on a couple of graphs to visually represent the results and to easily compare them. Where you will be able to easily see the differences between virtual and real-life examples. A conclusion at the end of the document will go into details on what has been found in the two representation of the circuit.

• Simulation/circuit setups

With the use of Proteus, the circuit seen in Figure 1 was reproduced and can be seen below in Figure 2. The circuit in Figure 2 consists of a Signal generator (A), a resistor (R1), an inductor (L1), a capacitor (C1), an oscilloscope (B) and finally a ground (C). Channels C & D on the Oscilloscope are not in use for this experiment as well as the secondary output of the signal generator.

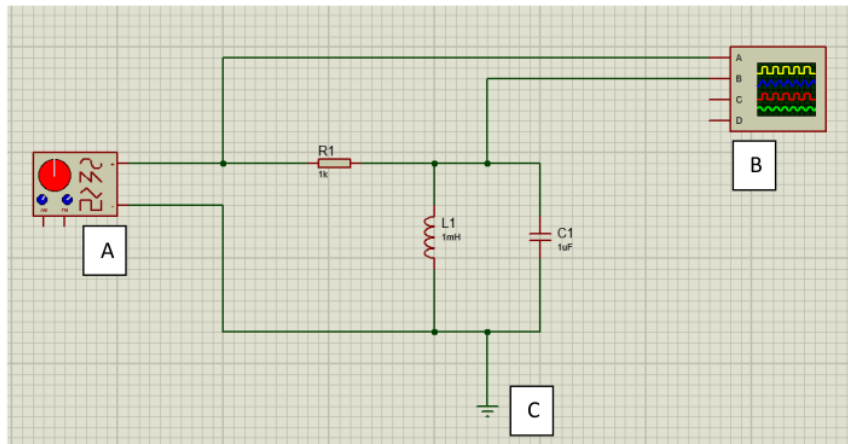


Figure 2

The following parameters were set within the circuit:

1. A – 2V pk-pk starting at 100Hz
2. R1 – 1k Ω
3. L1 – 1mH
4. C1 – 1 μ F

With these parameters in place the circuit was then measured at a range of frequency's starting at 100Hz up to 20000Hz increasing at regular intervals. This was done using the tool provided within Proteus shown below in Figure 3. Figure 3 shows one of the settings during the simulation.

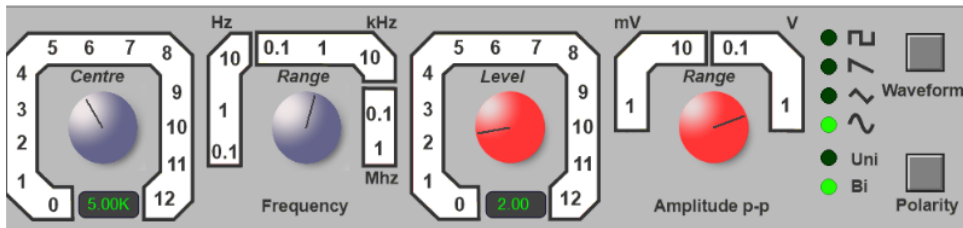


Figure 3

Below in Figure 4 you can see the oscilloscope measurements taken with the settings seen in Figure 3. Here you can see there is a 2V pk-pk (Yellow line) measurement at this point and a 64.50uS output (Blue line). If you take a look at the table in appendix 1 you will see all the results recorded both simulated and actually measured. At the 5000Hz point on the table you will see the results you can see in Figure 4.

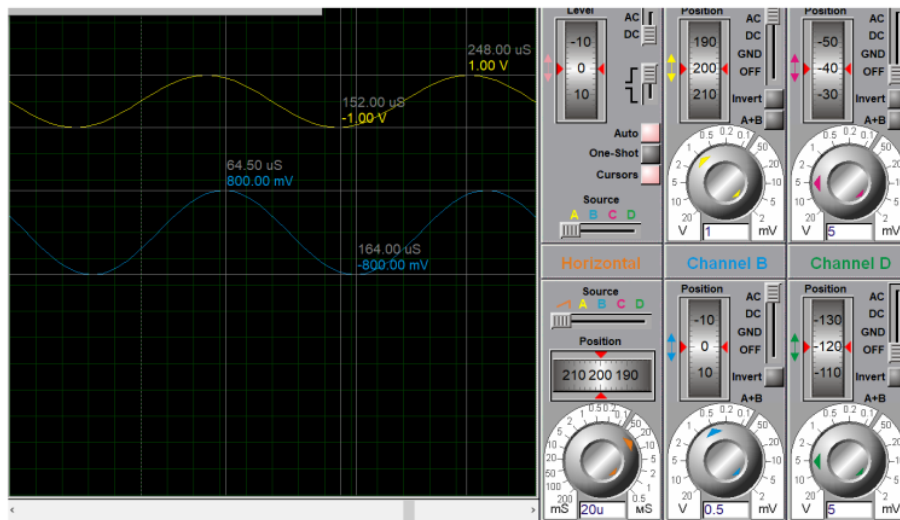


Figure 4

After the completion of the simulated measurements a real-life example of the circuit was produced, this can be seen below in Figure 5. Care was taken to make sure the real-life example was laid out as closely as possible to the virtual simulation. What cannot be seen in Figure 5 is the signal generator and the oscilloscope, but you can clearly see where they interact with the circuit present on the breadboard. The input and output of the signal generator can be seen in the top left corner of Figure 5 with the red and black plugs, these would then connect to the breadboard at the appropriate points (positive and negative wires). The measurements leads for the Oscilloscope can be seen connecting to the circuit either side of the resistor in parallel in keeping with the simulated circuit.

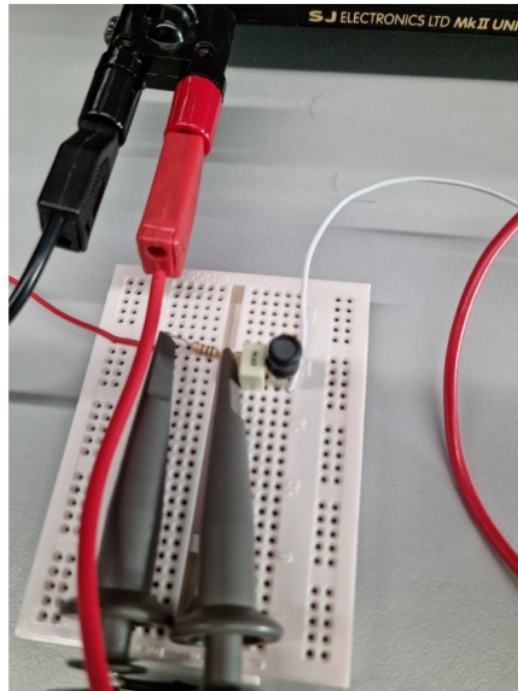
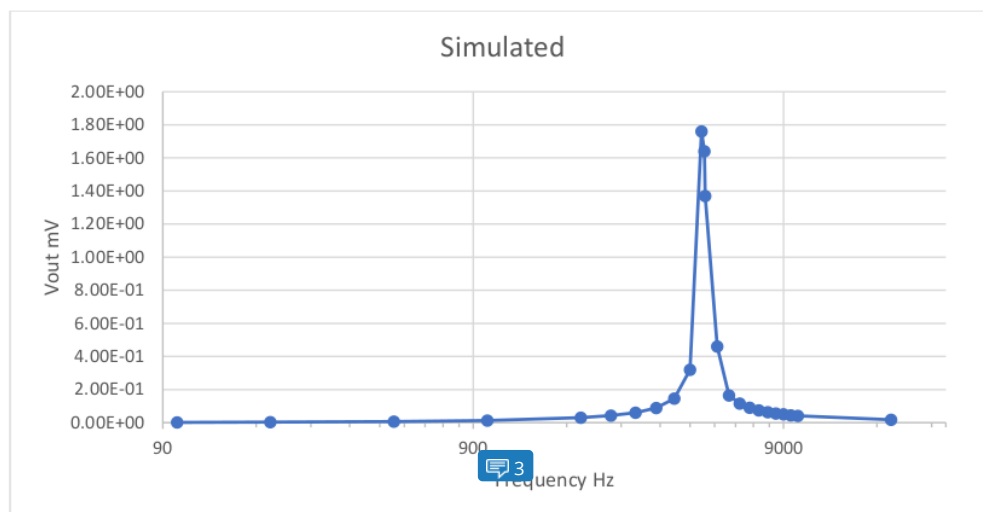


Figure 5



• Results

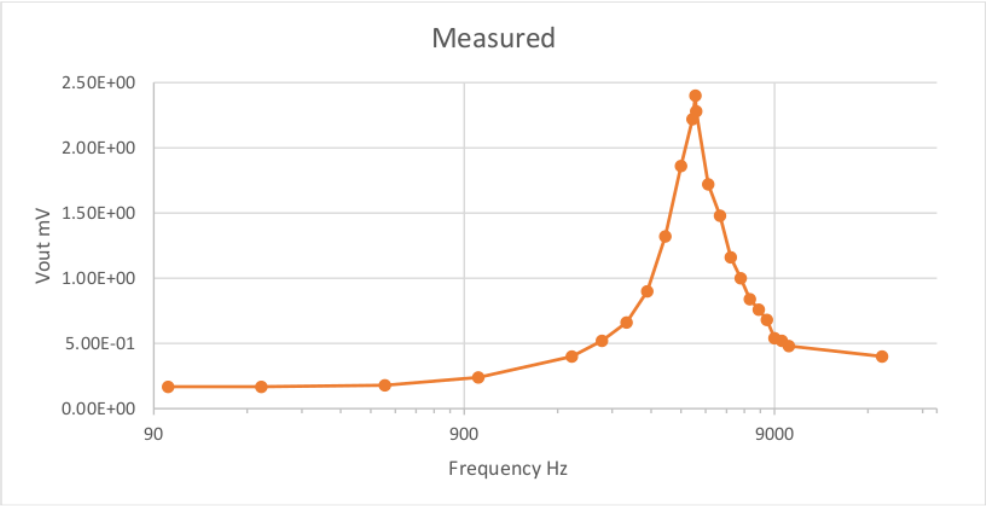
In Graph 1 you can see the plotted results from the simulated circuit with a peak around the 5000Hz area of the frequency.



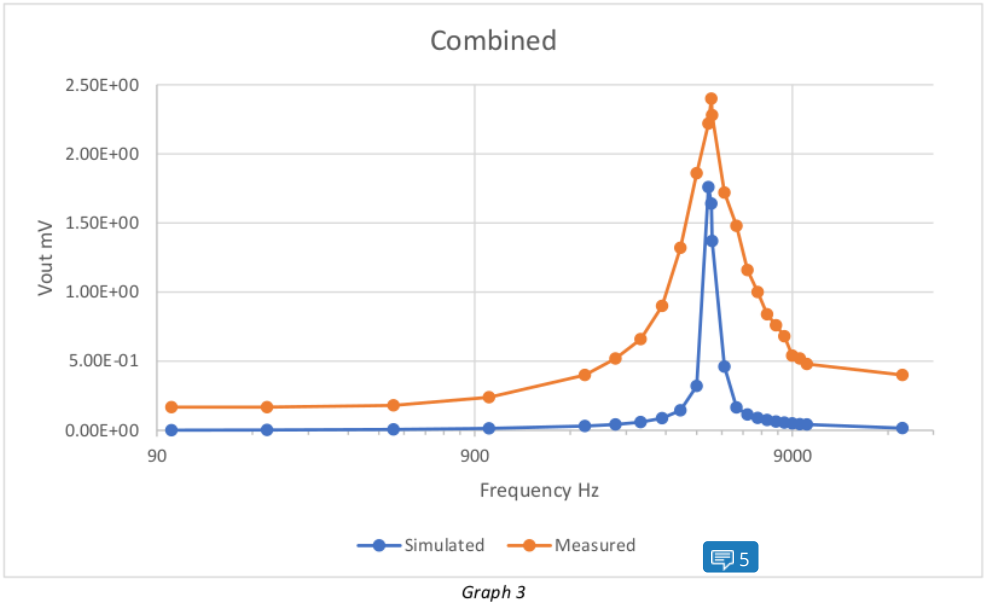
Graph 1



Below in Graph 2 we can see the results from the measured circuit on the real-life example. Again, we can see a peak around the 5000Hz part of the frequency. Although the results are very similar there are some differences.



Below in graph 3 we can see the combined data on one graph. This allows us to easily visualise the differences between the simulated and the measured results. We can easily see the peak that happens around the 5000Hz mark but what we can see better here is the difference in magnitude of the two peaks.



The peaks that we can see happening on the graphs are caused by Resonant frequency, this is happens when the oscillation between a capacitor and inductor reaches the maximum oscillation response in the circuit [2]. The resonant Frequency can easily be calculated with the below equation

$$f = \frac{1}{2 * \pi * \sqrt{L * C}}$$

Where f = Frequency in Hertz, L = Inductance in Henrys and C = Capacitance in Farads. If we replace the letters in the equation with the values, we have used in the circuit we can calculate what the resonant frequency should be for this circuit.

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

$$f = 5032.92121 \text{ Hz}$$



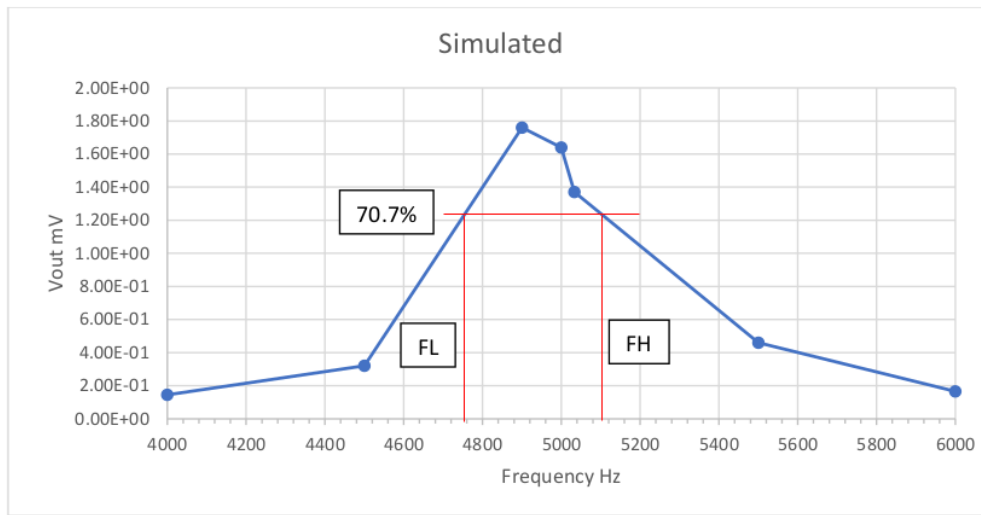
With the resonant frequency calculated to be at 5032.92121 Hz we can see how this fits in with what we see in the graphs above. They all have a peak around the 5000Hz mark of the graph. This peak at the resonant frequency is the optimum point for voltage to flow through the circuit as the impedance is at its least due to the oscillation.

Another thing we need to calculate is the Q factor for the circuit. Q factor is the quality of the resonant frequency of the circuit [3]. To find Q we first must find the bandwidth of the resonant frequency this is measured between the 70.7% line of the curve on the graph. To calculate at what point in the curve the 70.7% line should be drawn we need to know the highest point the curve reaches, we then multiply this by 0.7070 and this gives us voltage at which the 70.7% line should be applied. From there we can then determine the High Band edge (FH) and the Low band edge (FL). From there with a simple subtraction we will get the bandwidth frequency.

With the above in mind we can now calculate the bandwidth for the simulated circuit.

$$70.7\% \text{ of } 1.76 = 1.244V$$

With the 70.7% line in place we can then draw two vertical lines down from where it intersects the graph lines. For clarity graph 4 below is a zoomed in version of graph 1. With all the lines in place we can determine that FL is 4750Hz and FH is 5175Hz



Graph 4

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

$$\begin{aligned}\Delta f &= fh - fl \\ \Delta f &= 5175 - 4750 \\ \Delta f &= 425\text{Hz}\end{aligned}$$

$$\begin{aligned}FC &= \frac{\Delta f}{2} + fl \\ FC &= \frac{425}{2} + fl \\ FC &= 212.5 + 4750 \\ FC &= 4962.5\text{Hz}\end{aligned}$$

$$\therefore Bw = 425\text{Hz}$$

Now that we have worked out the bandwidth of the simulated curve, we can now determine the Q factor. With the below equation:

$$\begin{aligned}Q &= fC/BW \\ Q &= 4962.5/425 \\ Q &= 11.6\end{aligned}$$

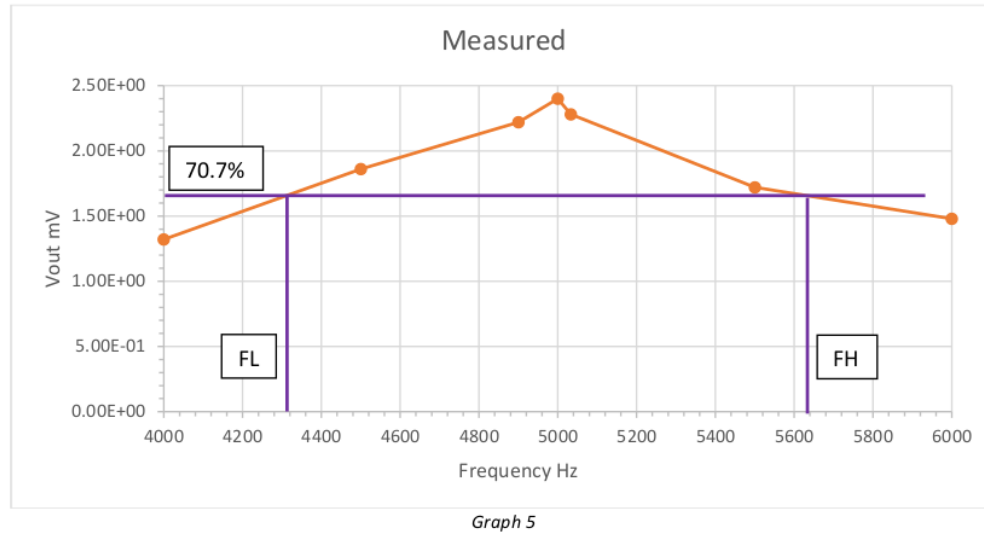
Rounded up to 7

$$Q = 12$$

Now that we have done it for the simulated circuit, we need to do the same for the measured equation.

$$70.7\% \text{ of } 2.40 = 1.6968\text{V}$$

With the 70.7% line in place we can then draw two vertical lines down from where it intersects the graph lines. For clarity graph 5 below is a zoomed in version of graph 2. With all the lines in place we can determine that FL is 4325Hz and FH is 5625Hz



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

$$\begin{aligned}\Delta f &= fh - fl \\ \Delta f &= 5625 - 4325 \\ \Delta f &= 1300Hz\end{aligned}$$

$$\begin{aligned}FC &= \frac{\Delta f}{2} + fl \\ FC &= \frac{1300}{2} + fl \\ FC &= 650 + 4325 \\ FC &= 4975Hz\end{aligned}$$

$$\therefore Bw = 1300Hz$$

Now that we have worked out the bandwidth of the simulated curve, we can now determine the Q factor. With the below equation:

$$\begin{aligned}Q &= fc/BW \\ Q &= 4975/1300 \\ Q &= 3.8\end{aligned}$$

Rounded up to

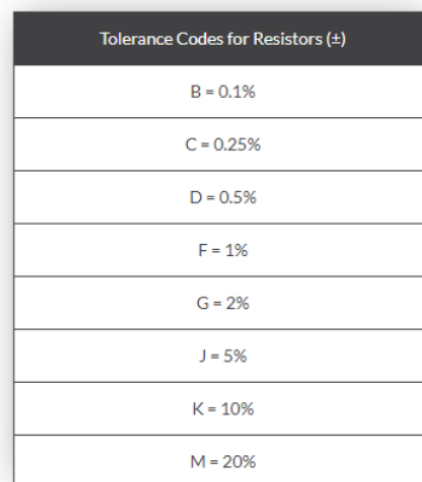
$$Q = 4$$

- **Discussion**

As we can see from the results there are some key differences between the two circuits. One thing that is clearly obvious looking at the graphs is that the measured real-life circuit results give a larger bandwidth and also a higher peak voltage than the simulated circuit. But we can also see that the V_{out} is higher for the real-life circuit across the whole frequency range than the simulated circuit.

There are many reasons that could contribute to the differences between the simulated and real-life circuit and the main factor that needs to be considered is the simulated circuit is in a pristine sanitary environment. This is an important thing to keep in mind as the results you get in a simulation do not take into account components wearing out over time, tolerances within the build quality of the components and also external factors effecting the circuit, as well as many other minor factors. For example, a steady power supply from the signal generators.

With anything that is being produced there is a tolerance level between what is acceptable output from that component compared to the designed output. Taking resistors as an example they can have tolerances as small as 0.1% of the indicated resistance value but also as large as 20%.



Tolerance Codes for Resistors (±)
B = 0.1%
C = 0.25%
D = 0.5%
F = 1%
G = 2%
J = 5%
K = 10%
M = 20%

Figure 6

Above in Figure 6 [4] we can see an example of the range in tolerances that can be found within just one component type. Taking a $1k\Omega$ resistor as an example with a 20% tolerance to it, this resistor could have an actual reading of anywhere between 800Ω and 1200Ω . Whereas in the simulation you would get exactly $1k\Omega$ every time. Proteus does give you the option to model component tolerances within the simulation but for this simulation it was decided not to incorporate them into the circuit so as to give a clearer definition between the two circuits and their measurements.

Another difference that can be seen between the two circuit results is the bandwidth and Q factor sizes. The simulated circuit has a narrow bandwidth with a high Q factor and the real-life circuit has a wider bandwidth and low Q factor. When a circuit has a high Q factor it is in relation to the energy stored within the circuit compared to it being lost through higher resistance [5]. As we can see in the results, the simulated circuit has a high Q factor of 12 thus indicating the circuit has a very lower energy loss in comparison to energy stored within the circuit. This again can be attributed to the sanitary environment found within a virtual simulation. As the circuit within the simulation is a near perfect example of a circuit it is going to have a high Q factor with a narrow bandwidth.

Having a near perfect circuit isn't always a bad thing to have, it would be able to give you an idea of what the perfect circuit would operate like. This would allow you to fine tune your circuit to meet the requirements you might need. Once you have done your fine tuning you can then start to incorporate component tolerance levels into the circuit design allowing you to accurately design a circuit to your requirements.

If the experiment was to be run again, then a second simulation with component tolerances incorporated into the circuit would be a good place to start. With a second simulated circuit to compare to we could simulate how accurate Proteus is at simulating circuits with tolerances added into the equation. It could be expected to see a results line very similar to that of the real-life measured circuit.

• Conclusion

In this experiment, it has been determined that although virtually simulated circuits are a great place to design and plan circuits, they are limited by the amount of information programmed into that circuit. Without parameters like component tolerances incorporated into the design the results seen will be fairly different to that experienced on a real-world counterpart.

If a circuit designer approaches a virtual circuit simulator like Proteus with the knowledge and understanding that the programme is only as good as the data they enter into it then there is no reason why this programme cannot be a great asset. Building the designed circuit in real life will always provide a better understanding if the design would work. It isn't always practical from an industrial point of view, when you take component and labour costs into account.

References

Refs missing info

Ref Qual

- [1] Unknown, "All about Circuits," 2021. [Online]. Available: <https://www.allaboutcircuits.com/tools/tank-circuit-resonance-calculator/>. [Accessed December 2021].

- [2] Unknown, "Cadence PCB Solutions," [Online]. Available: <https://resources.pcb.cadence.com/blog/2021-what-is-resonant-frequency>. [Accessed December 2021].
- [3] Unknown, "All about Circuits," [Online]. Available: <https://www.allaboutcircuits.com/textbook/alternating-current/chpt-6/q-and-bandwidth-resonant-circuit/>. [Accessed December 2021].
- [4] Unknown, "Electronics Tutorials," [Online]. Available: https://www.electronics-tutorials.ws/resistor/res_2.html. [Accessed December 2021].
- [5] Unknown, "Electronics Notes," [Online]. Available: https://www.electronics-notes.com/articles/basic_concepts/q-quality-factor/basics-tutorial-formula.php. [Accessed December 2021].

• Appendix

1.

Freq	Simulated		Measured	
	Vin Vpk-pk	Vout	Vin Vpk-pk	Vout
100	2	1.30E-03	2.065	1.68E-01
200	2	2.60E-03	2.06	1.68E-01
500	2	6.40E-03	2.06	1.80E-01
1000	2	1.33E-02	2.06	2.40E-01
2000	2	3.03E-02	2.06	4.00E-01
2500	2	4.25E-02	2.06	5.20E-01
3000	2	6.00E-02	2.06	6.60E-01
3500	2	8.85E-02	2.04	9.00E-01
4000	2	1.45E-01	2.08	1.32E+00
4500	2	3.20E-01	2.08	1.86E+00
4900	2	1.76E+00	2.08	2.22E+00
5000	2	1.64E+00	2.08	2.40E+00
5032.92	2	1.37E+00	2.08	2.28E+00
5500	2	4.60E-01	2.06	1.72E+00
6000	2	1.65E-01	2.08	1.48E+00
6500	2	1.15E-01	2.08	1.16E+00
7000	2	9.00E-02	2.06	1.00E+00
7500	2	7.40E-02	2.06	8.40E-01
8000	2	6.40E-02	2.06	7.60E-01
8500	2	5.60E-02	2.06	6.80E-01

9000	2	5.00E-02	2.06	5.40E-01
9500	2	4.50E-02	2.08	5.20E-01
10000	2	4.15E-02	2.04	4.80E-01
20000	2	1.68E-02	2.085	4.00E-01

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FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

PAGE 1



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Comment 1

tuning circuits and oscillators

PAGE 2

PAGE 3

PAGE 4



Comment 2

You should include a description of the figure in the caption



Comment 3

Your horizontal axis labels seem a bit odd. They should be 100, 1k, 10k

According to the axis labels your circuit resonates at about 4 kHz



Comment 4

include a description in the caption



Comment 5

I suspect there may be an issue with your measured data, it seems too high. The typical difference between the two at resonance is about a factor of 10



Comment 6

Do you need this many figures after the decimal point? Can you physically measure something to that precision?



Comment 7

Why are you rounding? Q does not have to be an integer



Comment 8

enlarged



Comment 9

grammar



Refs missing info

Some of your references are missing information. To understand what information should be included, see the university IEEE referencing handbook on the library website.

https://uwtsd.ac.uk/media/uwtsd-website/content-assets/documents/library-and-learning-resources/infoskills/IEEE-eng_v.1.2.pdf



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.

JAKE IAN SMITH

62.80

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

KNOWLEDGE & UNDERSTANDING

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



Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

18.6

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 / recommendations

18.3

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, materials, tools and/or techniques.

19.5

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.



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

3.4