

Fundamentals of Electrical and Electronic systems

Electrical and Electronic system logbook

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Abstract

This report investigated two tasks performed by a student as part of the OME Engineering degree Apprenticeship L4 Fundamentals of Electric and Electronic Systems module. The first task involved creating a DC circuit on the Proetus computer simulation software to verify the Maximum Power Transfer Theorem with a given circuit. At maximum power, the load resistance was found to be 12.9k, which equated to the circuit's internal resistance. The theoretical and simulated results were relatable to one another. The second task entailed determining the resonant frequency of an RLC AC circuit using the same software. The theoretical resonant frequency was calculated to be 7.118kHz, while the simulation provided a resonance frequency of approximately 7.1kHz. This report provides a detailed account of both activities.

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1.Introduction

The purpose of these assignments was to verify the student's understanding of the course material and their ability to apply it to real-world scenarios.

Task 1:

The task assigned to the student was to verify the maximum power transfer theorem using a given DC circuit. The student used Proteus simulation software and theoretical calculations to analyse the circuit and confirm that the maximum power was transferred from the source to the load when the load resistance was equal to the internal resistance of the source.

Task 2:

The second task required the student to identify the resonant frequency of an AC circuit. The resonant frequency is the frequency at which the circuit's impedance is at a minimum. The student was required to use Proteus simulation software and theoretical calculations to determine the resonant frequency of the given AC circuit to verify the theorem of task 1.

2. Task One- Maximum Power Transfer Theorem

2.1 Background Theory

This task required the student to verify the maximum power theorem using a DC circuit that was provided. The maximum power theorem is a fundamental concept in electrical engineering that states that the maximum amount of power can be transferred from a source to a load when the load resistance is equal to the internal and/or source resistance.

[1]

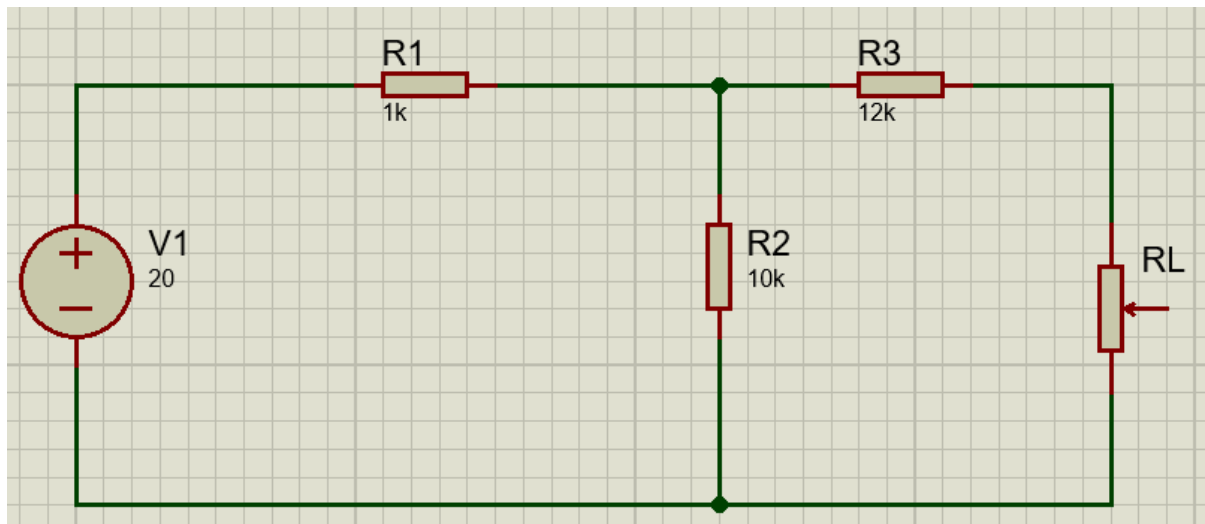


Figure 1- DC Circuit

For maximum power transfer theorem to be calculated on the circuit, the circuit needs to be simplified using Thevenin's theorem. This states that a linear circuit can be simplified to have only one single voltage source and a series resistance. To create this, Thevenin voltage (V_{TH}) and Thevenin resistance (R_{TH}) must be calculated. [2]

The Thevenin voltage is the voltage across the open circuit once the load resistor is removed. This voltage can be determined using the equation seen below.

$$v_{TH} = \frac{v_T}{R_T} \times R_2 \quad \text{Equation 1}$$

The total resistance of the closed loop circuit is denoted by R . The Thevenin resistance is the internal resistance within the circuit. For the task depicted in figure 1, R_1 and R_2 are in parallel and are also both in series with R_3 . The resistance of the circuit can be calculated using the following equation below.

$$R_{TH} = \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^{-1} + R_3 \quad \text{Equation 2}$$

After determining the Thevenin voltage (V_{th}) and Thevenin resistance (R_{th}), the Thevenin equivalence circuit can be drawn. This circuit consists of a power source in series with a resistor (R_{th}) and the load resistor (R_L). Figure2 illustrates this circuit.

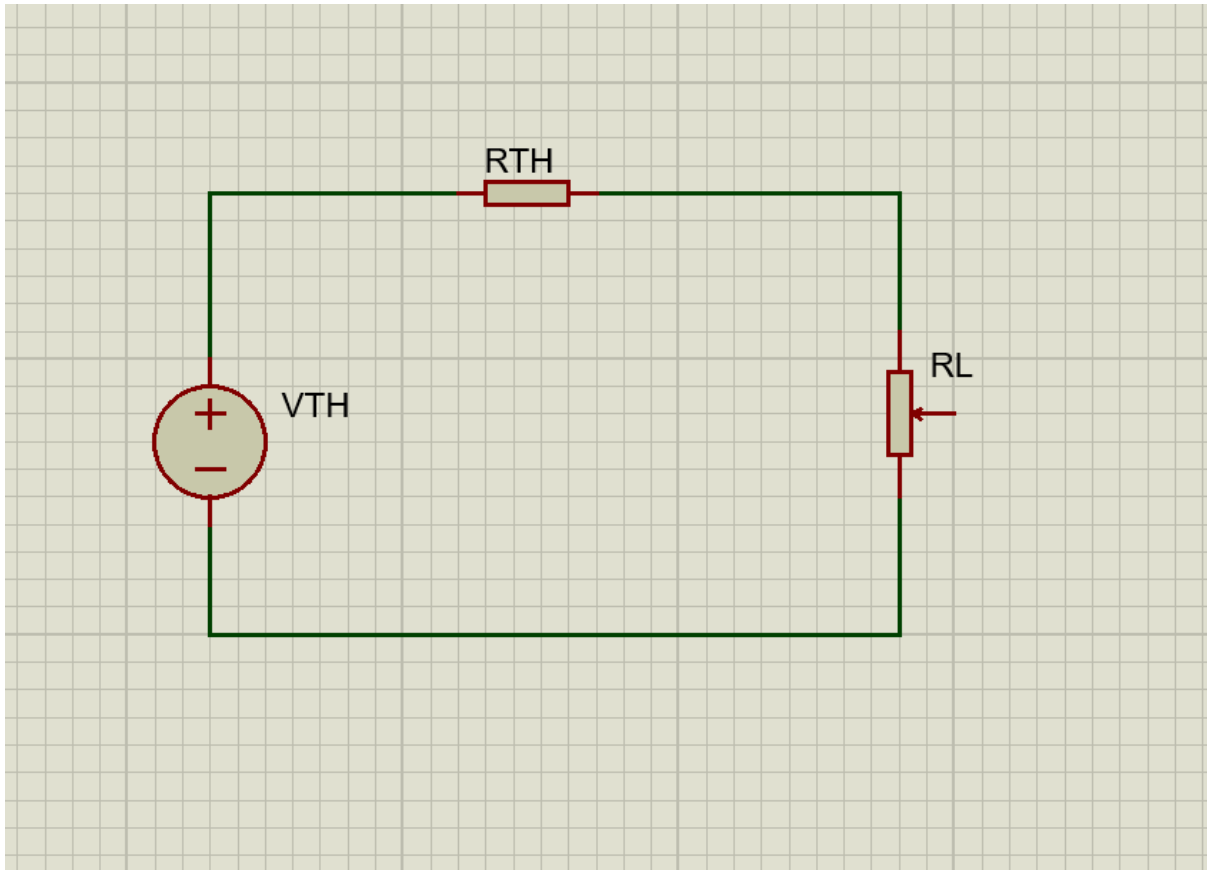


Figure 2- Thevenin's Equivalence Circuit

[3] This circuit demonstrates, the current through the load can be established through applying ohms law, ohms laws equation can be seen below.

$$I_{Total} = \frac{v_{Total}}{R_{Total}} \quad \text{Equation 3}$$

Current through the load can be found through applying the results to the theorem of maximum power transfer. This can be represented in the equation below.

$$I_L = \frac{v_{TH}}{R_{TH} + R_L} \quad \text{Equation 4}$$

- I_L -current through the load
- V_{TH} -Thevenin's Voltage
- R_{TH} - Thevenin's resistance
- R_L - load resistance

The maximum power can be determined by applying the following equation bellow, given this value.

$$p = I_L^2 R_L \quad \text{Equation 5}$$

- P- Power
- I_L - Current through the load
- R_L - Load resistance

2.2 Method

The student used Proteus simulation software to draw the circuit and measure Thevenin's voltage from the circuit, this had a power source of 20V and three resistors ($R_1=1k\Omega$, $R_2=12k\Omega$, and $R_3=12k\Omega$) connected as shown in figure3. The load resistor (R_L) was then removed and replaced it with a voltmeter. From this V_{TH} was found meaning R_{TH} could be measured with the use of an ohmmeter, but this could only be done if the power source was removed

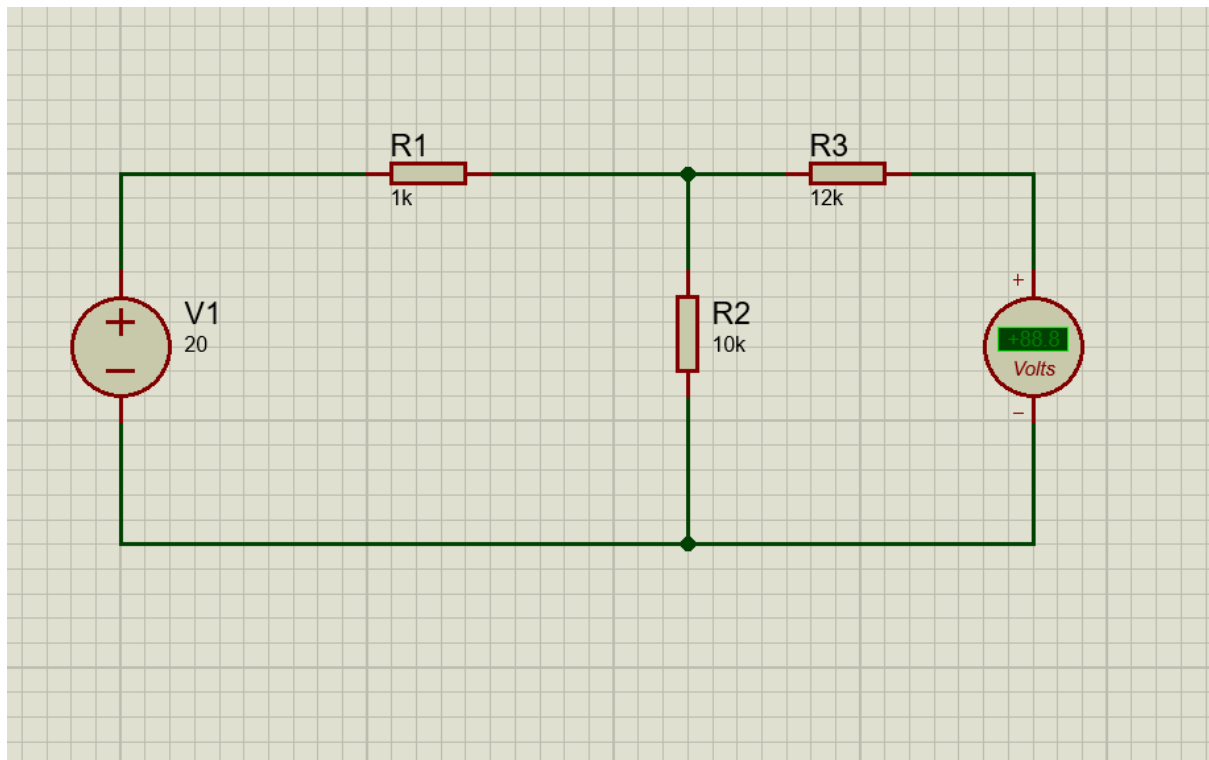


Figure 3- Thevenin's Voltage Circuit

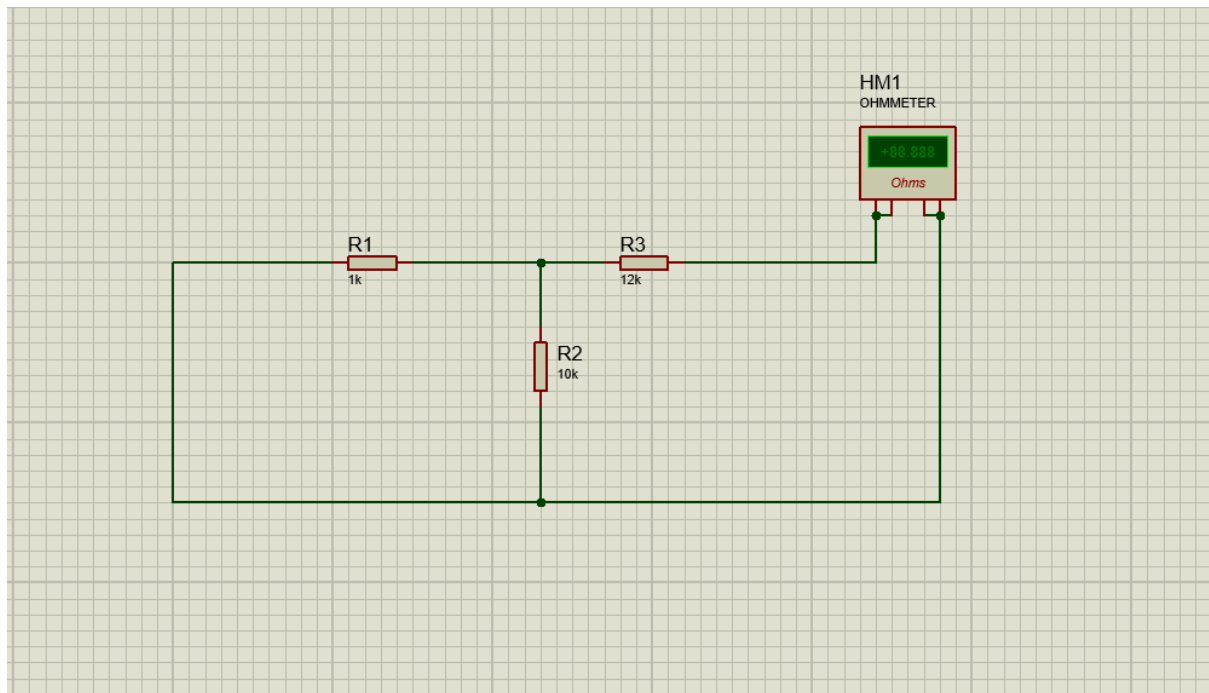


Figure 4- Thevenin's Equivalence Frequency Circuit

Following on from the collection of data for V_{TH} and R_{TH} Thevenin's equivalence circuit was built to obtain results for current through the load resistor, this was done by connecting an ammeter. This can be seen in figure 5

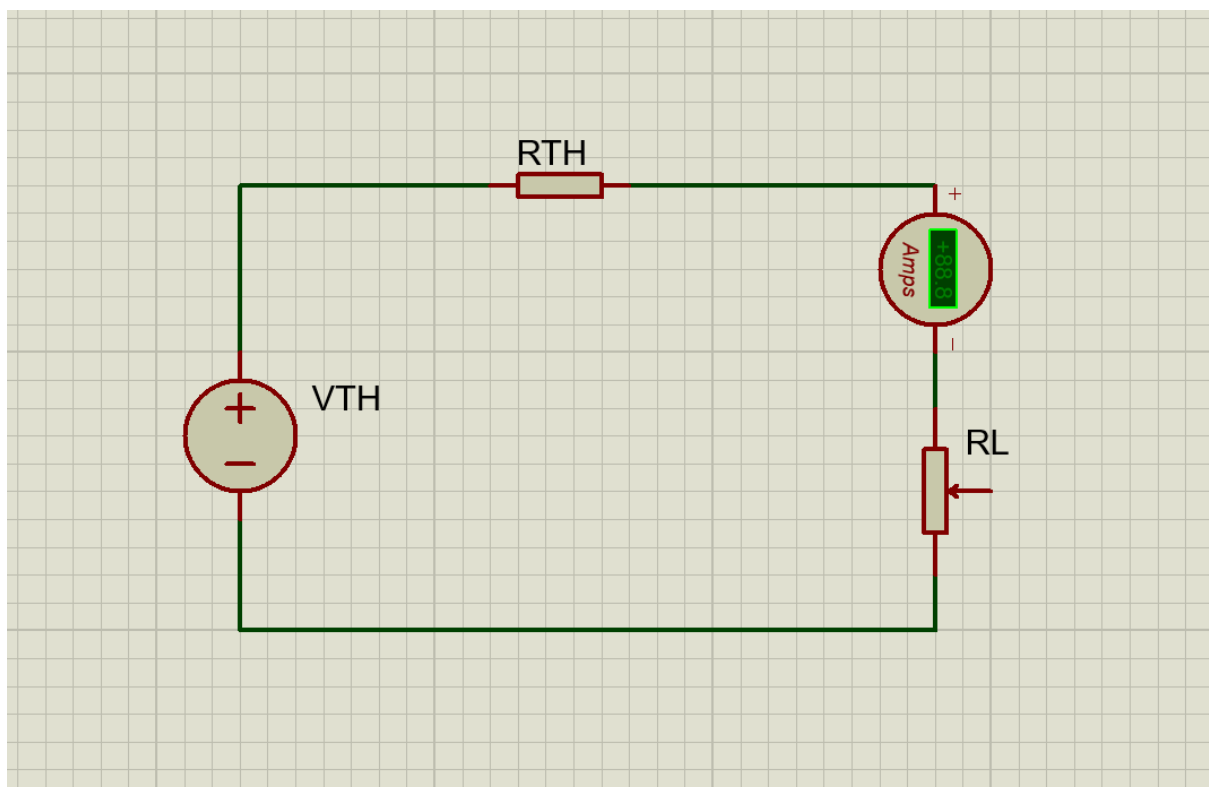


Figure 5- Thevenin's Load Current Circuit

2.3 Results & Conclusion

The current through the load resistor was measured using simulation software. The measurement was conducted through a range of resistance from 1k to 20k, although closer readings were taken when the resistance was around the value found for the equivalence resistance. Using equation 7 Power was able to be calculated and results were recorded in table 1.

Table 1- Load, Current & Power Results Task 1

Load Resistance (RL) Ohms (Ω)	Load Current (IL) Amps (I)	Power Watts (W)
1000	0.001310	0.001716
2000	0.001220	0.002977
3000	0.001140	0.003899
4000	0.001080	0.004666
5000	0.001020	0.005202
6000	0.000962	0.005553
7000	0.000914	0.005848
8000	0.000870	0.006055
9000	0.000831	0.006215
10000	0.000794	0.006304
11000	0.000761	0.006370
12000	0.000731	0.006412
13000	0.000702	0.006406
14000	0.000676	0.006398
15000	0.000652	0.006377
16000	0.000630	0.006350
17000	0.000609	0.006305
18000	0.000589	0.006245
19000	0.000570	0.006173
20000	0.000553	0.006116

By plotting the resistance against the power, the maximum power generated can be determined. The graph in figure 6 shows that the power peaks at 0.006412W when the load resistor had a resistance of 12.9k

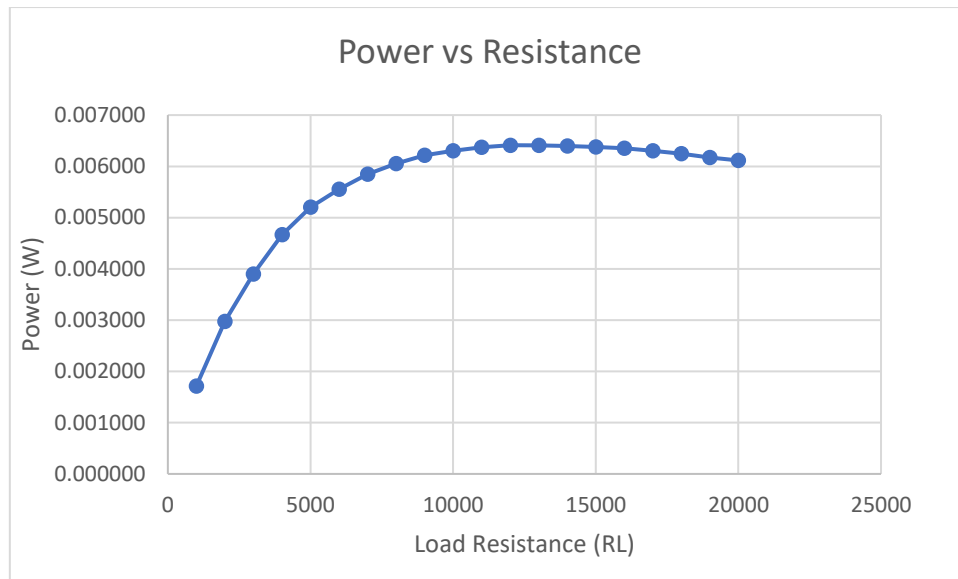


Figure 6- Power Through Load Graph

The full calculations can be found in Appendix A, and the results are provided to two decimal places. Thevenin Resistance and voltage were calculated using the values detailed in section 2.2 to provide a theoretical solution.

$$R_{TH} = 12909.09\Omega$$

$$v_{TH} = 18.20V$$

The current through the load resistor was calculated based on the theory that the load resistance is equal to the Thevenin resistance when the power is at its maximum level.

Equation 6

$$I_L = \frac{v_{TH}}{R_{TH} + R_L}$$

$$I_L = \frac{18.20}{12909.09 + 12909.09}$$

$$I_L = 0.0007049296271_A$$

$$I_L = 0.704_{mA}$$

Maximum power can be calculated from the current load using equation 7

Equation 7

$$P = I_L^2 R_L$$

$$P = (0.000704)^2 \times 12909.09$$

$$P = 0.00639795154W$$

$$P = 0.00640W$$

2.4 Discussion

The experiment verified the maximum power theorem, which states that the maximum power occurs when the load resistor equals the circuit's resistance. The resistance was 12.9kΩ. However, the maximum power generated was different, indicating limitations. The simulation software's meters generated results to a set number of significant figures, making it difficult to measure the current accurately. Smaller resistance increments did not show much change in the current, affecting the power results, which do not follow the predicted curve. To improve the experiment, the ammeter output could be changed for better accuracy.

3. Task Two

3.1 Background Theory

Task two aimed to determine the resonance frequency of an RLC AC circuit the circuit includes a resistor, inductor, and capacitor in series. [4]

When the inductor and capacitor's reactance is equal, a RLC series circuit experiences series resonance. At this point, the applied voltage and current are in phase. Reactance (X) is measured in ohms and represents the opposition to the change of current flow in an AC circuit. This opposition can be due to capacitance (X_c) or inductance (X_L), which are calculated using the following calculation below. Combining the equations for X_L and X_c, we can calculate the resonant frequency when X_L = X_c.

Equation 8

$$x_L = 2\pi fL$$

$$x_c = \frac{1}{2\pi fc}$$

$$x_L = x_c$$

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

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

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

The resonant frequency is measured in Hertz (Hz) and is calculated using the inductance (L) measured in Henry (H) and the capacitance (C) measured in Farads (F).

3.2 Method

To determine the resonance frequency of the AC Circuit. This circuit included a 0.1F capacitor, 100 Ω resistor, and a 5mH inductor connected in series with an AC signal generator. A signal generator was connected, as shown in the figure below.

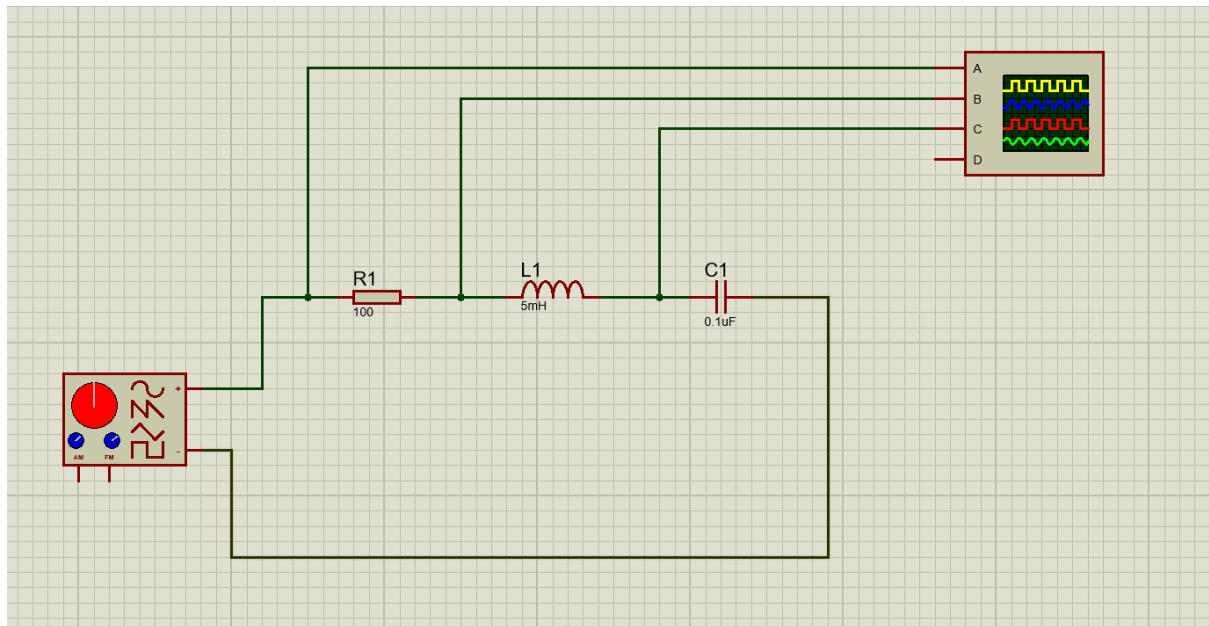


Figure 7- AC Proteus Software Circuit

During the experiment, the voltage was set to 10V. The frequency started at 1kHz and ranged up to 20kHz, increasing in 1kHz each time the circuit ran to collect data. Smaller increments began being measured when X and X_c were not far from being equal. The VSM Signal Generator had the job of inputting the voltage and the frequency.

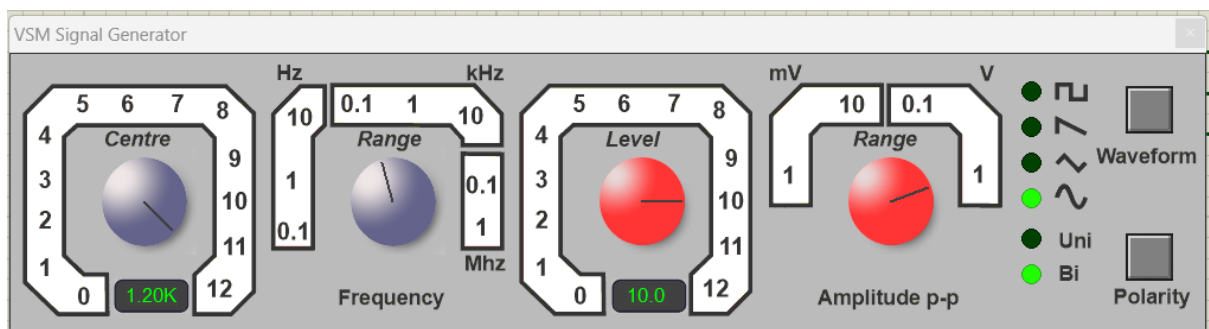


Figure 8- VSM Signal Generator Input

Figure 8 shows the output generated with the amplitudes highlighted for an input frequency of 1.2kHz.

Measured next was the output on the oscilloscope, the voltage through the three components was displayed. For each component the peak-to-peak voltage, and input frequency was measured.

By doubling the amplitude of the waves produced on the oscilloscope, one can find the peak-to-peak voltage.

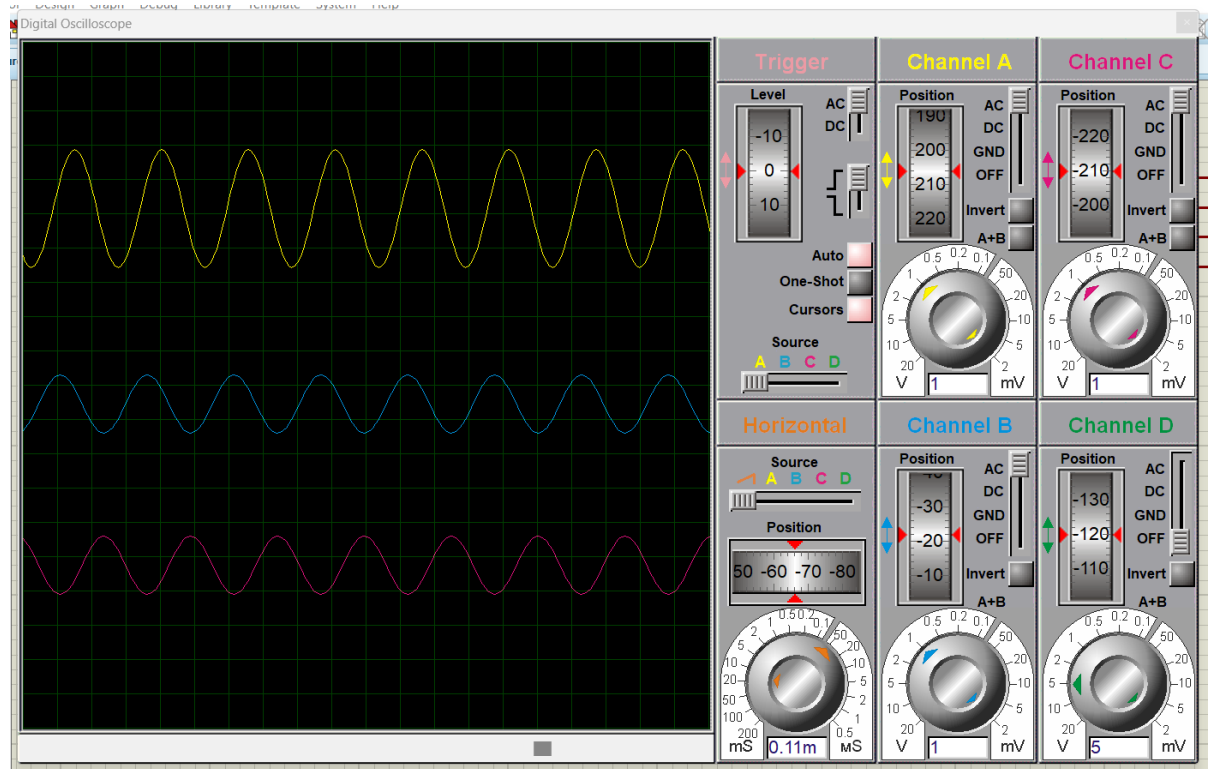


Figure 9- Oscilloscope Output, Frequency 7.1kHz

Chanel A is the Resistor, Chanel B is the Inductor, Finally Chanel C is the Capacitor.

- 1) [5]To find Resonate frequency theoretically the following equation was re-arranged,

Equation 9

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

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

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

- 2) Then values given were input to calculate Resonate Frequency.

$$L_1 = 5\text{mH and } C_1 = 0.1\mu\text{F}$$

- 3) To find X_L

$$2\pi = fL$$

$$2\pi \times 7117.625434 \times 0.005 = 223.606798\Omega$$

4) To find X_c

Equation 10

$$\frac{1}{2\pi \times f \times C}$$

$$\frac{1}{2\pi \times 7117.625434 \times 0.0000001} = 223.606798\Omega$$

5) Resonant Frequency is known when X_L and X_c values are equal

$$X_C = 223.606798\Omega \quad X_L = 223.606798\Omega$$

$$F = 7117.625434\text{Hz}$$

3.3 Results & Conclusion

Calculating the Values of X_L and X_c was vital in determining the resonant frequency. To determine the reactance to be calculated the peak-to-peak voltages had to be measured, these were recorded within table 2. Using this data and the calculation from section 3.1 reactance values could be confirmed.

Table 2-Voltage across Resistor, Inductor & Capacitance Results Task 2

Frequency (fr) (kHz)	Resistor Voltage (VR) (V)	Inductor Voltage (VL) (V)	Capacitor Voltage (VC) (V)	Reactance from Inductor (Ω)	Reactance from Capacitor (Ω)
1000	5	10	10	31.42	1591.55
2000	5	10	10.76	62.83	795.77
3000	5	9.76	12	94.25	530.52
4000	5	9.26	13.76	125.66	397.89
5000	5	8.26	17	157.08	318.31
6000	5	5.76	21.26	188.50	265.26
7000	5	0.145	22.26	219.91	227.36
7100	5	0.53	21.76	223.05	224.16
7200	5	1.15	21.5	226.19	221.05
7300	5	1.7	21	229.34	218.02
7400	5	2.28	20.5	232.48	215.07
7500	5	2.82	19.76	235.62	212.21
7600	5	3.36	19.26	238.76	209.41
7700	5	3.8	18.76	241.90	206.69
7800	5	4.26	18	245.04	204.04
7900	5	4.66	17.26	248.19	201.46
8000	5	5.04	16.76	251.33	198.94
9000	5	7.4	11.5	282.74	176.84
10000	5	8.5	8.26	314.16	159.15
11000	5	9	6.26	345.58	144.69
12000	5	9.3	4.76	376.99	132.63
13000	5	9.5	4	408.41	122.43
14000	5	9.6	3.2	439.82	113.68
15000	5	9.6	2.7	471.24	106.10

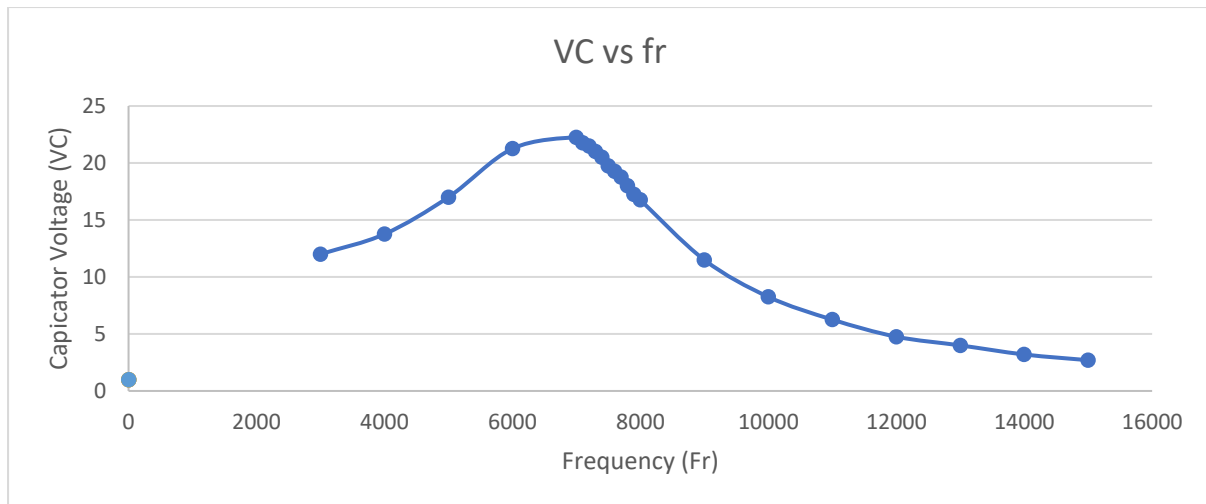


Figure 10- Resonance Frequency Graph

Using the results table 2 the student was able to make a graph comparing the Capacitor Voltage (Vc) against Frequency (Fr) from the data acquired from the simulation software.

3.4 Discussion

When analysing the data from table two Resonate frequency was found at 7100 kHz, this is because at this frequency, Reactance from Inductor (Ω) and Reactance from Capacitor (Ω) showed to be closest together this demonstrate resonance frequency because it indicates that the inductive and capacitive reactance's are equal and opposite, resulting in their cancellation and maximum energy storage in the circuit., although it should be noted that the frequency input is constrained to one decimal place and cannot be made more precise, particularly when comparing it to the [6]theoretical value.

4. Conclusion

In conclusion, the lab report aimed to measure the internal resistance of a circuit and the behaviour of a circuit under different conditions. For the internal resistance measurement, a circuit was built using a simulation software and a table was drawn to record the values of load resistance, load current, and power. A graph of power vs resistance was plotted, and the value of internal resistance were obtained from the graph. Theoretical calculations were also used to determine the internal resistance and load current, which were compared with the values obtained from the simulation.

For the AC circuit experiment, a circuit was designed and simulated using a software simulator. V_R , V_C , and V_L were measured at 1KHz and for a range of frequencies up to a maximum of 20KHz. A fully labelled graph of V_C against frequency (fr) was plotted, and the resonant frequency (fr) was determined from the graph and compared with basic theory. The results showed that the experiments were successful in achieving their objectives and providing valuable insights into the behaviours of the circuits under different conditions.

5. References

- [1 [Online]. Available: <https://ecstudiosystems.com/discover/textbooks/basic-electronics/dc-circuits/ohms-law/> .
]
- [2 [Online]. Available: <https://www.allaboutcircuits.com/textbook/direct-current/chpt-10/thevenins-theorem/#:~:text=Thevenin's%20theorem%20states%20that%20any,determining%20the%20Thevenin%20equivalent%20circuit..>
]
- [3 [Online]. Available: <https://byjus.com/physics/thevenin-theorem/>.
]
- [4 [Online]. Available: <http://hyperphysics.phy-astr.gsu.edu/hbase/electric/serres.html>.
]
- [5 [Online]. Available: <https://courses.lumenlearning.com/suny-physics/chapter/23-11-reactance-inductive-and-capacitive/>.
]
- [6 [Online]. Available: https://www.electronics-tutorials.ws/filter/filter_1.html.
]

Appendix A- task 1 Calculations

- 1) Find the Thevenin Voltage (V_{TH}).

Equation 11

$$I = \frac{v}{R} = \frac{20}{11000} = 182mA$$

$$V = IR = 1.82 \times 10^{-3} \times 10000 = 18.182V$$

- 2) Find the Thevenin Resistance (R_{TH}).

$$R_{TH} = 12000 + \left(\frac{1}{1000} + \frac{1}{1000} \right)^{-1} = 12909.091\Omega$$

- 3) Find the current of the load resistor.

$$I_L = \frac{v_{TH}}{R_{TH} + R_L}$$

At maximum power $R_{TH} = R_L$

$$I_L = \frac{18.182}{12909.091 + 12909.091} = 7.0423 \times 10^{-4}A$$

- 4) Calculate the maximum power

$$p = I_L^2 R_L = (7.0423 \times 10^{-4})^2 \times 12909.091 = 6.402 \times 10^{-3}W$$