UNIVERSYTI OF WEST LONDON

Electrical Theory

Technical Report

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Introduction

The aim of this assignment was to test the thermotical knowledge on advance circuit theories and their practical application in the design, building and testing in a series of task. The task for this assignment were three the first was an RC integrator circuit, this circuit required a series measurements of charging and discharging values of the capacitor, the second a symmetrical T-network attenuator, for which the resistor values had to be calculated to verify it`s attenuation, and the third a resonant LCR circuit, for this simulations of the circuit had to be run to confirm that the circuit is resonant.

RC circuit

For this task the circuit had to be constructed following the diagram given in the handout sheet, as shown in figure 1, after breadboard circuit was made the task required to find the values for voltage and current of the capacitor during the charging and discharging proses. Then after obtaining the practical measurement they had to be compared with the calculated values, obtained in the calculations, and plotted in a graph to confirm the results.

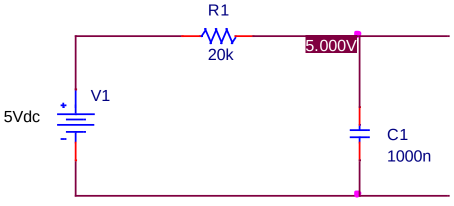

Figure 1:RC circuit

Practical measurement

For this measurement to be accrued first the time constant and the time that the capacitor takes to charge had to be calculated, then by knowing that it would take 100 seconds it was decide in this report to record a total of 10 samples that were taken every 10 seconds. To obtain the measured values two voltmeters were used one connected in series to the circuit to measure current and the other connected in parallel to measure the voltage value, then before the power supply was turn on a camera was set to record the values as the capacitor was charging, turning on the power supply allowed to record the charging values. After the capacitor was charged the power supply was turn of and the discharging values were recorded by the camera.

$$\tau = R \times C = 20000 \times (1000 \times 10^{-9}) = 20\ s$$

$$5\tau = 5 \times 20 = 100\ s$$

Charge	Time (s)	Voltage (V)	Current (mA)
	0	0	0.22
	10	2.1	0.14
	20	3.18	0.09
	30	3.77	0.06
	40	4.2	0.04
	50	4.44	0.02
	60	4.6	0.02
	70	4.71	0.01
	80	4.79	0.009
	90	4.84	0.006
	100	4.9	0.003

Table 1

Discharge	Time	Voltage (V)	Current (mA)
	0	4.9	-0.23
	10	3.07	-0.153
	20	1.9	-0.095
	30	1.26	-0.062
	40	0.82	-0.04
	50	0.59	-0.027
	60	0.36	-0.018
	70	0.24	-0.012
	80	0.16	-0.008
	90	0.1	-0.005
	100	0	0

Table 2

Calculations

In this section all the values for the capacitor were calculated and displayed in a table of values 3. The examples below show the formulas used to calculate the voltage and current values and the values at 0 seconds, 50 seconds and 100 seconds. It can be noted that the calculated values differ for the practical values by a small margin of error.

$$V_C = V\left(1 - e^{-\frac{t}{\tau}}\right)$$

$$V_C = 5\left(1 - e^{-\frac{0}{20}}\right) = 0\ V$$

$$V_C = 5\left(1 - e^{-\frac{50}{20}}\right) = 4.589\ V$$

$$V_C = 5\left(1 - e^{-\frac{100}{20}}\right) = 4.966\ V$$

$$V_D = V \times e^{-\frac{t}{\tau}}$$

$$V_D = 5 \times e^{-\frac{0}{20}} = 5V$$

$$V_D = 5 \times e^{-\frac{50}{20}} = 0.41\ V$$

$$V_D = 5 \times e^{-\frac{100}{20}} = 0.033\ V$$

$$I = \frac{V}{R} = \frac{5}{20000} = 250\ \mu A$$

$$I_C = I \times e^{-\frac{t}{\tau}}$$

$$I_C = (250 \times 10^{-6}) \times e^{-\frac{0}{20}} = 0.25\ mA$$

$$I_C = (250 \times 10^{-6}) \times e^{-\frac{50}{20}} = 0.021 mA$$

$$I_C = (250 \times 10^{-6}) \times e^{-\frac{100}{20}} = 0.002\ mA$$

Time (s)	Charge (V)	Discharge (V)	Current (mA)
0	0	5	0.25
10	1.967	3.032	0.151
20	3.161	1.839	0.091
30	3.884	1.116	0.055
40	4.323	0.677	0.034
50	4.589	0.41	0.021
60	4.751	0.249	0.012
70	4.849	0.151	0.008
80	4.908	0.092	0.005
90	4.944	0.056	0.002
100	4.966	0.033	0.002

Table 3

Plot graph

All the measured values were plotted in this graph to compare the values and to visualise the transient curves created by the charging and discharging values of the circuit.

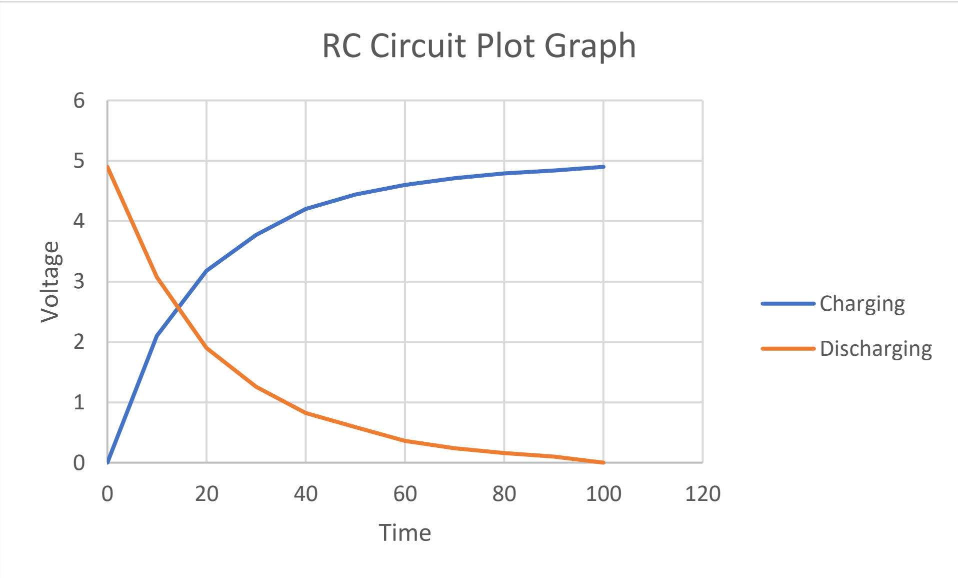

Figure 2: charge and discharge transient curves

T-network attenuator circuit

For this task a several symmetrical T-network attenuators had to be designed. The task required that 8 dB and a 32dB attenuator with characteristic impedance of 50Ω were to be design ed and simulated, then does the designs had to be revised, by changing the resistor to the nearest preferred resistor value, and all the new values calculated and simulated to compare results. After all the designs were completed the power supply of all the circuit had to be changed to 500 mV and the output voltage calculated to check the attenuation of the circuit.

8 dB attenuator

To design this attenuator first a series of calculations had to be made, the first value that had to be calculated was N, this value was calculated by using the invers formula for the attenuation since the attenuation was known. Then the resistor values were calculated the calculated N value and the characteristic impedance in the formula for resistors in a symmetrical t-network attenuator, after the resistor were calculated to check if results were corrected the values were plug in the formula for the characteristic impedance and the results compared with known value. The output voltage was calculated using an inverse formula of N and the result was compared with value of the simulation, as shown in figure 3 the result of the simulation agrees with the result of calculations.

calculations

$$8dB = 20\log(N) \rightarrow N = 10^{\frac{8}{20}} = 2.5$$

$$Z_A = Z_0 \times \frac{(N-1)}{(N+1)} = 50 \times \frac{(2.5-1)}{(2.5+1)} = 21.43\ \Omega$$

$$Z_B = 50 \times \left(\frac{2 \times N}{N^2 - 1}\right) = 50 \times \left(\frac{2 \times 2.5}{2.5^2 - 1}\right) = 47.62\ \Omega$$

$$Z_0 = \sqrt{Z_A^2 + Z_A \times 2 \times Z_B} = \sqrt{21.43^2 + 21.43 \times 2 \times 47.62} = 49.99\ \Omega$$

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{10}{2.5} = 4V$$

Simulation

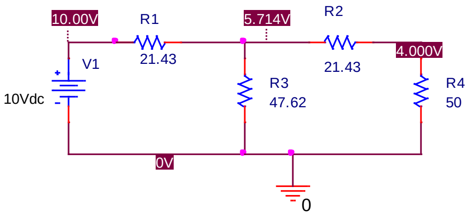

Figure 3:8dB t-network attenuator circuit

32 dB attenuator

For this circuit a similar approach to the 8-dB t-network attenuator was made most of the values were calculated using the same formulas but with different values and different results. The simulation in figure 4 shows that results of the calculation differ by a negligible amount to the simulation values.

Calculations

$$32dB = 20\log(N) \to N = 10^{\frac{32}{20}} = 39.8$$

$$Z_A = Z_0 \times \frac{(N-1)}{(N+1)} = 50 \times \frac{(39.8-1)}{(39.8+1)} = 47.55\ \Omega$$

$$Z_B = 50 \times \left(\frac{2 \times N}{N^2 - 1}\right) = 50 \times \left(\frac{2 \times 39.8}{39.8^2 - 1}\right) = 2.5\ \Omega$$

$$Z_0 = \sqrt{Z_A^2 + Z_A \times 2 \times Z_B} = \sqrt{47.55^2 + 47.55 \times 2 \times 2.5} = 49.99\ \Omega$$

$$N = \frac{Vin}{Vout} \to Vout = \frac{Vin}{N} = \frac{10}{39.8} = 251\ mV$$

simulation

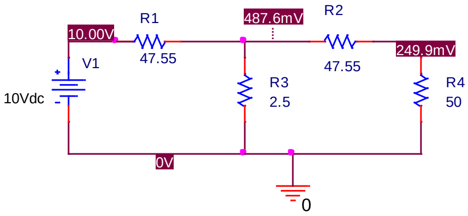

Figure 4: 32 dB t-network attenuator circuit

Revised 8dB attenuator

This circuit is the revised version of the 8-dB attenuator circuit. This circuit was revised by changing the resistor values of the circuit to the closest integer number to the original value, the change in the resistor values changed the values for all the previous calculation which had to be redone. The first value that had to be calculated was the characteristic impedance which was done by plugging the new resistor values in the formula, then the N value was calculated by using the invers formula of the resistor and rearranging the values for N, the attenuation was calculated using the N value plugged in the formula for attenuation. The Vout was calculated using the invers formula of N and the value was compared with the simulation in figure 5, as seen the values differ by a small amount.

Calculations

$$Z_0 = \sqrt{Z_A^2 + Z_A \times 2 \times Z_B} = \sqrt{21^2 + 21 \times 2 \times 48} = 49.57\ \Omega$$

$$Z_A = Z_0 \times \frac{(N-1)}{(N+1)} \to Z_A(N+1) = Z_0(N-1) \to 21N + 21 = 49.57N - 49.57$$

$$\frac{28.57N}{28.57} = \frac{70.57}{28.57} \to N = 2.47$$

$$Attenuation = 20\log(N) = 7.85dB$$

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{10}{2.47} = 4.05\,V$$

Simulation

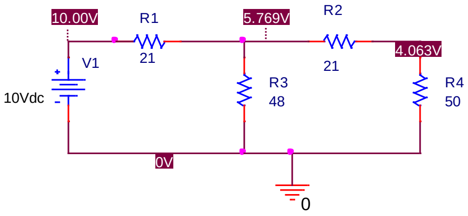

Figure 5: revised 8dB attenuator

Revised 32 dB attenuator

Here again the same calculations as the 8-dB circuit were made with the values of this circuit. The simulation of this circuit in figure 6 shows that the results are correct

Calculation

$$Z_0 = \sqrt{Z_A^2 + Z_A \times 2 \times Z_B} = \sqrt{48^2 + 48 \times 2 \times 3} = 50.91\,\Omega$$

$$Z_A = Z_0 \times \frac{(N-1)}{(N+1)} \rightarrow Z_A(N+1) = Z_0(N-1) \rightarrow 48N + 48 = 50.91N - 50.91$$

$$\frac{2.91N}{2.91} = \frac{98.91}{2.91} \rightarrow N = 34$$

$$Attenuation = 20\log(N) = 30.63\,dB$$

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{10}{34} = 0.294\,V$$

Simulation

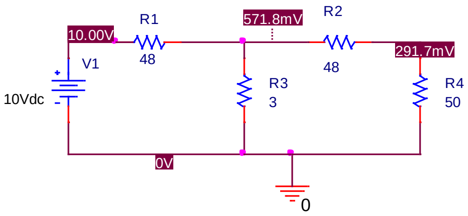

Figure 6: revised 32dB attenuator

500mV power supply

For this part of the task all the design had the power supply to a 500mV power supply to check the attenuation of the circuit, and all the output voltage of all circuit were calculated and compared to the results of their simulations.

8dB attenuator

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{0.5}{2.5} = 0.2\ V$$

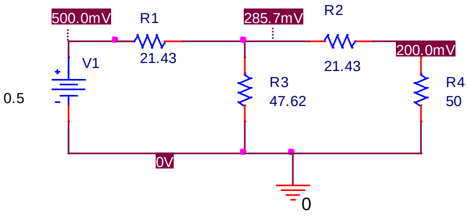

Figure 7: 8dB attenuator with 500mv power supply

32dB attenuator

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{0.5}{39.8} = 0.0126\ V$$

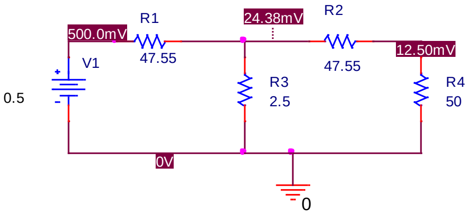

Figure 8: 32dB attenuator with 500mv power supply

Revised 8dB attenuator

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{0.5}{2.47} = 0.2024\ V$$

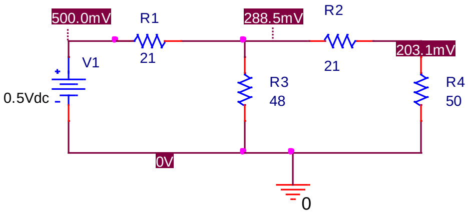

Figure 9: revised 8dB attenuator with 500mv power supply

Revised 32dB attenuator

$$N = \frac{Vin}{Vout} \rightarrow Vout = \frac{Vin}{N} = \frac{0.5}{34} = 0.0147\ V$$

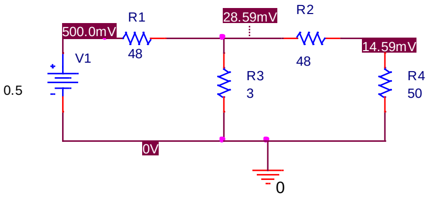

Figure 10: revised 32 dB attenuator with 500mv power supply

LCR circuit

For this task an LCR resonant circuit had to be designed and a series of simulation of the circuit were made to verify that the circuit is resonant and the calculated values. Before designing the circuit, calculations had to be made to determine the values of the components of the circuit, the first calculation was to calculate the capacities of the capacitor for which the invers formula for the resonant frequency and setting it for the capacitance. Then the known Q factor was used to calculate the resistor value, the current was calculated by using simple Ohm's because the circuit was resonant, and the impedance of the capacitor and the inductor cancel each other. The voltage across all components were calculated, the voltage across the inductor was calculating the impedance of the inductor ad multiplying it with the current, the voltage across the capacitor is the same as the inductor since the circuit is resonant, the circuit across the resistor was calculated with Ohm's law.

calculations

$$f_r = \frac{1}{2\pi\sqrt{LC}} \to C = \left(\frac{1}{2\pi f_r}\right)^2 \times \frac{1}{L} = \left(\frac{1}{2\pi \times 250}\right)^2 \times \frac{1}{8 \times 10^{-3}} = 50.7\mu f$$

$$Q = \frac{1}{R} \times \sqrt{\frac{L}{C}} \to R = \frac{1}{Q} \times \sqrt{\frac{L}{C}} = \frac{1}{12} \times \sqrt{\left(\frac{8 \times 10^{-3}}{50.7 \times 10^{-6}}\right)} = 1.05\Omega$$

$$I = \frac{V}{R} = \frac{50}{1.05} = 47.6$$

$$V_L = I \times X_L = I \times 2\pi f_r L = 47.6 \times 2\pi \times 250 \times (8 \times 10^{-3}) = 598.16\, V$$

$$V_C = V_L$$

$$V_R = I \times R = 47.6 \times 1.05 = 49.98\, V$$

Frequency response

In this simulation for the frequency response shown in figure 12 proves that the circuit is resonant since the point for which the amplitude higher is around the value of frequency that was given.

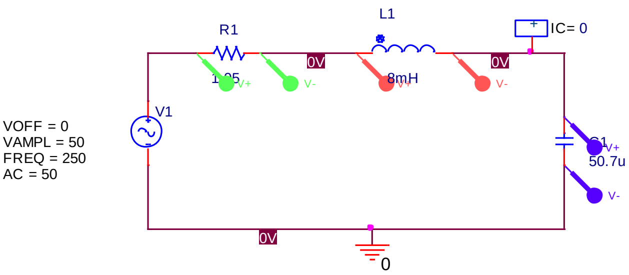

Figure 11: LCR circuit

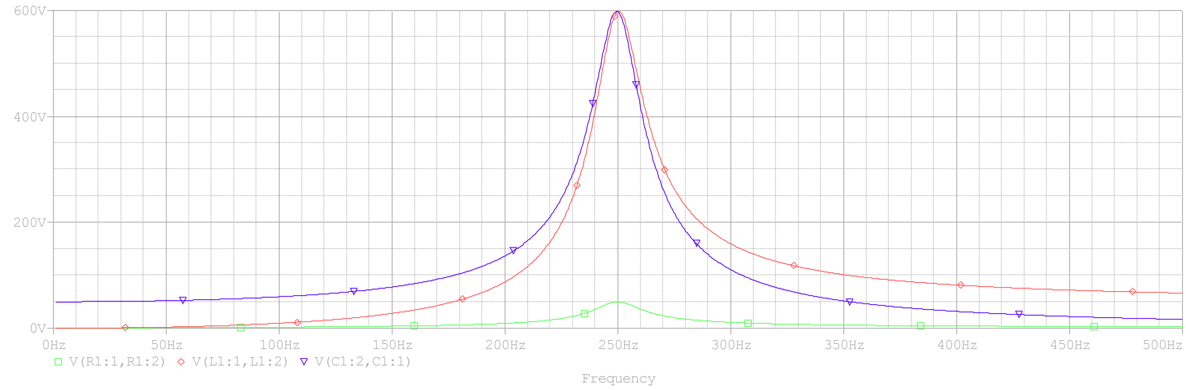

Figure 12 : frequency response

Voltage across all components

This simulation in figure 14 show the voltage across all the components, and it can be observed that the values of voltage for the capacitor and the inductor were equal but invers, which is as expected for a resonant circuit since the should cancel each other.

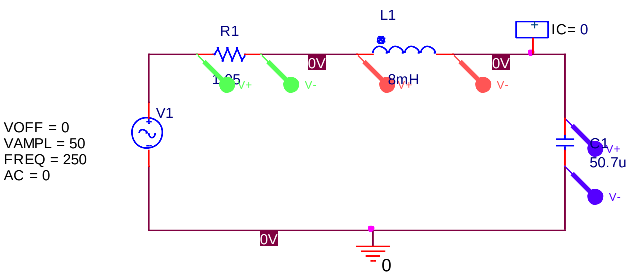

Figure 13: LCR circuit

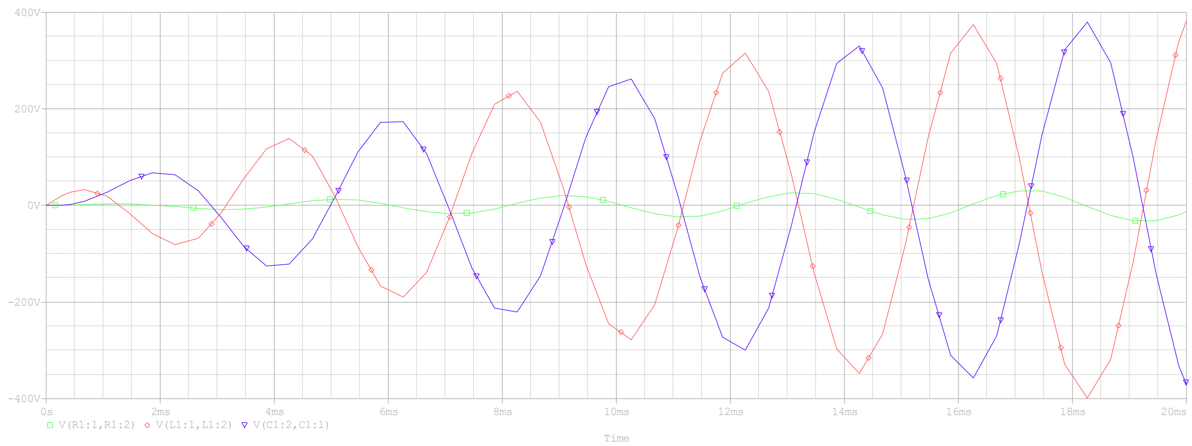

Figure 14: voltage across all resistor

Current across all components

This simulation shown in figure 16 shows the current through all components. As show in the graph the current through all components is the same, which is expected since the circuit is connected in series and in a resonant circuit none of the components should interfere with the current since the inductor and the capacitor cancel each other.

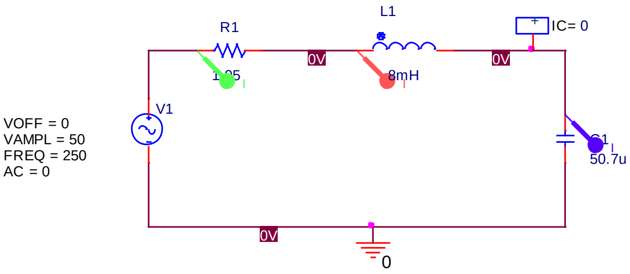

Figure 15: LCR circuit

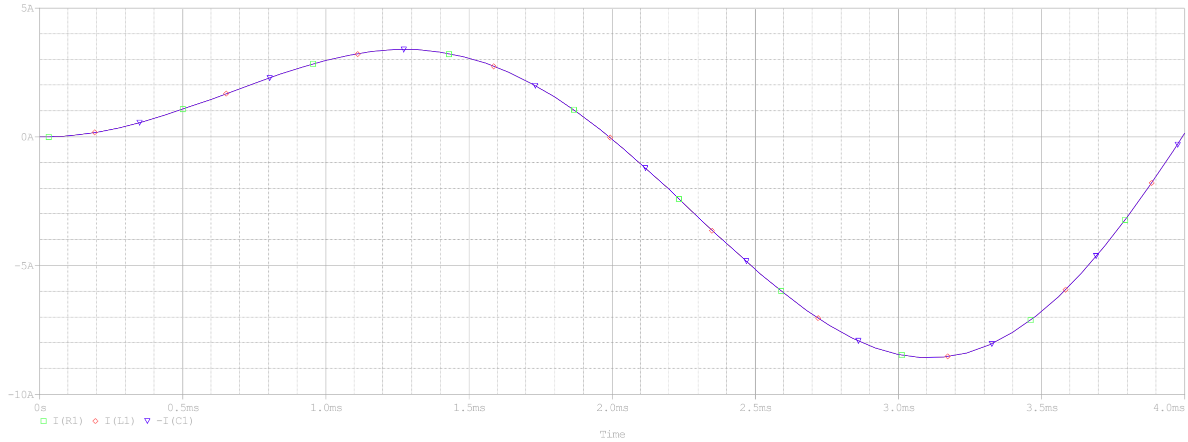

Figure 16: current across all components