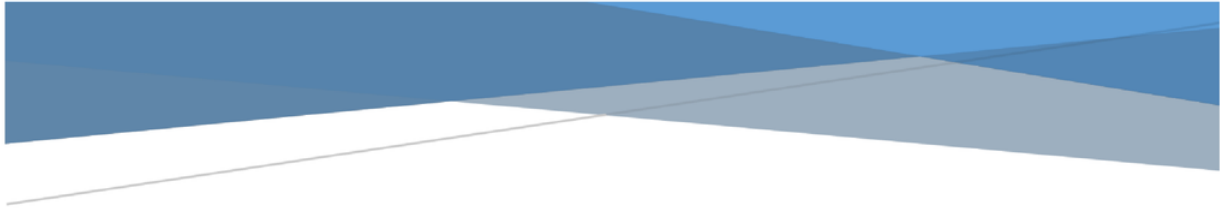


PSDE4001 Assignment 1

by Jordan Gough

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PSDE4001

Electrical and Electronic Principles

Assignment 1 – Investigation into DC Transients

21/01/2018

Jordan Gough

4233 Words

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1. Introduction

This report is going to study the behaviour of resistor-inductor circuits, R-L, and resistor-capacitor circuits, R-C, when used under DC conditions. This will be done by means of simulation and construction, along with theoretical prediction, with the main area of focus being the transient analysis. Once completed, the results taken from all three testing methods will be compared and a suitable conclusion will be made.

2. Transient Behaviour for the Charging of a Capacitor

The following circuit was built using a 6V power supply, a 10,000uF capacitor and a 5.6kΩ resistor to allow the testing of a DC transient circuit and how it behaves when

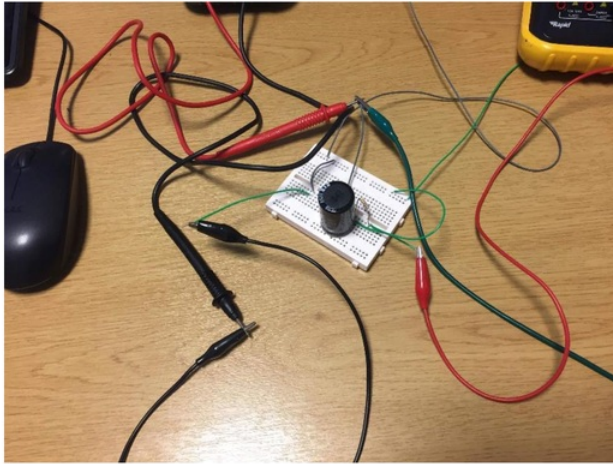


FIGURE 1

the capacitor is charging. The testing procedure consisted of measuring the voltage and current in the circuit over the time it took for the capacitor to charge. To ensure that it was possible to measure these values, a large time constant needs to be used. The chosen combination of the 5.6kΩ resistor and the 10,000uF capacitor provide a time constant of 56s, which is large enough to take any required measurements. The time constant is calculated as follows;

$$T = R \times C$$
$$T = 5.6 \times 10^3 \times 10000 \times 10^{-6} = 56s$$

However, this is not the total time to charge the capacitor, but the time taken to charge to roughly 63%. The total time taken to charge the capacitor, known as the Transient Period, is calculated as follows;

$$\text{Transient Period} = 5 \times T$$
$$5 \times 56 = 280s$$

Therefore, after 280s the capacitor will be “fully charged”. Capacitors will not charge to 100%, but rather to approximately 99.3%. Although, the Time Constant and the Transient Period have both been calculated, both the resistor and the capacitor will have tolerances that need to be accounted for, meaning that the Time Constant and the Transient Period may both be incorrect when used practically.

The testing of the circuit is being done to find the instantaneous voltage (V_c) and current (I_c) at any given time. Once the test has been completed, the measured voltage can be verified using the formula;

$$V_c = V_{max} \left(1 - e^{-\frac{t}{T}} \right)$$

Where;

$$V_{max} = \text{Supply Voltage } (V_s)$$

The measured current can also be verified using the formula;

$$I_c = I_{max} \left(e^{-\frac{t}{T}} \right)$$

Where;

$$I_{max} = \frac{V_s}{R}$$

The circuit was setup with two digital multimeters, with one used to measure the current and the other used to measure the voltage. The multimeter being used to measure current was connected in parallel to the circuit, to ensure that the correct current values were obtained.

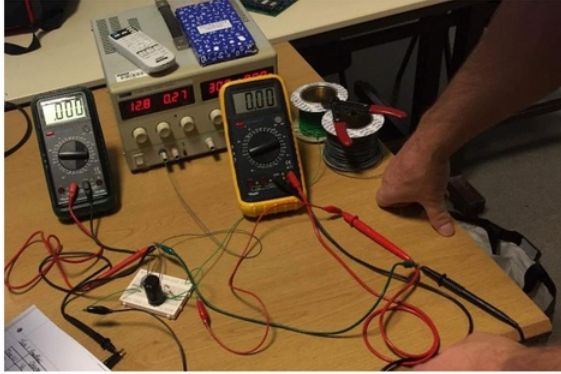


FIGURE 2

When measuring the voltage of the capacitor, it should reach roughly 6v after 280s, which will be demonstrated in the table of results. The table will measure the instantaneous voltage and current from 20s to 280s. The table is shown below.

Charging the Capacitor (DC Transients)		
Time (s)	Instantaneous Voltage, V_c (V)	Instantaneous Current, I_c (mA)
20	2.09	0.710
40	3.46	0.491
60	4.06	0.346
80	4.66	0.246
100	5.02	0.179
120	5.31	0.129
140	5.50	0.093
160	5.65	0.068
180	5.75	0.049
200	5.82	0.037
220	5.87	0.027
240	5.91	0.021
260	5.94	0.017
280	5.96	0.012

As shown in the table, after 280s the capacitor had reached a steady state of 5.96v, which is 99.3% of 6v, thus conforming to the approximate "fully charged" percentage. A steady state is the point at which the measured values stop varying and remain constant. Until the system reaches a steady state, it is in a transient state, in which the values are constantly varying. The table begins at 20s, rather than 0s, because there is a greater need for human reaction to take the measurements at 0s. The values were moved into a scatter graph to display the change of the results.

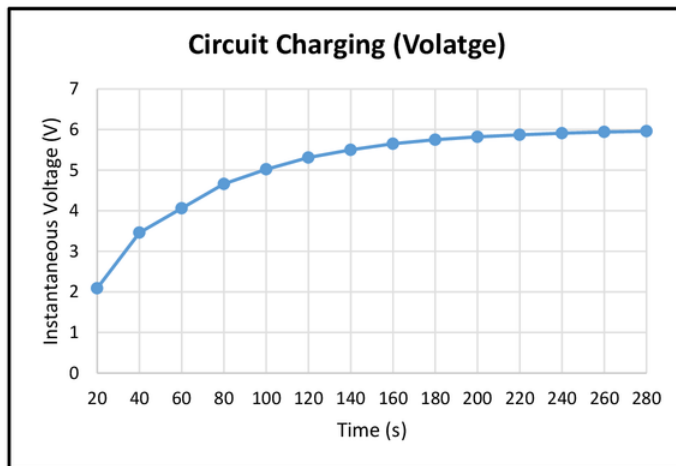


FIGURE 3

transient period, 280s, is complete, the voltage is just under 6v, which is expected. The graph shows that the voltage increased rapidly until 120s, then it began to increase much slower.

This graph shows the voltage in the circuit during the charging of the capacitor over the transient period. After one time constant (56s), the voltage is approaching 4v. This value should be equal to approximately 63% of V_{max} , which would be 3.8v. At 0.7T, the voltage is just above 3V. The value should be equal to approximately, 50% of V_{max} , which would be 3v. After the

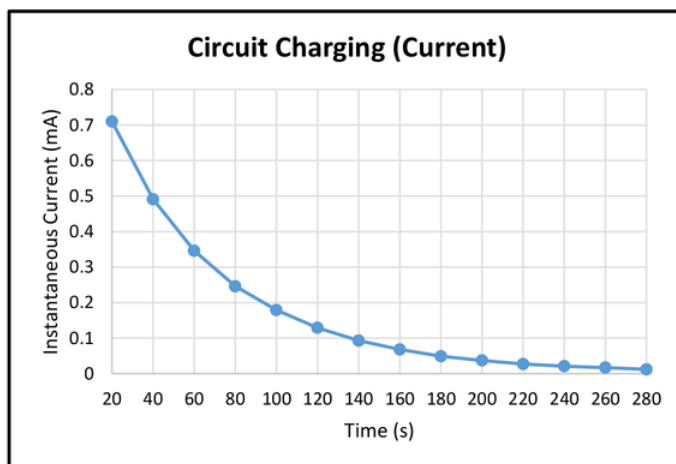
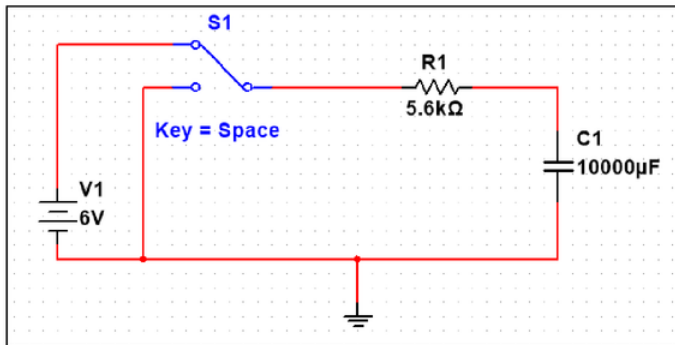


FIGURE 4

This graph shows the current in the circuit during the charging of the capacitor over the transient period. The graphs general trend is a fast decrease in the current, until 120s. After that, the gradient began to decrease much slower. After 0.7T, the current was just under 0.4mA, while it should be roughly 0.42mA. After 1T, the value was roughly 0.35mA and after 5T, the value was nearly 0mA.

The graphs are exponential graphs because, when the supply voltage is a constant value, the capacitor is charging, thus increasing the voltage. However, the resistance is also constant, therefore, due to Ohm's law, the current must decrease. The transient state of the circuit is when the capacitor is charging, thus when the voltage is increasing. The steady state of the circuit is when the voltage remains constant and the capacitor is fully charged.



The circuit was also built on Multisim to compare the practical results to a digitally simulation, shown in Figure 5. Once the circuit was a built, a transient charging graph was created using the software.

FIGURE 5

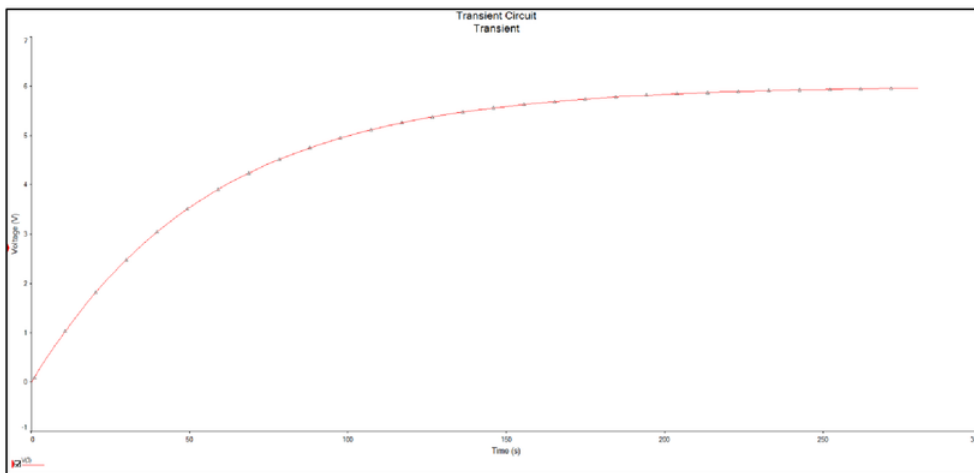


FIGURE 6

Figure 6 shows the voltage charging response for an RC circuit.

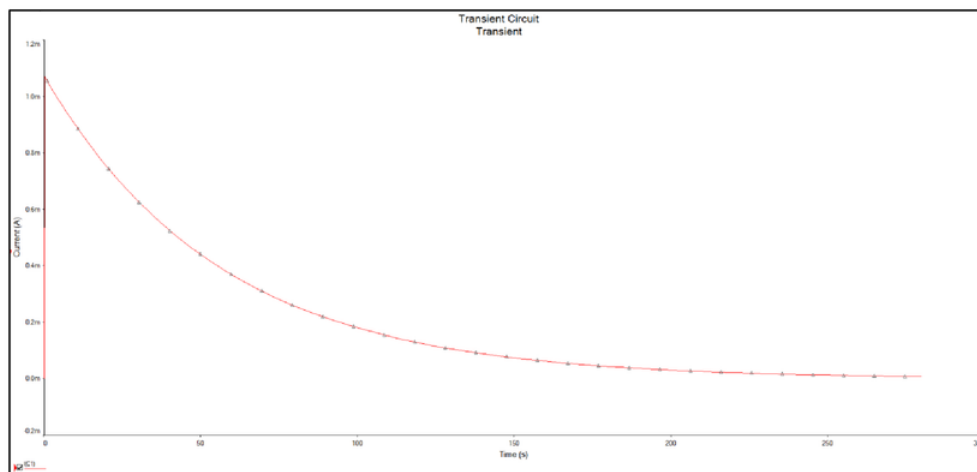


FIGURE 7

Figure 7 shows the current response for a charging RC circuit.

This graph from Multisim takes the first reading at 0 seconds, whereas the practical started at 20 seconds. However, the graph follows the same shape for charging a capacitor. The graph was set to run until 280 seconds, but it could have been extended to display the circuit's steady state.

To ensure that the practical values and the simulated values are correct, the values of instantaneous voltage and instantaneous current can be calculated using selected time values.

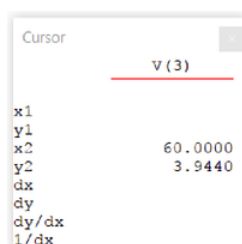


FIGURE 8

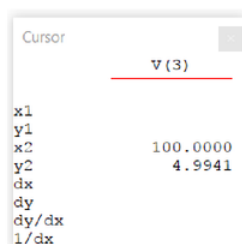


FIGURE 9

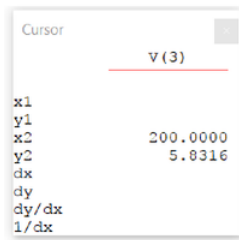


FIGURE 10

Figure 8, Figure 9 and Figure 10 show the simulated voltage values at the chosen time intervals.

Voltage Calculations

The voltage will be calculated at 60s, 100s and 200s.

$$V_c = V_{max} \left(1 - e^{\frac{-t}{T}} \right)$$

$$V_c = 6 \left(1 - e^{\frac{-60}{56}} \right) = 3.944V$$

$$V_c = 6 \left(1 - e^{\frac{-100}{56}} \right) = 4.994V$$

$$V_c = 6 \left(1 - e^{\frac{-200}{56}} \right) = 5.831V$$

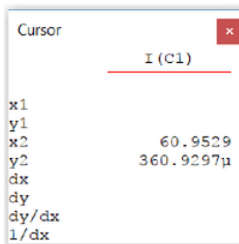


FIGURE 11

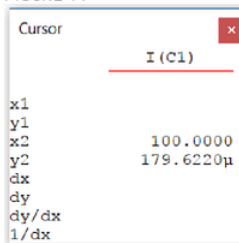


FIGURE 12

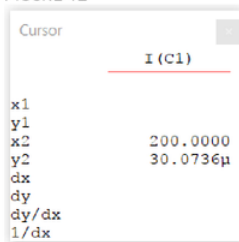


FIGURE 13

Figure 11, Figure 12 and Figure 13 show the simulated current values at the chosen time intervals.

Current Calculations

The current will also be calculated at 60s, 100s and 200s.

$$I_{max} = \frac{V_s}{R}$$

$$I_{max} = \frac{6}{5600} = 1.07mA$$

$$I_c = I_{max} \left(e^{\frac{-t}{\tau}} \right)$$

$$I_c = 1.07 \times 10^{-3} \left(e^{\frac{-60}{56}} \right) = 0.366mA$$

$$I_c = 1.07 \times 10^{-3} \left(e^{\frac{-100}{56}} \right) = 0.179mA$$

$$I_c = 1.07 \times 10^{-3} \left(e^{\frac{-200}{56}} \right) = 0.0301mA$$

Time (s)	Voltage (V)			Current (mA)		
	Practical	Simulation	Calculation	Practical	Simulation	Calculation
60	4.06	3.94	3.94	0.346	0.367	0.366
100	5.08	4.99	4.99	0.179	0.179	0.179
200	5.82	5.83	5.83	0.037	0.0301	0.0301

Apart from the current value taken from the simulation at 60 seconds, all the simulated values matched the calculated values. The practical values were all different to the calculated values, with the exception of the current reading taken at 100 seconds. This is likely due to human error with matching the timing and the measurements, due to reaction time of each group member or errors in the components. Whereas, the simulation does not have slow response time and can accurately find the voltage and current values. There may also be errors that are derived from rounding errors in the calculations. Although, this is unlikely due to the simulation matching the calculations.

3. Transient Behaviour for the Discharging of a Capacitor

Once the capacitor had finished charging, a wire in the circuit was moved to begin the capacitor discharging phase. There were no changes made to the circuit's components, so it still had the same time constant of 56 seconds. While discharging, readings were taken for the voltage and current at 20 second intervals, until the capacitor had fully discharged.

Time (s)	Discharging the Capacitor (DC Transients)	
	Instantaneous Voltage, V_c (V)	Instantaneous Current, I_c (mA)
20	4.14	-0.734
40	2.90	-0.519
60	2.06	-0.369
80	1.45	-0.261
100	1.05	-0.186
120	0.75	-0.131
140	0.53	-0.095
160	0.39	-0.069
180	0.29	-0.052
200	0.21	-0.036
220	0.15	-0.026
240	0.11	-0.020
260	0.09	-0.015
280	0.06	-0.011

The table above shows that after 280 seconds, the capacitor had fully discharged, although it had not reached 0v. Due to the circuit now discharging, the current went negative immediately after the discharging began. This is because of how the current flows from the positive plate on the capacitor to the negative. The results table starts at 20 seconds, meaning that the first voltage reading is 4.14v, rather than the fully charged 5.96v. Whereas, the negative current values are very similar to the positive values.

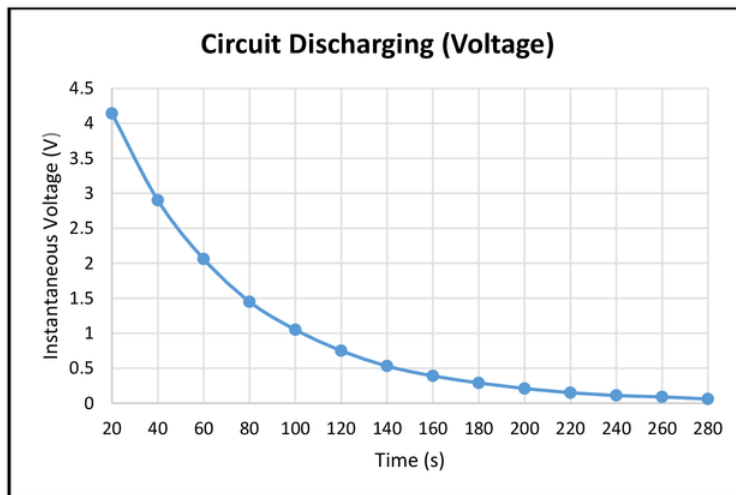


Figure 14

Using the results gathered from the practical circuit, tables of voltage against time and current against time were made. The voltage curve in Figure 14 shows that the voltage decreases over time. Like charging, the discharging graphs are also exponential graphs. While charging, the graph reached roughly 3.8v after one time constant, 56 seconds. While discharging, the graph is showing roughly 2.2v after 56s. At $0.7T$, the graph shows 3v, which is expected.

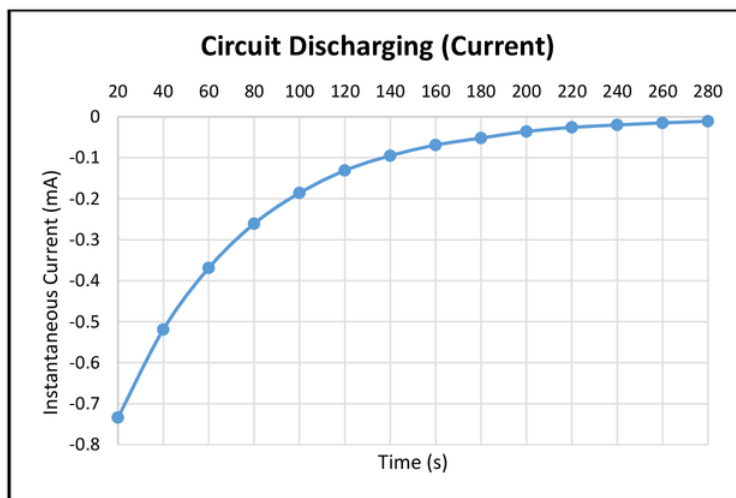


FIGURE 15

The current discharge graph, shown in Figure 15, follows the same shape as the voltage charging graph, but it is on the negative part of the y-axis. Again, the capacitor did not reach 0A, but instead stopped at -0.011mA. After one time constant, the current was -0.38mA, which is near to the expected value. After $0.7T$, the current showed -0.519mA, which is lower than expected.

The circuit was again simulated, but for the capacitor's discharge state.

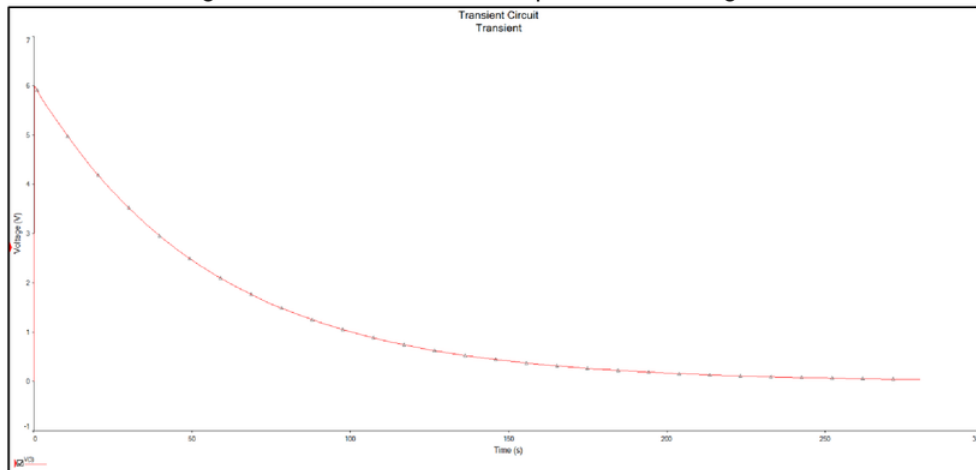


FIGURE 16

Figure 16 shows the discharging voltage.

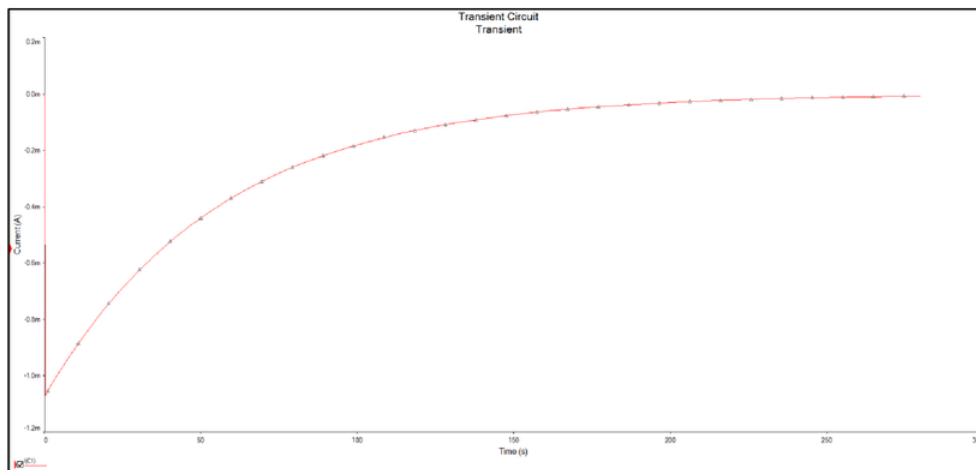


FIGURE 17

Figure 17 shows the discharging current. The graphs both start at 0 seconds and end at 280 seconds because the discharge was timed separately to the charging stage. Both the voltage and current discharge graphs follow the same shape as the graphs created from the practical experiment. This proves that the practical was successful. However, this does not prove that the values are correct. Therefore, the values will be compared to calculated values.

Voltage Calculations

The voltage will again be calculated at 60s, 100s and 200s.

$$V_c = V_s \left(e^{\frac{-t}{T}} \right)$$

$$V_c = 6 \left(e^{\frac{-60}{56}} \right) = 2.055V$$

$$V_c = 6 \left(e^{\frac{-100}{56}} \right) = 1.006V$$

$$V_c = 6 \left(e^{\frac{-200}{56}} \right) = 0.169V$$

Current Calculations

The current will also be calculated at 60s, 100s and 200s.

$$I_c = -I_{max} \left(e^{\frac{-t}{T}} \right)$$

$$I_c = -1.07 \times 10^{-3} \left(e^{\frac{-60}{56}} \right) = -0.366mA$$

$$I_c = -1.07 \times 10^{-3} \left(e^{\frac{-100}{56}} \right) = -0.179mA$$

$$I_c = -1.07 \times 10^{-3} \left(e^{\frac{-200}{56}} \right) = -0.0301mA$$

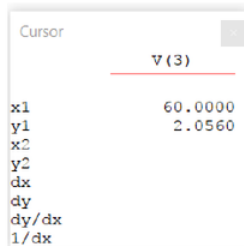


FIGURE 18

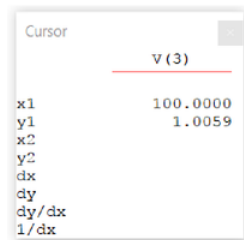


FIGURE 19

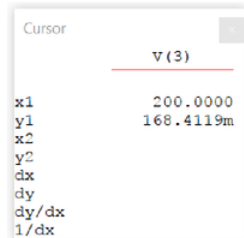


FIGURE 20

Figure 18, Figure 19 and Figure 20 show the simulated voltage values for the discharging RC circuit at the selected time intervals.

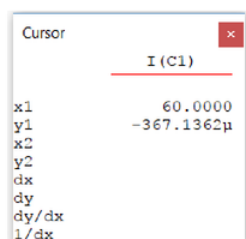


FIGURE 21

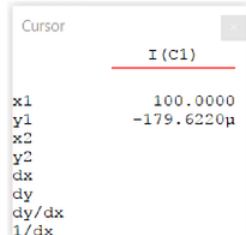


FIGURE 22

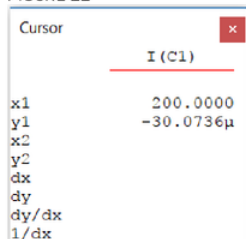


FIGURE 23

Figure 21, Figure 22 and Figure 23 show the current values for a discharging RC circuit at the chosen time values. These values are negative, due to the direction of current flow.

Time (s)	Voltage (V)			Current (mA)		
	Practical	Simulation	Calculation	Practical	Simulation	Calculation
60	2.06	2.06	2.06	-0.37	-0.37	-0.37
100	1.05	1.01	1.01	-0.19	-0.18	-0.18
200	0.21	0.17	0.17	-0.036	-0.030	-0.030

It was found by the group that all the simulation values matched the calculation values, which further proved that the simulation is accurate to the calculations. However, the practical values were different to the other values, with the exception of the 60 second voltage reading. Again, this was likely due to the human error that is introduced when working in groups, given that each person will have a different reaction time for taking readings at the precise times required. Another issue that could affect the accuracy of the results would be rounding errors that may be present from the calculations. This can especially cause problems for the practical measurements, due to the number of significant figures that the test equipment can measure to.

4. Transient Behaviour for a more Complex Circuit

Charging

In an RC circuit, the time constant can be found by multiplying the circuit's resistance and the capacitance. However, some RC circuits have two or more resistors, so the circuit's total resistance must be found first. This section of the report is going to look at how this can be achieved by researching complex RC circuits. The circuit is shown below in Figure 24.

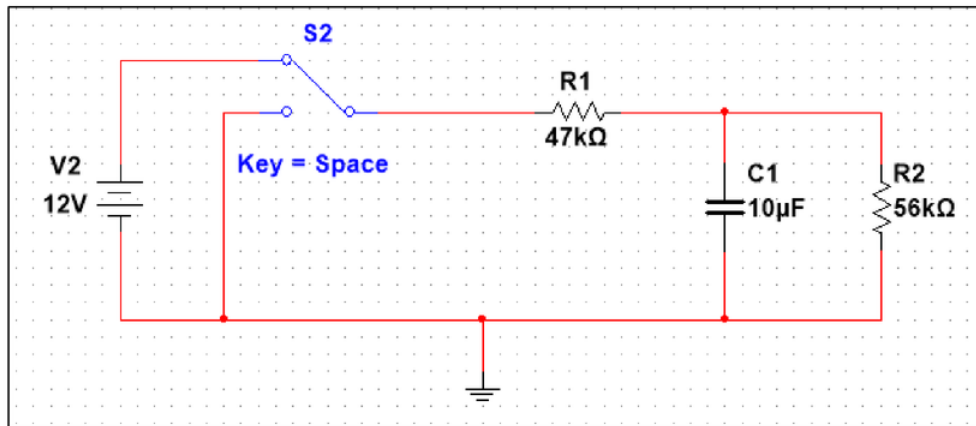


FIGURE 24

When the capacitor is not charged, it acts as a short circuit, so the resistors are in parallel with each other. The total resistance of the circuit can be found using the following formula;

$$R_T = \frac{PRODUCT}{SUM}$$

Therefore, the circuit's total resistance is;

$$R_T = \frac{47,000 \times 56,000}{47,000 + 56,000}$$

$$R_T = \frac{2632 \times 10^6}{103000}$$

$$R_T = 25553\Omega$$

The total circuit resistance can replace the parallel resistors to create an equivalent circuit, as shown below.

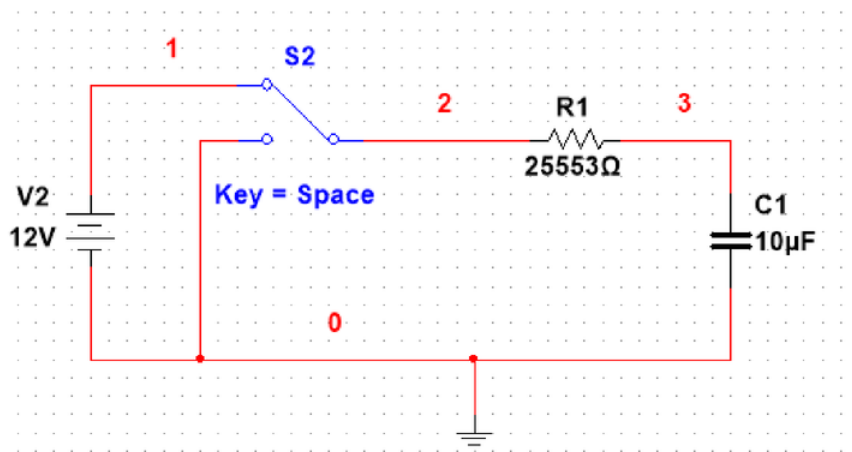


FIGURE 25

Figure 25 shows the equivalent circuit for the complex RC. Once the total resistance of the circuit is found, the time constant can be found. This is found using;

$$T = R_T \times C$$

Therefore, the time constant is;

$$T = 25553 \times 10 \times 10^{-6}$$

$$T = 0.26s$$

The total capacitor charging time is 5T, therefore it is;

$$5 \times 0.26 = 1.3s$$

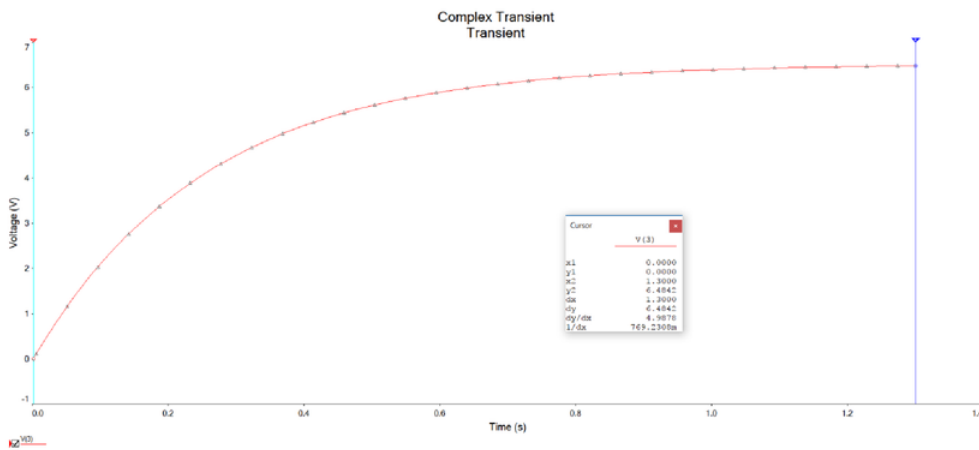


FIGURE 26

The simulated transient analysis for the complex circuit shows a maximum circuit voltage, or V_{OUT} , of 6.48V, as seen in Figure 26. This value can be calculated using the formula;

$$V_{OUT} = \frac{R_2}{R_1 + R_2} \times V_S$$

$$V_{OUT} = \frac{56,000}{(47,000 + 56,000)} \times 12 = 6.52V$$

The simulated value is different to the calculated value by 0.04V. To determine whether the error is just with V_{OUT} or with the entire analysis, the instantaneous voltage can be calculated at multiple points and compared to the simulation.

Instantaneous Voltage Calculations

$$V_C = V_{max} \left(1 - e^{-\frac{t}{T}} \right)$$

$$V_C = 6.48 \left(1 - e^{-\frac{0.2}{0.26}} \right) = 3.48V$$

$$V_C = 6.48 \left(1 - e^{-\frac{0.4}{0.26}} \right) = 5.09V$$

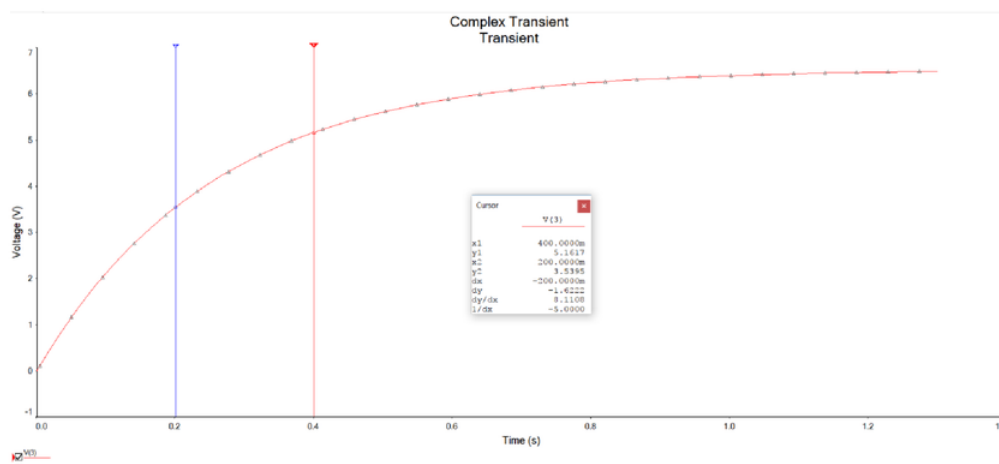


FIGURE 27

The simulation shows that at 0.2s, the voltage is at 3.54V and at 0.4s, the voltage is at 5.16V. The calculated values are lower than the simulated values, due to the rounding error encountered when calculating V_{OUT} . If the calculated value of V_{OUT} was more accurate, the calculated values of instantaneous voltage would match the simulated values.

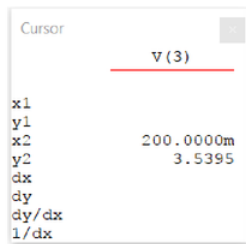


FIGURE 28

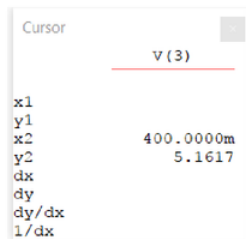


FIGURE 29

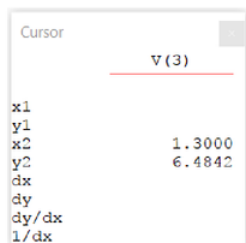


FIGURE 30

Figure 28, Figure 29 and Figure 30 show the charging current values for the selected time intervals.

Charging Voltage		
Time	Calculations	Simulations
0.2s	3.48V	3.54V
0.4s	5.09V	5.16V
1.3s	6.52V	6.48V

The maximum current in the circuit can be found using Ohm's Law. The formula to calculate the current is as follows;

$$Current = \frac{V_{OUT}}{R_T}$$

Therefore, the circuit's current is;

$$Current = \frac{6.48}{25553} = 0.254mA$$

The transient analysis for the circuit's current shows a maximum current of 0.255mA. The calculated value is once again lower than the simulated value, due to the calculated value of V_{OUT} .

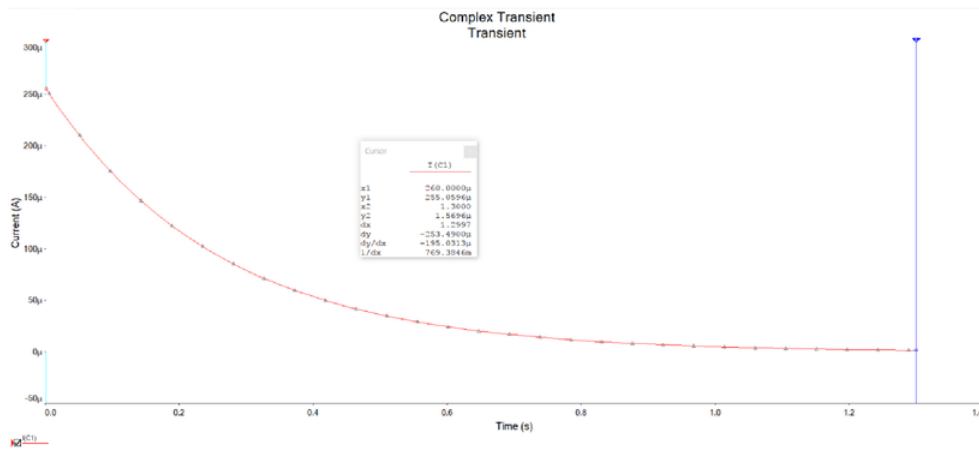


FIGURE 31

Figure 31 shows the current analysis for the circuit's transient. As displayed, the current decreases very quickly whilst being drawn through the circuit, during charging. This is due to how the capacitor acts like a short circuit, meaning that the current is only flowing through R_1 and through the capacitor to take the shortest possible route to ground. After the total charging period, $5T$, the capacitor is fully charged, resulting in "zero" current flow. After 1.3s, the current in the circuit is $1.57\mu\text{A}$. Again, the instantaneous current in the circuit can be calculated to compare to the simulated values.

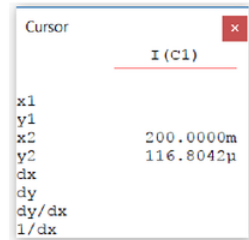


FIGURE 32

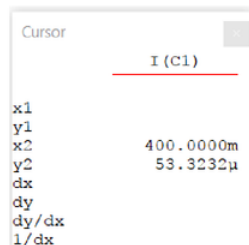


FIGURE 33

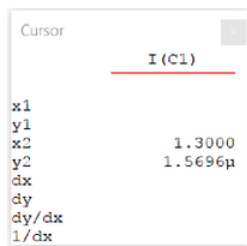


FIGURE 34

Figure 32, Figure 33 and Figure 34 show the current values for the circuit's charging, at the chosen time intervals.

Instantaneous Current Calculations

$$I_c = I_{max} \left(e^{\frac{-t}{T}} \right)$$

$$I_c = 0.254 \left(e^{\frac{-0.2}{0.26}} \right) = 0.118mA$$

$$I_c = 0.254 \left(e^{\frac{-0.4}{0.26}} \right) = 0.055mA$$

$$I_c = 0.254 \left(e^{\frac{-1.3}{0.26}} \right) = 1.65\mu A$$

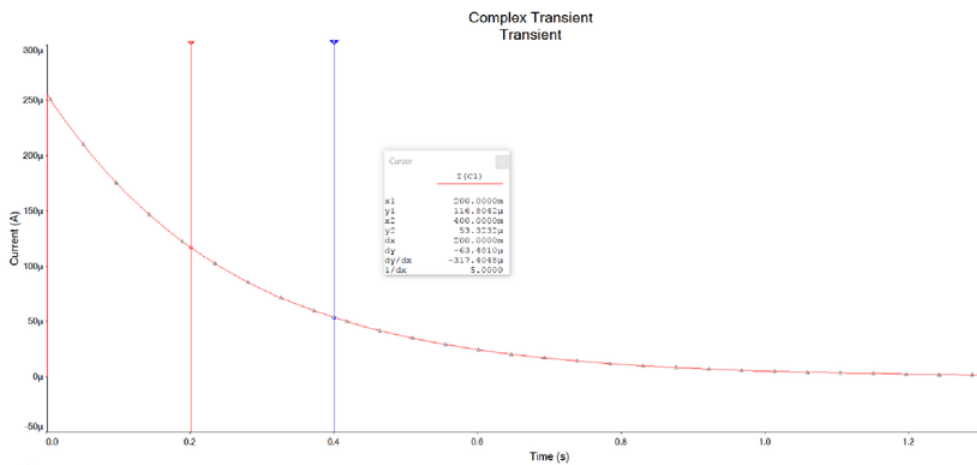


FIGURE 35

As shown in Figure 35, the simulated current after 0.2s is 0.116mA and the current after 0.4s is 0.053mA. In this case, the calculated values are larger than the simulated values, again due to rounding.

Charging Current		
Time	Calculations	Simulations
0.2s	0.118mA	0.116mA
0.4s	0.055mA	0.053mA
1.3s	1.65μA	1.57μA

These graphs can be used to find the time constant for the circuit. On the voltage graph, the time constant should be roughly 63% of the maximum voltage, which is 4.1V. The capacitor reaches 4.1V after 0.253s, which is lower than the calculated time constant. The current should have decreased to roughly 37% of the maximum current after one time constant, which would be 0.094mA. The time taken to reach 0.92mA is 0.255s. This value is also lower than the calculated time constant.

Discharging

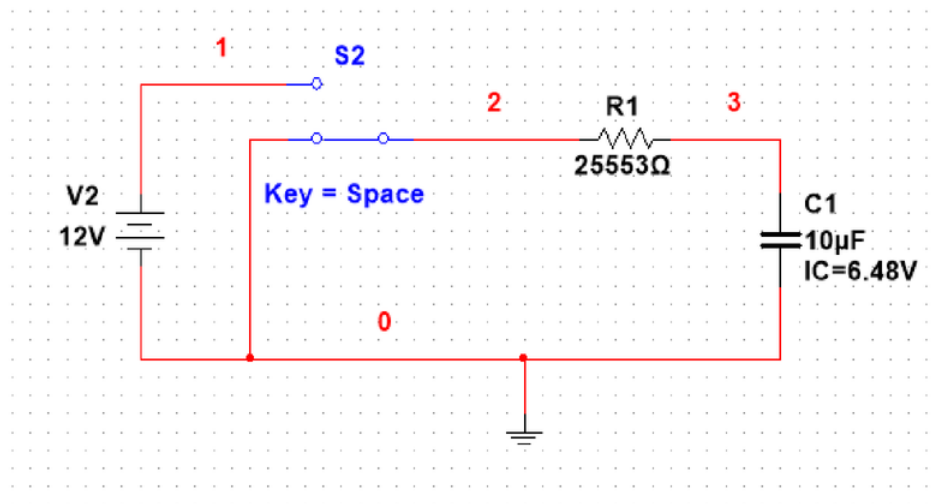


FIGURE 36

After charging the capacitor fully, the circuit can be switched to its discharging state. In this state, the voltage will decrease, and the current will increase.

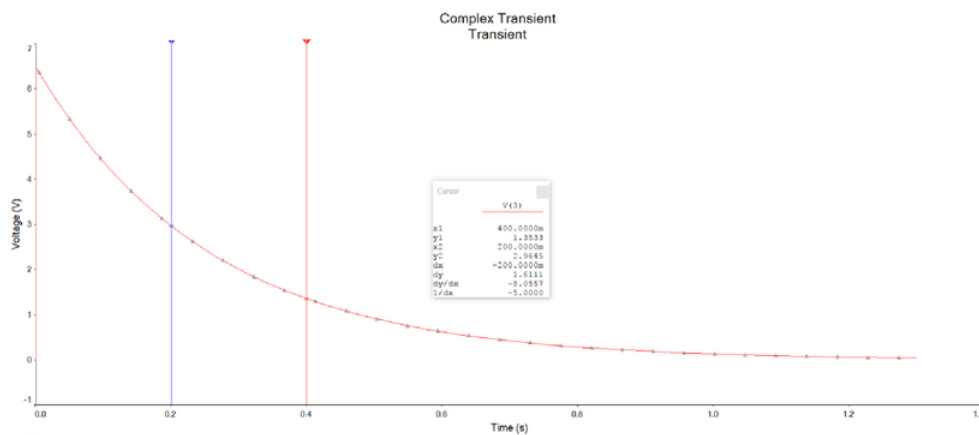


FIGURE 37

Figure 37 shows the transient response for the voltage in the circuit when it is in its discharging state. At 0.2s, the voltage value is 2.96V and after 0.4s, the voltage is 1.35V. When discharging, the capacitor discharges its voltage through both resistors to earth. Before the discharging begins, the capacitor has 6.48V stored in it. The 6.48V was the maximum voltage that it could charge up to whilst charging, due to the voltage dropped across R1. The voltage dropped prevented the capacitor from reaching the 12V supplied to the circuit, hence why 6.48V has been used in the calculations. After the capacitor is fully discharged, the remaining voltage is 39.8mV. This value should be correct, due to the capacitor not discharging to 0V.

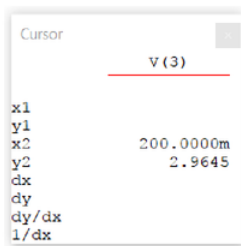


FIGURE 38

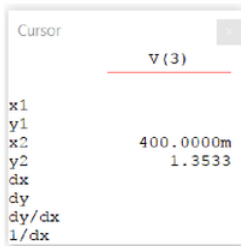


FIGURE 39

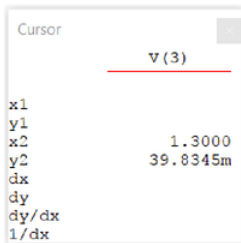


FIGURE 40

Figure 38, Figure 39 and Figure 40 show the voltage values for the discharging response at the selected time intervals.

Instantaneous Voltage Calculations

$$V_c = V_s \left(e^{\frac{-t}{T}} \right)$$

$$V_c = 6.48 \left(e^{\frac{-0.2}{0.26}} \right) = 3.00V$$

$$V_c = 6.48 \left(e^{\frac{-0.4}{0.26}} \right) = 1.39V$$

$$V_c = 6.48 \left(e^{\frac{-1.3}{0.26}} \right) = 43.6mV$$

The calculated values are larger than the simulated values, which is likely due to rounding errors with the time constant.

Discharging Voltage		
Time	Calculations	Simulations
0.2s	3.00V	2.96V
0.4s	1.39V	1.35V
1.3s	43.6mV	39.8mV

When the capacitor discharges, the current flows through the parallel resistors to ground. Due to the direction of flow, the current values become negative, as shown below in Figure 41.

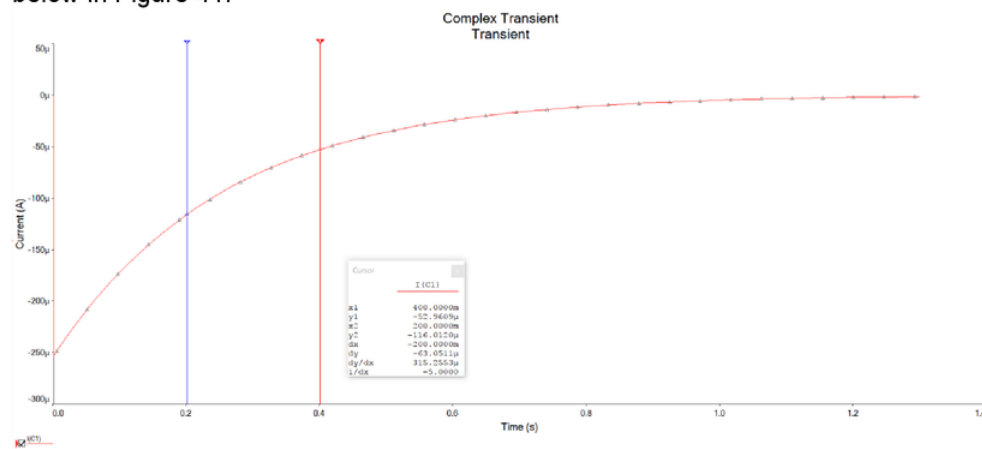


FIGURE 41

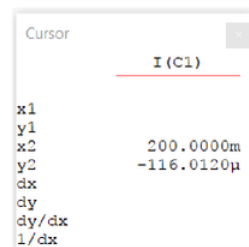


FIGURE 42

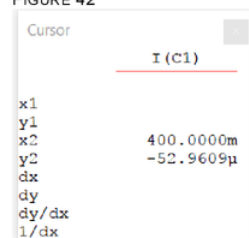


FIGURE 43

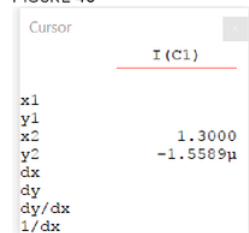


FIGURE 44

Figure 42, Figure 43 and Figure 44 shows the discharging current values at the selected time intervals.

The instantaneous current can be calculated using the formula;

$$-I_c = I_{max} \left(e^{\frac{-t}{T}} \right)$$

Instantaneous Current Calculations

$$-I_c = 254 \left(e^{\frac{-0.2}{0.26}} \right) = -117.7mA$$

$$-I_c = 254 \left(e^{\frac{-0.4}{0.26}} \right) = -54.5mA$$

$$-I_c = 254 \left(e^{\frac{-1.3}{0.26}} \right) = -1.71\mu A$$

Again, the current does not reach 0A after the discharge is complete.

Discharging Current		
Time	Calculations	Simulations
0.2s	-0.117mA	-0.116mA
0.4s	-0.54mA	-0.53mA
1.3s	-1.71 μ A	-1.55 μ A

Due to the discharging current being the negative integers of the charging current, the values should be the same as the charging values. The simulated values were the same numbers, but instead negative, except for the current after 1.3s, which was slightly different. However, all the calculated values did come out different to their positive values.

5. Transient Behaviour for the Inductive Circuit

Charging

Transient analysis can also be used on inductive, or RL, circuits. Figure 12 shows an inductive circuit that is using a 10Ω resistor and a 2H inductor. The values of the resistor and the inductor provide the time constant for the circuit's charging. The time constant is calculated using;

$$T = \frac{L}{R}$$

Therefore, the time constant is;

$$T = \frac{2}{10} = 0.2s$$

The circuit will be fully charged after $5T$, or 1 second. The maximum current in the circuit can be found using;

$$I_{MAX} = \frac{V_S}{R}$$

Therefore, the current is;

$$I_{MAX} = \frac{2}{10} = 0.2A \text{ or } 200mA$$

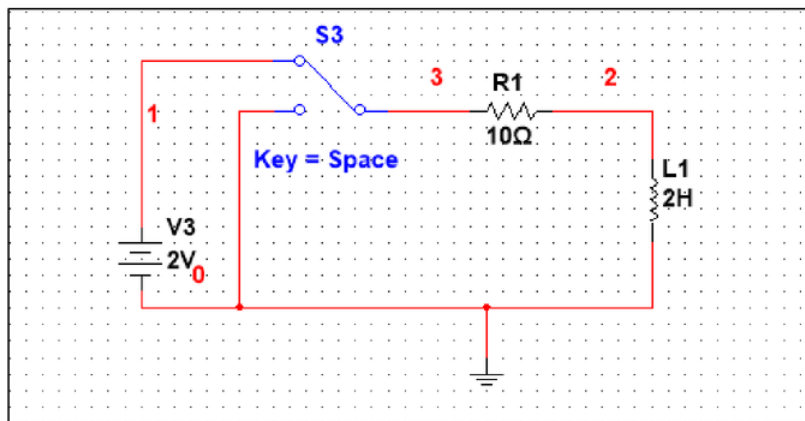


FIGURE 45

The transient response for both the inductor's current and voltage, whilst charging, were taken. The circuit was built and simulated, to allow the circuit to be analysed.

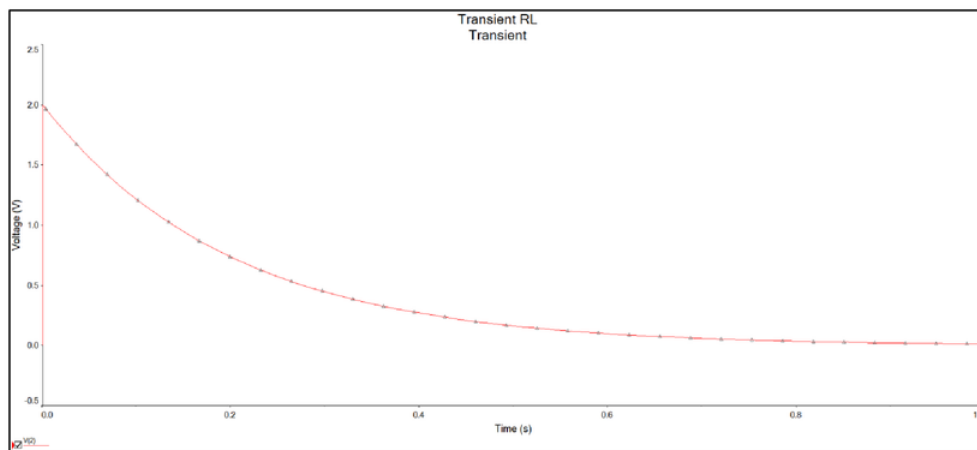


FIGURE 46

Figure 46 shows the voltage response for the inductor, during charging. An inductor's voltage, unlike a capacitor's, decreases over time. The voltage starts at 2v at 0 seconds and decreases to nearly 0v, after 1 second. Using the analysis graph, the time constant can be confirmed. At 0.2s, the voltage is 0.74V, which is roughly 36.8% of 2V. This is the expected time constant value.

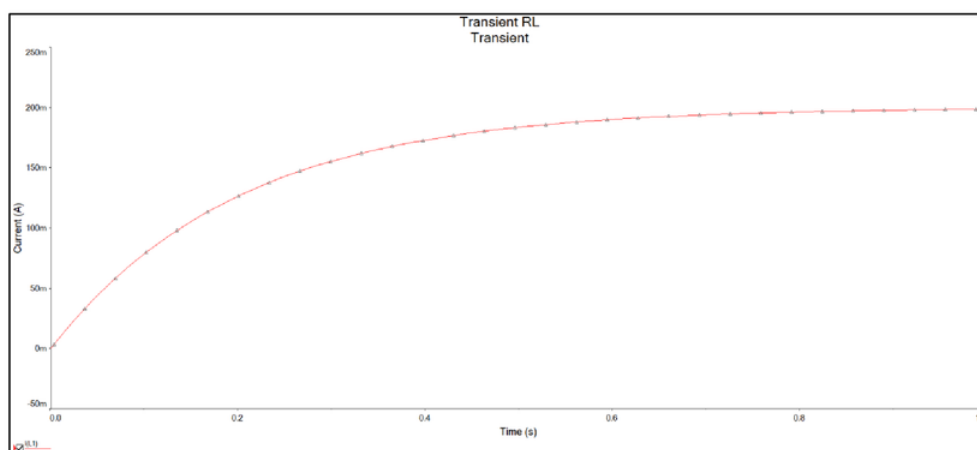


FIGURE 47

Figure 47 shows the transient response for the current in the inductive circuit. In an inductive circuit, the current increases over 1 second, starting at 0A and reaching a maximum current of 200mA as expected. Like an RC circuit, the current decreases and the voltage increases exponentially. Again, the time constant can be checked. This time the value should be roughly 63.2%, or 126mA, which it is at 0.2s.

To ensure that the simulation was successful, some calculations can be completed and used for comparison. This will prove if the simulation is correct or not.

Voltage Calculations

The formula used to calculate inductor voltage is as follows;

$$V_L = V_S(e^{\frac{-t}{T}})$$

Three calculations will be completed, at times of 0.2 seconds, 0.5 seconds and 1 second.

$$V_L = 2 \left(e^{\frac{-0.2}{0.2}} \right) = 0.736V$$

$$V_L = 2 \left(e^{\frac{-0.5}{0.2}} \right) = 0.164V$$

$$V_L = 2 \left(e^{\frac{-1.0}{0.2}} \right) = 0.013V$$

Current Calculations

The formula used to calculate inductor voltage is as follows;

$$I_L = I_{MAX}(1 - e^{\frac{-t}{T}})$$

Another two calculations will also be completed, at times of 0.2 seconds and 0.5 seconds.

$$I_L = 0.2 \left(1 - e^{\frac{-0.2}{0.2}} \right) = 126.4mA$$

$$I_L = 0.2 \left(1 - e^{\frac{-0.5}{0.2}} \right) = 183.6mA$$

After 5T, or 1 second, the current is;

$$I_L = 0.2 \left(1 - e^{\frac{-1}{0.2}} \right) = 198.7mA$$

To compare to the transient analysis, additional current calculations are required.

Time (s)	Equation	Current (mA)
0.1	$I_L = 0.2 \left(1 - e^{\frac{-0.1}{0.2}} \right)$	78.69
0.2	$I_L = 0.2 \left(1 - e^{\frac{-0.2}{0.2}} \right)$	126.4
0.3	$I_L = 0.2 \left(1 - e^{\frac{-0.3}{0.2}} \right)$	155.4
0.4	$I_L = 0.2 \left(1 - e^{\frac{-0.4}{0.2}} \right)$	172.9
0.5	$I_L = 0.2 \left(1 - e^{\frac{-0.5}{0.2}} \right)$	183.6
0.6	$I_L = 0.2 \left(1 - e^{\frac{-0.6}{0.2}} \right)$	190.0
0.7	$I_L = 0.2 \left(1 - e^{\frac{-0.7}{0.2}} \right)$	194.0

0.8	$I_L = 0.2 \left(1 - e^{\frac{-0.8}{0.2}} \right)$	196.3
0.9	$I_L = 0.2 \left(1 - e^{\frac{-0.9}{0.2}} \right)$	197.8
1.0	$I_L = 0.2 \left(1 - e^{\frac{-1.0}{0.2}} \right)$	198.7

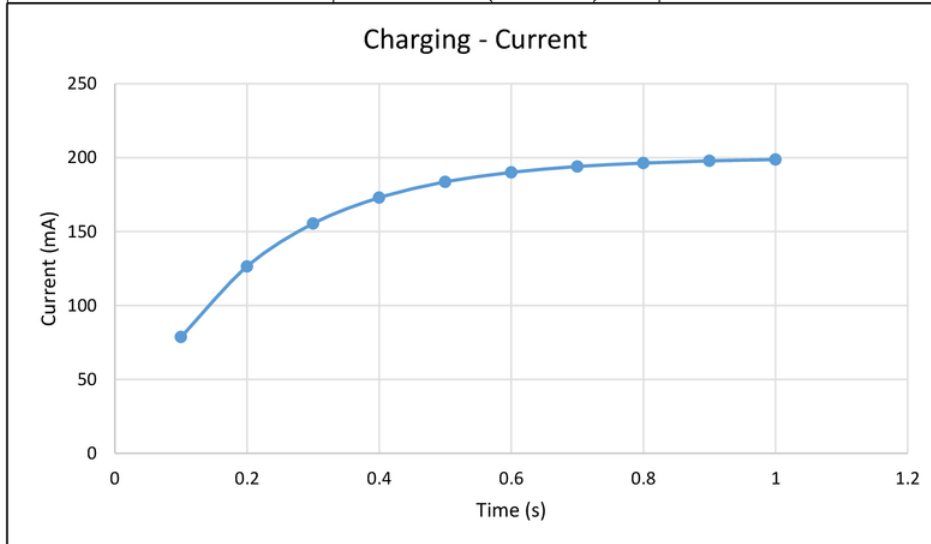


FIGURE 48

The graph, seen in Figure 48, was produced from the calculations follows the same shape as the graph created from the simulation. The simulation will be used to take readings at 0.1 second intervals between 0.1 seconds and 1 second.

RL Charge		
Time (s)	Voltage (V)	Current (mA)
0.1	1.214	78.61
0.2	0.736	126.4
0.3	0.446	155.4
0.4	0.271	172.9
0.5	0.164	183.6
0.6	0.099	190.1
0.7	0.060	194.0
0.8	0.037	196.3
0.9	0.022	197.8
1.0	0.013	198.7

As shown in the table above, the calculated voltage values at 0.2s, 0.736V, and at 0.5s, 0.164V, are the same as the values taken from the simulation. The current values calculated at 0.2s, 126.4mA, at 0.5s, 183.6mA, and at 1s, 198.7mA, are the same values as taken from the simulation.

Time (s)	Voltage (V)		Current (mA)	
	Simulation	Calculation	Simulation	Calculation
0.2	0.736	0.736	126.4	126.4
0.5	0.164	0.164	183.6	183.6
1	0.013	0.013	198.7	198.7

Discharge

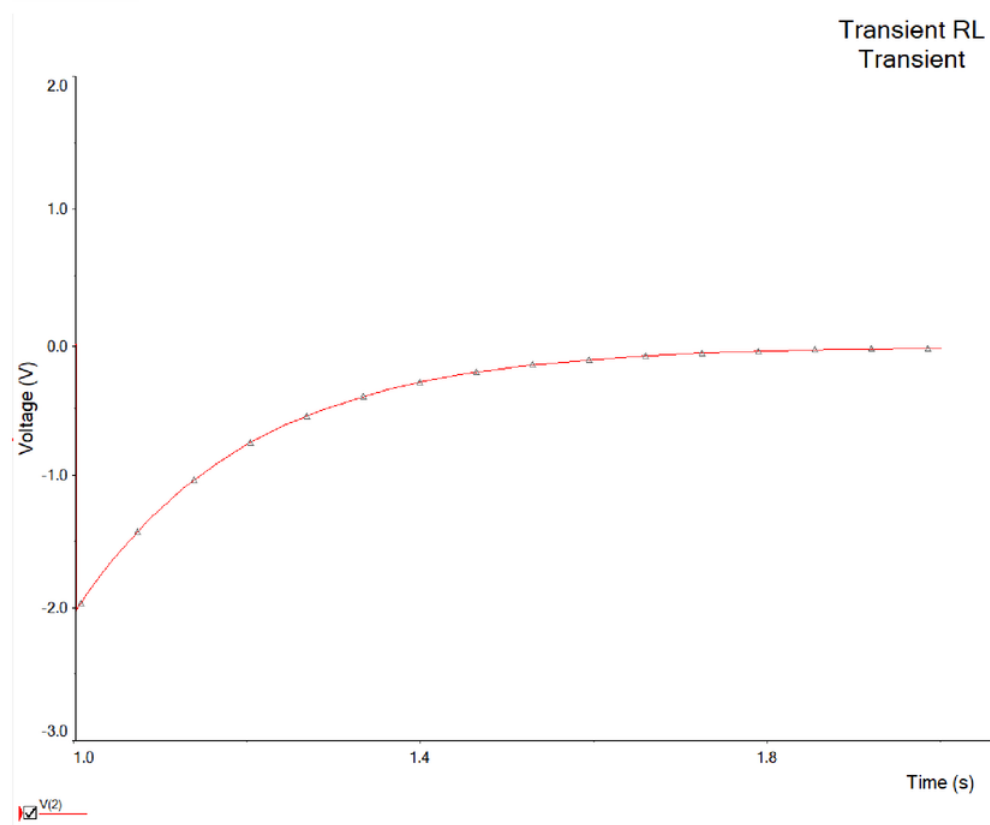


FIGURE 49

Figure 49 shows the transient behaviour for the inductive circuit's voltage while it is in its discharging state. This graph starts at 0V, and instantly inverts to -2V and discharges to 0V after 1 second has passed. This is due to the back EMF created when the switch changes state.

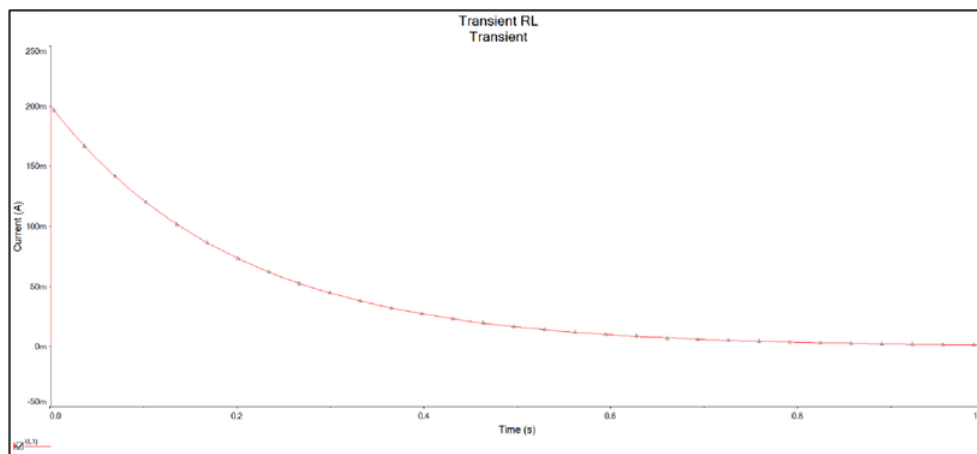


FIGURE 50

Figure 50 displays the transient behaviour for the inductive circuit's current, while it is discharging. As expected, the current starts at 200mA, which is I_{MAX} , and decreases to 0A.

RL Discharge (Simulation)		
Time (s)	Voltage (V)	Current (mA)
0.1	-1.21	121.4
0.2	-0.73	73.6
0.3	-0.44	44.6
0.4	-0.27	27.1
0.5	-0.16	16.4
0.6	-0.099	9.94
0.7	-0.060	6.02
0.8	-0.036	3.65
0.9	-0.022	2.22
1.0	-0.013	1.34

Again, calculations and a graph can be used to compare to the simulation, to confirm that it is correct.

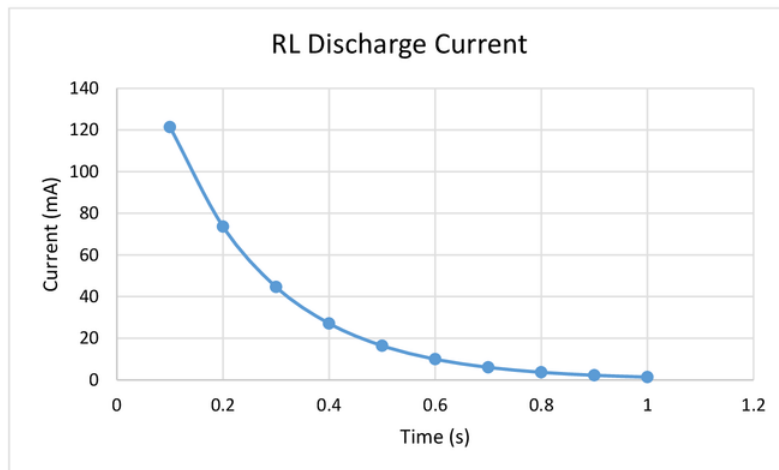


FIGURE 51

Voltage Calculations

The time values used for the following calculations will be the same as were used for the charging calculations. These being 0.2s, which is the time constant, 0.5s and 1 second.

$$V_L = -V_S(e^{\frac{-t}{T}})$$

$$V_L = -2 \left(e^{\frac{-0.2}{0.2}} \right) = -0.736V$$

$$V_L = -2 \left(e^{\frac{-0.5}{0.2}} \right) = -0.164V$$

$$V_L = -2 \left(e^{\frac{-1}{0.2}} \right) = -0.013V$$

Current Calculations

The same values will again be used for the current calculations, along with a calculation after 5T, or 1 second. The equation for calculating current during the discharge is as follows;

$$I_L = I_{MAX}(e^{\frac{-t}{T}})$$

Therefore, the calculated values are;

$$I_L = 0.2 \left(e^{\frac{-0.2}{0.2}} \right) = 73.6mA$$

$$I_L = 0.2 \left(e^{\frac{-0.5}{0.2}} \right) = 16.4mA$$

$$I_L = 0.2 \left(e^{\frac{-1}{0.2}} \right) = 1.35mA$$

Time (s)	Voltage (V)		Current (mA)	
	Simulation	Calculation	Simulation	Calculation
0.2	-0.73	-0.74	73.6	73.6
0.2	-0.16	-0.16	16.4	16.4
1.0	-0.013	-0.013	1.34	1.35

Some of the voltage and current calculations are slightly different to the simulated values; however, this is likely due to rounding errors in the calculations.

Calculations can also be used to find the amount of time taken to reach a specific current value. This can be done by transposing the I_L equation, as follows;

$$I_L = I_{MAX}(e^{\frac{-t}{T}})$$

$$\frac{I_L}{I_{MAX}} = (e^{\frac{-t}{T}})$$

$$\ln\left(\frac{I_L}{I_{MAX}}\right) = \frac{-t}{T}$$

$$\ln\left(\frac{I_L}{I_{MAX}}\right)T = -t$$

The time taken to reach 100mA, is calculated as;

$$-t = \ln\left(\frac{0.1}{0.2}\right)0.2 = -0.13$$

Therefore;

$$t = 0.13s$$

The time taken to reach 10mA, is calculated as;

$$-t = \ln\left(\frac{0.01}{0.2}\right)0.2 = -0.6$$

Therefore;

$$t = 0.6s$$

In comparison to the simulation, the values of t are low. However, this is due to rounding error.

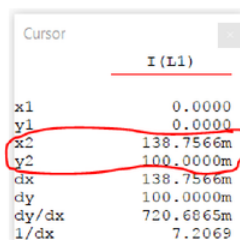


FIGURE 52

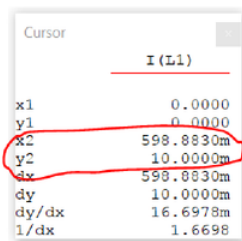


FIGURE 53

Figure 52 and Figure 53 show the time taken to reach 10mA and 100mA, as per the simulation.

6. Conclusions

During this report, research was completed into the transient response for electronic circuits. These circuits included an RC circuit, an RC circuit with parallel resistors and an RL circuit. All three circuits were investigated from both a charging and discharging standpoint, using practical and simulated testing to analyse the voltage and current and through completing a series of calculations to both compare to the measured values, to validate them, and to predict the circuits response at given currents. All the results were successfully compared, which highlighted the errors found in practical research, such as component value errors and human response errors, thus proving that simulations can be used to find more suitable answers

PSDE4001 Assignment 1

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FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: CSG-RUBIC

JORDAN GOUGH

0

RESEARCH-INFORMED LITERATURE

KNOWLEDGE AND UNDERSTANDING



Very good demonstration of understanding.

21/25

ANALYSIS



Analysis is very good and explained.

33/40

PRACTICAL APPLICATION AND DEP.



Theory tied in nicely with practical and good explanations.

22/25

SKILLS FOR PROFESSIONAL PRAC.



V good report

8/10