

# Thomas Grennan - PSDE4001

## Assignment 1

*by* Thomas Grennan

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HNC Electrical and Electronic Engineering

PSDE4001 – Electrical and Electronic Principles

Assignment 1 – Transient Analysis

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*Good table of contents and list of figures*

## 1. Introduction

This assignment is to analyse the behaviour of various circuits and their components. RC, RL and complex RC circuits will be analysed under DC conditions and their components will be analysed to monitor how they act under these conditions. Analysis will be undertaken in the form of multisim simulations, mathematical calculations and practical tests. Results from these tests will be obtained and compared and contrasted to show any discrepancies or errors.

*Introduction is short  
but to the point.*

## 2. Transient behaviour for the Charging of a capacitor

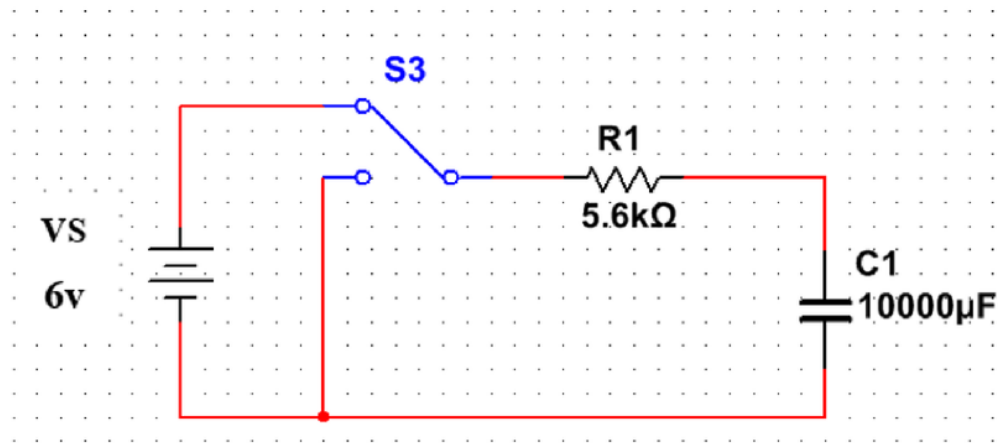


FIGURE 1 – RC CIRCUIT

For this task the circuit that is going to be analysed consists of a 6V DC power supply, a 5.6kΩ resistor which is in series with a 10kμF capacitor [Figure 1]. The power will flow from the positive terminal from the power supply through the resistor which will resist the current flow, the power will then flow into the capacitor and will charge it up. A resistor is in this circuit to prevent the capacitor from over charging instantly so that a transient is visible otherwise with no resistance the capacitor could potentially explode due to this equation,  $I = V/R$ .

The component values have been chosen to give a time constant of around 60 seconds, using the equation  $T = R \times C$  we can find that this circuits time constant will be 56 seconds as  $10,000\mu F \times 5.6k\Omega = 56$  seconds, 56 seconds is one time constant, the capacitor will charge to 63% of its capacity after 1T, these components will have tolerances which could affect the results of the practical test.

*Significant point identified*

For this task the transients are being looked into, a transient is a period of change, the period after a transient is known as the steady state, in this case the steady state for the voltage charge will be 6V as this is when the capacitor will be fully charged therefore there will no longer be a period of change, Maximum growth for this circuit will be after 5T, therefore the transient period for this circuit is  $5 \times 56s = 280s$ , The capacitor will be charged to its full capacity at 5T.

The first method of testing will be through a practical circuit built on a PCB, test equipment will be connected to test the voltage and current charge over the transient period, readings will be taken down every 20 seconds for the transient period, the next test will be through multisim, on multisim the circuit will be built and then the transients are viewed as graphs where the results can be seen. the final method of testing will be mathematical with theory and formulas to find out what the voltage and current will be at a specific time within the transient period. The values from these 3 tests will then be compared and contrasted to see if there are any discrepancies or differences

*Explanation is good but could have rounded it all in a single paragraph.*

## Practical Test

For the practical test the circuit was constructed on a breadboard, and then recorded with a voltmeter and an ammeter in order to record the Voltage and Current that the capacitor gets charged to every 20 seconds over the transient period. However, these components will have tolerances which can affect the results that the multimeter will pick up the tolerances of these components, these tolerances can be up to  $\pm 10\%$ . Due to these tolerances the practical results may be different to the Simulated and calculated results as these will calculate it with the exact value with no tolerances or human error. The capacitor will be charged at roughly 63% after 1 time constant, capacitors only charge to around 99%, this may cause discrepancies when comparing the results.

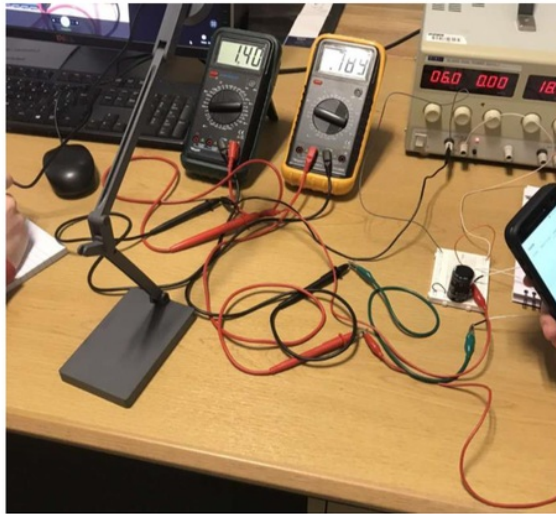


FIGURE 2 – PRACTICAL CIRCUIT

*Good  
image and  
intro to  
practical*

### Table of results

Figure 3 shows the values obtained from the practical tests. The table shows that as the voltage increases the current decreases. At 280s the voltage is at 5.86v which is close to 99% of 6v proving that the capacitor will only charge to 99%. After the transient period the circuit will enter the steady state, steady state is the period after the transient state where the values stop varying.

| Charge   |        |         |
|----------|--------|---------|
| Time (t) | VC (V) | IC (mA) |
| 20       | 1.91   | 0.701   |
| 40       | 3.09   | 0.491   |
| 60       | 3.91   | 0.352   |
| 80       | 4.47   | 0.25    |
| 100      | 4.89   | 0.179   |
| 120      | 5.18   | 0.127   |
| 140      | 5.39   | 0.094   |
| 160      | 5.54   | 0.069   |
| 180      | 5.64   | 0.051   |
| 200      | 5.72   | 0.038   |
| 220      | 5.77   | 0.028   |
| 240      | 5.81   | 0.022   |
| 260      | 5.84   | 0.016   |
| 280      | 5.86   | 0.013   |

*good table of results*

FIGURE 3 – CHARGE RESULTS TABLE

The exponential graphs are created next from the table results, as VS is a constant value and the capacitor charges increasing its voltage. However, Ohms law is introduced stating that as the voltage increases the current must decrease, however, the current is also a constant.

### VC Charge

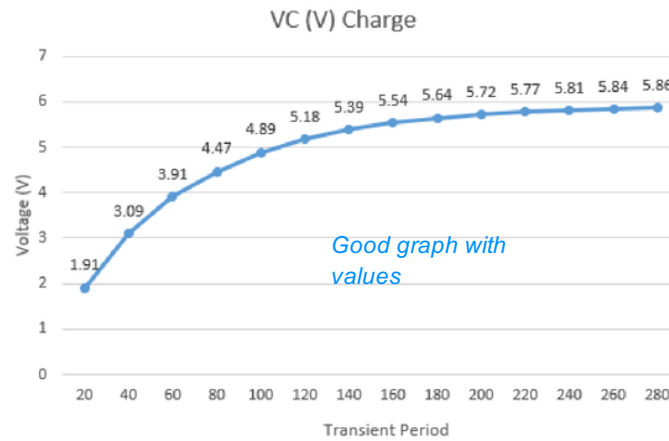


FIGURE 4 – VOLTAGE CHARGE PLOT

Figure 4 is an excel graph of the practical for the charging voltage. At 56s which is 1T the voltage has charged to around 3.8v, as 1T 63% of  $V_{max}$  this is correct as 63% of 6v is 3.8v. 0.7T is the equivalent of half of  $V_{cc}$ , therefore 0.7T should equal 3V, 0.7T is around 39 seconds, at 0.7T the voltage is around 3.04v which is very near to Half  $V_{cc}$  proving that this theory is correct. The graph shows a quick voltage increase between 20s and 120s, after 120s it begins to slow down and enter the steady state. At 5T it has nearly fully charged to around 98% of the capacitors 99% capacity.

### IC Charge

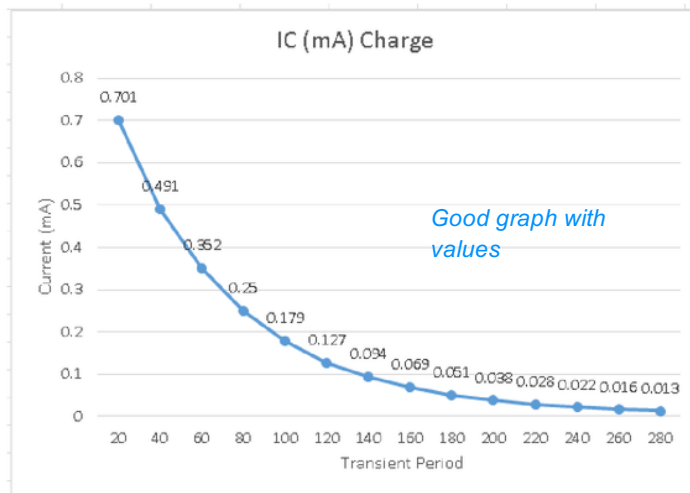


FIGURE 5 – CURRENT CHARGE PLOT

Figure 5 shows the current charge of the capacitor over the transient period. The graph shows the current decreases very quickly until around 180 seconds whereby it begins to enter the steady state. At 0.7T (39.2s) the current was around 0.49mA, it should be around 0.42mA. At 1 time constant the current was around 0.35mA. After the transient period the current has fallen to 0.013mA which is 99% of  $I_{max}$ . The current falls rapidly until 120seconds. After this it starts to enters steady state.

*Explanations are good  
and include the  
significant points 0.7T  
and 1T.*

## Multisim

For the multisim simulation the circuit was run and a transient analysis was undertaken at three instantaneous times during the transient period, at these times the voltage will be noted and then compared with the mathematical values and the practical values. These simulations were proved over 3 instantaneous times as shown in Figures 6, 7 and 8.

VC Charge at 60 Seconds = 3.944v

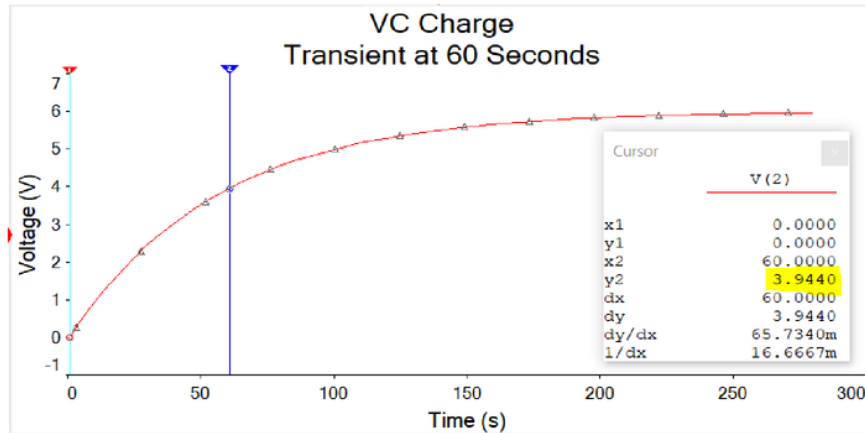


FIGURE 6 – VC CHARGE AT 60 SECONDS

*Graph is clear and  
values are correct*

VC Charge at 120 seconds = 5.29V

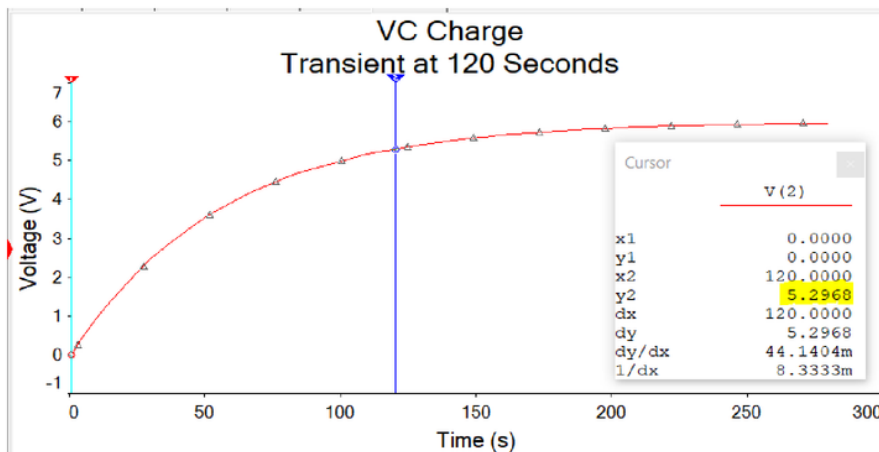
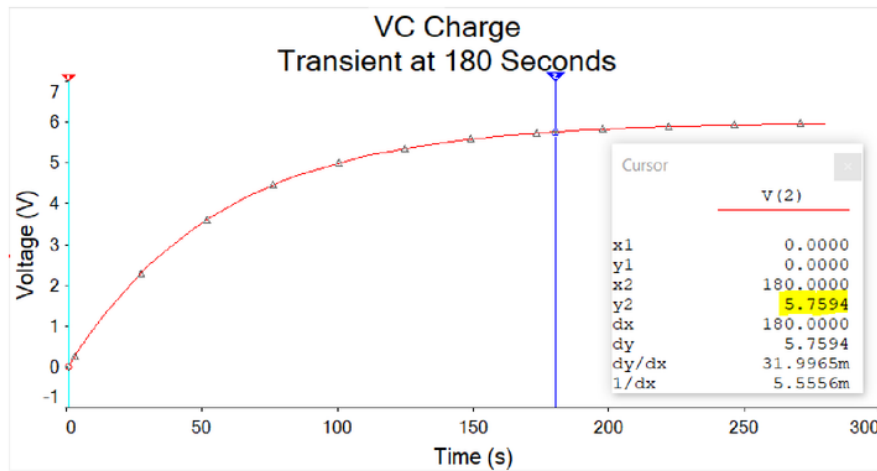


FIGURE 7 – VC CHARGE AT 120 SECONDS

*Graph and value is  
correct*

VC Charge at 180s: 5.7594V

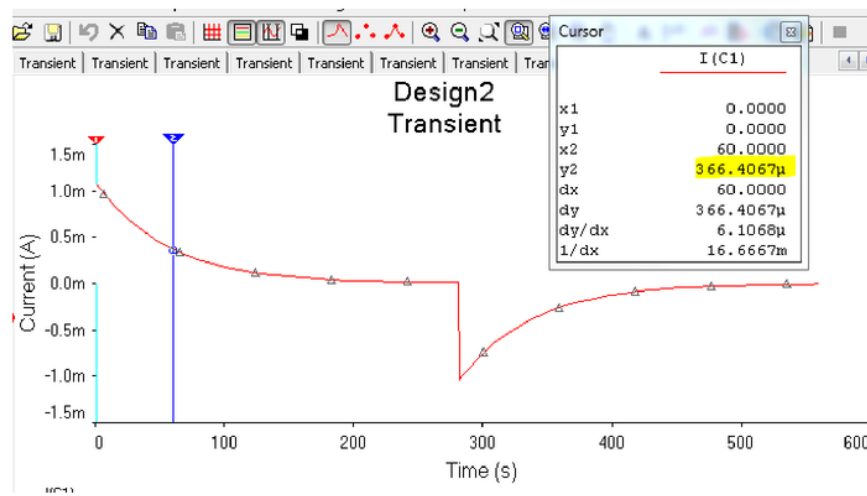


*graph is correct*

FIGURE 8 – VC CHARGE AT 180 SECONDS

Charge Current Values

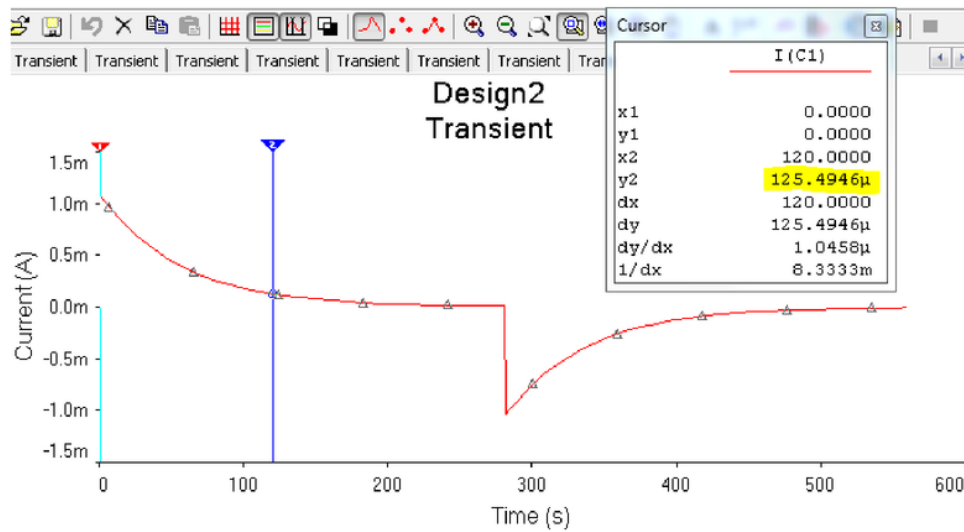
IC Charge at 60 seconds: 0.366mA



*Good graph of results*

FIGURE 9 – IC CHARGE AT 60S

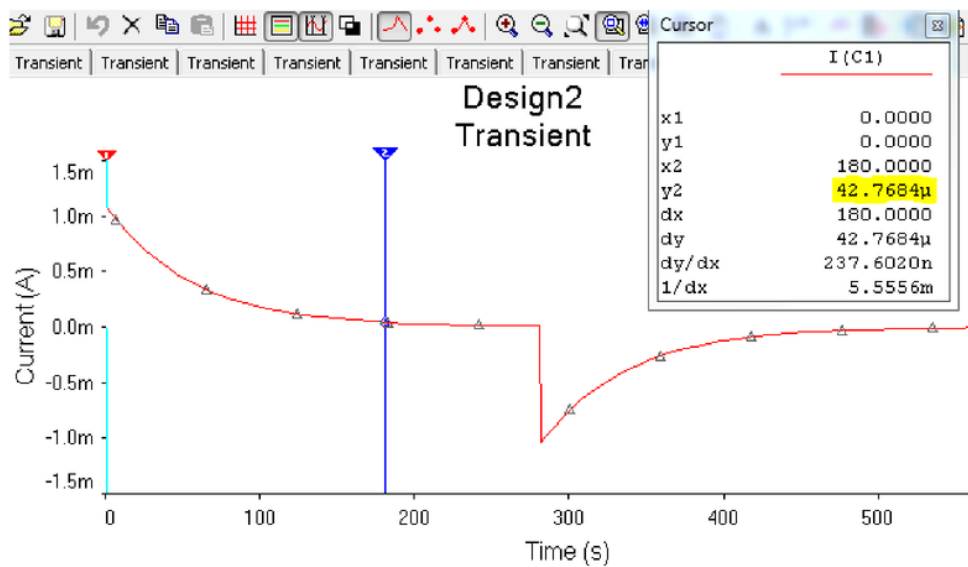
IC Charge at 120 seconds: 0.125mA



Graph is correct

FIGURE 10 – IC CHARGE AT 120s

IC Charge at 180 seconds: 0.042mA



Good graph

FIGURE 11 – IC CHARGE AT 180s

### Voltage Calculations

The third and final test to investigate the voltage charge of a capacitor is through mathematic theory. These were calculated at 60s, 120s and 180s using the calculation:

$$V_c = V_{max} \left( 1 - e^{\frac{-t}{T}} \right)$$
$$60s = V_c = 6 \left( 1 - e^{\frac{-60}{56}} \right) = 3.944V$$
$$120s = V_c = 6 \left( 1 - e^{\frac{-120}{56}} \right) = 5.296V$$
$$180s = V_c = 6 \left( 1 - e^{\frac{-180}{56}} \right) = 5.759V$$

### Current Calculations

The current is also calculated using the equation:

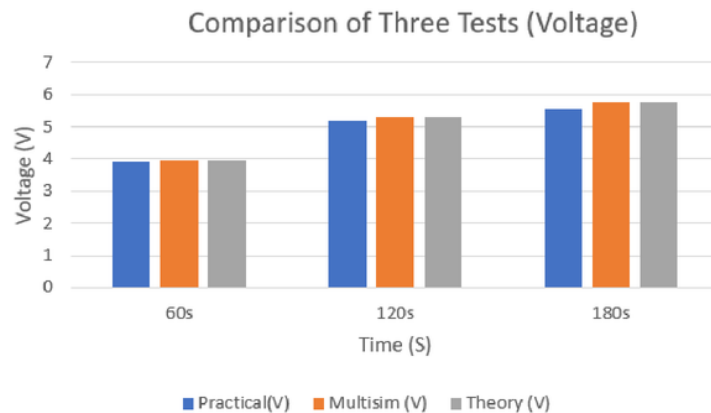
$$I_{max} = \frac{Vs}{R}$$
$$I_{max} = \frac{6}{5600} = 1.07mA$$
$$I_c = I_{max} \left( e^{\frac{-t}{T}} \right)$$
$$60s = I_c = 1.07 \times 10^{-3} \left( e^{\frac{-60}{56}} \right) = 0.367mA$$
$$120s = I_c = 1.07 \times 10^{-3} \left( e^{\frac{-120}{56}} \right) = 0.125mA$$
$$180s = I_c = 1.07 \times 10^{-3} \left( e^{\frac{-180}{56}} \right) = 0.0429mA$$

## Charge Comparison

*Excellent table of results with explanation.*

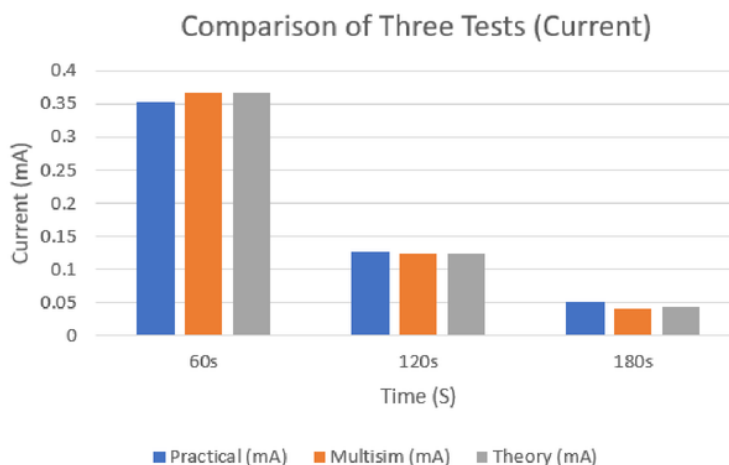
| Time (s) | Voltage (V) |            |             | Current (mA) |            |             |
|----------|-------------|------------|-------------|--------------|------------|-------------|
|          | Practical   | Simulation | Calculation | Practical    | Simulation | Calculation |
| 60       | 3.91        | 3.944      | 3.945       | 0.352        | 0.367      | 0.367       |
| 120      | 5.18        | 5.296      | 5.296       | 0.127        | 0.125      | 0.125       |
| 180      | 5.54        | 5.759      | 5.759       | 0.051        | 0.042      | 0.0429      |

The comparison table shows that overall the simulation and calculation are very accurate as there are no discrepancies between them other voltage at 60s and the current at 180s, however this is down to human error from rounding of the figures. The practical figures are all different to the calculated figures, this is due to reaction time when noting down the values, component tolerances, whereas multisim and the calculations are accurate to the millisecond and have no component tolerances. These figures have been placed in a bar chart to visually prove the discrepancies that the practical had with the multisim and calculations.



*Good analysis representation graph. This explains better than text.*

FIGURE 12 – COMPARISON OF THREE TESTS (VOLTAGE)



*Excellent representation for analysis. This is a better method than just text.*

FIGURE 12 - COMPARISON OF THREE TESTS (CURRENT)

### 3. Transient behaviour for the Discharging of a capacitor

When the capacitor had fully charged, a wire in the circuit was moved to ground to effectively open the switch to discharge the capacitor. The circuit stayed the same therefore the time constant and transient period were the same time. The same tests were performed just for the discharging of the capacitor.

As the circuit is discharging the current is now negative as it is flowing out of the negative capacitor terminal. The discharge period shows as the voltage decreases the current increases from negative to almost 0mA at 5T.

| Discharge |        |         |
|-----------|--------|---------|
| Time (t)  | VC (v) | IC (mA) |
| 20        | 4.09   | -0.705  |
| 40        | 2.92   | -0.506  |
| 60        | 2.05   | -0.357  |
| 80        | 1.45   | -0.253  |
| 100       | 1.04   | -0.181  |
| 120       | 0.75   | -0.129  |
| 140       | 0.53   | -0.092  |
| 160       | 0.38   | -0.066  |
| 180       | 0.27   | -0.047  |
| 200       | 0.2    | -0.034  |
| 220       | 0.14   | -0.025  |
| 240       | 0.1    | -0.018  |
| 260       | 0.08   | -0.013  |
| 280       | 0.05   | -0.01   |

*Good explanation and good results*

FIGURE 14 – DISCHARGE TABLE

At 5T it shows that the capacitor has discharged to 99%, the voltage falls to almost 0V and the current has almost returned to positive current

*Current rises  
exponentially to  
zero.*

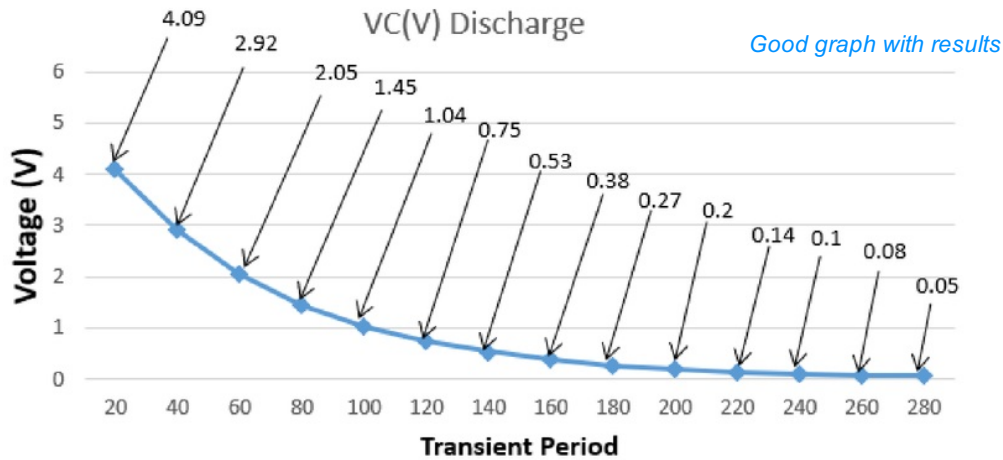


FIGURE 15 – VC DISCHARGE PLOT

The practical results were entered into a table and a curve line graph was created from the figures. The graph in Figure 15 shows that the voltage decreases from  $V_{max}$  to 4.09V after 20 seconds. At 1T it shows that the voltage has decreased to around 2.15V. At 0.7T the graph should show 3V as it 0.7T is half of the 6V ( $V_{CC}$ ). At 39.2 seconds (0.7T) the voltage is around 3V proving that this theory is correct.

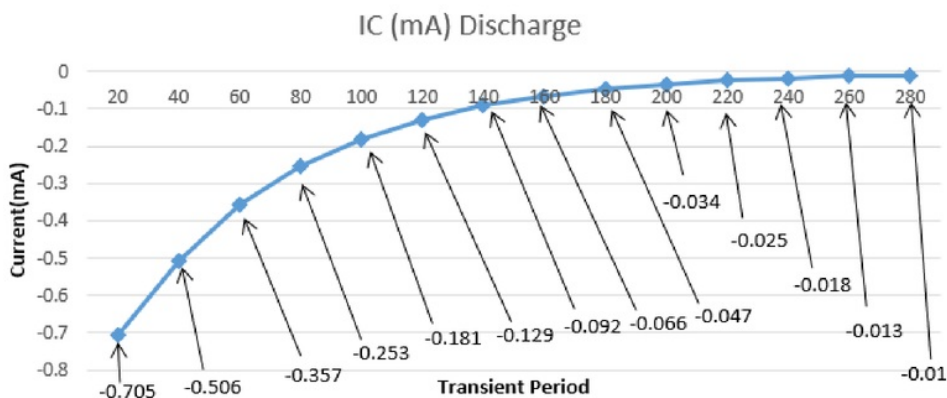


FIGURE 16 – IC DISCHARGE

The practical results for the current discharge were also entered into a table. The current flows exponentially from -0.705mA to almost 0mA after 5T, this is because the capacitor will never fully discharge. At 0.7T (39.2s) the current is around -0.51mA which is lower than the -0.527mA expected. At 1T the current is around -0.35mA whereas the expected current is around -0.39mA showing that the practical gave readings which were not accurate due to component tolerances and human error.

*Good graph with results with a good explanation including the significant points*

### Multisim Readings

#### Voltage Discharge at 60s = 2.04V

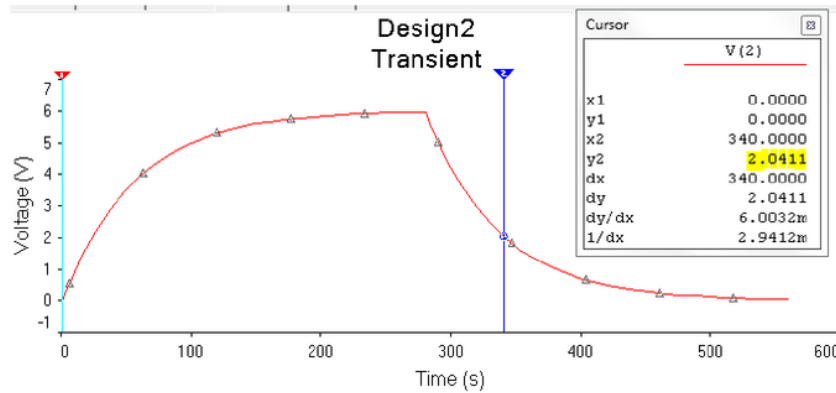


FIGURE 17 – VC DISCHARGE AT 60s

*Good graph which demonstrates a good understanding of test procedures.*

#### Voltage Discharge at 120s = 0.697 V

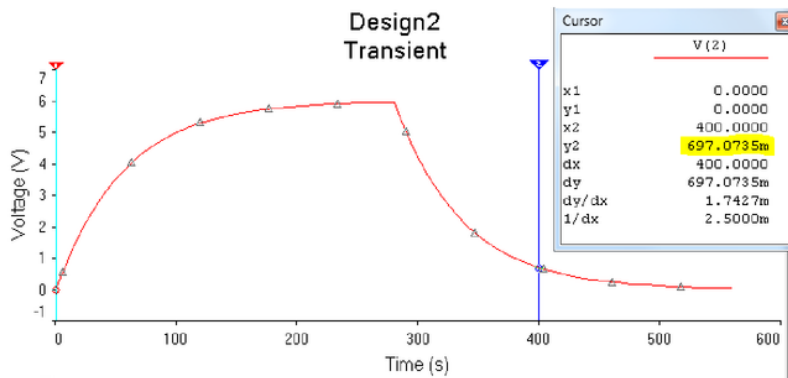


FIGURE 18 – VC DISCHARGE AT 120s

*Graphs are excellent with clear values*

#### Voltage Discharge at 180s = 0.238 V

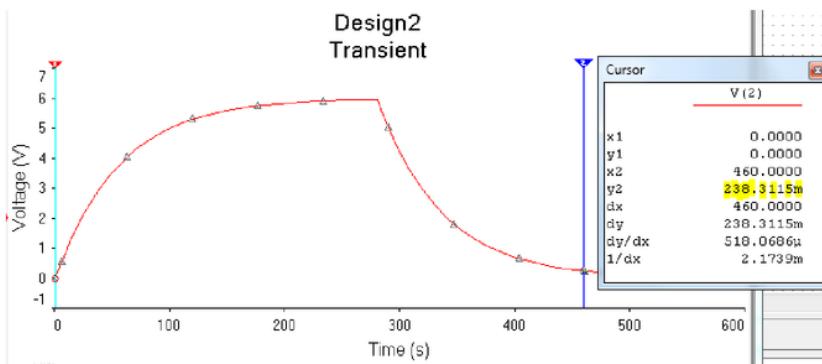


FIGURE 19 – VC DISCHARGE AT 180s

## Current Discharge Multisim

### Current Discharge at 60s: -0.364mA

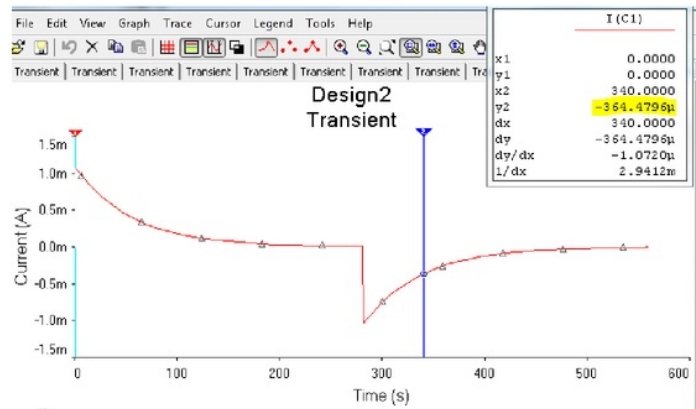
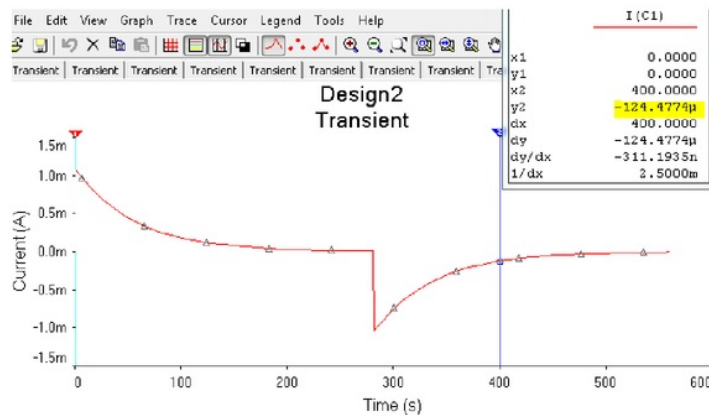


FIGURE 20 – IC DISCHARGE AT 60s

### Current Discharge at 120s: -0.124mA



Good graphs showing accurate values

FIGURE 21 – IC DISCHARGE AT 120s

### Current Discharge at 180s: -0.042mA

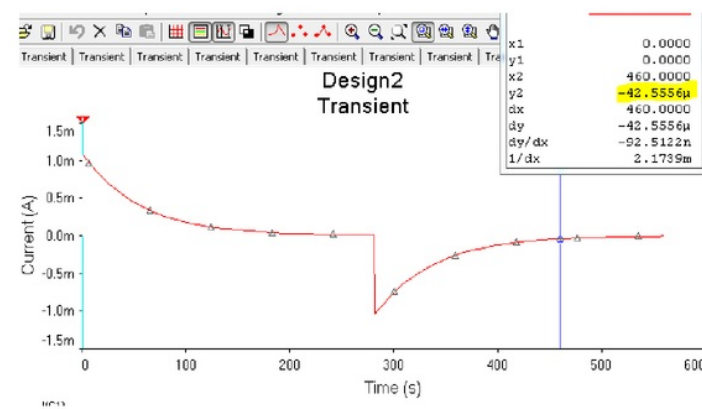


FIGURE 22 – IC DISCHARGE AT 180s

Both of these graphs follow the same shaped curve as the ones in the practical experiment, this proves that the practical experiment was accurate other than the discrepancies from the components.

### Voltage Calculations

To calculate the voltage, discharge the formula used is:

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

Where  $V_s = 6\text{v}$ ,  $T = 56\text{s}$  and  $t$  = the variable time constant

The voltage will again be calculated at 60s, 120s and 180s.

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

$$120\text{s} = V_c = 6 \left( e^{\frac{-120}{56}} \right) = 0.704\text{V}$$

$$180\text{s} = V_c = 6 \left( e^{\frac{-180}{56}} \right) = 0.241\text{V}$$

### Current Calculations

To calculate the discharge, current the formula used is:

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

Where  $-I_{\text{max}} = -1.07$ ,  $T = 56\text{s}$  and  $-t$  = negative time constant

The current will also be calculated at 60s, 120s and 180s.

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

$$120\text{s} = I_c = -1.07 \times 10^{-3} \left( e^{\frac{-120}{56}} \right) = -0.13\text{mA}$$

$$180\text{s} = I_c = -1.07 \times 10^{-3} \left( e^{\frac{-180}{56}} \right) = -0.05\text{mA}$$

Discharge Comparisons

*Excellent table of  
values and calcs  
match the sim values*

| Time (s) | Voltage (V) |            |             | Current (mA) |            |             |
|----------|-------------|------------|-------------|--------------|------------|-------------|
|          | Practical   | Simulation | Calculation | Practical    | Simulation | Calculation |
| 60       | 2.05        | 2.04       | 2.055       | -0.357       | -0.364     | -0.36       |
| 120      | 0.75        | 0.697      | 0.704       | -0.129       | -0.124     | -0.13       |
| 180      | 0.27        | 0.238      | 0.241       | -0.047       | -0.042     | -0.05       |

From looking at the comparison table it shows that for the discharge tests there were small discrepancies between some of the readings. These discrepancies again would be down to human error when calculating the formulas as they could have been rounded differently and from the component tolerances and the speed to reading the figure off the multimeter, if the multimeter is not calibrated this can give off wrong readings.

These values have been placed in bar charts to show the discrepancies visually. From these charts it is easy to see that all three tests are very close, but have minor discrepancies, it is clear to see that the practical test has the most discrepancies as the simulation and calculation are quite even with each other.

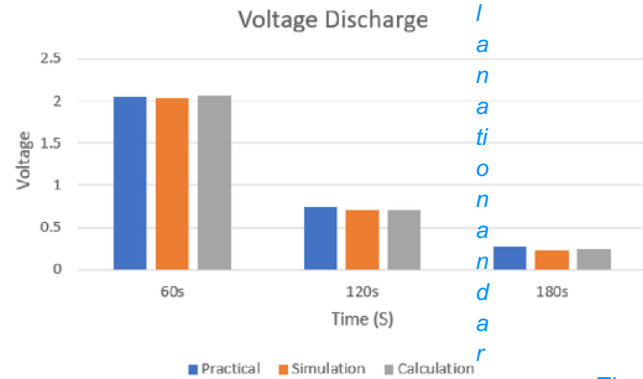


FIGURE 23 – VOLTAGE DISCHARGE COMPARISON

*The charts are an excellent  
method for analysis and are  
much better than text alone.*

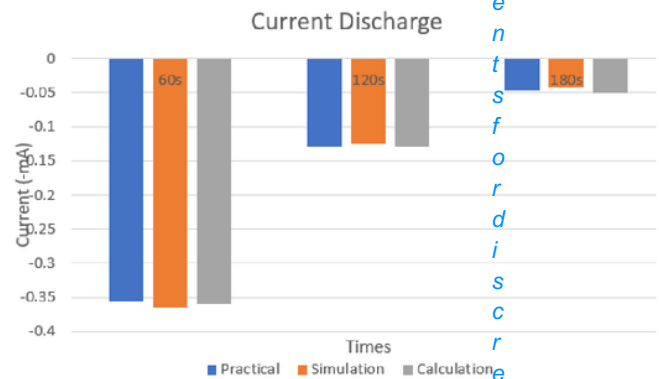


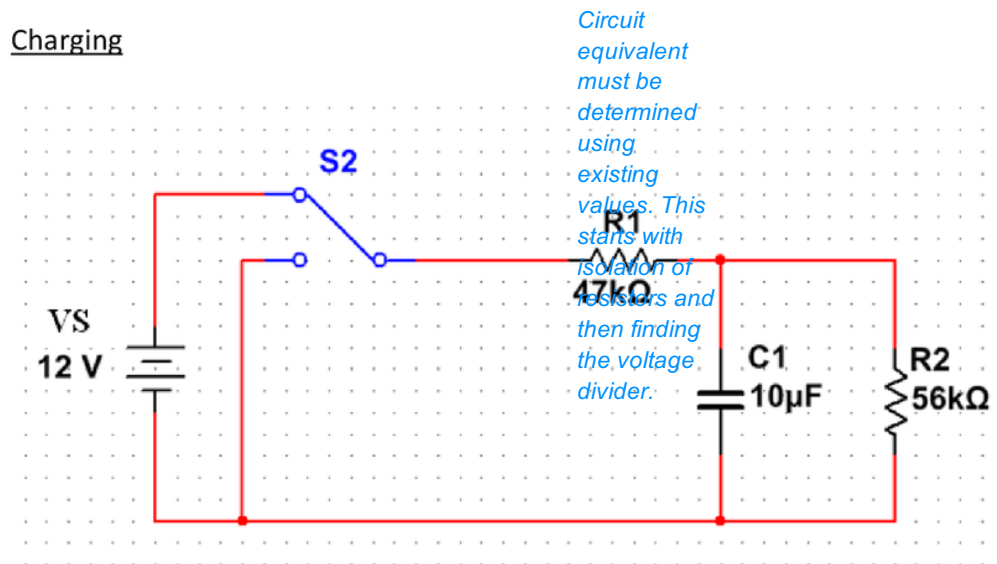
FIGURE 24 – CURRENT DISCHARGE COMPARISON

G  
o  
o  
d  
e  
x  
p  
l  
a  
n  
a  
t  
i  
o  
n  
a  
n  
d  
a  
r  
g  
u  
m  
e  
n  
t  
s  
f  
o  
r  
d  
i  
s  
c  
u  
s  
s  
i  
o  
n  
s

#### 4. Transient Behaviour for a more Complex Circuit

This task is an investigation on complex resistor-capacitor circuits. The time constant will be calculated with the use of mathematical theory, the time constant will be calculated using formula to predict instantaneous values of V and I. This mathematical theory will predict the instantaneous values of voltage and current throughout the charge and discharge cycle. The time constant in an RC circuit is found by multiplying the resistance and capacitance, however complex RC Circuits have multiple resistors or capacitors therefore there is a different method to find the circuit resistance.

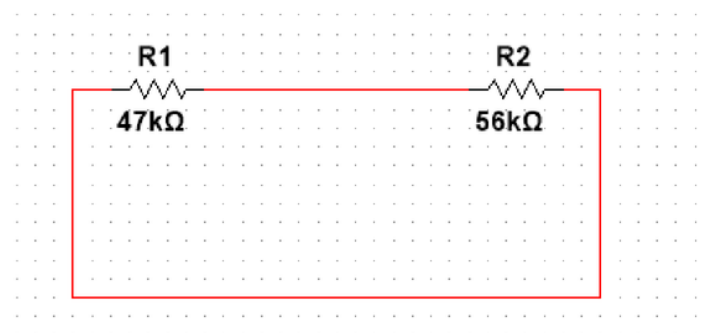
##### Charging



*Circuit equivalent must be determined using existing values. This starts with isolation of resistors and then finding the voltage divider.*

FIGURE 25 – COMPLEX RC CIRCUIT

When the circuit powers up and the capacitor is not charged it acts as a short circuit therefore the resistors are in parallel with each other. Therefore, the circuit resistance is a parallel combination of R1 and R2, by removing the power supply and capacitor this shows that the resistance is a parallel combination of both of the resistors as  $R_T = \frac{47K \times 56K}{47K + 56K} = 25.5K$



*This is a series circuit and should be a parallel cct*

FIGURE 26 – PARALLEL RESISTORS

New Equivalent Circuit.

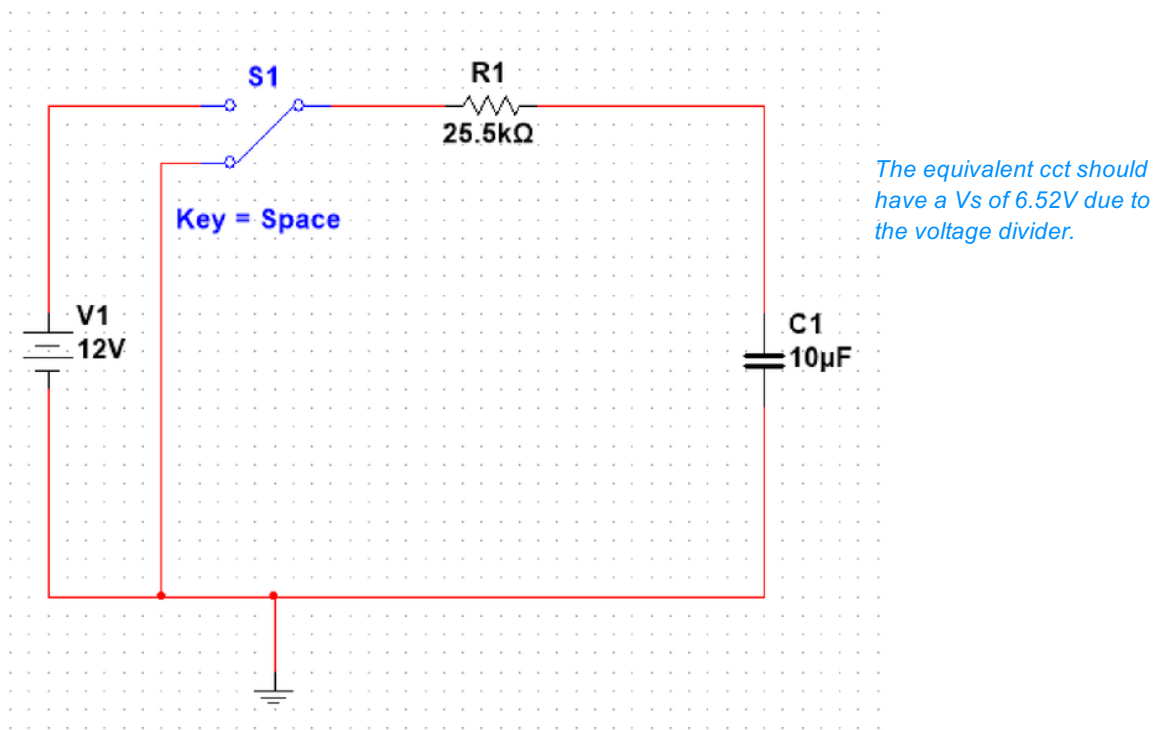


FIGURE 27 – COMPLEX RC EQUIVALENT CIRCUIT

Figure 27 shows the new equivalent circuit for the RC circuit. As the new resistance is found the time constants and transient periods can also be found;

$$T = R_T \times C$$

$$T = 25.5k \times 10 \times 10^{-6}$$

$$T = 0.255s \text{ (1T)}$$

As the time constant has been calculated, the transient period for the capacitor charging is calculated:

$$5T = 5 \times T$$

$$5T = 5 \times 0.255s$$

$$5T = 1.275s$$

*These are correct*

Now that all of the needed values to calculate the maximum voltage of the circuit ( $V_{out}$ ) can be calculated with the equation:

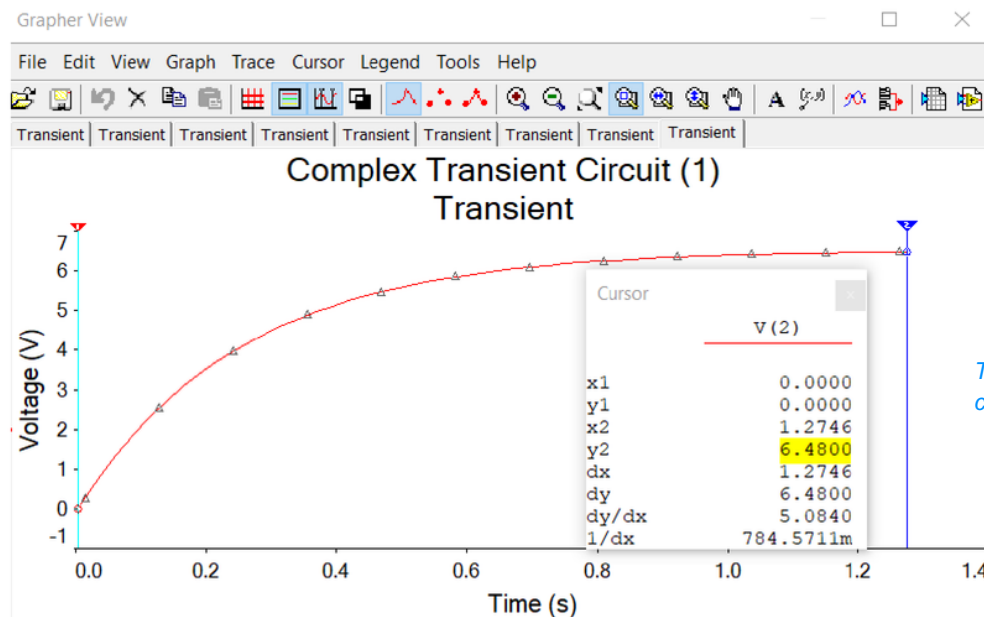
$$V_{OUT} = \frac{R_2}{R_1 + R_2} \times V_s$$

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

*This is the new  $V_s$  for the equivalent cct*

This calculation shows that the maximum voltage that the capacitor charges to is 6.52 V.

To prove that this calculation is correct I compared it with the maximum voltage that the circuit charges to on multisim below:



*The graph is correct*

FIGURE 28 – VMAX FOR COMPLEX TRANSIENT EQUIVALENT CIRCUIT

The simulated circuit shows that the maximum voltage during the transient period is 6.48v which is around 0.04v difference. This discrepancy can be checked to see if the circuit is wrong or there is just a minor error with the one reading. This discrepancy will be checked by calculating the voltage over instantaneous times.

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Voltage Calculations over Instantaneous times

To calculate the voltage over instantaneous times the calculation below is used:

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

The instantaneous times over the transient period will be substituted in for -t in the equation. The times chosen to test are 0.4s, 0.8s and 1.2s.

$$V_c = 6.52 \left( 1 - e^{\frac{-0.4}{0.255}} \right) = 5.16v$$

$$V_c = 6.52 \left( 1 - e^{\frac{-0.8}{0.255}} \right) = 6.24v$$

$$V_c = 6.52 \left( 1 - e^{\frac{-1.2}{0.255}} \right) = 6.46v$$

*Calcs are correct*

After obtaining the voltage readings of the capacitor from the mathematical equations they can now be compared to the multisim readings at them instantaneous times.

Multisim Reading at 0.4s

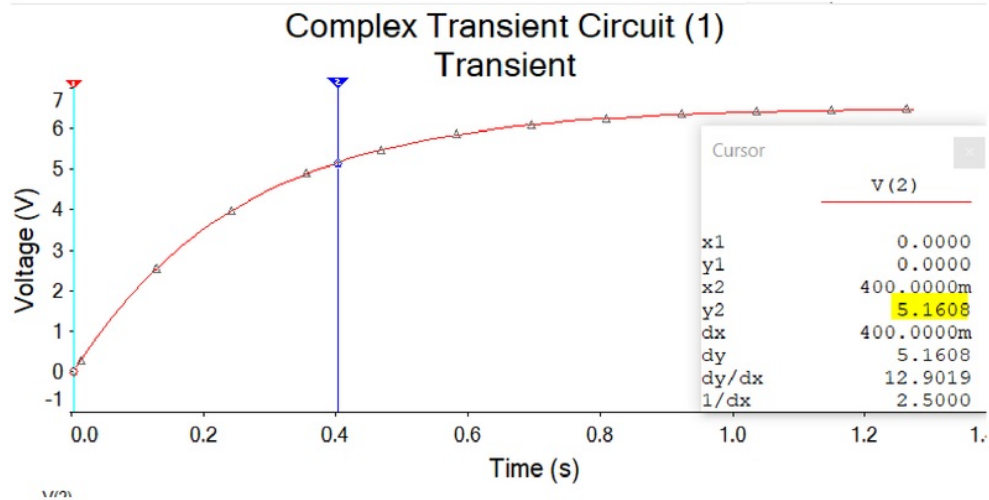


FIGURE 29 – COMPLEX RC VC AT 0.4s

*Graph is correct*

Multisim Reading at 0.8s

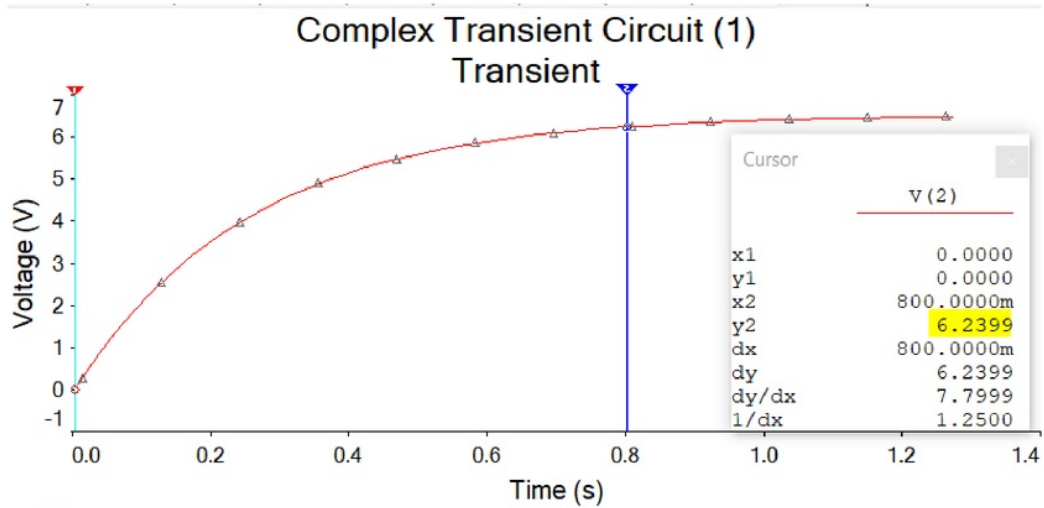


FIGURE 30 – COMPLEX RC VC AT 0.8s

*Graph is correct*

Multisim reading at 1.2s

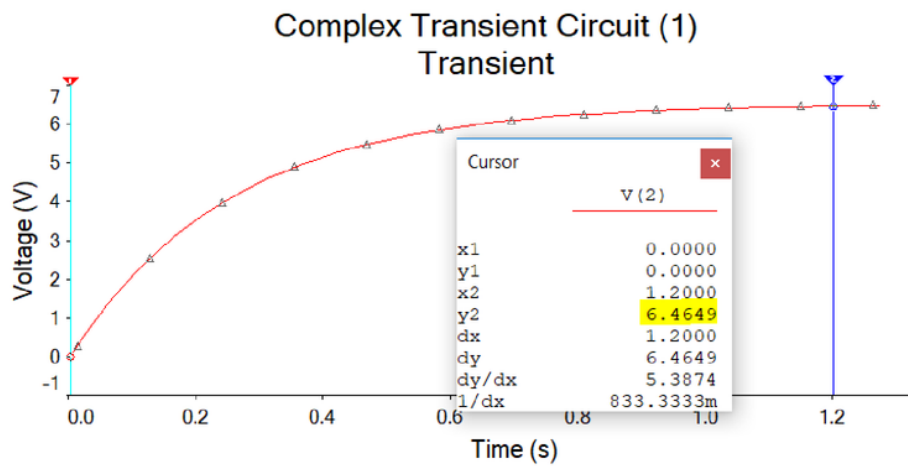


FIGURE 31 – COMPLEX RC VC AT 1.2s

*Graph is correct*

For this circuit 1T should equal 63% of the maximum voltage of 6.52V, this should be 4.11v, as proved by multisim as at 1T (0.255s) the voltage is 4.11v

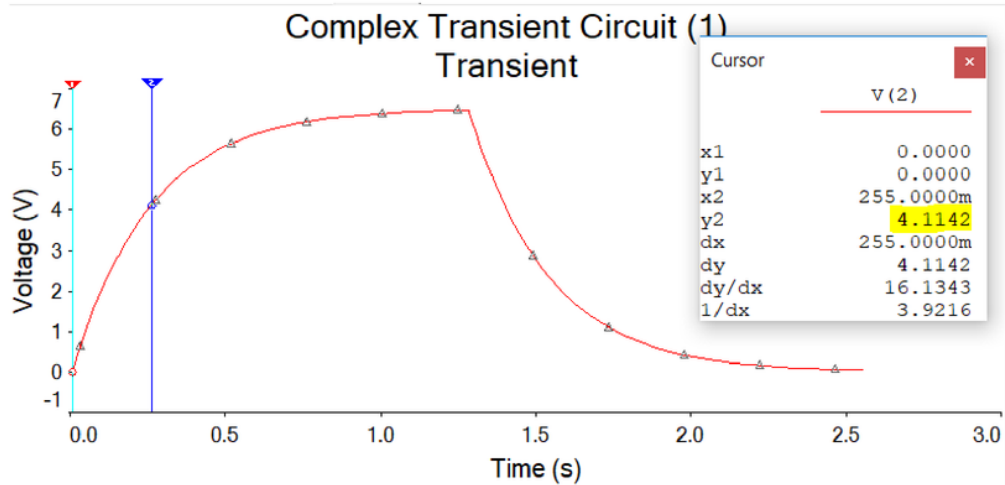


FIGURE 32 – COMPLEX RC 1T VOLTAGE

*Good graph showing 1T result*

Also, at  $0.7T$  ( $0.1785s$ ) the voltage should be half of maximum voltage of  $6.52$ , this should be  $3.26v$ , on multisim it shows that it is  $3.27V$ , this could be due to rounding error in the calculation.

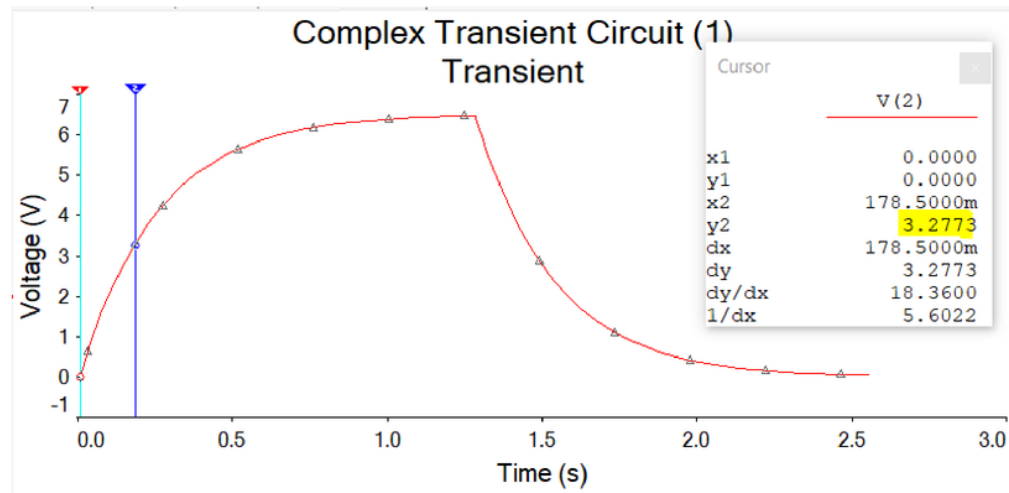


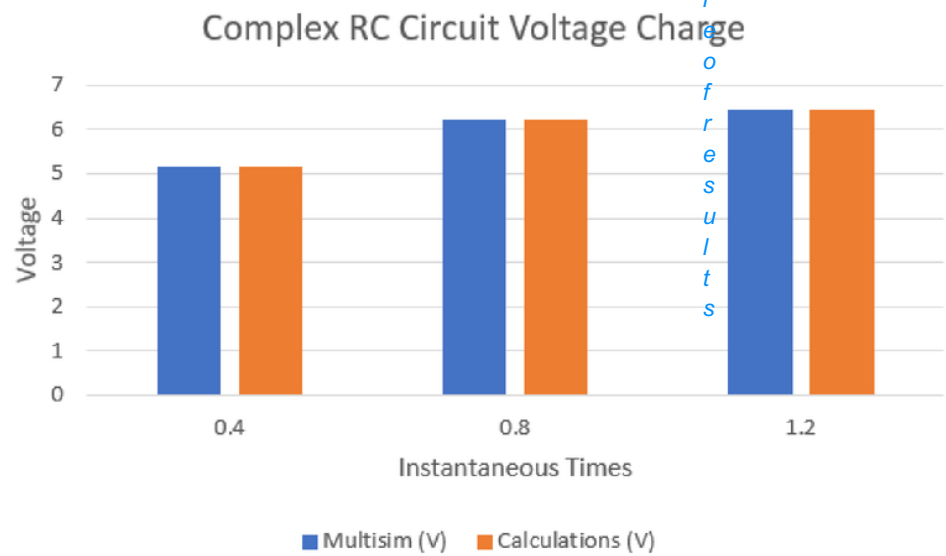
FIGURE 33 - COMPLEX RC  $0.7T$  VOLTAGE

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T

Comparison of Complex RC voltage charge

| Charging Voltage |              |             |
|------------------|--------------|-------------|
| Time             | Calculations | Simulations |
| 0.4s             | 5.16V        | 5.16V       |
| 0.8s             | 6.24V        | 6.24V       |
| 1.2s             | 6.46V        | 6.46V       |

The bar chart and table show how the multisim readings and the calculations are identical proving that the circuit reduction technique coincides with the formula.



Analysis chart is a very good idea.

FIGURE 34 – COMPLEX RC CIRCUIT VC COMPARISON

## Complex RC Circuit – Current Charge

In order to find the maximum current in the circuit the ohms law equation is used whereby:

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

Therefore, for this circuit the current is calculated:

$$\text{Current} = \frac{6.52}{25500} = 0.255\text{mA}$$

*Calc is correct. The other way to calc this is to use the initial current in the circuit :  $12/47K = 0.255\text{mA}$*

The multisim transient shows that the maximum current is 0.253mA, therefore the multisim analysis has a lower current by 0.002mA which would not affect many things due to it being a miniscule current, this minor discrepancy is down to the rounding of the Vout value.

*Fair argument*

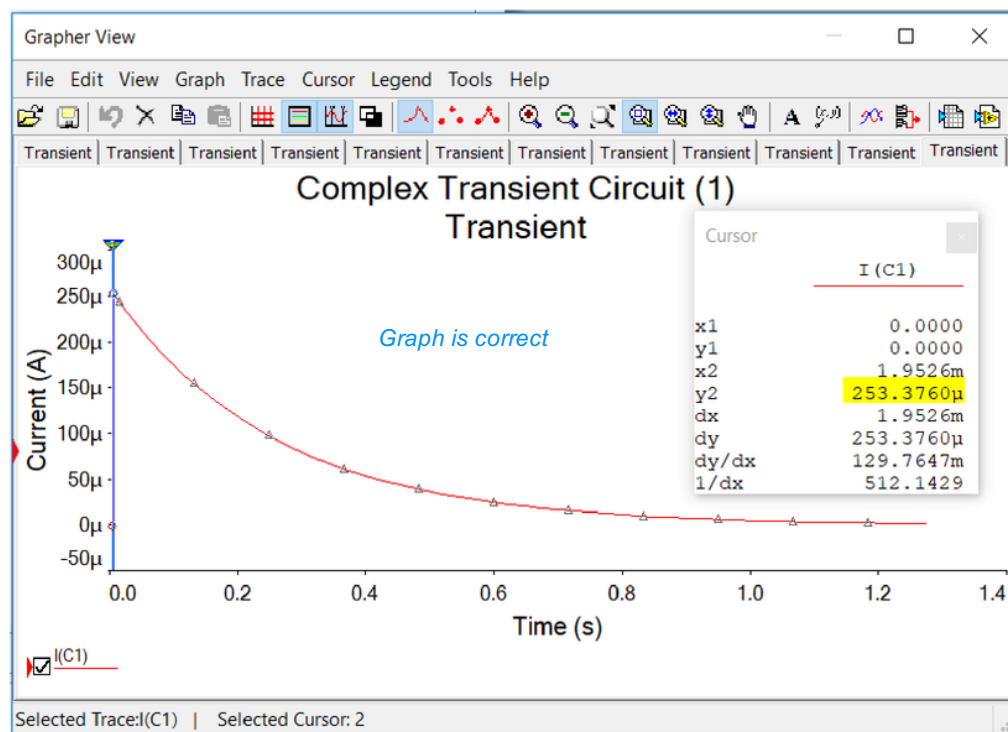


FIGURE 35 – COMPLEX RC CURRENT MAX

*Good graph with*

Figure 35 shows that the circuits current decreases rapidly up to around 0.7s where it begins to level out as the capacitor charges. As the capacitor initially acts like a short circuit as the current wants to take the path of least resistance to flow to ground. After the transient period and the capacitor has charged current flow will fall to near 0 amps.

Current Charge at 0.2s: 0.116mA

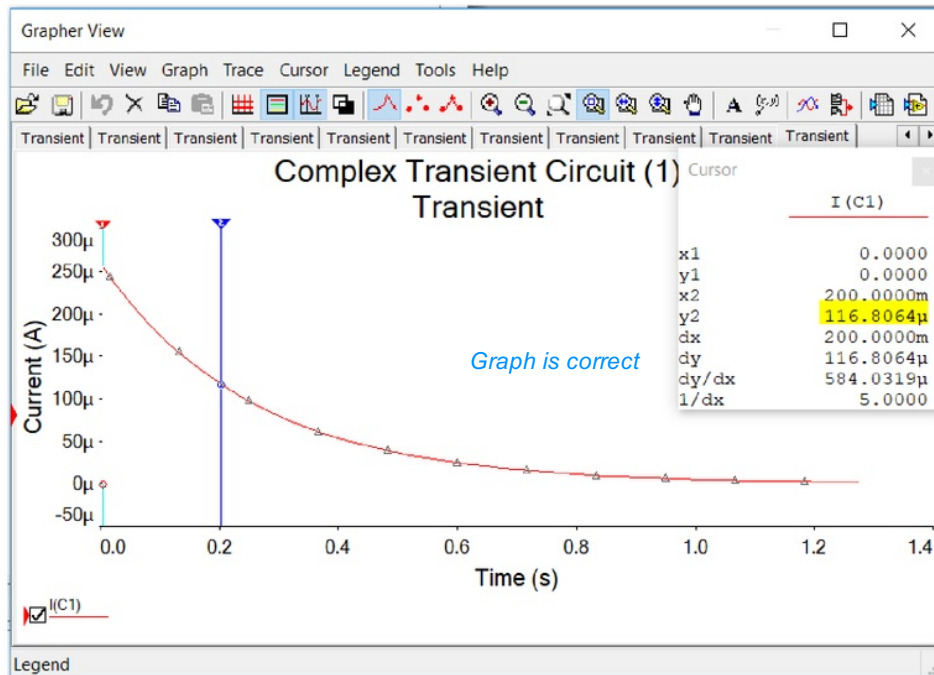


FIGURE 36 – COMPLEX RC IC CHARGE AT 0.2S

Current charge at 0.6s: 0.024mA

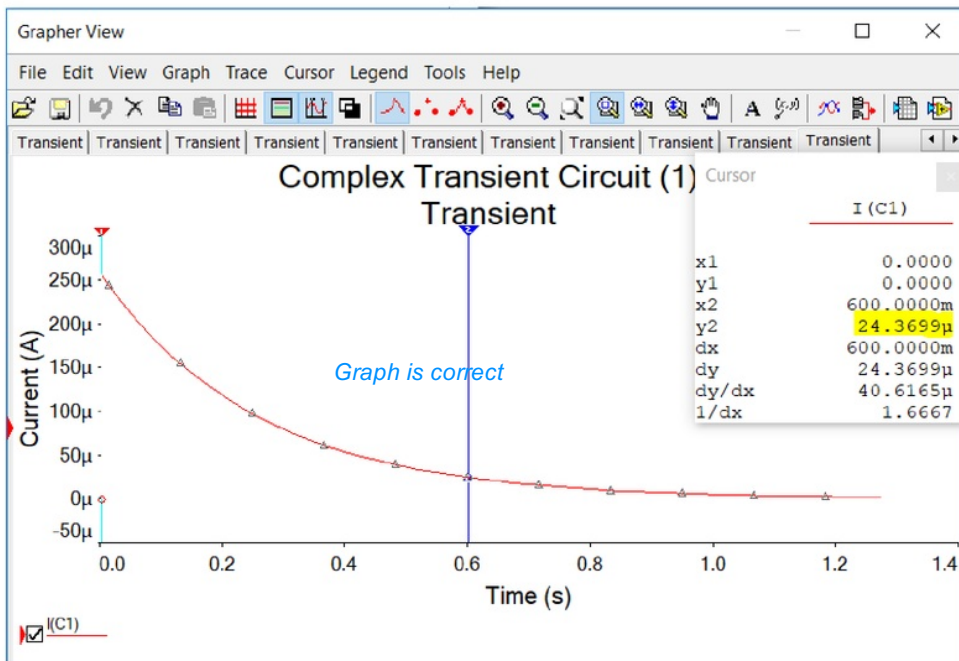


FIGURE 37- COMPLEX RC IC CHARGE AT 0.6S

Current at 1.0s: 0.00508mA

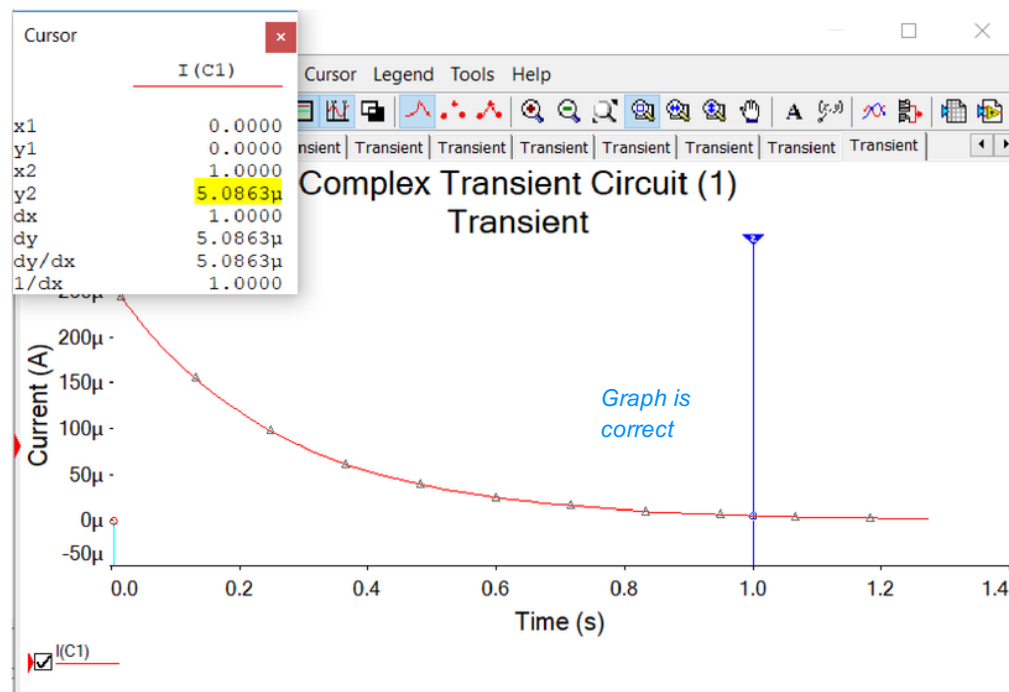


FIGURE 38 – COMPLEX RC IC CHARGE AT 1.0S

### Current Calculations at Instantaneous times

The current is calculated at instantaneous times of the transient period using the calculation:

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

$$I_c = 0.255 \left( e^{\frac{-0.2}{0.255}} \right) = 0.116mA$$

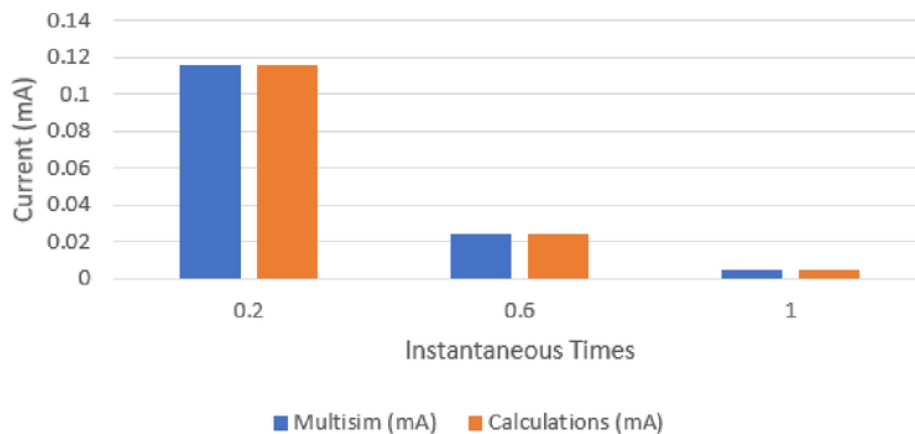
$$I_c = 0.255 \left( e^{\frac{-0.6}{0.255}} \right) = 0.024mA$$

$$I_c = 0.255 \left( e^{\frac{-1.0}{0.255}} \right) = 0.00506mA$$

*Good table of  
results for  
comparison*

| Charging Current |              |             |
|------------------|--------------|-------------|
| Time             | Calculations | Simulations |
| 0.2s             | 0.116mA      | 0.116mA     |
| 0.6s             | 0.024mA      | 0.024mA     |
| 1.0s             | 0.00506mA    | 0.00508mA   |

### Complex RC Circuit Current Charge



*Good method of  
analysis here  
again.*

FIGURE 39 – COMPLEX RC CIRCUIT IC COMPARISON

The comparison shows that the multisim and calculations are identical other than a small 0.00002mA discrepancy between them at 1s. This is down to error in rounding the figures. These currents should be the same for the discharging current just in positive as the discharging current is in integers which are negative.

### Voltage discharge of a complex RC Circuit

When the capacitor has fully charged, the circuit can then be switched over in order for the capacitor to discharge, the capacitor will discharge to ground. Under discharging conditions, the capacitors voltage and current will act in the opposite way of the charging state. The current will increase and the voltage will decrease.

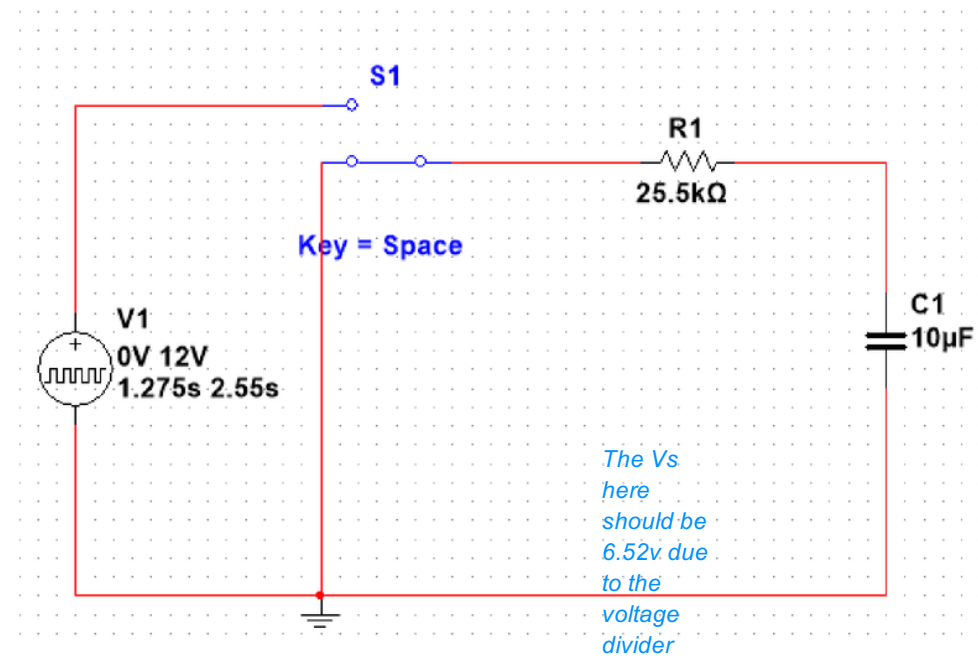


FIGURE 10 – COMPLEX RC CIRCUIT DISCHARGE

The maximum voltage that the capacitor could charge to was 6.52v, this was due to the voltage drop across the resistor which prevented the capacitors ability to charge up to the full supply voltage.

The graph results are correct which suggest you used the correct Vs for the analysis. This looks like an excellent piece of work to your comprehensive understanding of the subject.

Graph is correct with correct value

#### Discharge at 0.2s – 2.9V

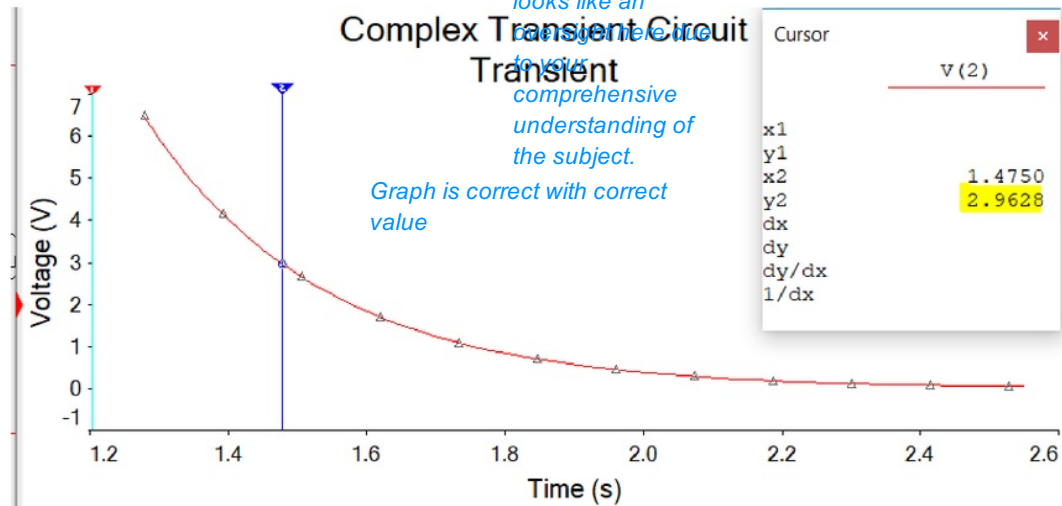


FIGURE 11 – COMPLEX RC CIRCUIT VC DISCHARGE AT 0.2S

#### Discharge at 0.6s – 0.618V

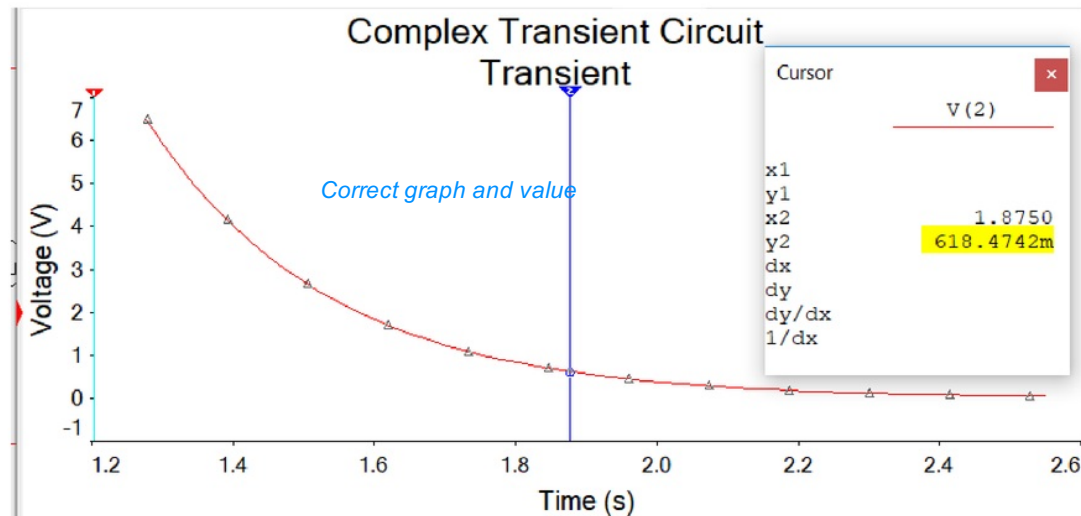


FIGURE 42 – COMPLEX RC CIRCUIT VC DISCHARGE AT 0.6S

Discharge at 1.0s – 0.129V

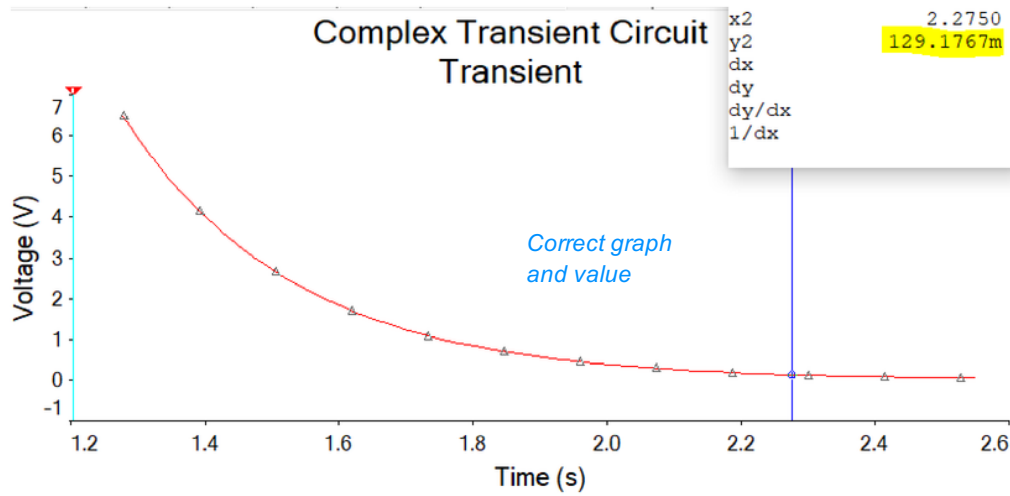


FIGURE 43 – COMPLEX RC CIRCUIT VC DISCHARGE AT 1.0s

Instantaneous Voltage discharge calculations

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

$$V_C = 6.52 \left( e^{\frac{-0.2}{0.255}} \right) = 2.975V$$

$$V_C = 6.52 \left( e^{\frac{-0.6}{0.255}} \right) = 0.619V$$

$$V_C = 6.52 \left( e^{\frac{-1.0}{0.255}} \right) = 0.129V$$

Calcs are correct

For these calculations there are minor discrepancies between the multisim readings and the calculated readings, this will be down to the rounding of the calculations.

Comparison of Multisim and Mathematical Formula

*Excellent table of values for comparison*

| Discharging Voltage |              |             |
|---------------------|--------------|-------------|
| Time                | Calculations | Simulations |
| 0.2s                | 2.975V       | 2.96V       |
| 0.6s                | 0.619V       | 0.618V      |
| 1.0s                | 0.129V       | 0.129V      |

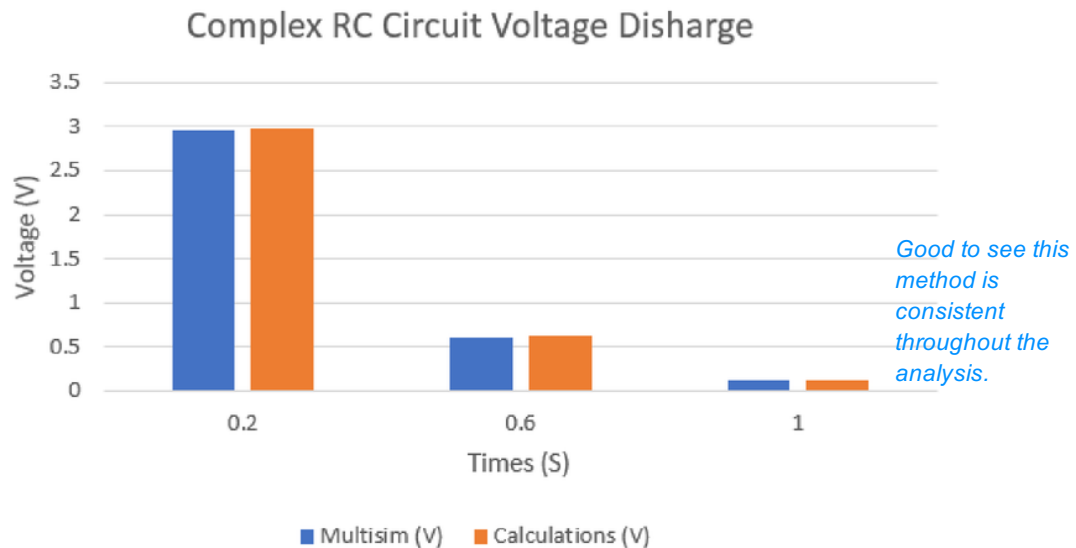


FIGURE 44 – COMPLEX RC CIRCUIT VOLTAGE DISCHARGE COMPARISON

The comparison table and graph show how the mathematical calculations were slightly higher than the readings obtained from the multisim simulation. These discrepancies are because of rounding errors of the formulas.

### Current discharge of a complex RC Circuit

When the capacitor is discharging the current is negative. This is due to the path it takes to ground as it flows through both of the resistors, therefore, the discharge current readings will be in -mA.

#### Current discharge at 0.2s

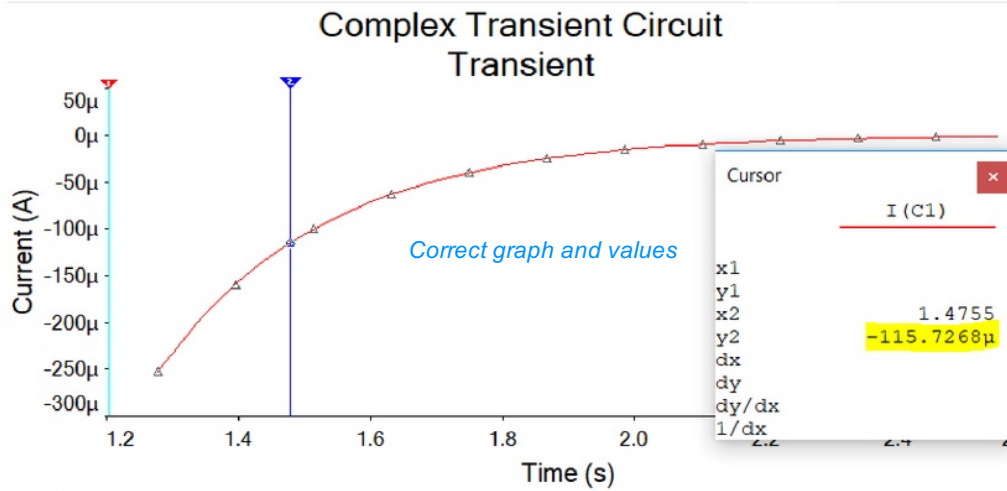


FIGURE 45 – COMPLEX RC CIRCUIT CURRENT DISCHARGE

#### Current discharge at 0.6s

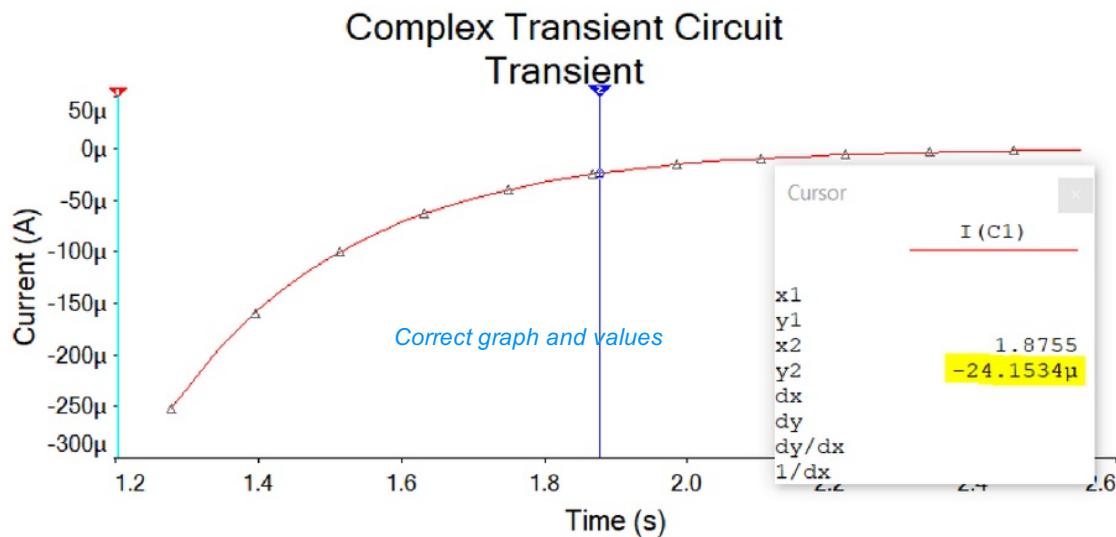


FIGURE 46 - COMPLEX RC CIRCUIT CURRENT DISCHARGE AT 0.6S

Current discharge at 1.0s

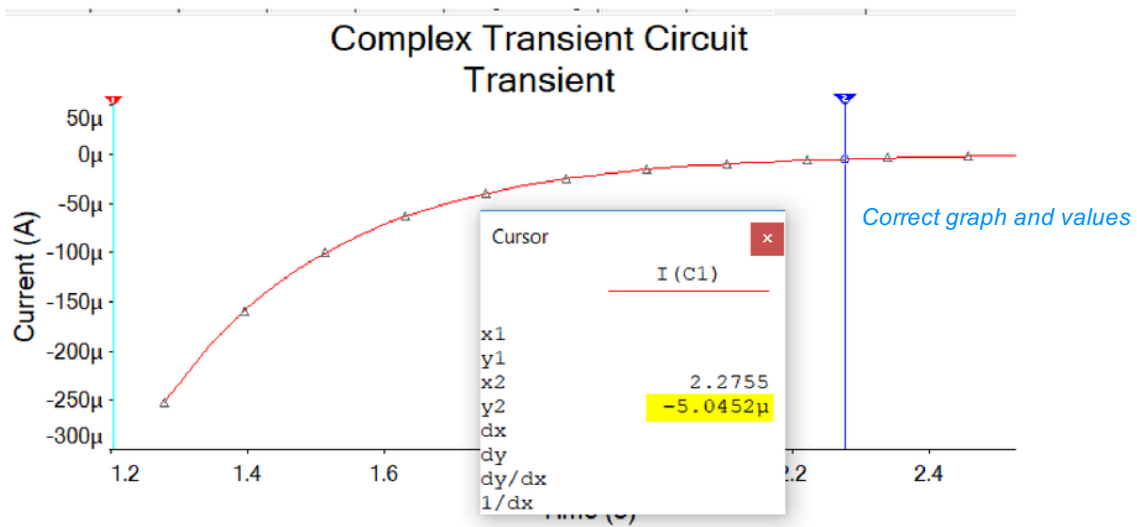


FIGURE 47- COMPLEX RC CIRCUIT CURRENT DISCHARGE AT 1.0S

Instantaneous Current discharge calculations

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

$$0.2s = -I_c = 0.255 \left( e^{\frac{-0.2}{0.255}} \right) = -116.4mA$$

$$0.6s = -I_c = 0.255 \left( e^{\frac{-0.6}{0.255}} \right) = -24.2mA$$

$$1.0s = -I_c = 0.255 \left( e^{\frac{-1.0}{0.255}} \right) = -5.05mA$$

*Calcs are correct*

Current discharge comparisons

*Excellent table of  
results for  
comparison*

| Discharging Current |              |             |
|---------------------|--------------|-------------|
| Time                | Calculations | Simulations |
| 0.2s                | -0.116mA     | -0.116mA    |
| 0.6s                | -0.24mA      | -0.24mA     |
| 1.0s                | -5.05mA      | -5.05mA     |

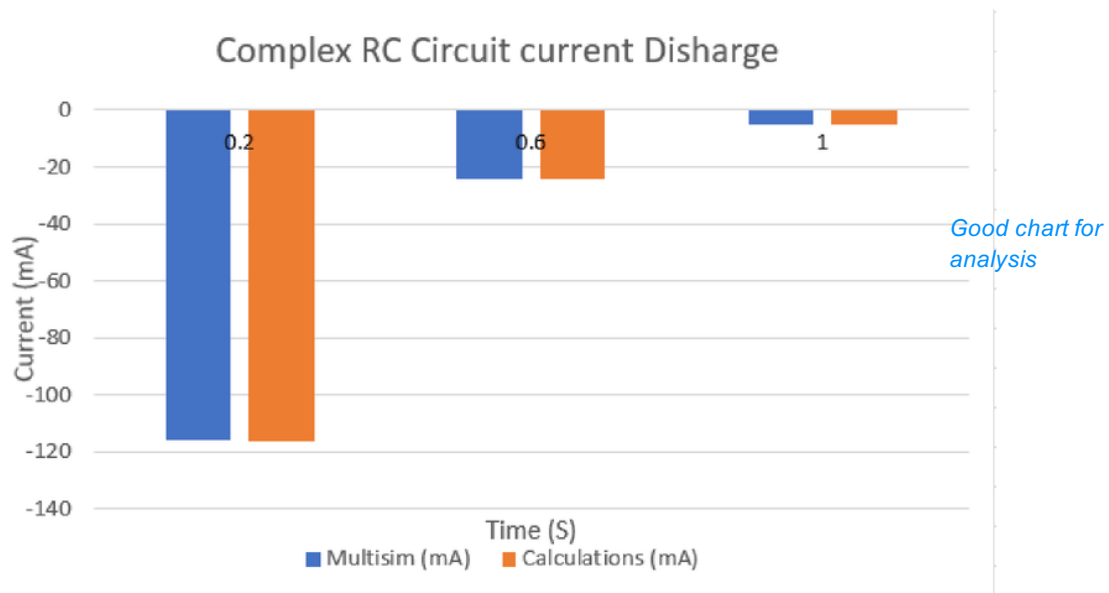


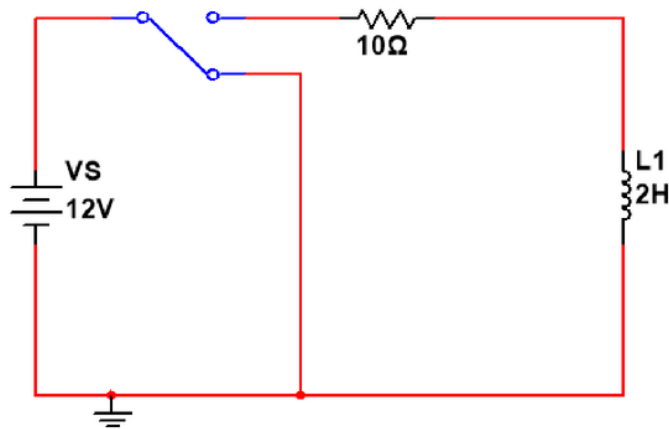
FIGURE 48 – COMPLEX CIRCUIT CURRENT DISCHARGE COMPARISON

For 0.2s and 0.6s the negative current values are the same for the charging current but in a negative form as the discharging of the capacitor puts turns the current into a negative integer. However, the readings for 1 second were minorly different, this could be due to rounding incorrectly or from the cursor on multisim being out by a small margin.

*There is no explanation or calculation to explain initial and final current values in the circuit. Initial current is:  $12V / 47k = 0.255mA$  because the capacitor acts like a short circuit and bypasses  $R2$ . Final value:  $12V / (47k + 56k) = 116\mu A$  due to the capacitor now acting as an open cct.*

## 5. Transient Behaviour for the Inductive Circuit

An inductive circuit is one which includes an inductor, an inductor is a component constructed of a coil of wire wrapped around a core, this core could be a magnet or just air. Transient analysis can also be used on resistor inductor circuits, the circuit that will be analysed has a 12v power supply, a 10Ω and an inductor rated at 2 Henry's.



*Good intro to task*

FIGURE 49 – RL CIRCUIT

The time constant for the circuit is used using the equation:

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

Therefore, for this circuit the resistor and inductor values will be substituted into the equation:

$$T = \frac{2H}{10\Omega}$$

$$T = 0.2s$$

The circuits transient period is found using the equation:

*Correct calcs*

$$\text{Transient Period} = 5 \times T = 1s$$

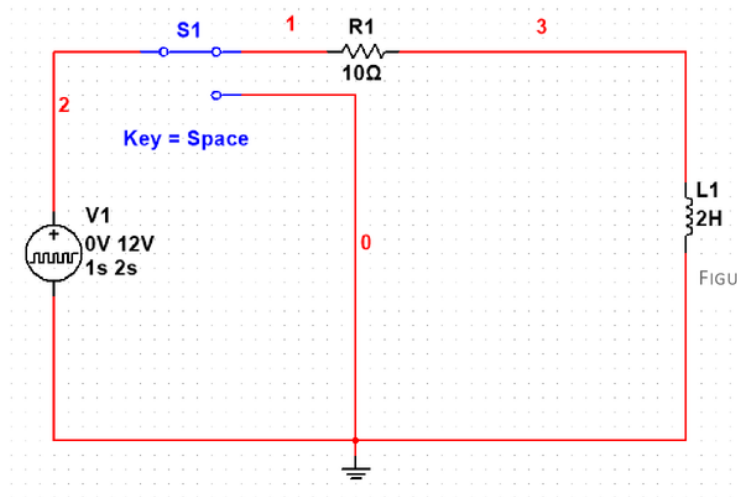
After the transient period has passed, the circuits current will be at the maximum, this current can be determined before the circuit has been built using the equation:

$$I_{MAX} = \frac{V_S}{R} = \frac{12v}{10\Omega} = 1.2a$$

*Imax is identified*

### Charging Transient of an RL Circuit.

The circuit was built on multisim and the circuits transient for voltage and current charge was taken and monitored over the transient period. During the charging period the switch is closed between the power source and the resistor completing the circuit.



*God testing methods shown  
here with pulsed Vs and  
masking*

FIGURE 50 – RL CIRCUIT WITH SWITCH

Calculated Results

In order to calculate the growth in current across the inductor the equation is used:

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

*T  
a  
b*

| Time (s) | Equation                                      | Current (A) |
|----------|-----------------------------------------------|-------------|
| 0.2      | $I_L = 1.2(1 - e^{\frac{-10}{2} \times 0.2})$ | 0.7585A     |
| 0.4      | $I_L = 1.2(1 - e^{\frac{-10}{2} \times 0.4})$ | 1.0376A     |
| 0.6      | $I_L = 1.2(1 - e^{\frac{-10}{2} \times 0.6})$ | 1.1403A     |
| 0.8      | $I_L = 1.2(1 - e^{\frac{-10}{2} \times 0.8})$ | 1.1780A     |
| 1.0      | $I_L = 1.2(1 - e^{\frac{-10}{2} \times 1.0})$ | 1.1919A     |

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### Plotted Results

The mathematical equations were then placed into a table on excel and a graph was plotted from the figures:

| RL Circuit Charge |             |
|-------------------|-------------|
| Time (s)          | Current (A) |
| 0                 | 0           |
| 0.2               | 0.7585      |
| 0.4               | 1.0376      |
| 0.6               | 1.1403      |
| 0.8               | 1.178       |
| 1                 | 1.1919      |

FIGURE 51 – RL CIRCUIT FIGURE TABLE

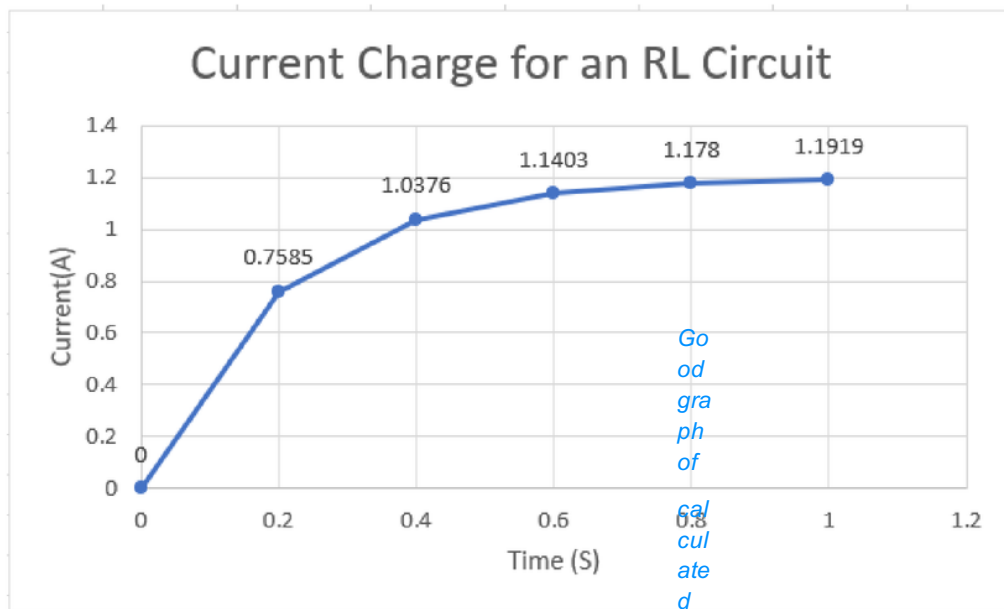


FIGURE 52 – RL CIRCUIT CURRENT CHARGE GRAPH

This graph is plotted with the figures obtained from the calculations, the shape of the curve is very similar as the one seen in figure 52, however it is more staggered as there are less points in the graph.

*Fair argument*

### Multisim Results

Figure 53 shows the transient analysis for the current charge for the RL circuit. The circuit starts off at 0A at 0s and rises to just below  $I_{max}$  (1.1919A) at 1.0s. In an RL circuit the current increases as the voltage decreases. Calculations and Simulations will be tested to check their credibility

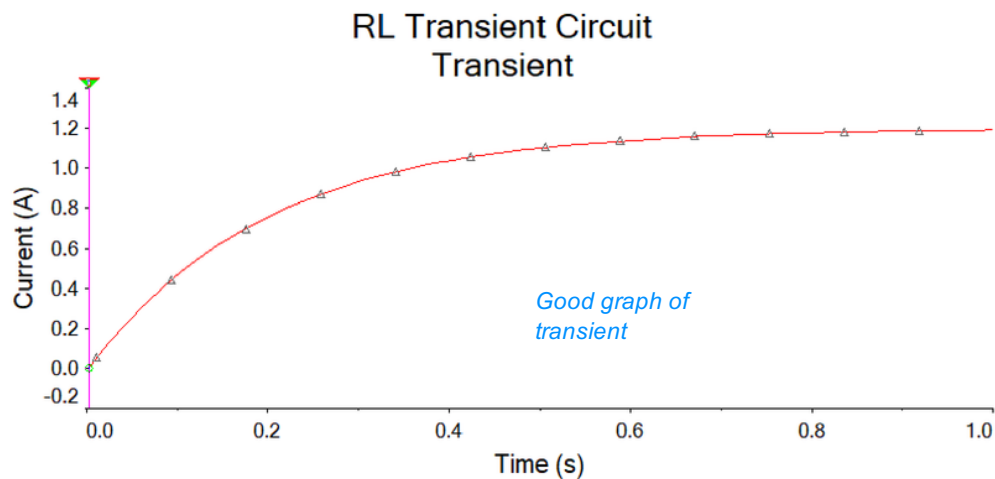


FIGURE 53 – RL CIRCUIT TRANSIENT

### Current at 0.2s = 0.758A

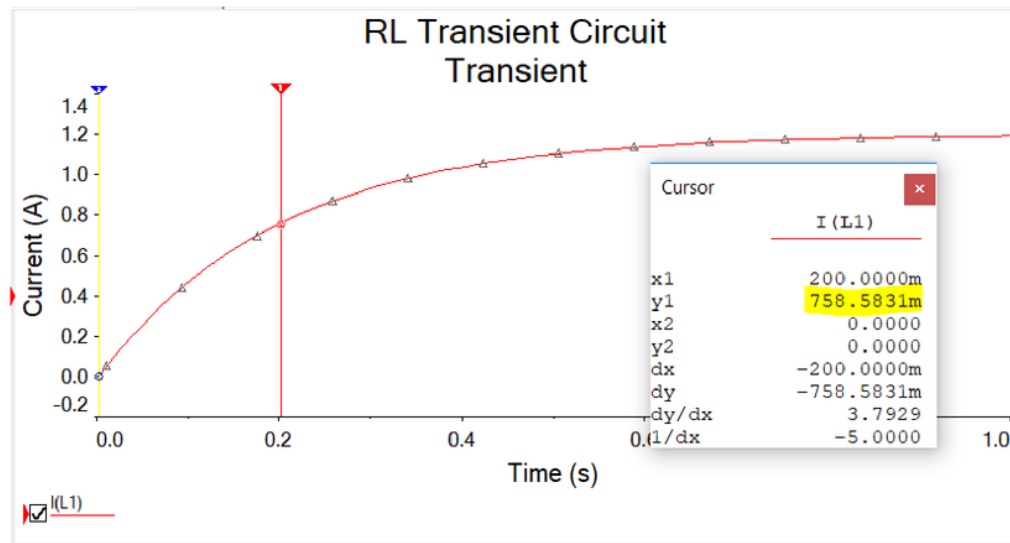


FIGURE 54 – RL CIRCUIT TRANSIENT AT 0.2s

Current at 0.4s = 1.0377A

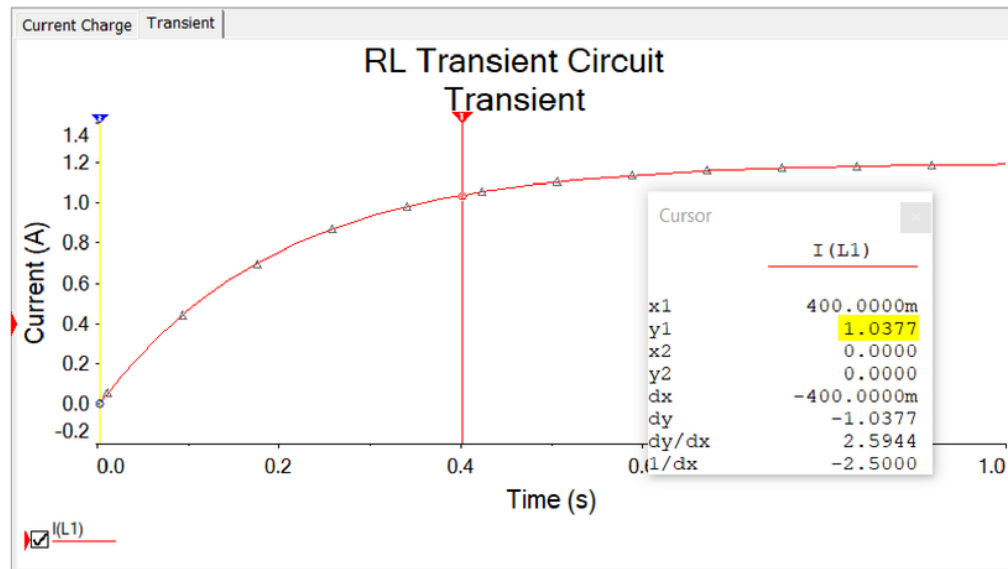


FIGURE 55 – RL CIRCUIT TRANSIENT AT 0.4s

Current at 0.6s = 1.1404A

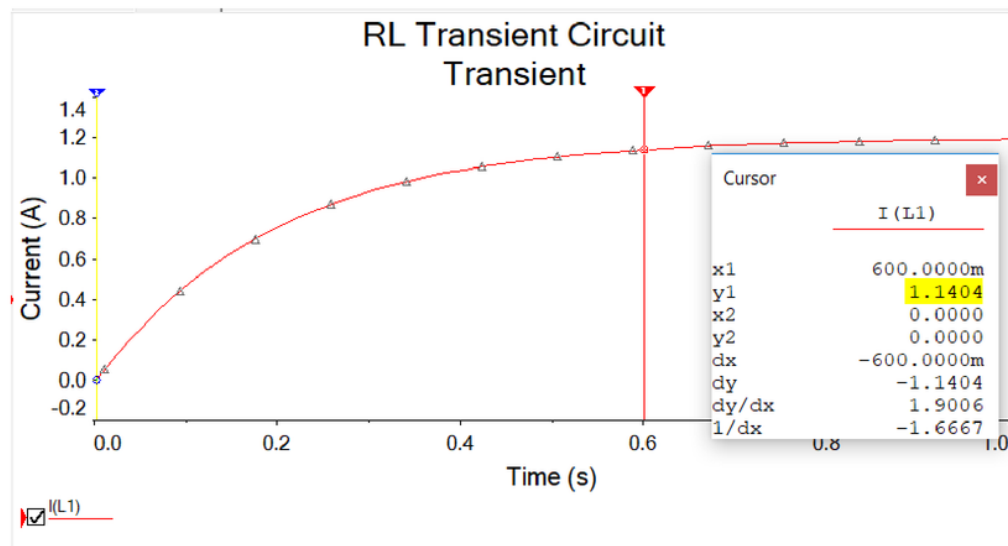


FIGURE 56 – RL CIRCUIT TRANSIENT AT 0.6s

Current at 0.8s = 1.1781A

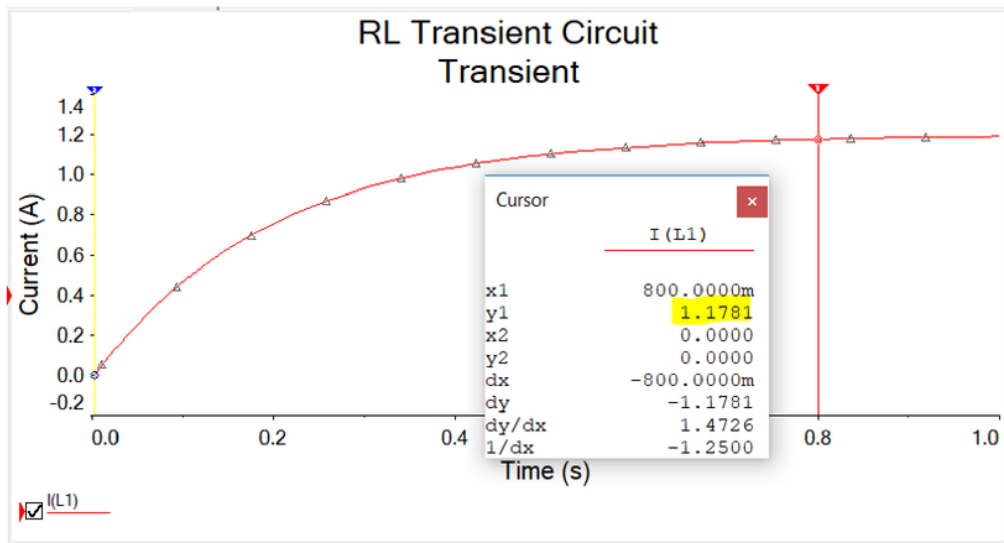


FIGURE 57 – RL CIRCUIT TRANSIENT AT 0.8s

Current at 1.0s – 1.1919A

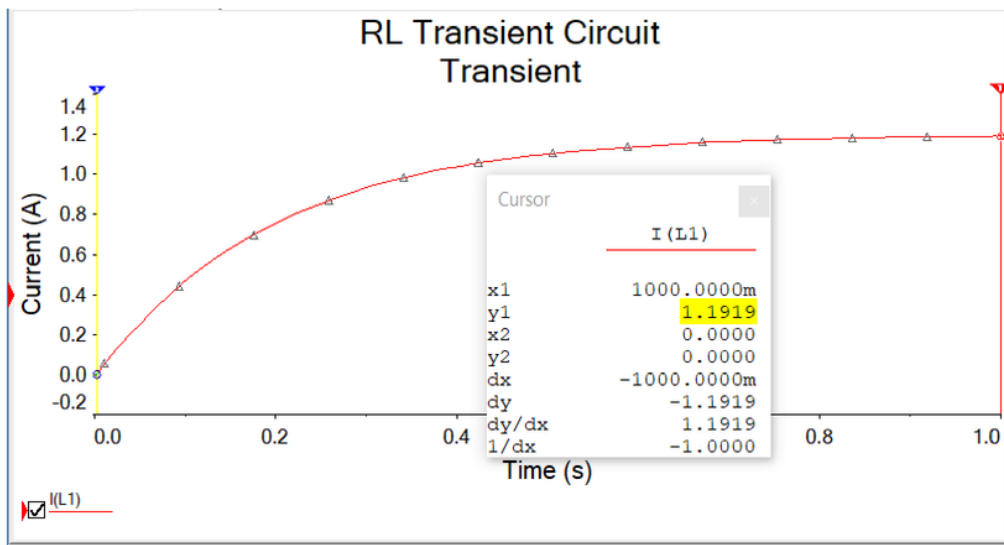


FIGURE 58 – RL CIRCUIT TRANSIENT AT 1.0s

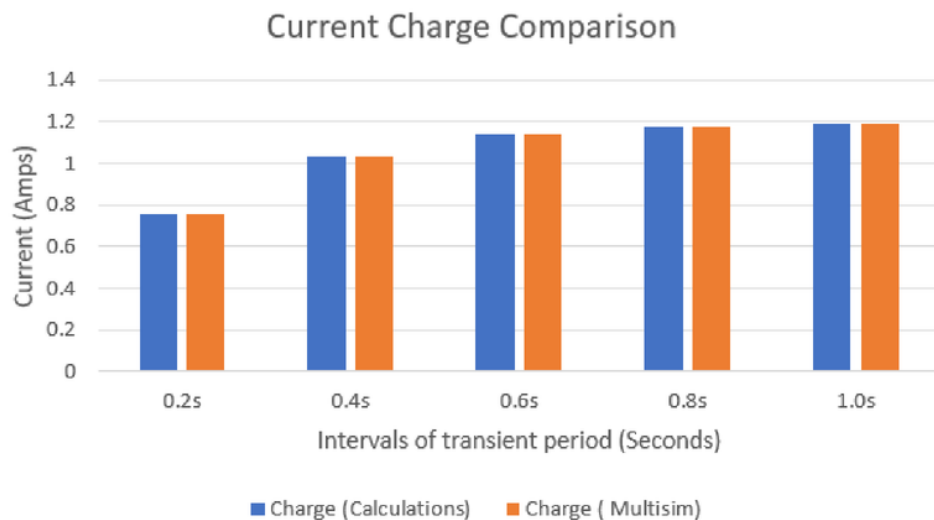
*Graph  
s and  
values  
are all  
correct*

After carrying out the approximate method of calculation and then comparing my values with the multisim values it shows that both methods of obtaining the current value are very accurate as there is only one minor discrepancy at 0.6s whereby the calculated current is lower than the multisim reading, however this is miniscule at 0.014A. The graph below shows that both methods give identical outcomes.

| Time | Charge (Calculations) | Charge ( Multisim) |
|------|-----------------------|--------------------|
| 0.2s | 0.7585                | 0.758              |
| 0.4s | 1.0376                | 1.038              |
| 0.6s | 1.1403                | 1.1404             |
| 0.8s | 1.178                 | 1.178              |
| 1.0s | 1.1919                | 1.1919             |

*Good table of results for comparison*

FIGURE 59 – COMPARISON TABLE OF RL CHARGE



*Good method for analysis*

FIGURE 60 – RL CURRENT CHARGE COMPARISON TABLE

In order to calculate the time that it takes for the current to fall to a certain time the following equation is used:

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

However, this equation has to be rearranged in order to make the equations subject 't', this is done by replacing 'e' with log rules:

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

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

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

In order to find the time taken for the circuit to elapse to 100mA and 10mA these figures and the values of  $I_L$  and  $I_{MAX}$  are substituted into the equation

100mA:

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

$$t = 0.2 \left[ \ln\left(\frac{100 \times 10^{-3}}{1.2}\right) \right] = -0.496981329s$$

$$t = 0.497 \text{ seconds}$$

*Calcs are correct*

10mA:

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

$$t = 0.2 \left[ \ln\left(\frac{10 \times 10^{-3}}{1.2}\right) \right] = -0.9574983s$$

$$t = 0.957 \text{ seconds}$$

These equations credibility can now be proved on the multisim circuit:

10mA: 0.956seconds

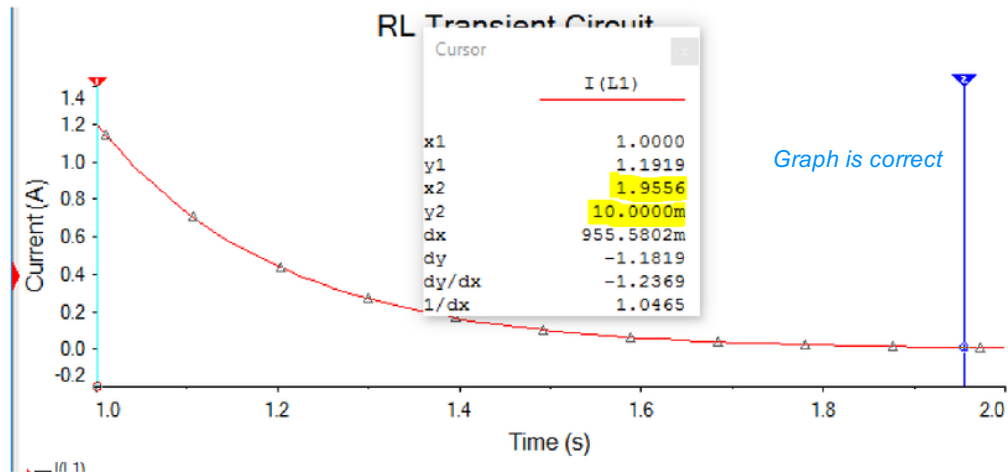


FIGURE 61 – CURRENT FALLEN TO 10mA

100mA: 0.495seconds

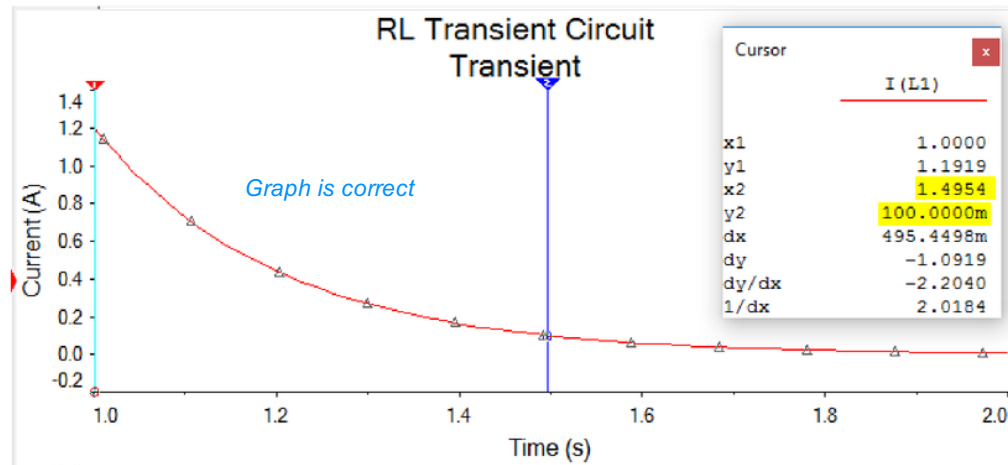


FIGURE 62 – CURRENT FALLEN TO 100mA

Figures 61 and 61 show the multisim simulation of the circuits elapsing to 10mA and 100mA. There are minor discrepancies of 0.001 second due to the rounding of the equation.

*Fair argument*

## 6. Conclusion

From this assignment great knowledge was gained into electrical circuits and the transient response that these circuits have to different components. Knowledge was gained of RC circuits, a complex resistor capacitor circuit whereby the resistors were in parallel with each other and a resistor inductor circuit.

The circuits were tested during their charging and discharging periods, in order to analyse how the voltage and current reacted in the different circuits with different components.

All of the obtained results were compared and contrasted highlighting the errors and discrepancies from the practical task including component value errors and human errors when rounding figures and writing down the readings from the meter as this wasn't calibrated and the component tolerances will also affect the results in essence proving that simulations and calculations are the best way to obtain reliable answers. In order to have fully reliable results in future when using mathematical formula the full number should be used not just up to 2d.p.

*This  
paragraph  
is  
helpless*

*This  
should be  
divided  
into 2  
paragraph  
s with  
shorter  
sentences.  
However  
the points  
made are  
valid.*

# Thomas Grennan - PSDE4001 Assignment 1

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## GRADEMARK REPORT

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FINAL GRADE

GENERAL COMMENTS

**Instructor**

81/100

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PAGE 1

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PAGE 2

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PAGE 3

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**Text Comment.** Good table of contents and list of figures

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PAGE 4

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**Text Comment.** Introduction is short but to the point.

---

PAGE 5

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**Text Comment.** Significant point identified

**Text Comment.** Explanation is good but could have rounded it all in a single paragraph.

---

PAGE 6

---

**Text Comment.** Good image and intro to practical

---

PAGE 7

---

**Text Comment.** good table of results

---

PAGE 8

---

**Text Comment.** Good graph with values

**Text Comment.** Good graph with values

**Text Comment.** Explanations are good and include the significant points 0.7T and 1T.

PAGE 9

---

**Text Comment.** Graph is clear and values are correct

**Text Comment.** Graph and value is correct

PAGE 10

---

**Text Comment.** graph is correct

**Text Comment.** Good graph of results

PAGE 11

---

**Text Comment.** Graph is correct

**Text Comment.** Good graph

PAGE 12

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PAGE 13

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**Text Comment.** Excellent table of results with explanation.

**Text Comment.** Good analysis representation graph. This explains better than text.

**Text Comment.** Excellent representation for analysis. This is a better method than just text.

PAGE 14

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**Text Comment.** Good explanation and good results

**Text Comment.** Current rises exponentially to zero.

PAGE 15

---

**Text Comment.** Good graph with results

**Text Comment.** Good points identified here

**Text Comment.** Good graph with results with a good explanation including the significant points

PAGE 16

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**Text Comment.** Good graph which demonstrates a good understanding of test procedures.

**Text Comment.** Graphs are excellent with clear values

PAGE 17

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**Text Comment.** Good graphs showing accurate values

PAGE 18

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PAGE 19

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**Text Comment.** Excellent table of values and calcs match the sim values

**Text Comment.** Good explanation and arguments for discrepancies

**Text Comment.** The charts are an excellent method for analysis and are much better than text alone.

PAGE 20

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**Text Comment.** Circuit equivalent must be determined using existing values. This starts with isolation of resistors and then finding the voltage divider.

**Text Comment.** This is a series circuit and should be a parallel cct

PAGE 21

---

**Text Comment.** The equivalent cct should have a  $V_s$  of 6.52V due to the voltage divider.

**Text Comment.** These are correct

PAGE 22

---

**Text Comment.** This is the new  $V_s$  for the equivalent cct

**Text Comment.** The graph is correct

**Text Comment.** A reasonable argument but remember as you stated earlier the max growth will reach appx 98%

PAGE 23

---

**Text Comment.** Calcs are correct

PAGE 24

---

**Text Comment.** Graph is correct

**Text Comment.** Graph is correct

PAGE 25

---

**Text Comment.** Graph is correct

**Text Comment.** Good graph showing 1T result

PAGE 26

---

**Text Comment.** Good graph showing 0.7T

PAGE 27

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**Text Comment.** Excellent table of results

**Text Comment.** Analysis chart is a very good idea.

PAGE 28

---

**Text Comment.** Calc is correct. The other way to calc this is to use the initial current in the circuit :  $12/47K = 0.255mA$

**Text Comment.** Fair argument

**Text Comment.** Graph is correct

**Text Comment.** Good graph with explanation

PAGE 29

---

**Text Comment.** Graph is correct

**Text Comment.** Graph is correct

PAGE 30

---

**Text Comment.** Graph is correct

PAGE 31

---

**Text Comment.** Good table of results for comparison

**Text Comment.** Good method of analysis here again.

PAGE 32

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**Text Comment.** The Vs here should be 6.52v due to the voltage divider

PAGE 33

---

**Text Comment.** The graph results are correct which suggest you used the correct Vs for the analysis. This looks like an oversight here due to your comprehensive understanding of the subject.

**Text Comment.** Graph is correct with correct value

**Text Comment.** Correct graph and value

PAGE 34

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**Text Comment.** Correct graph and value

**Text Comment.** Calcs are correct

PAGE 35

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**Text Comment.** Excellent table of values for comparison

**Text Comment.** Good to see this method is consistent throughout the analysis.

PAGE 36

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**Text Comment.** Correct graph and values

**Text Comment.** Correct graph and values

PAGE 37

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**Text Comment.** Correct graph and values

**Text Comment.** Calcs are correct

PAGE 38

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**Text Comment.** Excellent table of results for comparison

**Text Comment.** Good chart for analysis

**Text Comment.** There is no explanation or calculation to explain initial and final current values in the circuit. Initial current is:  $12V / 47k = 0.255mA$  because the capacitor acts like a short circuit and bypasses R2. Final value:  $12V / (47k + 56k) = 116\mu A$  due to the capacitor now acting as an open cct.

PAGE 39

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**Text Comment.** Good intro to task

**Text Comment.** Correct calcs

**Text Comment.** I<sub>max</sub> is identified

PAGE 40

---

**Text Comment.** Good testing methods shown here with pulsed Vs and masking

PAGE 41

---

**Text Comment.** Table of calculated values is very good

PAGE 42

---

**Text Comment.** Good graph of calculated values showing trend

**Text Comment.** Fair argument

**Text Comment.** Good graph of transient

**Text Comment.** Graphs and values are all correct

**Text Comment.** Good table of results for comparison

**Text Comment.** Good method for analysis

**Text Comment.** Calcs are correct

**Text Comment.** Graph is correct

**Text Comment.** Graph is correct

**Text Comment.** Fair argument

**Text Comment.** This paragraph is not necessary

**Text Comment.** This should be divided into 2 paragraphs with shorter sentences. However the points made are valid.

GRADING FORM: CSG-RUBIC

THOMAS GRENNAN

0

## RESEARCH-INFORMED LITERATURE

 N/a

## KNOWLEDGE AND UNDERSTANDING

 Intro to practical and assessment topic area was good and showed a good comprehensive understanding. A good intro was given to each task. 8/10 Results and discussion were good and good points were identified. There were some minor errors which have been highlighted and a minor missing section in task 3. 12/15

**20/25**

## ANALYSIS

 Testing was carried out with explanations and good methods used. A minor part of task 3 is missing but all other parts are covered in full. Inventive methods of analysis used showing initiative. 25/30 Good conclusions given throughout report and at the end. 7/10

**32/40**

## PRACTICAL APPLICATION AND DEP.

 Circuit testing was carried out competently and the results were obtained effectively. Minor part of task 3 was missing. 12.5/15 The quality of the results were exceptional despite a missing minor part and

**21/25**

included good quality explanations. Methods of testing showed a good understanding of the tasks.  
8.5/10

#### SKILLS FOR PROFESSIONAL PRAC.



Quality of report was exceptional in parts and very good overall. 8.10

**8/10**