Nanyang Technological University (NTU)

**CE2004**

**Circuits & Signal Analysis**

# Lab Report (1 & 2)

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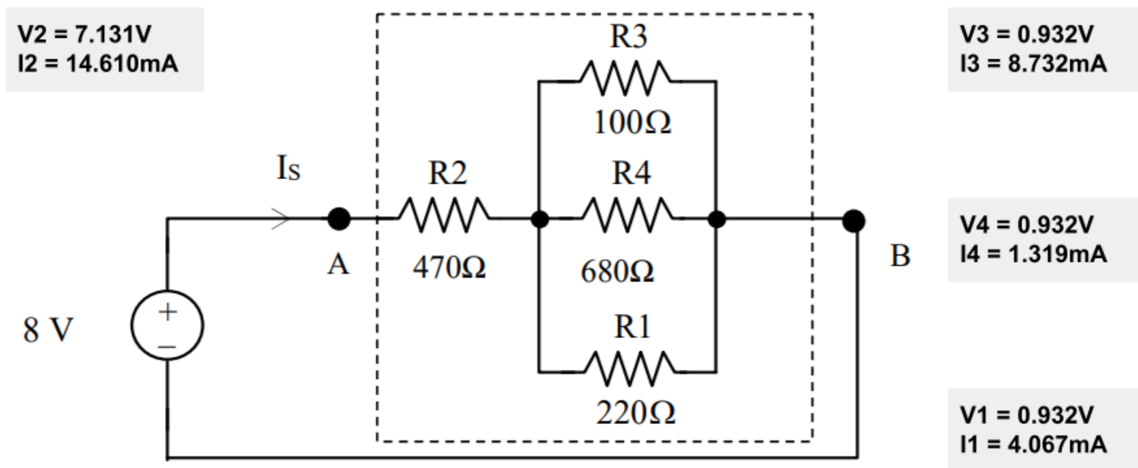
# Experiment 1: Circuit Analysis Techniques

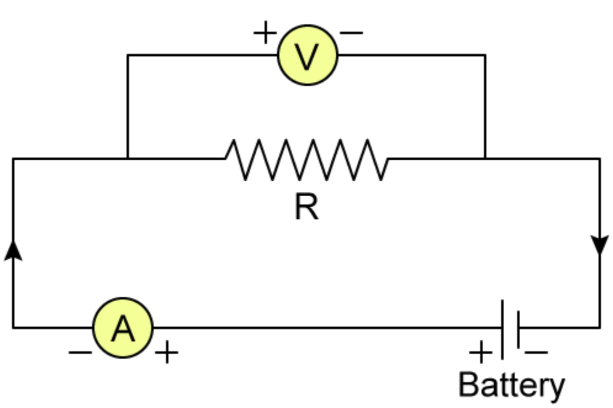
## 5.2 Series-Parallel Circuit (Understanding Ohm's Law, Kirchhoff's Laws)

**Measure the current and voltage for each resistor in the circuit. Indicate the readings on a circuit diagram.**




**State Ohm's Law with the help of a diagram, indicating the voltage polarity and the current direction**

Ohm's law states that the current (measured with ammeter A) through a conductor (represented by resistor R) between two points is directly proportional to the potential difference (measured with voltmeter V) across the two points ⇒ $V = IR$.



**From the measurements made, determine the resistance between terminals A‐B of the given circuit. Verify your answer through calculation using the known circuit configuration and resistor values.**

| Resistor # | Voltage | Current | Resistance |
|---|---|---|---|
| 1 | 0.932V | 4.067mA | 229.16Ω |
| 2 | 7.131V | 14.610mA | 488.09Ω |
| 3 | 0.932V | 8.732mA | 106.73Ω |
| 4 | 0.932V | 1.319mA | 706.60Ω |

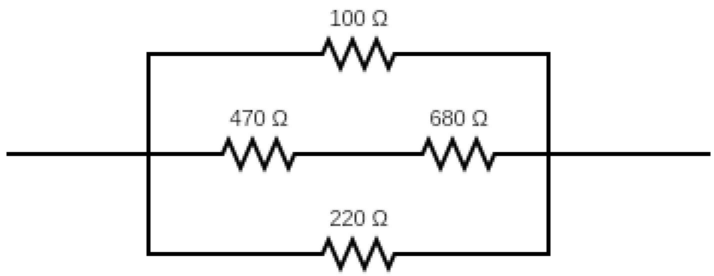
$$Effective\ Resistance\ (from\ our\ results)$$
$$= R2\ +\ (R3\ //\ R4\ //\ R1)$$
$$= 488.09\Omega\ +\ (\frac{1}{106.73\Omega} + \frac{1}{706.60\Omega} + \frac{1}{229.16\Omega})^{-1}$$
$$= 554.10\Omega$$

$$Effective\ Resistance\ (from\ the\ given\ circuit\ diagram)$$
$$= R2\ +\ (R3\ //\ R4\ //\ R1)$$
$$= 470\Omega\ +\ (\frac{1}{100\Omega} + \frac{1}{680\Omega} + \frac{1}{220\Omega})^{-1}$$
$$= 532.44\Omega$$

There's a slight deviation between the resistance from our experiment and the calculated resistance from the circuit diagram because the individual resistors deviate in their resistance. This is because the resistors used in the experiment are not ideal and have a tolerance value of 5% (as indicated by the 4th band being gold).

**If all resistors between terminals A‐B are allowed to be connected in any configuration except for four resistors in parallel, re‐arrange the resistors so that the current IS is maximum. What is this maximum value of IS?**

By Ohm's law, to achieve the maximum value of I(s), we need to have the lowest R(AB) value. We can achieve so by arranging the same set of resistors as shown below.




$Effective\ Resistance\ (of\ new\ arrangement)$
$= (\frac{1}{100\Omega} + \frac{1}{470\Omega + 680\Omega} + \frac{1}{220\Omega})^{-1}$
$= \ 64.871\Omega$

$Highest\ I(s)\ value$
$= \frac{8V}{64.871\Omega}$
$= \ 123mA$

## 5.3 Thevenin's Theorem

**Connect the circuit of figure 3 without the load resistor RL(open a‑b). Measure the input voltage, E, at the terminals c‑d with the multimeter.**

7.009V

**Measure the voltage at the terminals a‑b. This open‑circuit voltage Vo/c is the Thevenin's equivalent voltage of the circuit as seen by the load resistor at the terminals.**

4.431V

**Short circuit the terminals a‑b and measure the current flowing from terminal a to terminal b. This short‑circuit current Is/c is the Norton's equivalent current.**

1.351mA

**Calculate the value of the Thevenin's (or Norton's) equivalent resistance using the formula: Rth = Vo/c / Is/c.**

$$\frac{4.431V}{1.351mA} = \ 3.280k\Omega$$

**Remove the short circuit across a‑b, the voltage source E and short circuit c‑d. Measure the resistance at the terminals a‑b. This is the measured Thevenin's equivalent**

**resistance at the terminals. Compare this value of Thevenin's equivalent resistance with that calculated earlier.**

$$3.279k\Omega$$

The difference in the two values is very small (almost negligible).

**Connect a load resistor RL at the terminals a-b. Measure the voltage across RL and calculate the current through it. Make measurements for these values of RL (ohms): 1k, 4.7k, 10k and put your results in a table.**

| R(L) | V(L) | I(L) |
|---|---|---|
| 1kΩ | 1.031V | 1.041mA |
| 4.7kΩ | 2.629V | 0.557mA |
| 10kΩ | 3.334V | 0.338mA |

**Using the circuit of figure 4, repeat the measurements as before with the same values of RL and again put your results in a table. Compare and comment on the results in these two tables. Are they as expected?**

| | Theoretical | | My measurements | |
|---|---|---|---|---|
| R(L) | V(L) | I(L) | V(L) | I(L) |
| 1kΩ | 1.024V | 1.035mA | 1.031V | 1.041mA |
| 4.7kΩ | 2.616V | 0.549mA | 2.629V | 0.557mA |
| 10kΩ | 3.311V | 0.336mA | 3.334V | 0.338mA |

The results for the theoretical calculated values and the measured values are quite similar, and thus we can assume that they are equivalent. This is expected, because similarly to Thevenin's theorem, we replaced all the components with a much simpler circuit.

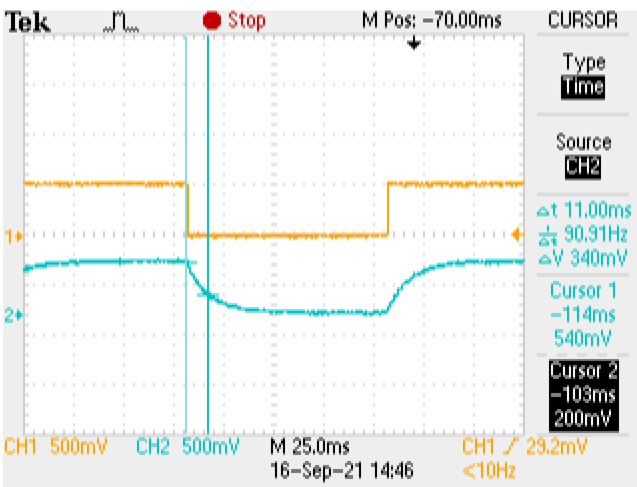
# Experiment 2: Circuit Analysis Techniques

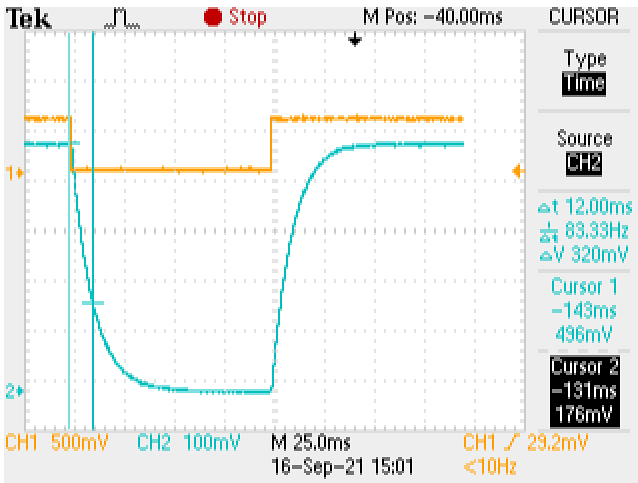
*Note: I thought I uploaded all the recordings into my computer but turned out most of them were not saved. I could not find a fitting time slot in my schedule to access the lab again, so some of these answers do not come with the charts. Thankfully, the values were recorded on paper.*

## 5.1 Behaviour of a Capacitor (in a RC Circuit)

**Repeat your measurements for at least three different values for R and C (refer to Table 1) in your comparison of observation and theory and thus calculate/measure the three time constant.**

**Calculate the time constant using the Step-by-Step method that you have learnt in class.**

| | |
|---|---|
| <br><br>TDS 2012C - 3:58:37 PM 16/9/2021 | <u>R=100 kΩ, C=100nF</u><br><br>T(1) = -114ms<br>V(1) = 540mV<br><br>T(2) = -103ms<br>V(2) = 200mV (= 540 / e)<br><br>t = (-103ms) - (-114ms) = 11ms |
| **(no screenshot)** | <u>R=100 kΩ, C=1μF</u><br><br>T(1) = -92ms<br>V(1) = 332mV<br><br>T(2) = 12ms<br>V(2) = 122mV (= 332 / e)<br><br>t = (12ms) - (-92ms) = 104ms |

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<u>R=10 kΩ, C=1 μF</u>

T(1) = -143ms
V(1) = 496mV

T(2) = -131ms
V(2) = 176mV (= 496 / e)

t = (-131ms) - (-143ms) = 12ms

| | R=100 kΩ<br>C=100nF | R=100 kΩ<br>C=1μF | R=10 kΩ<br>C=1 μF |
|---|---|---|---|
| Calculated $\tau$ | 10ms | 100ms | 10ms |
| Measured $\tau$ | 11ms | 104ms | 12ms |
| Sec/Div Used<br>(for Oscilloscope) | - | - | - |

**Make a qualitative record of your observations; can you give a qualitative explanation?**

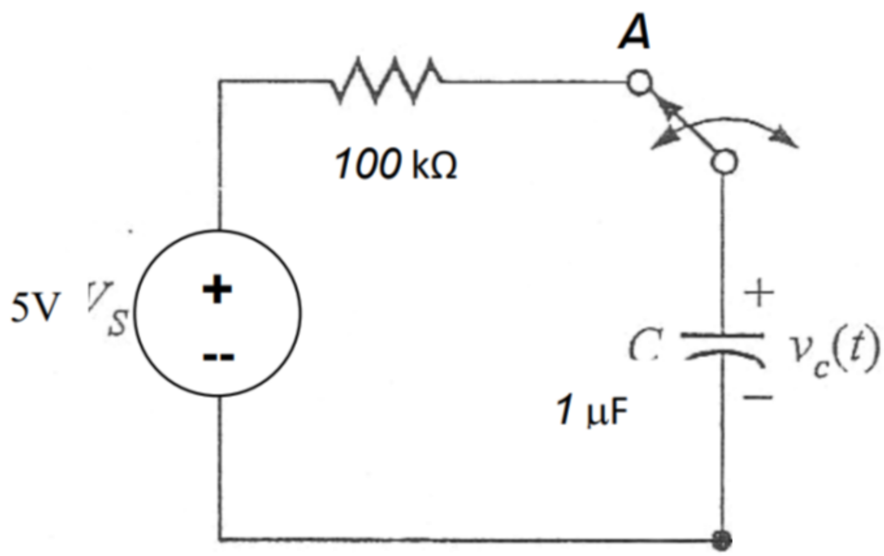
$\tau$ value obtained from measurement is rather close and consistent to the calculated value. The reasons behind the slight deviation between the values is similar to that of the previous lab, where the resistors used in the experiment are not ideal and have a tolerance value of 5% (as indicated by the 4th band being gold). In addition, there's both a hardware and software limitation in terms of how accurate the oscilloscope can both measure and display the results.

## <u>5.2 A First-Order Transient Circuit</u>

**Calculate the time constant using the Step-by-Step method that you have learnt in class.**

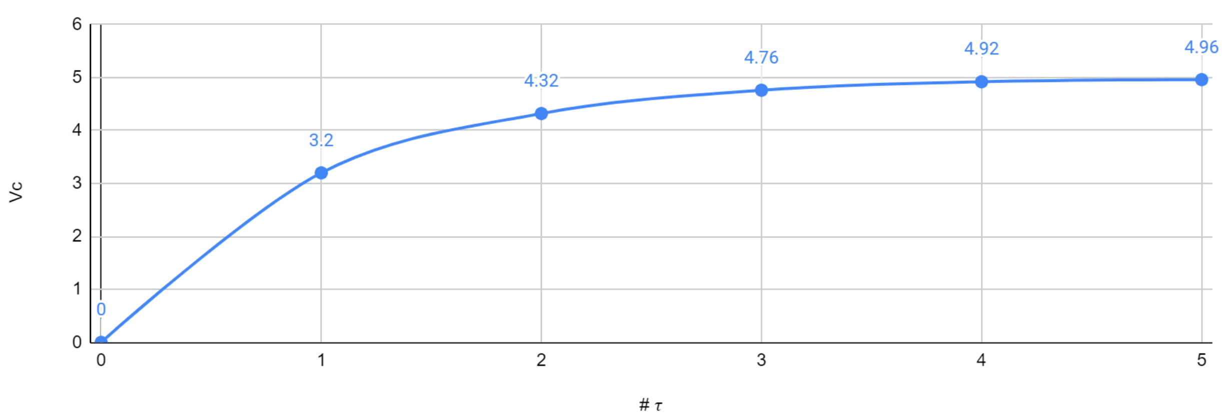
**Use the oscilloscope to determine time and voltage values for components used in Circuit (Figure 3) and plot (for one cycle) the VC as a function of t during both the charging and discharging time.**

Charging phase

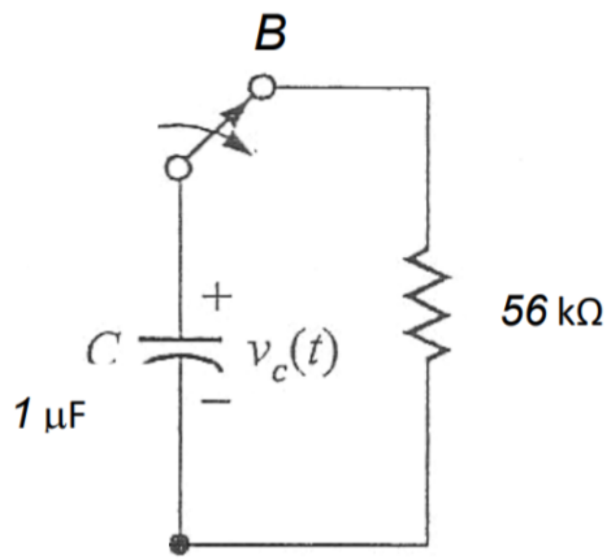



- Calculated
  - $\tau = (100k) \times (1\mu) = 100ms$
- Measured
  - V(1) = 0V (fully discharged at time = 0s)
  - V(2) = $(0) + (5 \times (1 - 1/e)) = 3.161V$
  - (-345ms) - (-450ms) = 105ms

| No. of $\tau$ | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Vc(t) | 0 | 3.20 | 4.32 | 4.76 | 4.92 | 4.96 |
| t | -450 | -345 | -240 | -135 | -30 | 75 |



Discharging phase




- Calculated
  - $\tau = (56k) \times (1\mu) = 56ms$
- Measured
  - V(1) = 5V (fully charged at time = 0s)
  - V(2) = $5 \times 1/e = 1.839V$
  - (-875ms) - (-815ms) = 60ms

| No. of $\tau$ | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Vc(t) | 5.00 | 1.84 | 0.68 | 0.24 | 0.09 | 0.03 |
| t | -875 | -815 | -755 | -695 | -635 | -575 |