Ex. No: 2 Date:11-5-2023

Roll No:AM.EN.U4AIE22055

VERIFICATION OF KIRCHHOFF'S LAWS

Aim: To verify Kirchhoff's current law and Kirchhoff's voltage law experimentally by using ADALM 2000 module.

Components and Equipments required:

Sl.No	Components/ Equipments	Range	Quantity
1	ADALM 2000 module		1
2	Resistor	1K, 1.5K, 2.2K	1 each
3	Laptop		1
4	Bread Board		1
5	Connecting Wires		as required

Theory:

Kirchhoff's laws are basic analytical tools in order to obtain the solutions of currents and voltages for any electric circuit; whether it is supplied from a direct-current system or an alternating current system.

A. Kirchhoff's Current Law (KCL)

This is also known as Kirchhoff's first law. The algebraic sum of the currents meeting at any node is Zero. Or KCL states that at every instant of time the sum of the currents flowing into any node of a circuit must equal the sum of the currents leaving the node. The law represents the law of conservation of charge.

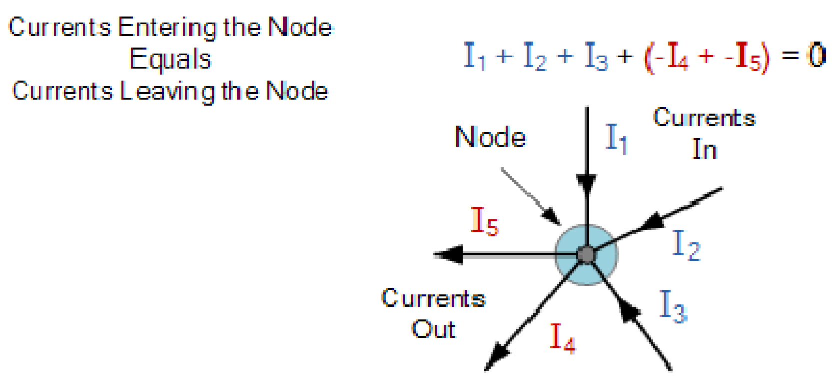


Fig. 1. Kirchhoff's current law

B. Kirchhoff's Voltage Law (KVL)

This is also known as Kirchhoff's second law. The algebraic sum of the voltage around any closed path is zero. KVL can be stated as the sum of the voltage rises in any loop equals the sum of the voltage drops around the loop. This law represents the law of conservation of energy.

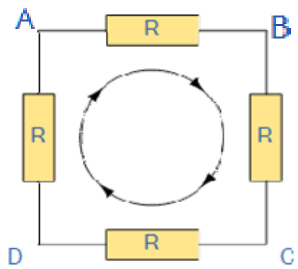


Fig. 2. Kirchhoff's Voltage law

Circuit Analysis:

For KCL

Consider a circuit consisting of three resistors in parallel connected to a voltage source. The sum of the current through individual resistors will be equal to the total current supplied from the voltage source.

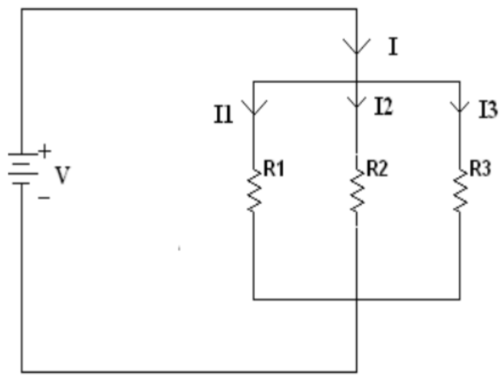


Fig. 3. KCL

$R_{eq} = 1/\{(1/R_1) + (1/R_2) + (1/R_3)\}$

$I = V/R_{eq}$

$I_1 = V/R_1$

$I_2 = V/R_2$

$I_3 = V/R_3$

According to KCL

$\mathbf{I = I_1+I_2+I_3}$

For KVL

Consider a circuit consisting of three resistors in series connected to a voltage source. The sum of the voltage across individual resistors will be equal to the total voltage applied.

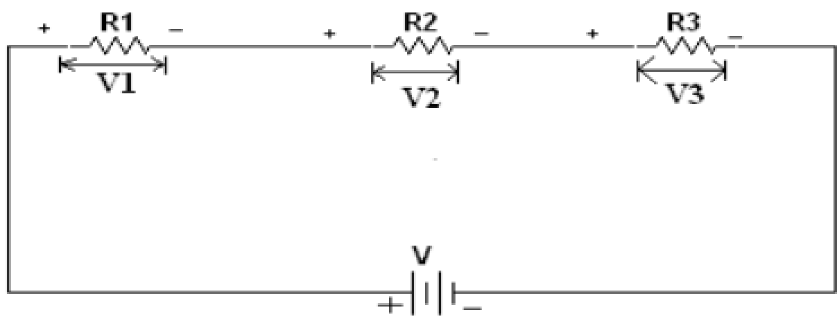


Fig. 4. KVL

$V_1 = V*R_1/(R_1+R_2+R_3)$

$V_2 = V*R_2/(R_1+R_2+R_3)$

$V_3 = V*R_3/(R_1+R_2+R_3)$

According to KVL

$\mathbf{V = V_1+V_2+V_3}$

Procedure:

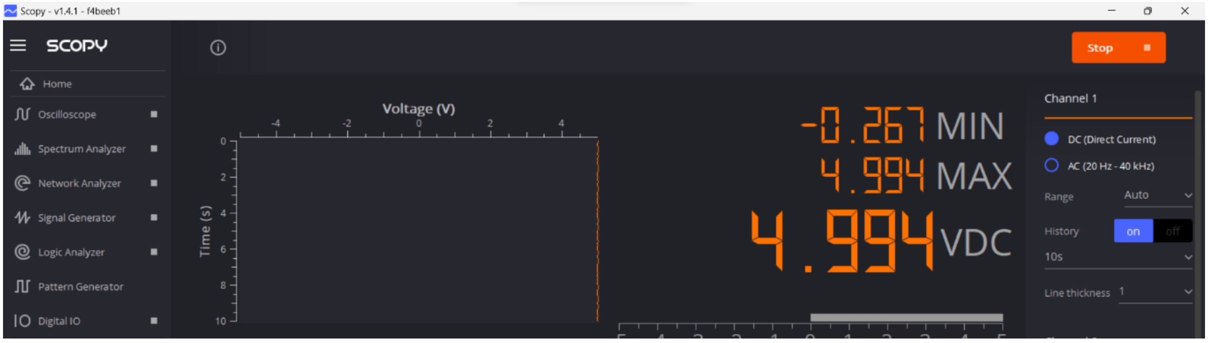
Section 1:

Construct the circuit as in Fig.3 and Fig. 4 using the breadboard and the resistors. R1 = 1KΩ, R2 = 1.5KΩ, R3 = 2.2KΩ. Complete the connections using ADALM 2000 module to the laptop with Scopy installed.

To verify the KCL apply 5 V from source and accurately measure all currents in the circuit using the Tool from Scopy. Record the measurements in a tabular form as shown below.

Branch current label	**Theoretical value I [amps]**	**Experimental value I [amps]**
I	10.60 mA	10.4872 mA
I_1	5.00 mA	4.944 mA
I_2	3.33mA	3.296 mA
I_3	2.27mA	2.2472 mA

The Source Voltage :



Sample Calculations

Session 1 Sample Calculations:

KCL; Given, $R_1 = 1\,k\Omega$, $R_2 = 1.5\,k\Omega$, $R_3 = 2.2\,k\Omega$ and $V = 6V$ (V will be same for all 3 registers)

$$i_{total} = \frac{V_{eq}}{R_{eq}} = \frac{5V}{\left(\frac{1}{1+\frac{1}{1.5}+\frac{1}{2.2}}\right)} = \frac{5V}{0.47142\,k\Omega} = 10.6\,mA$$

$$i_1 = \frac{V_1}{R_1} = \frac{5V}{1\,k\Omega} = 6\,mA$$

$$i_2 = \frac{V_2}{R_2} = \frac{5V}{1.5\,k\Omega} = 3.33\,mA$$

$$i_3 = \frac{V_3}{R_3} = \frac{5V}{2.2\,k\Omega} = 2.27\,mA$$

$$i_{total} = i_1 + i_2 + i_3$$

$$10.6 = 6 + 3.33 + 2.27$$

$$10.6\,mA = 10.6\,mA$$

Hence Verified.

Sample Calculations for Experimental Value;

Section 1; (Exp Value)

KCL; From the Voltage $V = 4.994\,V$ $\quad i_1 = \frac{V}{R_1} = \frac{4.944}{1k\Omega} = 4.944\,mA$

$\left.\begin{array}{l} i_1 = 4.994\,mA \\ i_2 = 3.296\,mA \\ i_3 = 2.2472\,mA \end{array}\right\}$ in parallel;

$i_{tot} = i_1 + i_2 + i_3$

$i_{tot} = 4.944 + 3.296 + 2.2472$

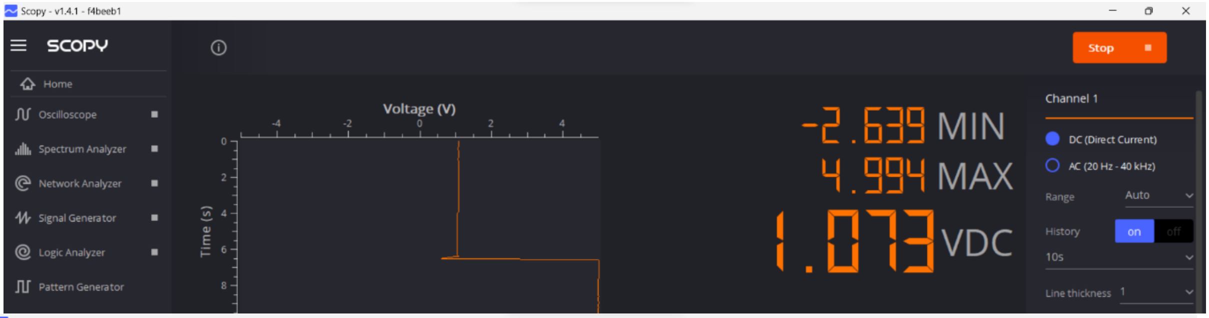
$\boxed{i_{tot} = 10.4872\,mA}$

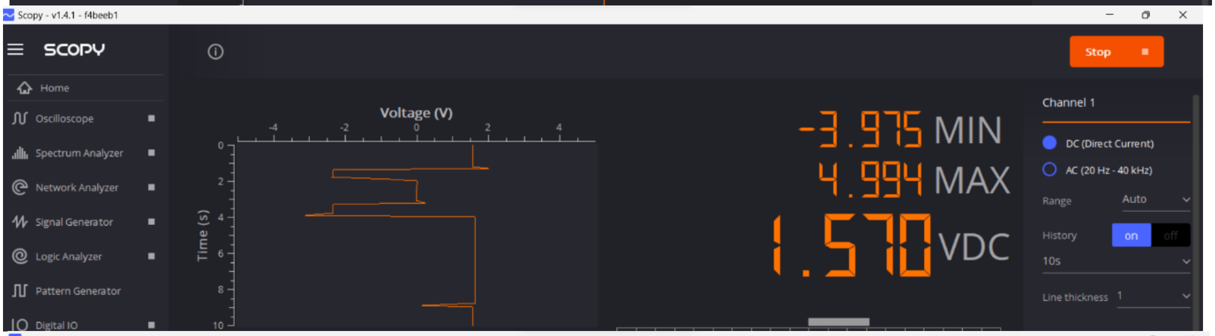
To verify the KVL accurately measure all voltages in the circuit using the Tool from Scopy. Record the voltage measurements in a tabular form as shown below.

Branch voltage label	Theoretical value V [volts]	Experimental value V [volts]
V	5 V	4.994 V
V_1	1.06383 V	1.073 V
V_2	1.59574 V	1.570 V
V_3	2.34042 V	2.34 V

SOURCE :

Voltages across each resistor :





Sample Calculations

KVL; Given, $R_1 = 1k\Omega$, $R_2 = 1.5k\Omega$, $R_3 = 2.2k\Omega$ $\Big\}$ $V = 5V$ (Source)
(Current will be same in series)

$$i = \frac{V}{R_{eff}} = \frac{5V}{1+1.6+2.2} = \frac{5V}{4.7k\Omega} = 1.0638\ mA$$

$V_1 = iR_1 = 1.0638 \times 1k\Omega = 1.06383\ V$
$V_2 = iR_2 = 1.0638\ mA \times 1.5k\Omega = 1.5957\ V$
$V_3 = iR_3 = 1.0638\ mA \times 2.2k\Omega = 2.34042\ V$

$V_{total} = V_1 + V_2 + V_3$
$5 = 1.06383 + 1.5957 + 2.34042$
$5V \approx 4.99993\ V$
$5V \approx 5V$

Hence Verified

KVL; From the Scopy; V values are;
$V_1 = 1.073V$
$V_2 = 1.570V$
$V_3 = 2.347V$

Total voltage;
$V_{total} = V_1 + V_2 + V_3$
$V_{tot} = 1.073V + 1.570V + 2.347V$
$\boxed{V_{tot} = 4.994\ V}$

We can see the sum of currents eq to total in KCL & sum of voltage in KVL is equal to total voltage in closed loop.

Section 2:

Verify KCL for the following circuit: R1 = 1KΩ, R2 = 1.5KΩ R3 = 2.2KΩ considering the source voltage as 3 and 5 Volts

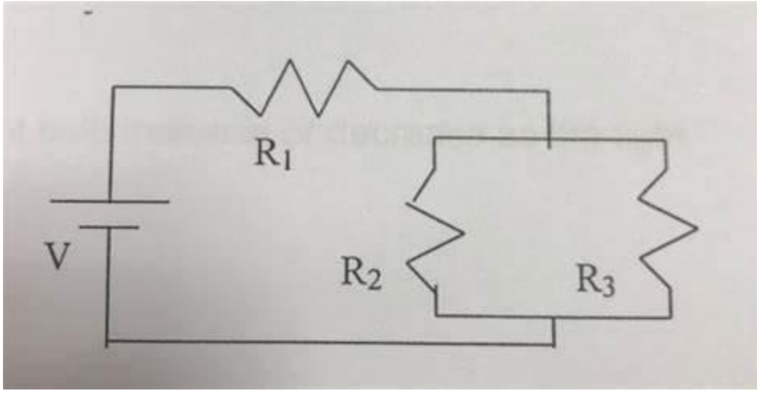
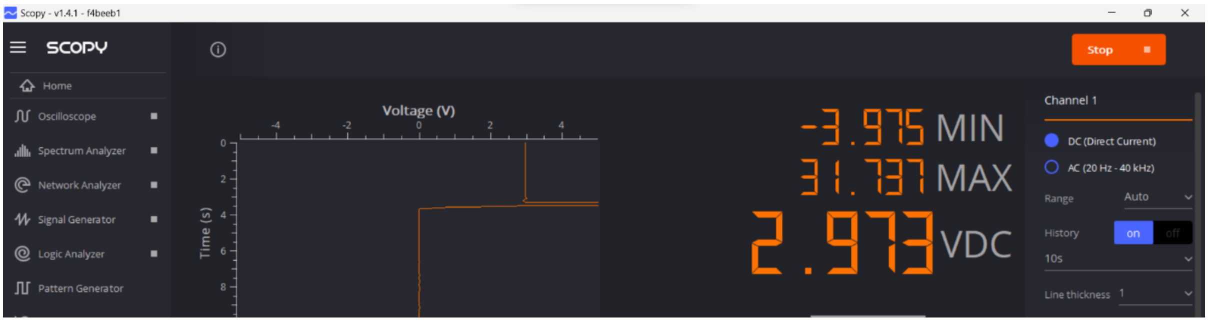


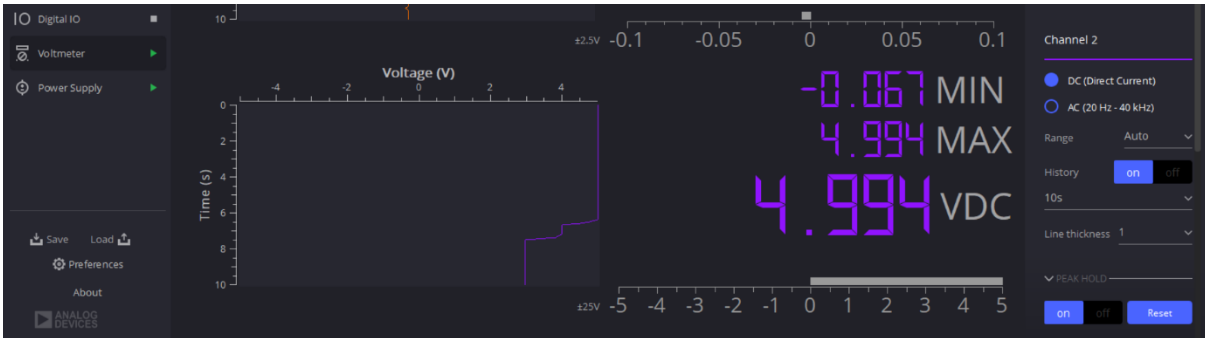
Fig 5. Circuit for KCL

Branch current label	**Theoretical value I [mAmps]**		**Experimental value I [mAmps]**	
	V = 3V	**V = 5V**	**V=3V**	**V=5V**
I	**1.5805mA**	**2.5628mA**	**1.571 mA**	**2.639 mA**
I1	**1.5805mA**	**2.6428mA**	**1.59 mA**	**2.606 mA**
I2	**0.9433mA**	**1.5712mA**	**0.95 mA**	**1.586 mA**
I3	**0.6431mA**	**1.0713mA**	**0.649 mA**	**1.081 mA**

SOURCE V= 3V :



SOURCE V = 5V :



Digital IO
Voltmeter
Power Supply
Save
Load
Preferences
About
Voltage (V)
Time (s)
-0.067 MIN
4.994 MAX
4.994 VDC
Channel 2
DC (Direct Current)
AC (20 Hz - 40 kHz)
Range
Auto
History
on
off
10s
Line thickness
1
PEAK HOLD
Reset

Sample Calculations

Session 2 Sample Calculations;

$\boxed{I_1 = I_2 + I_3}$

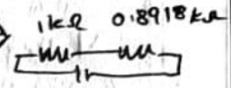
* KCL;

$R_1 = 1\,k\Omega$

$R_2 = 1.5\,k\Omega$

$R_3 = 2.2\,k\Omega$

$V = 3V$ & $5V$



for V = 3V;

Voltage Division =

$V_{2\&3} = 1.5805\,mA \times R_{23\,eff}$

$V_{2\&3} = 1.5865\,mA \times 0.8918\,k\Omega$

$V_{2\&3} = 1.41498\,V$

Total Current

$i_{5V} = 5/1.8918 = 2.642858\,mA$

$i_{3V} = 3/1.8918 = 1.5865\,mA$

$i_2 = V_{2\&3}/R_2$; $i_3 = V_{2\&3}/R_3$

$i_2 = 1.41498V/1.5k\Omega$; $i_3 = 1.41498V/2.2k\Omega$

$\boxed{i_2 = 0.9433\,mA}$; $\boxed{i_3 = 0.64319\,mA}$

* i_1 will be same
* Current will get splitted at R_2 & R_3 as they are in parallel

$i_2 + i_3 = 0.94433 + 0.64317 = 1.59\,mA$

$\boxed{i_2 + i_3 = i_{tot}}$ ✓

Session 2 (KCL) V = 2.973

Current	Theoretical Values I - mA V=3V	V=5V	Practical or Experimental Values V=3V	V=5V
I	1.5805 mA	2.642858 mA	$\frac{2.973}{1.8918} = 1.571\,mA$	$\frac{4.994}{1.8918\Omega} = 2.639\,mA$
I_1	1.5805 mA	2.642858 mA	$\frac{1.590V}{1k\Omega} = 1.59\,mA$	$\frac{2.606V}{1k\Omega} = 2.606\,mA$
I_2	0.9433 mA	1.5712 mA	$\frac{\cancel{2.249V}\ 1.427V}{1.5k\Omega} = 0.951\,mA$	$\frac{2.379V}{1.5k\Omega} = 1.586\,mA$
I_3	0.64317 mA	1.07131 mA	$\frac{1.427V}{2.2k\Omega} = 0.648\,mA$	$\frac{2.379V}{2.2k\Omega} = 1.081\,mA$

* KCL applies for junction & it satisfies

$\boxed{I_1 = I_2 + I_3}$

for $V = 5V$;

$i_{total\,(5V)} = 2.642858\,mA$

Voltage Division;

$V_{2\&3} = i$[redacted]$\times R_{2\&3\,eff}$

$V_{2\&3} = 2.642858 \times 0.8918\,k\Omega$

$V_{2\&3} = 2.3569\,V$

$i_2 = V_{2\&3}/R_2$; $i_3 = \frac{V_{2\&3}}{R_3}$

$i_2 = 2.3569/1.5k\Omega$; $i_3 = 2.3569\,V/2.2k\Omega$

$\boxed{i_2 = 1.5712\,mA}$, $\boxed{i_3 = 1.07131}$

$i_2 + i_3 = 1.5712 + 1.07131\,mA = 2.6\ldots$

$\boxed{i_{total} = 2.6412}$

* In the circuit; the current will pass through R_1 & get splitted at R_2 & R_3 junction as they are parallel;

So, here, KCL applied at junction and according current flow;

$\boxed{I_1 = I_2 + I_3}$

Section 2 : (Exp Values) It is verified

KCL ; $V = 3V$ [in Scopy = 2.973]

$I_{tot} = \frac{2.973}{R_{eff}} = \frac{2.973\,V}{1.8918\,k\Omega} = 1.571\,mA$

$I_1 = \frac{1.590\,V}{1\,k\Omega} = 1.59\,mA$ [$V_1 = 1.590V$]

$I_2 = \frac{1.427V}{1.5\,k\Omega} = 0.951\,mA$ [$V_{23} = 1.427V$]

$I_3 = \frac{1.427\,V}{2.2\,k\Omega} = 0.648\,mA$ [$V_{23} = 1.427V$]

Here, $I_{tot} = I_1 = I_2 + I_3$

$1.571 \approx 1.590 \approx 0.951 + 0.648$

$1.571 \approx 1.590 \approx 1.589\,mA$

$V = 5V$ [In Scopy $V = 4.994$]

$I_{tot} = \frac{4.994}{1.8918\,k\Omega} = 2.639\,mA$

$I_1 = \frac{2.606V}{1k\Omega} = 2.606\,mA$ [$V_1 = 2.606V$]

$I_2 = \frac{2.379}{1.5k\Omega} = 1.586\,mA$ [$V_{23} = 2.379V$]

$I_3 = \frac{2.379}{2.2k\Omega} = 1.081\,mA$ [$V_{23} = 2.379V$]

$I_{tot} = I_1 = I_2 + I_3$

$2.639 \approx 2.606 \approx 1.586 + 1.081$

$2.639 \simeq 2.606 \simeq 1.661$

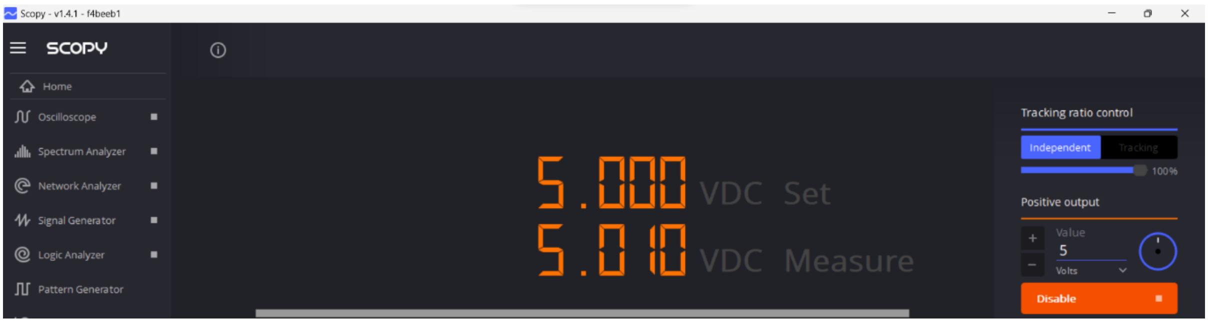
* It is satisfied ~~that~~ the KCL condition at R_1 & R_2, R_3 Junctions.

Section 3:

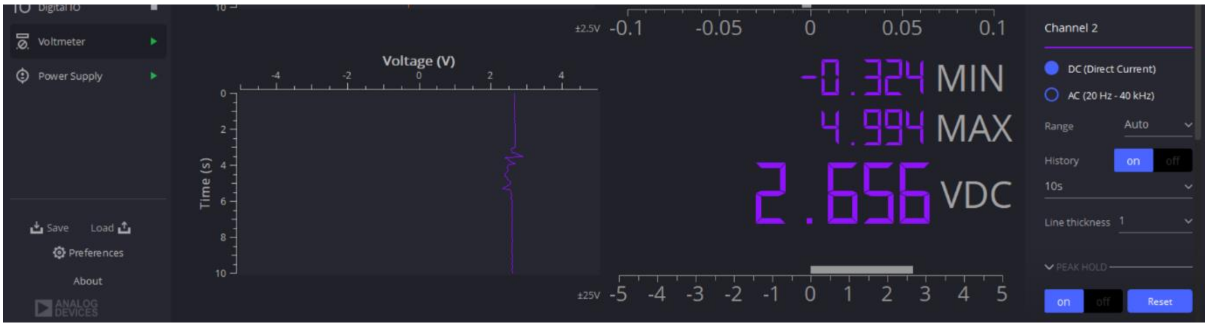
Verify KVL for the circuit in figure 5: R1 = 1KΩ, R2 = 1.5KΩ R3 = 2.2KΩ considering the source voltage as 2 and 5 Volts

Branch voltage label	Theoretical value V [volts]		Experimental value V [volts]	
	V = 2V	V = 5V	V = 2V	V = 5V
V	2.000 V	5.000 V	1.998 V	4.996 V
V_1	1.057 V	2.642 V	1.055 V	2.656 V
V_{2and3}	0.942 V	2.863 V	0.943 V	2.366 V

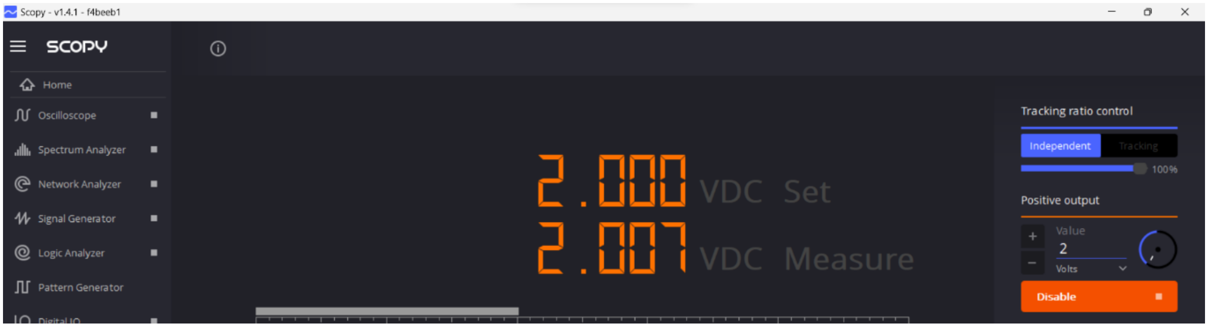
For Source V = 5V :



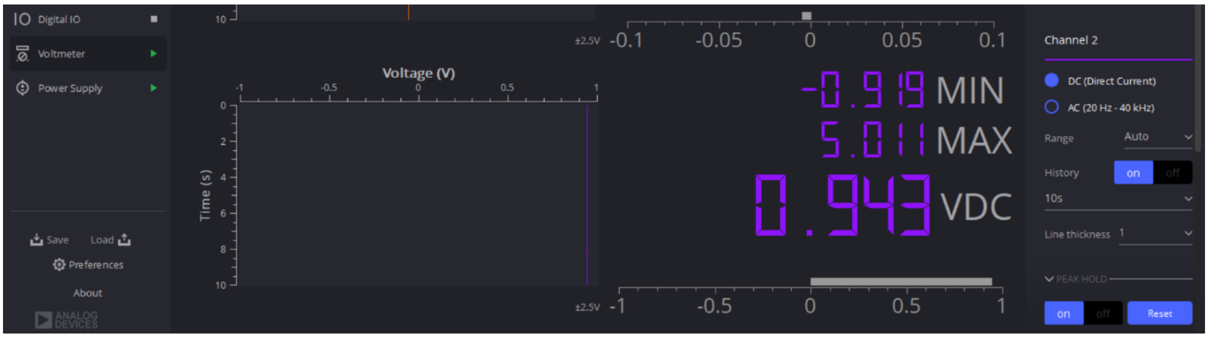
Voltages across each resistor when Source = 5V :



For **source V = 2V :**



Voltages across each resistor When V = 2V :

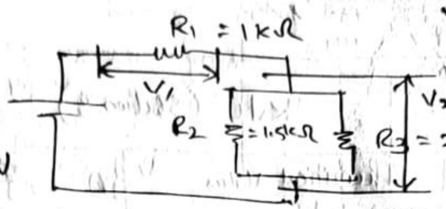


Sample Calculation

Section 3 ; Sample Calculations ;

$V_1 + V_2 = V = 2V$ (or 5V)

* KVL ;



V = 2V & 5V

For V = 2V ;

$i_{total} = \frac{V_{sou}}{R_{eff}} = \frac{2V}{1.8918\,k\Omega} = 1.0571\,mA$

$V_1 = i/R_1 = \boxed{1.0571V}$

$V_2 = i/R_{2\&3}$ eff

$V_2 = \frac{1.0571\,mA}{\frac{1}{\frac{1}{1.5}+\frac{1}{2.2}}} = \frac{1.0571\,mA}{0.8918\,k\Omega}$

$\boxed{V_2 = 1.185355\,V}$

$V_{total} = V_1 + V_2$

$2 = 1.05 + 1.18$

$2V \approx 2.2V$

$2V \approx 2V$

For $V_{sou} = 5V$;

$i_{total} = V_{sou}/R_{eff} = 2.642858\,mA$

$V_1 = i/R_1 = \boxed{2.642858\,V}$

$V_2 = i/R_{2\&3}$ eff

$V_2 = 2.642857 / 0.8918\,k\Omega$

$\boxed{V_2 = 2.8635\,V}$

$V_{total} = V_1 + V_2$

$5V = 2.64 + 2.863$

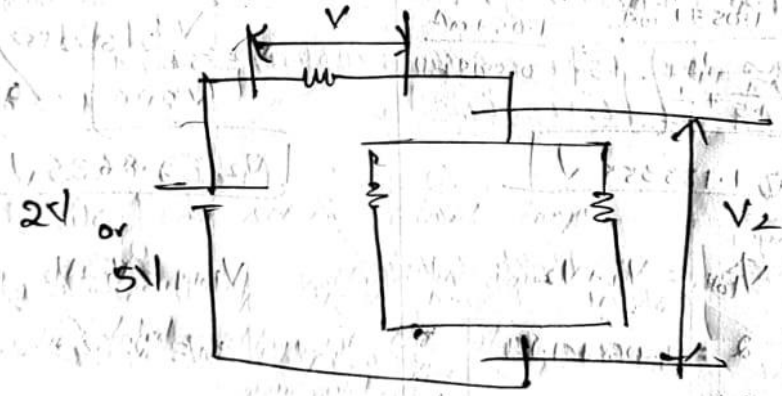
$5 \approx 5.4V$

$5 \approx 5V$

* Here, Voltage will be splitted at R_1 & $R_{2\&3}$ terminals as shown, So the KVL will be applied to the whole circuit & the verified will be as;

$\boxed{V_{total} = V_1 + V_2}$ (V_2 = V b/w $R_{2\&3}$ eff)

KVL (Section 3)				
Voltage	Theoritical Value		Experimental	
	V = 2V	V = 5V	V = 2V	V = 5V
V_{total}	2V	5V	1.996	4.994V
V_1	1.0571V	2.6428858V	1.055V	2.686V
V_2	1.185V	2.8635V	0.943V	2.366V



KVL for Section 3 circuit is verified as per above calculations.

* * *

Section 3 (Exp Values);

for V = 2V ;

In Series ;

$V_{tot} = 1.996V$

$V_1 = 1.055V$

$V_2 = 0.943V$

$V_{tot} = V_1 + V_2$

$V_{tot} = 1.055 + 0.943V$

$V_{tot} = 1.998V$

$\boxed{1.996 \simeq 1.998V}$

for V = 5V ;

In Series ;

$V_{tot} = 4.944V$

$V_1 = 2.656V$

$V_2 = 2.366V$

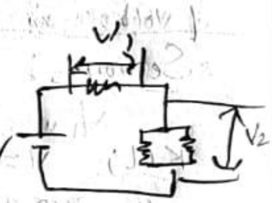
$V_{tot} = 2.656 + 2.366V$

$V_{tot} = V_1 + V_2$

$V_{tot} = 4.922V$

$\boxed{4.944 \simeq 49.22V}$

We can see in closed loop, algebraic sum of voltages is equal to the total voltage in the above experiment.



Hence it is verified.

Results and Inference

1. **Verification of Kirchhoff's Current Law (KCL):**
    - **Theoretical value of total current (I): 10.60 mA**
    - **Experimental value of total current (I): 10.4872 mA**
    - **Theoretical values of individual branch currents (I1, I2, I3): 5.00 mA, 3.33 mA, 2.27 mA**
    - **Experimental values of individual branch currents (I1, I2, I3): 4.944 mA, 3.296 mA, 2.2472 mA**

Inference: The experimental measurements of currents in the circuit align closely with the theoretical values, confirming Kirchhoff's Current Law (KCL) that the sum of currents entering and leaving a node is equal.

2. **Verification of Kirchhoff's Voltage Law (KVL):**
    - **Theoretical value of source voltage (V): 5 V**
    - **Experimental value of source voltage (V): 4.994 V**
    - **Theoretical values of individual branch voltages (V1, V2, V3): 1.06383 V, 1.59574 V, 2.34042 V**
    - **Experimental values of individual branch voltages (V1, V2, V3): 1.073 V, 1.570 V, 2.34 V**

Inference: The experimental measurements of voltages in the circuit align closely with the theoretical values, validating Kirchhoff's Voltage Law (KVL) that the sum of voltage rises and drops in a closed loop is zero.

I got the same results, i.e. very nearer to the theoritical values while doing KCL and KVL for the circuit where R2 and R3 are parallel and both are connected to R1 in series.

Overall, the experimental results obtained through the ADALM 2000 module and Scopy software confirm the validity of Kirchhoff's Current Law and Kirchhoff's Voltage Law in the tested circuits. The close agreement between the theoretical and experimental values supports the application of these laws in analyzing electrical circuits.

PRE LAB QUESTIONS :

Ex.NO: 2

Date: 11-5-2023

Roll no: AM.EN.U4AIE22055

VERIFICATION OF KIRCHOFF'S LAW

Pre-lab questions;

1. Differentiate Kirchoff's First Law and Second Law.

Ans: Kirchoff's first law and second law are both fundamental laws in electric sciences.

First law (or) Kirchoff's Current Law (KCL) states that the algebraic sum of current flowing into any node or junction in a circuit must equal to the algebraic sum of currents flowing out of the same node or junction. This is based on conservation of energy (charge).

Second law (or) Kirchoff's Voltage Law (KVL) states that the algebraic sum of voltage drops around any closed loop in a circuit must be equal to zero. This is based on principle of conservation of energy.

The first law deals with current and the second law deals with the voltage which are important and complementary laws in the electric circuits.

2) What is the main difference while applying Kirchoffs Law in DC and AC circuits?

Ans:- While applying KVL & KCL in AC & DC circuits, there is no fundamental difference between those two circuits, But, the analysis of AC circuits is more complex compared to DC circuits.

This is mainly due to the presence of reactive components such as capacitors and inductors in AC circuits, which can change the impedance of the circuit with respect to frequency. This means that the circuit needs to be analysed using complex numbers rather than just real numbers in DC circuits.

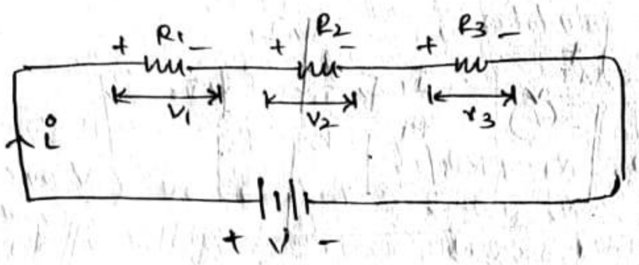
3) Name the laws which govern KCL and KVL respectively.

Ans:- Kirchoffs current law (KCL) governs the algebraic sum of current flowing into any node & junction in a circuit, while Kirchoffs voltage Law (KVL) governs the algebraic sum of the voltage drops around any closed loop in a circuit. They both work on the principle of conservation of charge & energy. (KCL-Charge & KVL-Ene

4) Prove the KVL law for the circuit given below considering $R_1 = 1\,k\Omega$, $R_2 = 1.5\,k\Omega$, $R_3 = 2.2\,k\Omega$ and source voltage as 5 Volts.

5) Proove KCL law for the circuit considering $R_1 = 1\,k\Omega$, $R_2 = 1.5\,k\Omega$, $R_3 = 2.2\,k\Omega$, & source voltage as 5V.

4 Ans:



KVL; Let 'i' is passing through the circuit;
Applying KVL in the circuit;

(Given $V_{eff} = 5V$)
$R_1 = 1k\Omega$
$R_2 = 1.5k\Omega$
$R_3 = 2.2k\Omega$

$$V - V_1 - V_2 - V_3 = 0$$
$$\boxed{V = V_1 + V_2 + V_3}$$

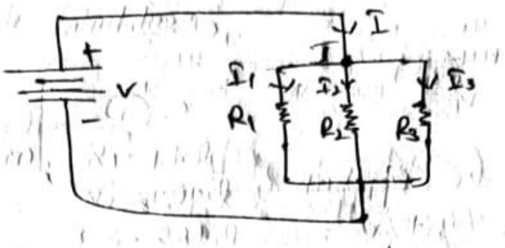
$$V_{eff} = i R_{eff}$$
$$i = \frac{V_{eff}}{R_{eff}}$$
$$i = \frac{5V}{R_1 + R_2 + R_3}$$
$$i = \frac{5V}{1 + 2.2 + 1.5}$$
$$i = \frac{5V}{4.7\,k\Omega}$$
$$i = 1.0638\,mA$$

$$V_1 = i R_1 = 0.0010638 \times 1k = 1.06 \times 10^{-3}.$$
$$V_1 = 1.06383\,V$$
$$V_2 = i R_2 = 1.06383 \times 10^{-3} \times 1.5k\Omega$$
$$V_2 = 1.595744\,V$$
$$V_3 = i R_3 = 1.06383 \times 10^{-3} \times 2.2k\Omega$$
$$V_3 = 2.3404255\,V$$

$$V = V_1 + V_2 + V_3$$
$$5 = 1.06383 + 1.595744 + 2.3404255$$
$$\boxed{5V = 5V}$$

Therefore, It is verified & proved the Satisfaction of KVL in the given circuit.

5 Ans.



KCL; Consider Junction 'J',

$$\boxed{I = I_1 + I_2 + I_3}$$

'V' is constant for all 3 resistors. $V_1 = V_2 = V_3 = V$

$I_1 = V/R_1$
$= 5 \times 10^{-3}$ A

$I_2 = V/R_2$
$= 5/1.5 = 3.333$mA

$I_3 = V/R_3 = 5/2.2 = 2.273$mA

$I = \frac{V}{R_{eff}}$

$I = I_1 + I_2 + I_3$

$\frac{V}{R_{eff}} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$

$\frac{V}{R_{eff}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

[In parallel, Same PD across for Resistor]

We know that the following equation is the way to the effective resistance and it is true for the resistors in parallel.
So, sum of current satisfy

The equation;
$I_{eff} = I_1 + I_2 + I_3$ | satisfies

Therefore, KCL is satisfied and verified for the current given loop (circuit).

$I = \frac{V}{R_{eff}} = \frac{5}{\frac{1}{1} + \frac{1}{1.5} + \frac{1}{2.2}} = \frac{5}{0.4714\text{k}\Omega} = 10.6$ mA

$I = I_1 + I_2 + I_3$
$10.6\text{mA} = 5\text{mA} + 3.33\text{mA} + 2.27\text{mA}$
$10.6\text{mA} \approx 10.6\text{mA}$

Hence, the sum of currents equals total current.

Exp Vol = 4.944V

R1 = 1kΩ, R2 = 1.5kΩ, R3 = 2.2kΩ	Kirchoff's ~~Voltage~~ Current Law	(Source Voltage = 5V)
Current	Theorical Values I - A [Amperes]	Experimental Values I - A [Amperes]
I	10.60mA	$I = \frac{V}{R} = I_1 + I_2 + I_3 = 10.4872mA$
I_1	5.00mA	$I_1 = \frac{V}{R_1} = \frac{4.944}{1k\Omega} = 4.944mA$
I_2	3.32mA	$I_2 = \frac{V}{R_2} = \frac{4.944V}{1.5k\Omega} = 3.296mA$
I_3	2.27mA	$I_3 = \frac{V}{R_3} = \frac{4.944V}{2.2k\Omega} = 2.2472mA$

R1 = 1kΩ, R2 = 1.5kΩ, R3 = 2.2kΩ	Kirchoff's ~~Current~~ Voltage Law	(Source Voltage = 5V)
Voltage	Theoritical Values V [Volts]	Experimental Value V [Volts]
V	5V	4.994V = 1.073V + 1.570V + 2.347V
V_1	1.06383V	1.073V
V_2	1.59574V	1.570V
V_3	2.34042V	2.347V

→ These are the theoritical values calculated, when applied KCL & KVL law respectively for the given circuits. and along with the Experimental values.

11/5/2023