North South University
Department of Electrical & Computer Engineering
LAB REPORT

Course Code: EEE141L

Course Title: Electrical Circuits I Lab

Course Instructor: Dr. Mohammad Abdul Matin (Mtn)

Experiment Number: 2

Experiment Name:

KCL, Current Divider Rule with Parallel and Ladder Circuit

Experiment Date: 11/3/2021

Date of Submission: 17/3/2021

Section: 3

Submitted To: Tabia Hossain

Submitted By	Score
Student Name and ID: 1. Md. Rifat Ahmed - 1931725042	

Objectives:

• Validate the current divider rules.
• Verify Kirchhoff's current law.
• Verify KCL and KVL in ladder circuit.

List of Equipment:

• OrCAD Software
• PSpice Software
• Resistors (1k, 3.3kΩ, 4.7kΩ, 5.6kΩ, 10k)
• Connecting Wires

Theory:

Kirchhoff's Current Law (KCL):

Kirchhoff's current law states that the algebraic sum of all the currents entering and exiting a node or a closed loop circuit is zero.
Alternatively, it could also be said that the total amount of currents entering a node is equal to the currents exiting from that node.

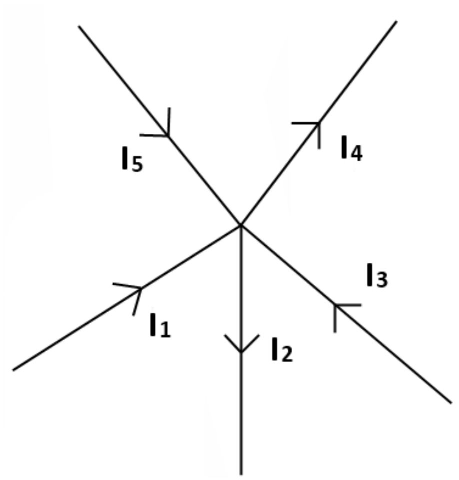


Figure – 1

For example, if we apply KCL to Figure-1 the algebraic sum of all the currents entering and exiting should be equal to zero. And if we consider the currents exiting from the node as negative, we get,

$$I_1 + I_3 + I_5 - I_2 - I_4 = 0$$

Or, if we consider the alternative form of KCL the sum of the currents entering the node (I_1, I_3, I_5) there should be equal to the currents exiting (I_2, I_4) from it. So,

$$I_1 + I_3 + I_5 = I_2 + I_4$$

Current Division Rule:

The current division rule states that the current entering the node of a parallel circuit is divided into the resistors of the branches in inverse proportion to their resistances.

So, when the current is flowing in a circuit if it encounters parallel branches it'll get divided into the resistors in those branches of the circuit.

For a circuit with two resistors in parallel the current flowing through each resistor will be, "the resistance in the opposite branch divided by the total resistance and multiplied by the total current" and the formula to calculate the currents divided into the resistor will be as following,

$$I_1 = \frac{R2}{R1+R2} \times I_S$$

$$I_2 = \frac{R1}{R1+R2} \times I_S$$

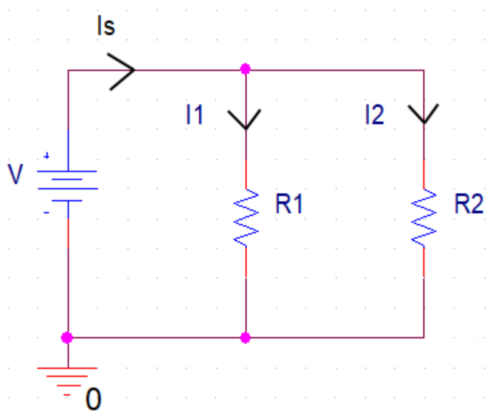


Figure – 2

For a circuit with three resistors in parallel the formula to calculate the currents divided into the resistors is a bit different from the formulas used for the circuit with two parallel resistors. They'll be,

$$R_{eq} = \left[\frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}\right]$$

$$I_1 = \frac{Req}{R1} \times I_S$$

$$I_2 = \frac{Req}{R2} \times I_S$$

$$I_3 = \frac{Req}{R3} \times I_S$$

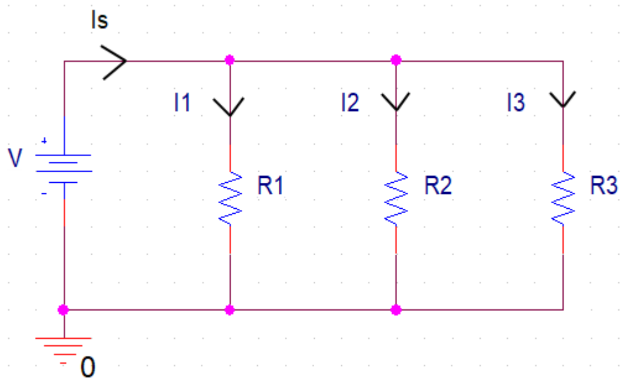


Figure – 3

So, the technique is to take the total resistance in the parallel circuit and divide it by the resistance of the resistor that we're trying to find the current flow of and multiply it with the total current.

Ladder Circuit:

A ladder circuit is the kind of circuit that we commonly use which is a mixture of both series and parallel circuits unlike the previous circuits we've seen where it's either only series or only parallel connections.

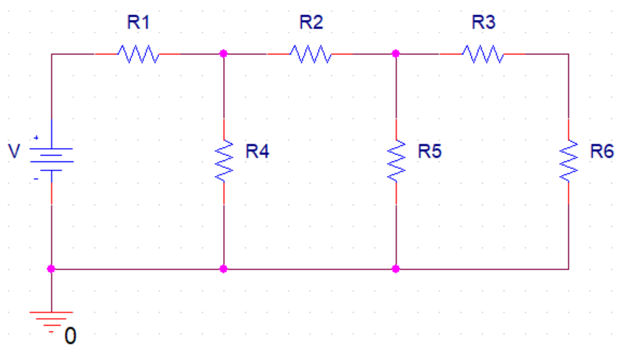
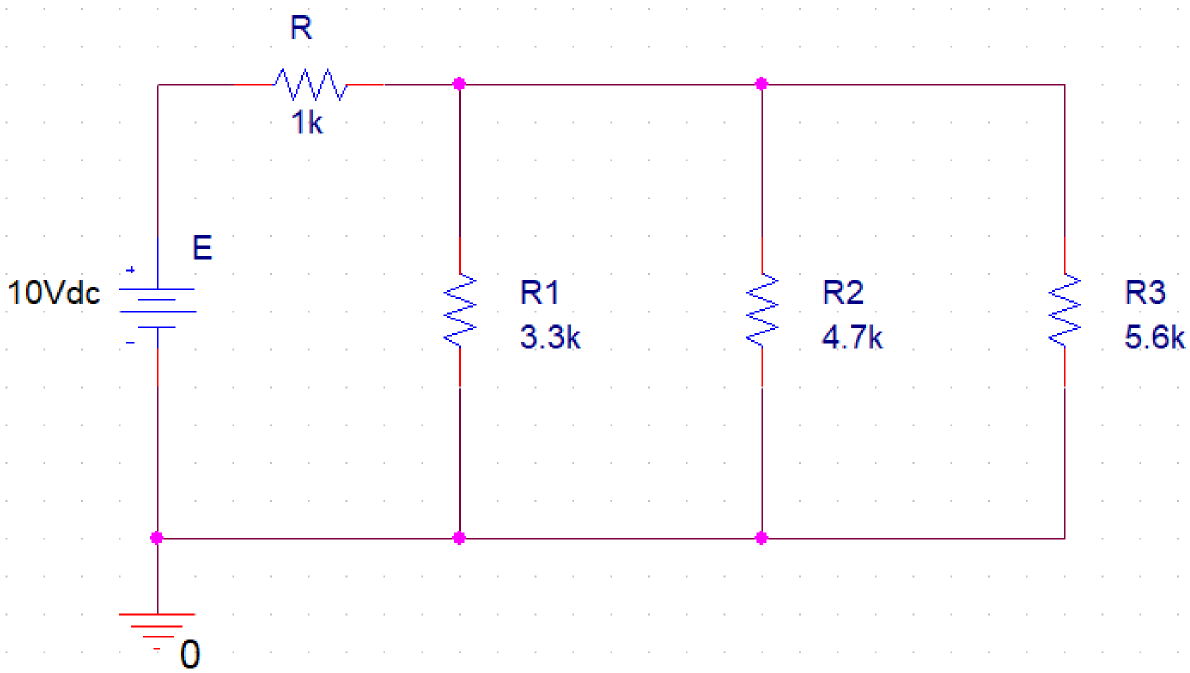
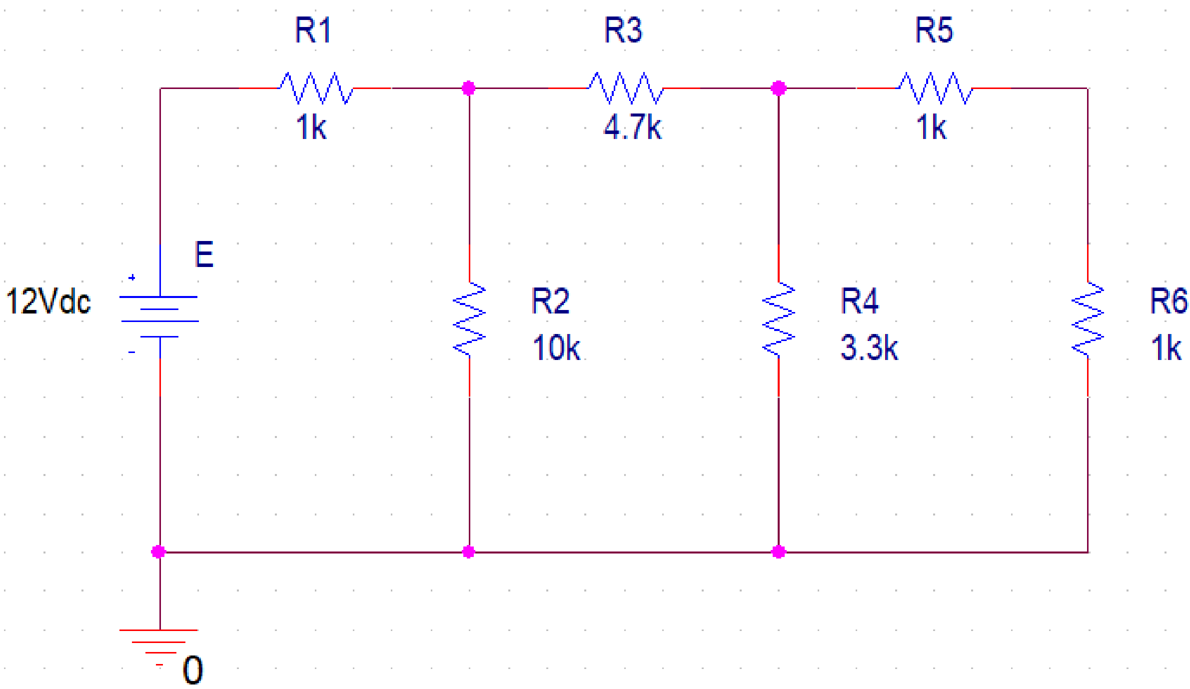


Figure – 4

Circuit Diagram:



Circuit – 1



Circuit – 2

Data, Readings and Results:

Table 2:

Experimental readings				Theoretical values			
I_S (mA)	I_{R1} (mA)	I_{R2} (mA)	I_{R3} (mA)	I_S (mA)	I_{R1} (mA)	I_{R2} (mA)	I_{R3} (mA)
4.098	1.789	1.256	1.054	4.098	1.788	1.256	1.054
% Error							
I_S		I_{R1}		I_{R2}		I_{R3}	
0%		0.06%		0%		0%	

Percentage Error Calculation:

% Error for $I_S = \left| \frac{\text{Experimental value} - \text{Theoretical value}}{\text{Theoretical value}} \right| \times 100\%$

$= \left| \frac{4.098 - 4.098}{4.098} \right| \times 100\% = 0\%$

% Error for $I_{R1} = \left| \frac{1.789 - 1.788}{1.788} \right| \times 100\% = 0.06\%$

% Error for $I_{R2} = \left| \frac{1.256 - 1.256}{1.256} \right| \times 100\% = 0\%$

% Error for $I_{R3} = \left| \frac{1.054 - 1.054}{1.054} \right| \times 100\% = 0\%$

Table 3:

I_S	4.098mA	**Is Total Current equal to the sum of individual current?**
Sum of individual Current ($I_{R1} + I_{R2} + I_{R3}$)	4.099mA	Almost Equal

Table 5:

Component	Voltage	Current
E	12V	2.538mA
R1	2.538V	2.538mA
R2	9.462V	0.946mA
R3	7.480V	1.592mA
R4	1.982V	0.601mA
R5	0.991V	0.991mA
R6	0.991V	0.991mA

Questions and Answers:

Answer of Question 1:

The current divider rule states that the current entering the node of a parallel circuit is divided into the branches in reverse proportion of the resistances of those branches.

Answer of Question 2:

Kirchhoff's current law states that the algebraic sum of all the currents entering and exiting a node is equal to zero.

Answer of Question 3:

Verifying KVL within each independent closed loop of circuit-2:
From Table 3 we get the experimental values,

$E = 12V$
$V_{R1} = 2.538V$
$V_{R2} = 9.462V$
$V_{R3} = 7.480V$
$V_{R4} = 1.982V$
$V_{R5} = 0.991V$
$V_{R6} = 0.991V$

There are total 3 independent closed loops in our circuit-2.

Now, Applying KVL at Loop 1,

$-E + V_{R1} + V_{R2} = 0$
$\Rightarrow E = V_{R1} + V_{R2}$
$\Rightarrow 12V = 2.538V + 9.462V$
$\Rightarrow 12V \approx 12V$

Applying KVL at Loop 2,

$-V_{R2} + V_{R3} + V_{R4} = 0$
$\Rightarrow V_{R2} = V_{R3} + V_{R4}$
$\Rightarrow 9.462V = 7.480V + 1.982V$
$\Rightarrow 9.462V \approx 9.462V$

Applying KVL at Loop 3,

$-V_{R4} + V_{R5} + V_{R6} = 0$

$\Rightarrow V_{R4} = V_{R5} + V_{R6}$

=> 1.982V = 0.991V + 0.991V

=> 1.982V ≈ 1.982V

Here, we can see that for all three loops the total voltage around the loop is equal to the sum of all the voltage drops within the same loop. Which means that all three loops follow KVL.

∴ KVL is verified for all the independent closed loops of the circuit.

Answer of Question 4:

Verifying Kirchhoff's current law at nodes a and b of circuit-2:

Applying KCL at node 'a' we get,

$I_{R1} = I_{R2} + I_{R3}$

With the experimental data from Table 5 we get,

2.538mA = 0.946mA + 1.592mA

= 2.538 mA

Here, we can see that the amount of current going into node a is equal to the total current going out of the node.

∴ KCL verified at node 'a'.

Now, again applying KCL at node 'b' we get,

$I_{R3} = I_{R4} + I_{R5}$

With the experimental data from Table 5 we get,

1.592mA = 0.601mA + 0.991mA

= 1.592mA

Here, we can see that the amount of current going into node b is equal to the total current going out of the node.

∴ KCL verified at node 'b'.

Answer of Question 5:

Calculating the theoretical values for Table 2:

Given,

$E = 10V$

$R = 1k\Omega$

$R_1 = 3.3k\Omega$

$R_2 = 4.7k\Omega$

$R_3 = 5.6k\Omega$

∴ Total Resistance in Parallel branches, $R_{eq} = \frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}$

$= \frac{1}{\frac{1}{3.3}+\frac{1}{4.7}+\frac{1}{5.6}} = 1.44\ k\Omega$

∴ Total Resistance, $R_T = R + R_{eq}$

$= 1k\Omega + 1.44k\Omega$

$= 2.44\ k\Omega$

∴ Total Current, $I_T = E/R_T$

$= 10V / (2.44 \times 10^3\ \Omega)$

$= 4.098 \times 10^{-3}$ A

$= 4.098$ mA

Now, Using Current Divider Rule,

∴ $I_{R1} = \frac{Req}{R1} \times I_T$

$= \frac{1.44\ k\Omega}{3.3\ k\Omega} \times 4.098mA = 1.788$ mA

∴ $I_{R2} = \frac{Req}{R2} \times I_T$

$= \frac{1.44}{4.7} \times 4.098mA = 1.256$ mA

∴ $I_{R3} = \frac{Req}{R3} \times I_T$

$= \frac{1.44}{5.6} \times 4.098mA = 1.054$ mA

From Table 2 we can see that the experimental and theoretical values of I_S, I_{R3}, I_{R4} are exactly the same and the value of I_{R2} is almost same. And from KCL we know that the total current entering and exiting should be zero. The amount of current entering in the Circuit is 4.098mA and the sum of the total amount of current going out is also 4.098mA so the algebraic sum of total current entering and exiting is zero.

∴ Our circuit follows KCL.

Answer of Question 7:

Given,

$E = 12$ V
$R_1 = 1$ kΩ
$R_2 = 10$ kΩ
$R_3 = 4.7$ kΩ
$R_4 = 3.3$ kΩ
$R_5 = 1$ kΩ
$R_6 = 1$ kΩ

In the circuit, R_5 and R_6 are in series. So,

$R_{S1} = R_5+R_6 = 1+1 = 2$kΩ

R_{S1} is in parallel with R_4,

$$R_{P1} = \frac{1}{\frac{1}{R4}+\frac{1}{Rs1}} = \frac{1}{\frac{1}{3.3}+\frac{1}{2}} = 1.25 \text{ k}\Omega$$

Then R_3 is in series with R_{P1},

$R_{S2} = 4.7+1.25 = 5.95$ kΩ

Then R_2 is in parallel with R_{S2},

$$R_{P2} = \frac{1}{\frac{1}{R2}+\frac{1}{Rs2}} = \frac{1}{\frac{1}{10}+\frac{1}{5.95}} = 3.73 \text{ k}\Omega$$

Finally, R_1 is in series with R_{P2}. So, the total resistance across the circuit,

$R_T = R_1+R_{P2} = 1+3.73 = 4.73$ kΩ

∴ Total Current across the circuit,

$I_S = E/R_T = 12V / (4.73 \times 10^3 \Omega) = 2.54 \times 10^{-3}$ A
$= 2.54$ mA

Now, $I_{R1} = I_S = 2.54$ mA

$V_{R1} = I_{R1} \times R_1 = 2.54 \times 1 = 2.54V$

$V_{R2} = E - V_{R1} = 12 - 2.54 = 9.46V$

$I_{R2} = V_{R2} / R_2 = 9.46/10 = 0.946mA$

$I_{R3} = I_{R1} - I_{R2} = 2.54 - 0.946 = 1.594mA$

$V_{R3} = I_{R3} \times R_3 = 1.594 \times 4.7 = 7.492V$

$V_{R4} = V_{R2} - V_{R3} = 9.46 - 7.492 = 1.968V$

$I_{R4} = V_{R4} / R_4 = 1.968/3.3 = 0.596mA$

$I_{R5} = I_{R3} - I_{R4} = 1.594 - 0.596 = 0.998mA$

$V_{R5} = I_{R5} \times R_5 = 0.998 \times 1 = 0.998V$

$I_{R6} = I_{R5} = 0.998mA$

$V_{R6} = I_{R6} \times R_6 = 0.998 \times 1 = 0.998V$

Discussion:

From this experiment we've learned the use of Kirchhoff's current law and the alternative form of KCL, then we learned the current division rule for circuits with two parallel resistors and for circuits with three parallel resistors and if there was more resistors, we could follow the same technique as we did for the three parallel resistor circuit and then we learned what's a ladder circuit. We've also learned to verify the KCL. Now coming to the result analysis, our experimental values and the theoretical values didn't vary much and were almost the same and because of that the error in our results were almost zero. Then we verified KVL for each independent closed loop and then by using KCL on node a and b of the circuit we saw that it follow KCL at those nodes too. After that in the Data, Reading and Results part we got almost a similar data readings and theoretical values. Due to that we got almost similar results for both experimental and theoretical values. So, the practical results were very much similar to the theoretical results as there wasn't any noticeable deviation there. Now the only problem during this experiment was that we had to rely on computer generated data using the OrCAD software to use as the experimental values as we can't do the experiment in real with actual circuits and resistors. So, the experimental values we had might not be as realistic as we had gotten if it was done in real life so doing the experiment online without using any actual hardware is a big drawback for our experiment.