Title: Study of combination of series and parallel circuits and voltage sources are in series.

Abstract: In this experiment the series circuit was solved by Kirchhoff's voltage law (KVL) and Voltage divider rule (VDR) and the parallel circuit was solved using the Kirchhoff's current law (KCL) and Current divider rule (CDR)

Introduction: The main object of this experiment is to:

1) Analyze the basic laws of series and parallel circuits.
2) Find the total circuit current of fixed circuit.
3) Observe the effect of two voltage sources in series.

Theory and Methodology:

Series Circuit:

A circuit consists of any number of elements joined at terminal points, providing at least one closed path through which charge can flow.

Two elements are in series if

a) They have only one terminal in common (i.e., one lead of one is connected to only one lead of the other).

b) The common point between the two elements is not connected to another current carrying element.

The current is the same through series elements. The total resistance of a series circuit is the sum of the resistance levels. In general, to find the total resistance of N resistors in series, the following equation is applied:

$R_T = R_1+R_2+R_3+...........+R_N$(Ohms) , $I=E/R_T$ (Amperes)

The voltage across each resistor (Figure 1) using Ohm's law; that is,

$V_1= IR_1$, $V_2= IR_2$, $V_3= IR_3$,........., $V_N= IR_N$ (Volts)

Using KVL, $E = V_1 + V_2$

The voltage divider rule states that the voltage across a resistor in a series circuit is equal to the value of that resistor times the total impressed voltage across the series elements divided by the total resistance of the series elements. The following VDR equation is applied:

$V_X=R_XE/R_T$ Similarly, $V_1=R_1E/R_T$, $V_2=R_2E/R_T$

Where, Vx is the voltage across Rx, E is the impressed voltage across the series elements, and RT is the total resistance of the series circuit.

Parallel Circuit:

Two elements, branches, or networks are in parallel if they have two points in common. In general, to find the total resistance of N resistors in parallel, the following equation is applied:

$1/R_T = (1/R_1) + (1/R_2) + (1/R_3) + ... + (1/R_N)$ (Ohms)

The voltage across parallel elements is the same (Figure 2). ($V_1 = V_2 = E$)

$I_1 = E/R_1$, $I_2 = E/R_2$ (Amperes)

Using KCL, $I_s = I_1 + I_2$ (Amperes)

The current divider rule states that the current through any parallel branch is equal to the product of the total resistance of the parallel branches and the input current divided by the resistance of

the branch through which the current is to be determined. The following CDR equation is applied:

$I_x = RT_I/Rx$ Similarly, $I_1 = RTI/R_1$, $I_2 = R_TI/R_2$

Where, the input current I equal V/RT, RT is the total resistance of the parallel branches. substituting V=IxRx into the above equation, Ix refers to the current through a parallel branch of resistance Rx.

Voltage Sources in Series:

Voltage sources can be connected in series, as shown in (Figure 3), to increase or decrease the

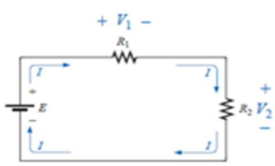


Figure 1: Series Circuit

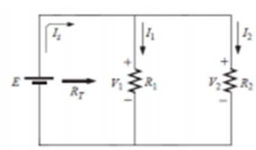


Figure 2: Parallel Circuit

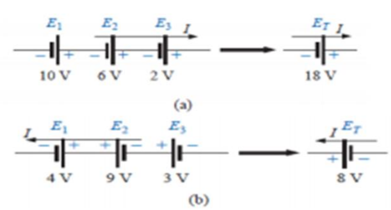


Figure 3: Voltage Sources in series

total voltage applied to a system. The net voltage is determined simply by summing the sources

with the same polarity and subtracting the total of the sources with the opposite "pressure." The

net polarity is the polarity of the larger sum.

In Figure 2.3(a), for example, the sources are all "pressuring" current to the right, so the net

voltage is $E_T = E_1 + E_2 + E_3 = 10V + 2V + 6V = 18V$ as shown in the figure.

In Figure 2.3(b), however, the greater "pressure" is to the left, with a net voltage of

$E_T = E_2 + E_3 - E_1 = 9V + 3V - 4V = 8V$ and the polarity shown in the figure.

Apparatus:

1. Trainer Board
2. Voltmeter
3. Ammeter
4. AVO meter or Multimeter
5. DC source
6. Resistors
7. Connecting Wires

Precautions:

Voltmeter was connected in the parallel through the resistor. Ammeter was connected in the series through the resistor.

Circuit Diagram:

Figure-4

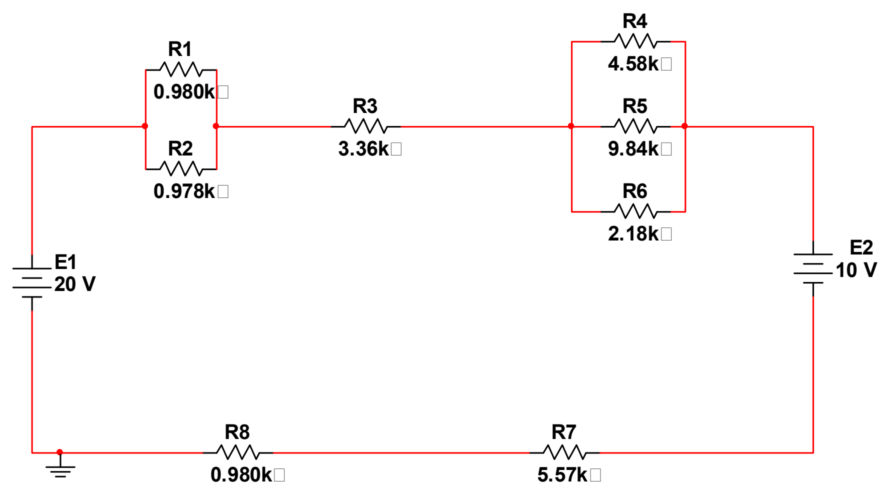
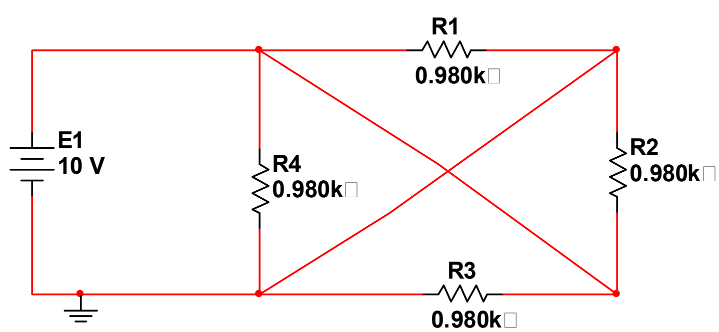


Figure-5

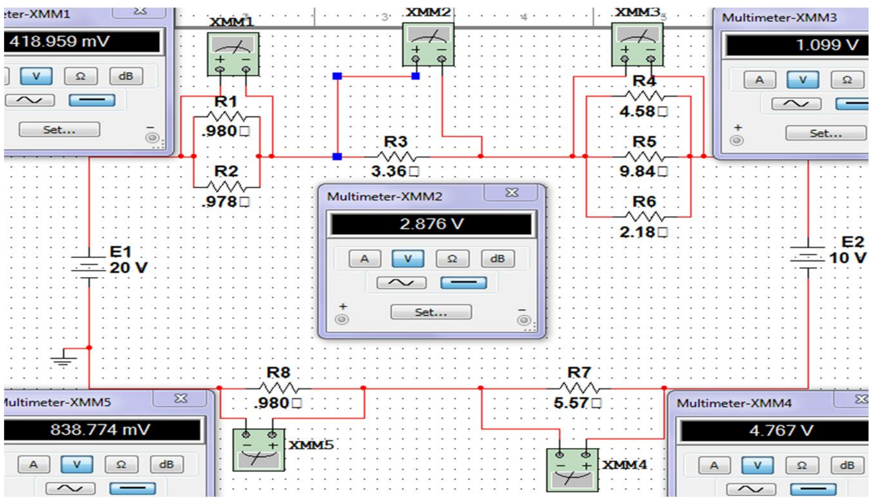


Experimental Procedure:

1) The circuit was connected as shown in the figure 4. Then the voltages was measured across each resistances and current of each branch.
2) After that the polarity of the voltage source E2 and the voltages was measured and currents was inverted again.
3) Then the circuit was connected as shown in figure 5. The total current and equivalent resistance was measured. Also the voltages across each resistance was measured.

Simulation and Measurement:

Simulation: 1 (For Figure-4)



Simulation: 2 (For Figure-5)

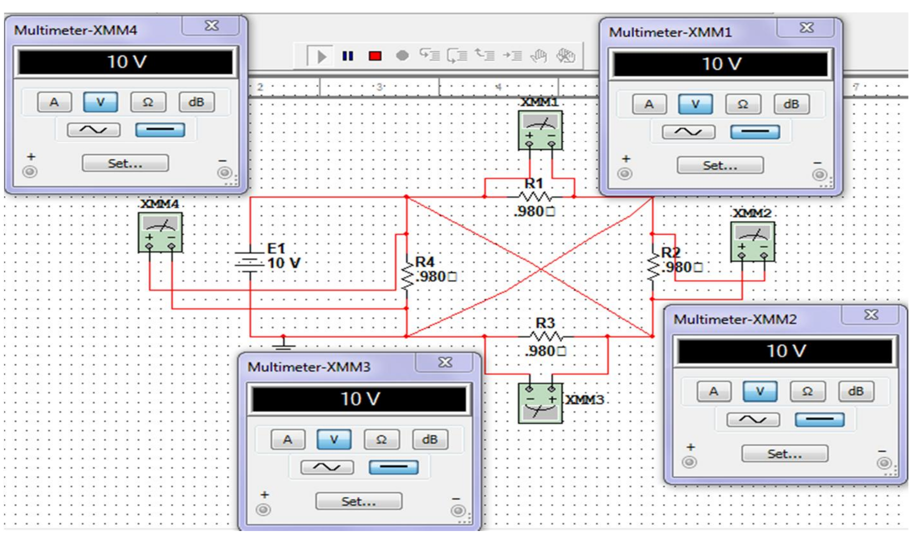


Table-1 (For Figure-4)

Value of Resistors:

R_1=.980kΩ, R_2=.978kΩ, R_3=3.36kΩ, R_4=4.58kΩ, R_5=9.84kΩ, R_6=2.18kΩ, R_7=5.57kΩ, R_8=.980kΩ. Value of Voltage Sources: E_1=20V, E_2=10V.

Calculated Value						Measured Value					
I A	V_{R12} mV	V_{R3} V	V_{R456} V	V_{R7} V	V_{R8} mV	I A	V_{R12} mV	V_{R3} V	V_{R456} V	V_{R7} V	V_{R8} mV
8.56×10^{-4}	419.1	2.877	1.096	4.88	839.077	8.56×10^{-4}	418.959	2.876	1.099	4.767	838.774

Table-2 (For Figure-5)

Value of Resistors:

R=.980kΩ. Value of Voltage Sources: E=10V

Calculated Value		Measured Value	
I (mA)	V_R (V)	I (mA)	V_R (V)
40.816	10	40.82	10

Calculations:

(In figure 4)

Given,

R1 = 0.980KΩ = 980Ω
R2 = 0.978KΩ = 978Ω
R3 = 3.360KΩ = 3360Ω
R4 = 4.580KΩ = 4580Ω
R5 = 9.840KΩ = 9840Ω
R6 = 2.180KΩ = 2180Ω
R7 = 5.570KΩ = 5570Ω
R8 = 0.980KΩ = 980Ω

Now,

$R12 = (1/R1 + 1/R2)^{-1} = (1/980 + 1/978)^{-1} = 489.449\Omega$

$R3 = 3.360K\Omega = 3360\Omega$

$R456 = (1/R4 + 1/R5 + 1/R6)^{-1} = (1/4580 + 1/984 + 2180)^{-1} = 1280\ \Omega$

$R7 = 5.570K\Omega = 5570\Omega$

$R8 = 0.980K\Omega = 980\Omega$

$RT = R12 + R3 + R456 + R7 + R8 = 489.499 + 3360 + 1280 + 5570 + 980 = 11679.499\ \Omega$

Then,

$VR12 = (E+R12)/RT = (10+489.499)/11679.499 = .4191\ V = 419.1\ mV$

$VR3 = (E+R3)/RT = (10+3360)/11679.499 = 2.877\ V$

$VR456 = (E+R456)/RT = (10+1280)/11679.499 = 1.096\ V$

$VR7 = (E+R7)/RT = (10+5570)/11679.499 = 4.88\ V$

$VR8 = (E+R8)/RT = (10+3360)/11679.499 = 839.077\ V$

And,

$I = E/RT = 10/11679.499 = 8.56\times10^{-4}\ A$

(In figure 5)

Given

$R1=R2=R3=R4=0.980K\Omega$

And

$V=10V$

So,

$I1=I2=I3=I4=I/RT=10/0.980=10.204\ A$

$I=4\times I1=4\times10.2=40.816\ A$

<u>Results:</u>

(In figure 4)

$I=8.56\times10^{-4}\ A$

$VR12 = 419.1\ mV$

$VR3=2.877\ V$

$VR456=1.096\ V$

$VR7=4.88\ V$

$VR8=839.077\ mV$

(In figure 5)

$V=10\ V$

$I=40.816\ A$

Questions and Answers:

1. Verify the measured value of total circuit current with calculated value. Show necessary calculation.

Ans: (For figure 4) Given,

R1 = 0.980KΩ = 980Ω
R2 = 0.978KΩ = 978Ω
R3 = 3.360KΩ = 3360Ω
R4 = 4.580KΩ = 4580Ω
R5 = 9.840KΩ = 9840Ω
R6 = 2.180KΩ = 2180Ω
R7 = 5.570KΩ = 5570Ω
R8 = 0.980KΩ = 980Ω

Calculated value:

$R12 = (1/R1 + 1/R2)^{-1} = (1/980 + 1/978)^{-1} = 489.449\Omega$
R3 = 3.360KΩ = 3360Ω
$R456 = (1/R4 + 1/R5 + 1/R6)^{-1} = (1/4580 + 1/984 + 2180)^{-1} = 1280\ \Omega$
R7 = 5.570KΩ = 5570Ω
R8 = 0.980KΩ = 980Ω
RT = R12 + R3 + R456 + R7 + R8 = 489.499 + 3360 + 1280 + 5570 + 980 = 11679.499 Ω

Then,

VR12 = (E+R12)/RT = (10+489.499)/11679.499 = .4191 V = 419.1 mV
VR3 = (E+R3)/RT = (10+3360)/11679.499 = 2.877 V
VR456 = (E+R456)/RT = (10+1280)/11679.499 = 1.096 V
VR7 = (E+R7)/RT = (10+5570)/11679.499 = 4.88 V
VR8 = (E+R8)/RT = (10+3360)/11679.499 = 839.077 V

And,

$I = E/RT = 10/11679.499 = 8.56\times10^{-4}$ A

Measured Value:

$R12 = (1/R1 + 1/R2)^{-1} = (1/980 + 1/978)^{-1} = 489.449\Omega$
R3 = 3.360KΩ = 3360Ω
$R456 = (1/R4 + 1/R5 + 1/R6)^{-1} = (1/4580 + 1/984 + 2180)^{-1} = 1280\ \Omega$
R7 = 5.570KΩ = 5570Ω
R8 = 0.980KΩ = 980Ω
RT = R12 + R3 + R456 + R7 + R8 = 489.499 + 3360 + 1280 + 5570 + 980 = 11679.499 Ω

Now,

$I=E/RT=10/11679.499=8.56\times10^{-4}$A

And,

VR12=418.959 mV
VR3=2.876 V
VR456=1.099 V
VR7=4.767 V

$VR8=834.774$ V

(For figure 5)

Given,

$R1=R2=R3=R4=0.980K\Omega$

And

$V=10V$

Calculated value:

$I1=I2=I3=I4=I/RT=10/0.980=10.204$ A

$I=4\times I1=4\times 10.2=40.816$ A

Measured value:

$RT=(1/R1+1/R2+1/R3+1/R4)=(4/R1)^{-1}=(4/.980)^{-1}=0.245\Omega$

$I=V/RT=10/0.245=40.82A$

2. Comment on the result as a whole.

Ans: All the results of the measured value and calculated are almost same. So, we can say all the calculations are approximately correct.

Discussion:

1. The trainer board and the multimeter was checked before the start of the experiment.
2. The resistor was placed properly according to the figure.
3. The value of the voltage was increased gradually as applying a large voltage can damage the resistors.
4. During the experiment some error was taken place due to the fault of voltage source. It was solved with the help of course instructor.
5. Finally all the data was placed in the data table. For the given equation, a result was obtained.

Conclusions:

In this experiment the data/findings were interpreted and determine to the extent to which the experiment was successful in complying. The goal was initially set. The ways of the study was improved, investigated and described by calculating and measuring the series and parallel circuit.

References: Robert L. Boylestad ,"Introductory Circuit Analysis", Prentice Hall, 12thEdition, New York, 2010, ISBN 9780137146666.sssss