UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 4 – SERIES CIRCUIT CHARACTERISTICS

OBJECTIVES

In this experiment students will investigate the characteristics of series circuits and the voltage divider rule for these circuits.

MATERIALS/EQUIPMENT NEEDED

Resistors: 1.2kΩ, 1.8kΩ, 2.2kΩ, 3.3kΩ, 4.7kΩ, 5.6kΩ, 9.1kΩ
Agilent U8031A DC Power Supply
Agilent 34461A Digital Multimeter

INTRODUCTION

A circuit is a path for electrons to flow through. The path is from a power source negative terminal, through the various components and on to the positive terminal. Although the physical picture of current is a flow of electrons, in engineering and science conventional current flow is used. Conventional current is the flow of positive charge, and electron flow can be modeled as a flow of positive charge in the reverse direction.

Note: The reason for this dilemma is that much of the literature in circuits was written before the true nature of current was understood.

Series Circuits: A series circuit is one with all the loads in a row. There is only ONE path for the electricity to flow. If this circuit was a string of light bulbs, and one blew out, the remaining bulbs would turn off. In this lab-session the student will verify experimentally, using measured and calculated values, the following series circuit rules:

1. Total circuit resistance equals the sum of the individual resistances.
2. The current is the same at all points in a series circuit.
3. The sum of the voltage drops equals the source voltage.

Voltage Divider Rule for Series Circuits: In any given series circuit, the current that flows through each circuit element (resistors and voltage source) is the same. If fixed resistors (not variable resistors) are used, then the voltage drops will be fixed and will be directly proportional to the ratio of the resistor sizes. If a reference point is established (usually called “common” or “ground) it is then possible to measure the voltage at all other points in the circuit, with respect to this “common” point. If the “common” point is then relocated to another point in the circuit, the voltage (measured with respect to the common point) at each other point will be different. This common point is usually chosen as ground.

The ratio of resistance values in a series circuit determines the ratio of voltage drops. Therefore, given the source voltage and the value of each resistor, the voltage drops can be found by expressing ratios of voltage to resistance:

$$\frac{V_{Source}}{R_{Total}} = \frac{V_1}{R_1} \quad \text{and} \quad \frac{V_{Source}}{R_{Total}} = \frac{V_2}{R_2}$$

If the equations above are solved for the voltage drops then

$$V_1 = V_{Source}\left(\frac{R_1}{R_{Total}}\right) \quad \text{and} \quad V_2 = V_{Source}\left(\frac{R_2}{R_{Total}}\right)$$

Therefore, the voltage divider rule states, “The voltage across a resistor is a fraction of the total voltage, and that fraction is one whose numerator is that RESISTANCE, and whose denominator is the TOTAL RESISTANCE.” Conversely, the size of a resistor can be determined when given the total resistance, source voltage and desired voltage drop:

$$R_1 = R_{Total}\left(\frac{V_1}{V_{Source}}\right) \quad \text{and} \quad R_2 = R_{Total}\left(\frac{V_2}{V_{Source}}\right)$$

Using the above expression, it is possible to design a voltage divider to supply various voltages with respect to “common” for a given source voltage, a group of resistors, and the values of desired voltages.

PRELAB

1. Use the voltage divider rule (VDR) calculate the voltage at each point, A, B, C, D and E
   a. For the circuit in Figure 4-1, record your calculations in Table 4-1.

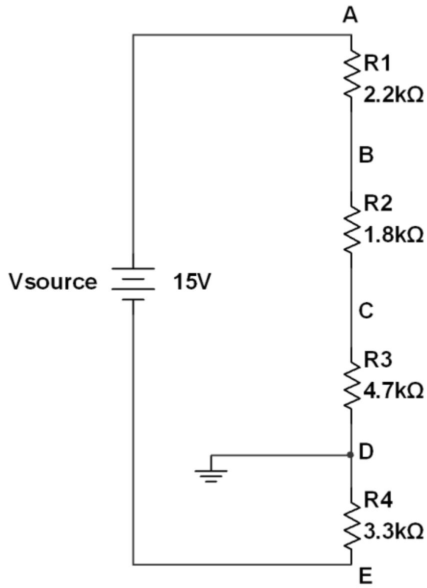

Figure 4-1 Circuit diagram for part 1a of the prelab

   b. For the circuit in Figure 4-2, record your calculations in Table 4-1.

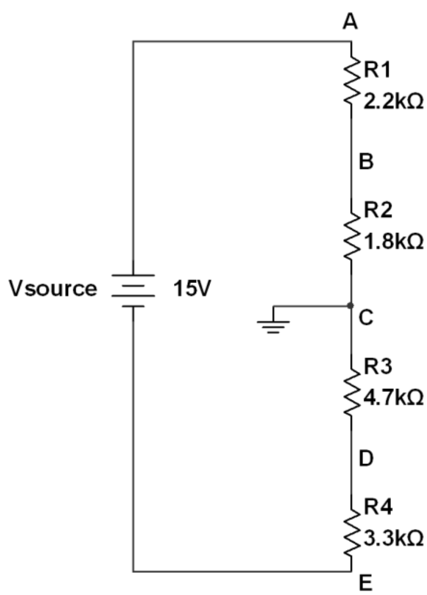

Figure 4-2 Circuit diagram for part 1b of the prelab

   c. For the circuit in Figure 4-3, record your calculations in Table 4-1.

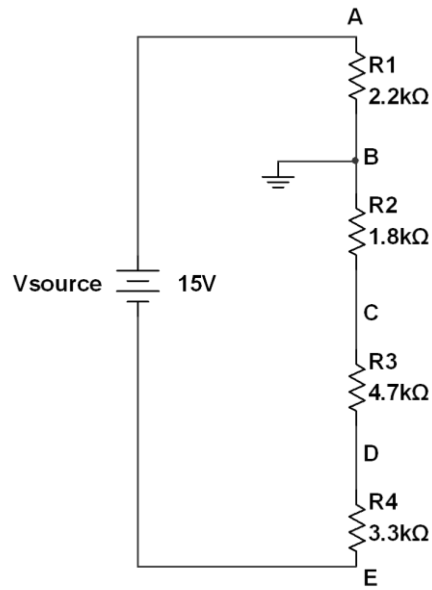

Figure 4-1 Circuit diagram for part 1c of the prelab

d. For the circuit in Figure 4-4, record your calculations in Table 4-1.

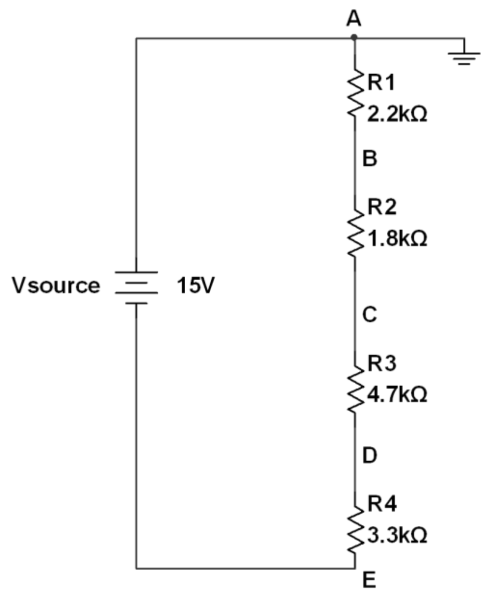

Figure 4-4 Circuit diagram for part 1d of the prelab

2. Refer to the circuit in Figure 4-5. R1, R2, R3 and R4 are 1.2kΩ, 5.6kΩ, 3.3kΩ and 9.1kΩ resistors, but not in that order. Using the VDR in the form that solves for resistance (R) rather than voltage (V), solve for the necessary resistor placements (or locations) that will result in the voltages as shown. Record in Table 4-2 below the resistor values you determined.

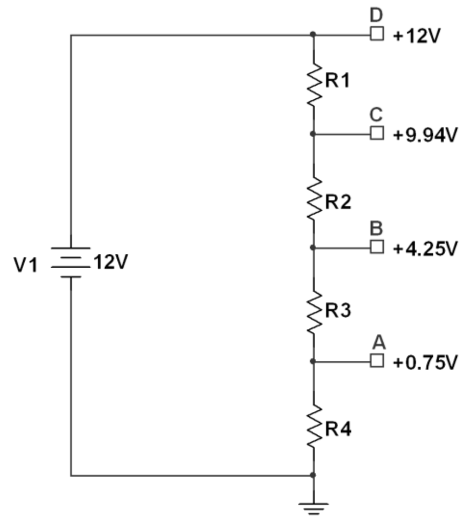

Figure 4-5 Circuit diagram for part 2 of the prelab

Table 4-1: Voltages calculated at points A, B, C, D and E for prelab, part 1

Voltage	Figure 4-1	Figure 4-2	Figure 4-3	Figure 4-4
A				
B				
C				
D				
E				

Table 4-2: Resistors values for circuit in Figure 4-5 (prelab, part 2)

Resistor	Resistance (Ω)
R_1	
R_2	
R_3	
R_4	
R_5	

PROCEDURE

Total Resistance in a Series Circuit

1. Show your pre-lab work to the instructor at the beginning of the lab session.
2. Before you connect the circuit in Figure 4-6, measure each individual resistor and record in Table 4-3.
3. Connect the circuit in Figure 4-6 with the voltage source removed measure the total resistance (R_{Total}) and record in Table 4-3.

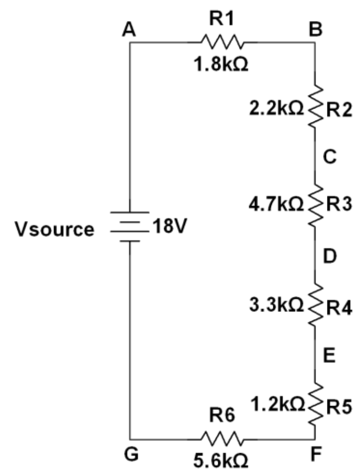

Figure 4-6 Series circuit diagram for measuring the total resistance, current and resistors voltage

Current Relationship in a Series Circuit

4. Connect the circuit in Figure 4-6, measure and record in Table 4-4 the current at nodes A, B, C, D, E, F, and G. To measure the current through a node, break the circuit at that node and remake the circuit by inserting the ammeter at that node. The ammeter must be connected in such a way that circuit current will be forced to flow through the meter.

Verifying Voltages in Series Circuit

5. For the circuit in Figure 4-6;
   a. Measure and record in Table 4-5 the voltage drop across each resistor. When measuring V_{AB}, the voltmeter probe should be connected to point A and the common lead to point B. This would be expressed as V_{AB}. Note that in the subscript "AB", the first letter "A" is the point to which the probe is connected and the second letter "B" is the point to which the common lead is connected. Therefore, the expression V_{AB} means the voltage at point "A" with respect to point "B".
   b. Properly label these measured voltage drops on each resistor in Figure 4-6. Mark the polarity (use a + and a - to indicate polarity) of the voltage drop on each resistor.
   c. Measure the voltage V_{CE} (record in Table 4-5), which is the voltage at point C with respect to point E. When measuring, the voltmeter probe should be connected to point C and the common lead to point E. Note that in the subscript "CE", the first letter "C" is the

point to which the probe is connected and the second letter “E” is the point to which the common lead is connected. Does $V_{CD} + V_{DE} = V_{CE}$?

   d. In similar manner, measure and record V_{AC}, V_{CA}, V_{DG}, V_{EA}, V_{BF}, and V_{CG}

6. Connect the circuit in Figure 4-7;
   a. Measure and record in Table 4-6 the voltage drop across each resistor. Recall that the probe is connected to the first subscripted node, and the common is connected to the second subscripted node.
   b. Properly label these measured voltage drops on each resistor in Figure 4-7. Mark the polarity (use a + and – to indicate polarity) of the voltage drop on each resistor.
   c. Connect the common lead of the DMM to ground, which is point E. With the DMM probe, measure and record the voltage at each of the points A, B, C, D, and E. A voltage listed with a single subscripted variable means that voltage is measured with respect to ground.

Note: According to Kirchhoff’s voltage law, $V_B = V_{DE} + V_{CD} + V_{BC} = V_{BE}$. Do your measured values from 6a and 6c show that $V_B = V_{DE} + V_{CD} + V_{BC}$?

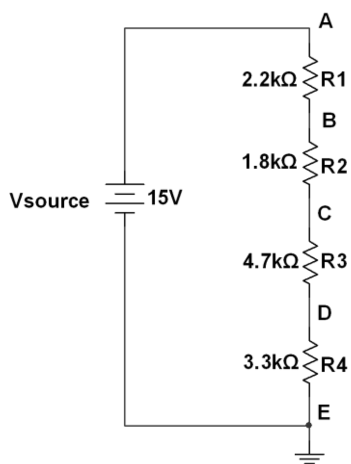

Figure 4-7 Series circuit diagram for part 6 of the procedure

7. For the circuits in Figures 4-1, 4-2, 4-3 and 4-4;
   a. Measure the voltage at all points (A, B, C, D, E) with respect to this new reference point. Record the measured voltage at each point in Table 4-7.
   b. Be sure to move the reference point (ground) to agree with the schematic, in each case.

Designing a Voltage Divider

8. Connect the circuit of Figure 4-5 based on the results obtained in part 2 of the prelab.
   a. Measure and record in Table 4-8 the voltage at points A, B, C and D

DATA/OBSERVATIONS

Table 4-3: Resistance measurements for circuit in Figure 4-6

Resistor	Resistance (Ω)
R_1	
R_2	
R_3	
R_4	
R_5	
R_6	
R_{Total}	

Table 4-4: Current measurements for circuit in Figure 4-6

Node	Current
A	
B	
C	
D	
E	
F	
G	

INSTRUCTOR'S INITIALS: DATE:

Table 4-5: Voltage measurements for circuit in Figure 4-6

Measurement Point	Voltage
$V_{R1}=V_{AB}$	
$V_{R2}=V_{BC}$	
$V_{R3}=V_{CD}$	
$V_{R4}=V_{DE}$	
$V_{R5}=V_{EF}$	
$V_{R6}=V_{FG}$	
V_{CE}	
V_{AC}	
V_{CA}	
V_{DG}	
V_{EA}	
V_{BF}	
V_{CG}	

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Table 4-6: Voltage measurements for circuit in Figure 4-7

Measurement Point	Voltage
$V_{R1}=V_{AB}$	
$V_{R2}=V_{BC}$	
$V_{R3}=V_{CD}$	
$V_{R4}=V_{DE}$	
V_A	
V_B	
V_C	
V_D	
V_E	

Table 4-7: Voltages measured at points A, B, C, D and E for part 7 of the procedure

Voltage	Figure 4-1	Figure 4-2	Figure 4-3	Figure 4-4
A				
B				
C				
D				
E				

INSTRUCTOR'S INITIALS:		DATE:	

Table 4-8: Voltages measured at points A, B, C, and D for part 8 of the procedure

Measurement Point	Voltage
V_A	
V_B	
V_C	
V_D	

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POST-LAB

1. Add the measured values of R_1, R_2, R_3, R_4, R_5, and R_6 recorded in step 2 of the procedure. Record the total.
2. Perform a computer simulation of the circuit in Figure 4-5 using PSpice or Multisim, and use the results to verify Prelab resistor value placement. Print the simulation with voltages, and submit it with this report.
3. Noting the relationship between the voltages measured between two points and the indicated individual voltage drops labeled on each resistor in Figure 4-6. Explain how the voltage between two points could be predicted prior to actually measuring with the DMM.
4. Explain how to determine the location of the 5.6 kΩ resistor in the voltage divider of Figure 4-5.
5. What conclusions can be made from the results of the experiment?

Be sure to include all items from the post-lab exercise above in your written lab report.