Experiment 5 — Voltage Divider Rule for Series Circuits

EL 111 - DC Fundamentals

By: Walter Banzhaf, E.K. Smith, and Winfield Young
University of Hartford
Ward College of Technology

Objectives:

1. For the student to examine the relationship between combinations of voltage drops and combinations of resistance values in a series circuit.
2. For the student to measure voltage with respect to a common reference point at various points in a series circuit.
3. For the student to apply the “voltage divider rule” in a series circuit.
4. For the student to design a voltage divider, given desired output voltages in respect to a “common” or “ground” point in a series circuit.

Equipment and parts:

- Meters: Agilent 34401A Digital Multimeter (DMM)
- Resistors: 1.2 kΩ, 1.8 kΩ, 2.2 kΩ, 3.3 kΩ, 4.7 kΩ, 5.6 kΩ, 9.1 kΩ
- Misc: Component Board
- Power Supply: Agilent E3631A DC power supply (0 to 20.0V DC)

Information:

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, called “common” or “ground” is established, 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. The symbol for this “common” point is () and is sometimes called “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:

the ratio of V_{source} is to R_{total} as V_1 is to R_1 and **the ratio of V_{source} is to R_{total} as V_2 is to R_2**, etc.

Mathematically stated:

$$\frac{V_{source}}{R_{total}} = \frac{V_1}{R1} \qquad \frac{V_{source}}{R_{total}} = \frac{V_2}{R_2}$$

NOTE: this is just Ohm’s law: I = V/R, where I is constant

If the equations above are solved for the voltage drops:

$$V_1 = V_{source}\left[\frac{R_1}{R_{total}}\right] \text{ and } V_2 = V_{source}\left[\frac{R_2}{R_{total}}\right]$$

This is called the VOLTAGE DIVIDER RULE.

Stated in words: "The voltage across a resistor is a fraction of the total voltage. 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 given the total resistance, source voltage and desired voltage drop:

$$R_1 = R_{total}\left[\frac{V_1}{V_{source}}\right]$$

Using the above, the student will design a voltage divider to supply various voltages in respect to "common" given a source voltage, a group of resistors, and the values of desired voltages.

Procedure:

1. **Verify by measurement, the voltages between various points in a series circuit:**

   a. Connect the circuit in Figure 1.

   b. Measure and record below 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" in respect to point "B".

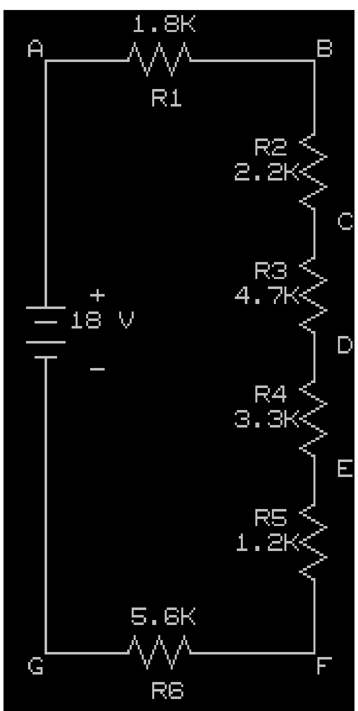


Figure 1

$V_{R1} = V_{AB}$ = ______________

$V_{R2} = V_{BC}$ = ______________

$V_{R3} = V_{CD}$ = ______________

$V_{R4} = V_{DE}$ = ______________

$V_{R5} = V_{EF}$ = ______________

$V_{R6} = V_{FG}$ = ______________

   c. Properly label these measured voltage drops on each resistor in Figure 1. Mark the polarity (use a **+** and a **-** to indicate polarity) of the voltage drop on each resistor.

d. Measure the voltage, V_{CE}, between point C and point E. When measuring, the voltmeter probe should be connected to point C and the common lead to point E. This would be expressed as V_{CE}. 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. Therefore, the expression V_{CE} means the voltage at point "C" in respect to point "E". Record this voltage.

V_{CE} = ______________

Does $V_{CD} + V_{DE} = V_{CE}$? V_{CD}__________ + V_{DE}_________ ≟ V_{CE}__________

e. In a like manner, measure and record the following:

V_{AC} = ____________ V_{CA} = ____________ (note opposite polarity!)

V_{DG} = ___________ V_{EA} = ___________ V_{BF} = ___________ V_{CG} = __________

f. Noting the relationship between the voltage measured between two points and the indicated individual voltage drops labeled on each resistor in figure 1, explain how the voltage between two points could be predicted prior to actually measuring with the DMM.

____

____

____

2. **Measuring voltage in respect to "ground" (⏚):**

a. Connect the circuit in Figure 2A.

b. Measure and record below 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.

$V_{AB} = V_{R1}$ = _______________

$V_{BC} = V_{R2}$ = _______________

$V_{CD} = V_{R3}$ = _______________

$V_{DE} = V_{R4}$ = _______________

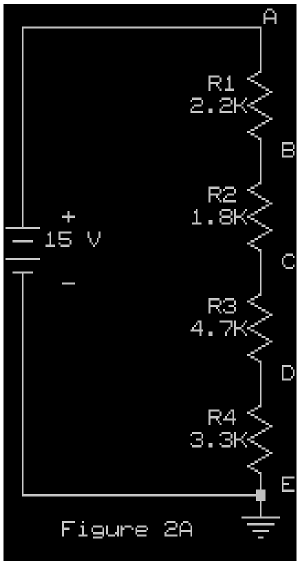


Figure 2A

Properly label these measured voltage drops on each resistor in Figure 2A. Mark the polarity (use a **+** and a **-** to indicate polarity) of the voltage drop on each resistor.

c. Connect the common lead of the DMM to the point with the symbol, which is point E. With the DMM probe, measure and record the voltage at each of the points A, B, C, D, E. A voltage with a ***single subscripted variable*** means that voltage is measured with respect to ***ground***.

V_D = _______ V_C = _____ V_B = _______ V_A = _______

V_E = _______

NOTE: According to Kirchhoff's voltage law, $V_B = V_{DE} + V_{CD} + V_{BC} = V_{BE}$. Do your measured values from 2.b and 2.c show that $V_B = V_{DE} + V_{CD} + V_{BC}$?

d. Refer to circuit 2B below, with the symbol at point D. Measure the voltage at all points (A, B, C, D, E) in respect to this new reference point. Record the measured voltage at each point on circuit diagram 2B.

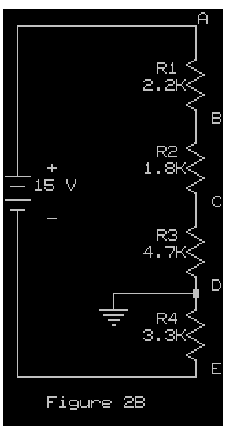


Figure 2B

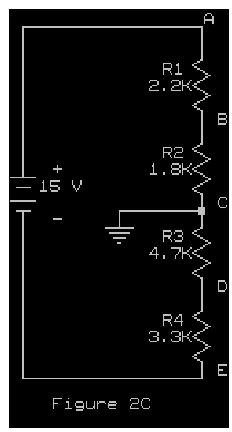


Figure 2C

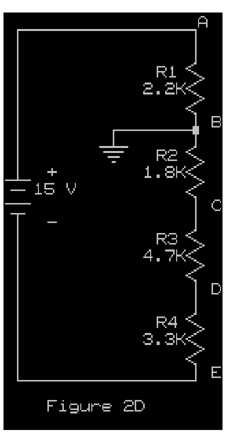


Figure 2D

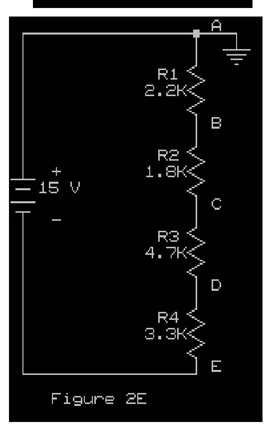


Figure 2E

e. Repeat step 2.d, above, three times: for Figures 2C, 2D and 2E.

Be sure to move the reference point (ground) to agree with the schematic, in each case. Record the results on Figures 2C, 2D and 2E.

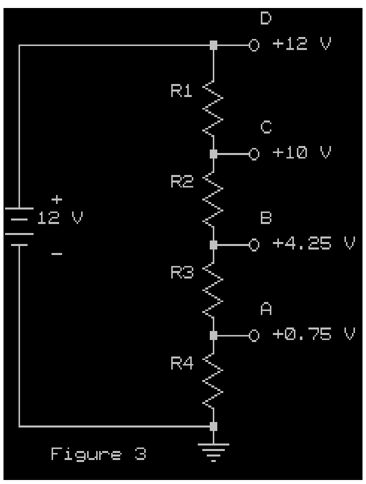
3. **Use the voltage divider rule (VDR) developed in procedure 1:**

   a. For the circuit in figure 2B, calculate (using the VDR) the voltage at each point, A, B, C, D, and E with respect to . Record the calculations on your data sheets (***separate sheets of paper***) and refer to them in your lab report.

   b. In the same manner, repeat step 3.a for each of the other circuits 2C, 2D and 2E.

4. **Designing a voltage divider:**

   a. Refer to the circuit of Figure 3. R_1, R_2, R_3, and R_4 are 1.2 kΩ, 5.6 kΩ, 3.3 kΩ and 9.1 kΩ resistors, **but not in that order**. Using the VDR in the form that solves for resistance (R) rather the voltage (V), solve for the necessary resistor placements (or locations) that will result in the voltages as shown. Record below the resistor value you determined for:



R_1 = ____________ R_2 = __________

R_3 = ____________ R_4 = __________

R_T = ______________________

   b. Connect the resistors in the progression developed in step 4a.

   c. Measure the voltage at points A,B,C, and D. Record.

V_A = ___________ V_B = ______________

V_C = __________ V_D = _____________

d. Explain how to determine the location of the 5.6 kΩ resistor in the voltage divider of Figure 3.

e. Explain how to determine the resistance size required in <u>any</u> voltage divider, when you are given the data in the same manner presented above.