RUTGERS UNIVERSITY
The State University Of New Jersey
School Of Engineering
Department Of Electrical And Computer Engineering

332:223 Principles of Electrical Engineering I Laboratory
Experiment #1
Title: Power Supplies, Multimeters, and Simple Resistive Circuits

1-INTRODUCTION:

The main objective of this laboratory experiment is to get acquainted with various typical equipment that is needed in order to do experiments involving circuits. Such equipment consists of Power Supplies, Multimeters, and Oscilloscopes. In this laboratory experiment we get acquainted with Power Supplies and Multimeters. We will study Oscilloscopes in another Subsequent experiment. In order to get acquainted with Power Supplies and Multimeters, we will perform some simple experiments dealing with Ohm's law, voltage and current division. For your laboratory report, you will also be asked to simulate in Pspice or Multisim the behavior of the circuits you worked with. If you need more time for such simulations, first submit the report except possibly the simulations, and then at a later time specified by the instructor submit the simulations.

1.1-THE POWER SUPPLIES:

The power supply is a device that provides a DC or AC voltage or current source whose level can be adjusted by a knob on the device.

1.2-THE MULTIMETER:

The Multimeter is a basic tool in circuits laboratory, and it is used to measure the primary signal variables, *current* (in amperes, A) and *voltage* (in volts, V), as well as an important parameter of an element called *resistance* (in ohms, Ω). There are two common types of multimeters, digital multimeter (DMM) and analog multimeter (AMM).

The value indicated by the analog multimeter is determined by comparing the pointer, or needle, to one of the scales printed in the face of the meter. The particular scale used for the measurement is determined by several controls on the front of the multimeter. These controls provide for combinations of three measurement parameters: *function, scale,* and *zero ohms.*

The function variable determines which variable the multimeter will measure: volts, amperes or ohms. This manual uses a widely accepted vernacular to describe the three standard functions on AMMs and DMMs. *Ohmmeter* identifies an instrument used to measure resistance. *Ammeter* and *Voltmeter,* as you might expect, describe instruments used to measure current and voltage.

The scale switch is used to set the sensitivity (or range) of the multimeter. Typically, multimeters can measure voltage and current on four or more different scales. For voltage and current functions, the number selected by the scale switch indicates the maximum value that can be measured on that particular scale. Therefore if you set the scale switch to 50 V, the scale that ends with 50 is used to determine the measured value. Resistance measurements are

Usually an iterative process. Unlike the voltage and current functions, the ohmmeter requires that it be zeroed on the particular resistance scale that is being used. A good practice is to set first the highest scale and go down to lower scales as necessary while zeroing on each scale every time it is selected. Zeroing a resistance scale can be done as follows: Select a scale and connect a simple copper wire between the two terminals of the meter. Since the resistance of a simple copper wire is considered as zero, the meter should indicate a zero value. If it is not so, adjust the knob on the meter until it reads zero.

2- THEORETICAL CONSIDERATIONS:

2.1 Ohm's Law:

Ohm's Law states that the voltage across a resistor is directly proportional to the current flowing through the resistor. The constant of proportionality is the resistance value of the resistor in ohms (Ω, **Capital omega**). The circuit symbol for the resistor is shown in fig. 1. For the current and the voltage shown, Ohm's Law is

$$v = Ri$$

where $R \geq 0$ is the resistance in ohms (Ω),
v is the voltage in volts (V), and
i is the current in amperes (A).

Fig. 1 Ohm's Law

We can calculate the instantaneous power consumed by a resistor in several ways:

$$P = vi = i^2R = v^2/R = v^2G, \quad \text{(Eq. 1)}$$

where $G = 1/R$ is the conductance in mhos.

2.2 Voltage Division:

There are times, especially in electronic circuits, when it is necessary to develop more than one voltage level from a single voltage supply. This can be done by the circuit shown in Fig. 2 which is known as a voltage divider circuit.

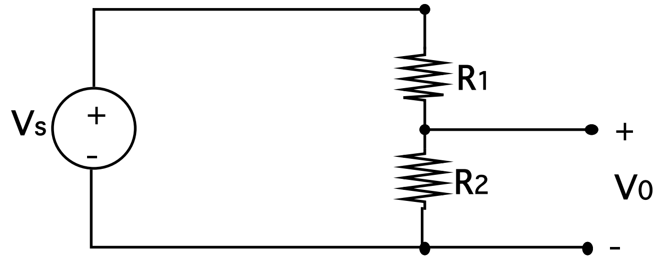


Fig. 2 The Voltage Divider Circuit

After direct application of Kirchhoff's Laws and Ohm's Law, we obtain

$$V_0 = V_s R_2/(R_1 + R_2). \quad \text{(Eq. 2)}$$

If the load on the voltage divider is symbolized by R_L as shown in Fig. 3, the expression for the output voltage becomes

$$V_0 = V_s R_2/[R_1(1 + R_2/R_L) + R_2]. \quad \text{(Eq. 3)}$$

In this case R_L loads the voltage divider (draws current from it), and consequently V_0 is smaller than for the ideal case when R_L is infinity. Note that as shown explicitly by the above equation, the output voltage V_0 depends on the load resistance R_L.

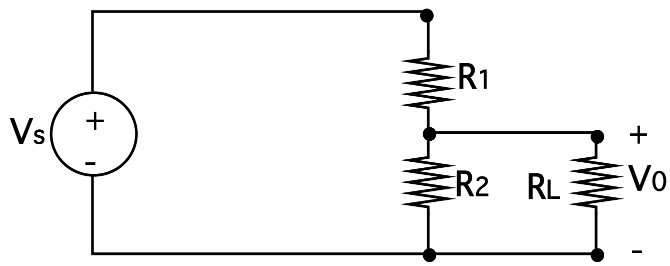


Fig. 3 A Voltage Divider Connected To A Load Of R_L ohms

2.3 Current Division:

The current divider circuit, shown in Fig. 4, consists of two resistors connected in parallel across a current source. The current divider is designed to divide the current **i** between R_1 and R_2. After direct application of Ohm's Law and Kirchhoff's Current Law, we obtain

$$i_1 = i R_2/(R_1 + R_2) \quad \text{(Eq. 4A)}$$
$$i_2 = i R_1/(R_1 + R_2). \quad \text{(Eq. 4B)}$$

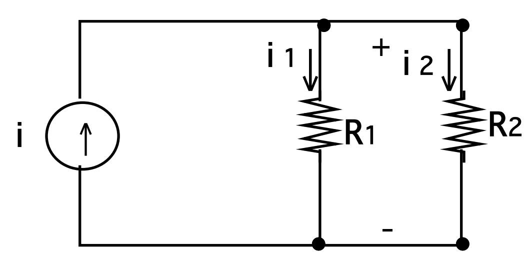


Fig. 4 A current Divider Circuit

3- PRE-LAB EXERCISES:

This being the very first lab no pre-lab exercises are included. In the subsequent lab experiments, pre-lab exercises are provided. Each student is expected to do the exercises and come prepared to the lab. Often, the theory course lags behind the lab in which case your lab instructor can help you with pre-lab exercises.

4- EXPERIMENT:

Suggested Equipment:

TEKTRONIX PS 503 Power Supply
Keithly 179A TRMS Multimeter
0-1000 Simpson Milliammeter or Suitable DMM as available
10 KΩ Resistor
Protoboard

4.1 Ohm's Law: This experiment is designed to verify Ohm’s law.

4.1.1 Wiring:

Arrange the circuit of fig. 5 on the lab bench where each circle indicates a device and the circled A is an ammeter. As a matter of safe practice and convenience, get in the habit of following these rules:

1- Wire always from the load toward the source, not vice-versa.
2- Never make the final connection to the power supply without instructor's approval. We lose a lot of milliammeters and blow a lot of unnecessary fuses the other way.
3- While ammeters must be hardwired into the circuit, it is usually better to add voltmeters last, on top of the existing functional circuit so to speak. (This makes it easy to change a voltmeter connection or to remove it temporarily for a resistance check or some other use.)
4- Make sure that an ammeter is always placed in series with a circuit element through which you want to measure the current.
5- Also, make sure that a voltmeter is always placed in parallel with the terminals across which you want to measure the voltage.

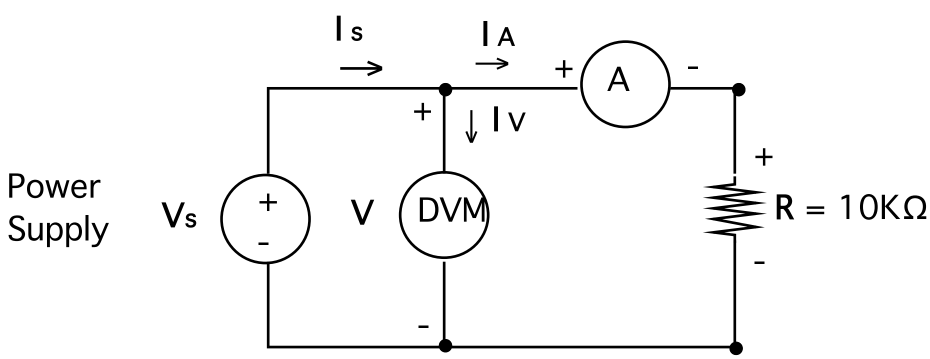


Fig. 5 Schematic Diagram of circuit for V-I measurement

4.1.2 Data Acquisition:

When the instructor has approved your connections, connect the source with an initial output voltage of 0 volts.
Slowly, increase the output voltage of the power supply from 0V to 10V in increments of 1v and read the current I_A on the ammeter. Prepare a table to enter the data V vs I_A.
Note: Prepare your own table with necessary assumptions but state clearly all your assumptions and abbreviations used.

Important notes:

1- The power supply has an internal resistance. This resistance is negligible and so the power supply will behave as almost ideal through our range of measurements.

2- The DVM has a 10MΩ internal resistance. Ammeter has a very small resistance compared to 10KΩ and hence can be neglected. Thus the DVM internal resistance and 10KΩ resistance together form a parallel connection. The resultant resistance of this parallel connection is equal to 9990Ω which is almost equal to 10KΩ. Therefore, the voltmeter current I_V is very small compared to I_A.

Neglecting I_V results in $I_S = I_A$.

Find out whether or not I_V is very small compared to I_A by including an ammeter in series with the DVM. (**Note**: If I_V is significant, it ought to be added to I_A to get I_S.)

4.1.3 Data Checking:

To detect any possible flaws in the data, plot the **V-I** data accurately (A rough plot can be made easily right after you take the data. Bring always some graph sheets to the lab so that you can plot the data easily.). If you do not like the looks of what you have, run the curve over again. Dismantle the circuit only when you are satisfied with the data acquired. Follow this throughout the course.

Note: For the lab reports, students are advised to use a Spreadsheet software like Excel for plotting the data.

4.2 Voltage And Current Division:

4.2.1 Design of A Voltage Divider:

Design the circuit of Fig. 6. Select R_1 and R_2 so that $V_{BC}/V_{AC} = 1/2$. Once you build the circuit, measure V_{BC}/V_{AC} by inserting appropriately the voltmeter to measure V_{BC} and then V_{AC}. Compare the experimental value of V_{BC}/V_{AC} to the theoretical value of $1/2$.
Select R_3 so, when shunted across the terminals **BC**, then $V_{BC}/V_{AC} = 1/4$. Note that R_3 loads the voltage divider circuit. After building the circuit, measure the value of V_{BC}/V_{AC}. Compare the experimental value of V_{BC}/V_{AC} to the theoretical value of $1/4$.

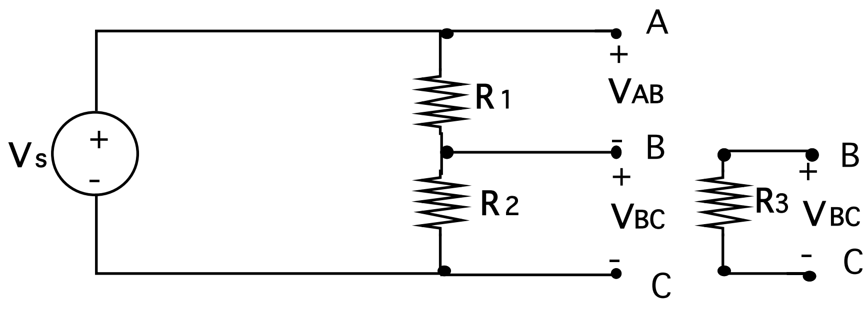


Fig. 6 A Voltage Divider Circuit

4.2.2 Design Of A Current Divider:

Design the circuit of Fig. 7. Select R_1 and R_2 so that $I_2/I_S = 1/2$. Once you build the circuit, measure I_2/I_S by inserting appropriately the ammeter to measure I_2 and then I_S. Compare the experimental value of I_2/I_S to the theoretical value of $1/2$.
Select R_3 so that when placed in series with R_2, then $I_2/I_S = 1/4$. After building the circuit, determine the experimental value of I_2/I_S by inserting appropriate ammeters in the circuit. Compare the experimental value of I_2/I_S with the theoretical value.

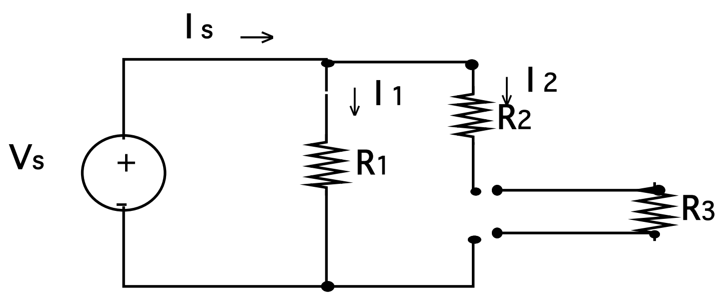


Fig. 7 A Current Divider Circuit

5- REPORT:

5.1 In the experiment corresponding to Fig. 5, compute the resistance R of the given resistor using the following three methods and compare the results:
(a) By reading the color code.
(b) Using the Ohmmeter.
(c) Using Ohms law i.e., by measuring the voltage across and current through the resistor.
(d) Using the formula,
%error = [(actual value - measured value)/measured value] * 100,
determine the % error in the resistance values.
(Use the ohmmeter reading as the actual value.)

5.2 A variable resistor is connected to a constant voltage source. Explain how the current through the resistor changes as its resistance varies from zero to infinity; when and how are these extreme cases feasible with a constant voltage source.

5.3 Derive Eqs. 2, 3, 4A, and 4B.

5.4 Prepare a table that includes the V-I data obtained in section 4.1.2.

5.5 Compare the data in item 5.4 with the values directly calculated from Ohm's Law.

5.6 Plot the data in item 5.4 on a graph paper with rectangular coordinates.

5.7 From the graph plotted in item 5.6 calculate the value of the experimental resistance used.

5.8 Submit the circuits designed in Section 4.2. Show mathematically how you selected all the resistors' values for your designs.

5.9 Simulate, in Spice or in Multisim, the voltage divider circuit designed in Section 4.2.1 for a DC source of 10V to find the voltage across the terminals **AC**, **AB**, and **BC** before and after the resistance load is added.

5.10 Simulate, in Spice or in Multisim, the current divider circuit designed in Section 4.2.2 for a DC source of 10V to find the currents I_S, I_1, and I_2 before and after the resistor R_3 is added.

5.11 Confirm the results of items 5.9 and 5.10 mathematically.

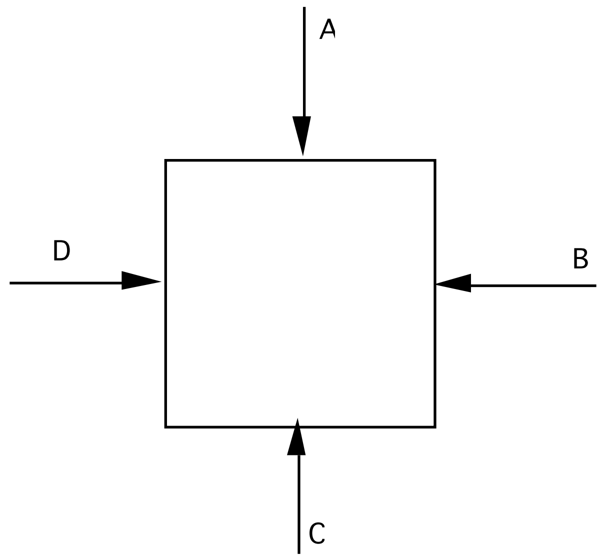
5.12 Prepare a summary.

(**NOTE**: For all the % error calculations, use the theoretical value as the actual value unless otherwise stated.)

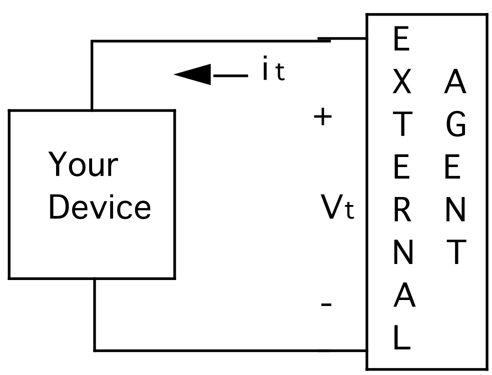
Design Exercises:
The following exercises are given to promote your understanding of the material that is being covered in the class.

5.13 Design circuits that produce equivalent resistance of 10 KΩ, 2 KΩ, 1 KΩ, 4.2 KΩ, and 3 KΩ **within 5% error** using only 3.3 KΩ resistors. Minimize the number of resistors used and never use more than six resistors. Show that all your designs do work. Note that all the designs may not be feasible within the given constraints. If so, explain why you cannot honor all the constraints in your design and point out which constraints you violated.

5.14 The box shown in the figure on the next page contains only resistors. An ohmmeter is used to measure the resistances between each pair of terminals and results obtained are $R_{A\text{-}B}$ = 8.33 KΩ,$R_{A\text{-}C}$ = 15 KΩ, $R_{A\text{-}D}$ = 15 KΩ, $R_{B\text{-}C}$ = 13.3 KΩ, $R_{B\text{-}D}$ = 13.3 KΩ and $R_{C\text{-}D}$ = 0 KΩ. Give one possible circuit that might exist inside the box.
You need to think carefully all possibilities; the problem is not difficult.



5.15 The voltage and current were measured at the terminals of the device shown in figure below. In the given network connection and for the marked current and voltage directions, the power $V_t I_t$ is supplied by the external agent to your device. The results of supplying various voltages and the corresponding currents are tabulated as shown.



v_t (V)	i_t (A)
100	0
180	4
260	8
340	12
420	16

a) Construct a circuit model consisting of a voltage source and a resistance in series for the device.

b) Use the model to predict the amount of power the device will deliver to a 5 Ω resistor. Note that the 5 Ω resistor is now connected in place of the external agent.

Note: In the theory course, the above type of problem will be done. By the time you write the report if the material is not covered, you are excused doing this problem. Check with your lab instructor by email.