ELECTRICAL ENGINEERING
School of Engineering

EGRE 206 -- ELECTRICAL CIRCUITS

Laboratory No. 1: Basic Laws and Meters

Week of January 23, 2001

***PRE-LAB ASSIGNMENT*: COMPLETE THE CALCULATIONS IN SECTION III BEFORE COMING TO LAB. THESE SHOULD BE IN YOUR LAB NOTEBOOKS. A CHECK WILL BE PERFORMED**

I. Abstract

This section will contain a brief summary of your lab objectives and results. No more than 50 – 100 words. It will be graded closely for grammar and style. It will also be graded for the effectiveness in communicating the appropriate ideas.

II. Introduction

This laboratory will investigate the basic circuit laws and operation of digital multimeters and power supplies. You are already familiar with Ohm's Law, Kirchhoff's Voltage Law, and Kirchhoff's Current Law from the course EGR101, An Introduction to Engineering. Therefore, in addition to verifying these laws, we will concentrate on understanding better the accuracy and errors associated with electrical measurements, and on the format and content of writing a good engineering laboratory report.

An accompanying handout [1] will provide introductory material on the accuracy and sources of error of various digital multimeters commonly used in the laboratory. Additional reading on the operation and accuracy of meters and on electrical safety may be found in your textbook [2].

The content of these sections will be outlined in these laboratory directions. For example, in this **Introduction**, the following material should be presented:

1. Statement of experimental purpose or objective
2. Brief review of existing information
3. Summary of experimental intention and procedure

III. Theory

The following outlines a sample **Theory** section. Complete the calculations where indicated in your report. The dc resistive circuit shown in Figure 1 is used for this investigation:

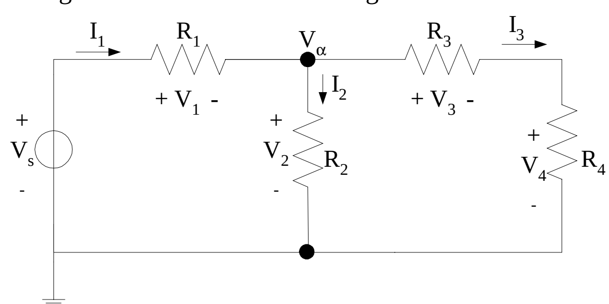

Figure 1: dc Resistive Circuit

A. Ohm's Law, V=IR, states that the voltage V across a resistive element is directly proportional to the current I flowing through it, and is related by a constant known as resistance R. Write the Ohm's Law equations for the four resistors in the circuit of Figure 1.

B. Kirchhoff's Voltage Law (KVL), $\Sigma V_i = 0$, states that the algebraic sum of the voltages around any closed path or loop in the circuit is zero. Write the KVL equations for the meshes in the circuit of Figure 1.

C. Kirchhoff's Current Law (KCL), $\Sigma I_i = 0$, states that the algebraic sum of the currents at any node in the circuit is zero. Write the KCL equation at node α in the circuit of Figure 1.

D. Write the solutions for I_1, V_1, I_2, V_2, I_3, V_3, and V_4 in terms of V_S, R_1, R_2, R_3, and R_4. (Note: use any circuit analysis techniques available to you.)

IV. Test Procedure

The following outlines a *sample* **Test Procedure** section. Details of experimental setup and measurement methodology should be **clearly and accurately** recorded in your laboratory notebook.

The laboratory work associated with this investigation is conducted in three stages. First, the resistors for the circuit in Figure 1 are selected and measured. The circuit is then assembled on the protoboard and connected to the dc power supply. Second, the measurements of currents and voltages are taken with the source voltage set to 20.0 Volts. Third, the measurements of currents and voltages are taken with the source voltage set to 2.0 Volts.

A. Resistor values are chosen for the circuit in Figure 1. Choose five different values for R_1, R_2, R_3, and R_4. Keep in mind that these are ¼ Watt resistors, and you do not want to burn up any of these resistors. Use the theoretical results derived above to help guide you in proper choices for these resistors. Measure the actual resistance values of the resistors and record the results in a Table in your lab notebooks.

B. Figure 2 shows a sample experimental set-up to measure voltages and currents. Measure I_1, V_1, I_2, V_2, I_3, V_3, V_4 for a source voltage V_S = 10.0 V. Record the results in a Table in your lab notebooks.

C. Repeat these measurements for a source voltage V_S = 1.0 V. Record the results in a Table in your lab notebooks.

NOTES: Since a voltmeter measures the voltage across an element in a circuit, it must be connected in **parallel** with element. To measure current through an element, an ammeter must be inserted in **series** with the element to force all of the element current through the ammeter. Care must be taken when using these meters so that the effects of internal meter resistance are considered when interpreting the results.

To measure resistance with an ohmmeter, the element to be measured must always be **isolated** (or disconnected) from the remainder of the circuit as well as any energy sources.

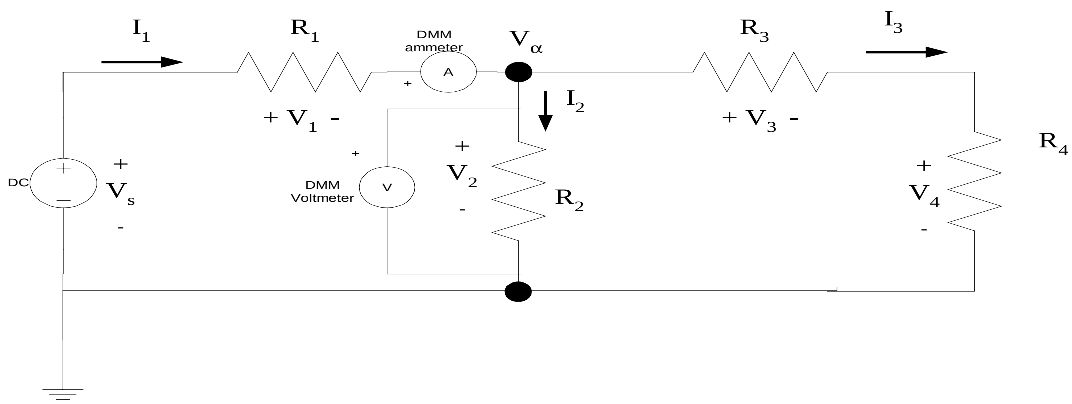

Figure 2: dc Resistive Circuit with Digital Multimeters

V. Results and Discussion

A. It is necessary for the experimental outcomes to be **clearly, factually, and prominently** stated. The experimental findings can then be objectively compared with the theoretical model and calculations. Discrepancies between theory and experiment should be explored by analyzing possible associated errors. The measured **Results** should be presented in your laboratory report in table and graphical form.

In this laboratory, two (2) tables should suffice. Table 1 would be for Vs = 10 V and Table 2 for Vs = 1.0 V. There should be at least three columns (calculated, measured, and percent error given by $\frac{M-C}{C} x100\%$, where *M* is measured value and *C* is the calculated value). Perhaps as a footnote in the table, the values of resistance used should be shown for further clarification.

NOTE: In the "calculated" column, make use of the actual, measured resistance values for the resistors in the theoretical expressions derived in Section II

B. The **Discussion** portion of this section should concentrate on two things:

First, explain if the data presented bears out the experimental purpose or objective. In this lab, do the measurements support Ohm's and Kirchhoff's Laws? One way to check this is by examining the various errors. The error in satisfying the basic circuit laws can be assessed by stating (or restating) each basic circuit law equation in a form Σ X = 0 + error. Thus, the error in satisfying the KVL equations is assessed from Σ V = 0 + error. Likewise, the error in satisfying the KCL equation is obtained from Σ I = 0 + error. The error in satisfying each Ohm's Law equation is found from V - IR = 0 + error. The basic circuit law errors found in this investigation should be recorded in Table 3.

Second, possible sources of error in both theoretical calculations and experimental measurements need to be identified and quantified. Two sources of theoretical error to be considered include:

1. Modeling Error: accounts for the many approximations and simplifications used to arrive at simple theoretical relationships, thus resulting in limited model accuracy. More complex component models, such as those used in PSpice, can be used to compare with experimental results when analytical models are not accurate enough.
2. Parametric Error: results from component and device parameter values differing from those used to calculate the theoretical or expected performance characteristics. Parametric error can be greatly reduced in most cases by measuring all specific device and component values.

Three sources of experimental error to be considered include:

1. Systematic Error: affects all measurements from a certain piece of test equipment in an equal or consistent manner. A primary source of this error is calibration error, such as a meter that is not "zeroed".
2. Measurement Error: occurs in all test instruments of limited precision. There is uncertainty in all measurements, usually expressed as a percentage of the center value. Examples are found in the handout [1] for voltage and current measurements made by modern DMMs, such as DC voltage measurements with ± 0.4% error.
3. Meter Loading Error: is a form of measurement error associated with real measurement equipment. As outlined in the handout [1], a practical voltmeter has a very large, but finite internal resistance that absorbs some small amount of energy from the circuit, hence perturbing the circuit. Likewise, a practical ammeter has a very small, but nonzero internal resistance that perturbs the circuit. These perturbations can lead to sizable errors. Caution must be exercised to make sure that the act of measuring a quantity does not significantly change the circuit under test. Avoid using several meters simultaneously to measure multiple quantities in a circuit.

A full quantitative analysis of the total error in both calculations and measurements can be very involved. Often a quantity of interest is obtained from a series of calculations or measurements, each with its own error. The total accumulated error can be estimated as a worst case calculation, or better, as a root-sum-squares of individual uncertainties. These estimates require knowledge of differentials of multivariable functions, and will be addressed in EGRE224.

VI. Conclusions and Recommendations

This section concludes your report. It is a summary of laboratory results and findings in concise form. **No new ideas are introduced in this section**! Include your recommendations on how you would modify measurement procedures, design methods, analysis presentation, etc. (perhaps to minimize error) **Don't simply state that the lab worked** but instead state what you learned and verified in performing the laboratory exercise. Do the results support the theory? Are there any recommendations you can make to perhaps make this a better experiment?

VII. References

List references when specific material has been cited from books, articles, notes, etc. A publication need only be listed once. Use the following format:

[1] "Meters and Measurements." ELE206 Course Handout, Electrical Engineering, Virginia Commonwealth University, 1997.

[2] J. Nilsson and S. Riedel, Electric *Circuits*, Fifth Edition. Reading, MA: Addison-Wesley, 1996. Pp. 26, 50-51, 71-75.

[3] D.C. Baird, *Experimentation, An Introduction to Measurement Theory and Experiment Design*, Third Edition. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1995. Chpt. 7.