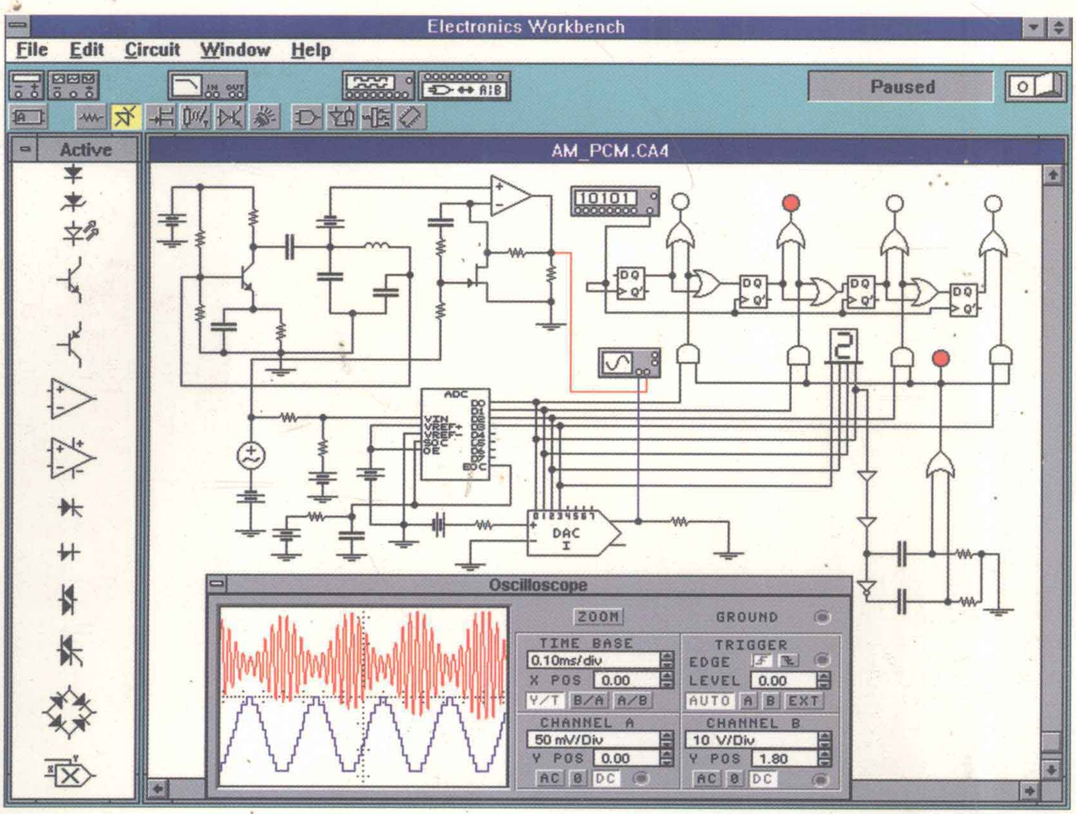
RICHARD H. BERUBE




# Computer Simulated Experiments for Electric Circuits Using Electronics Workbench®

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# Computer Simulated Experiments for Electric Circuits Using Electronics Workbench®

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# Preface

*Computer Simulated Experiments for Electric Circuits using Electronics Workbench* is a unique and innovative laboratory manual that uses Electronics Workbench to simulate actual laboratory experiments on a computer. Computer simulated experiments do not require extensive laboratory facilities, and a computer provides a safe and cost effective laboratory environment. Circuits can be modified easily with on-screen editing, and analysis results provide faster and better feedback than a series of experiments using hardwired circuits.

Electronics Workbench is similar to a workbench in a real laboratory environment except that circuits are simulated on a computer and results are obtained more quickly. Electronics Workbench includes a central workspace, a parts bin, and instruments stored on a shelf above the central workspace. A mouse is used to build the circuit in the central workspace, attach simulated test instruments, and run the simulation to display the results on the instruments chosen. The simulator will automatically run the proper simulation based on the particular instruments connected to the circuit. Because circuit faults can be introduced without destroying or damaging actual components, more extensive troubleshooting experiments can be performed using Electronics Workbench. Also, faulty components that are deliberately introduced in a computer simulated circuit can help make it easier to find the faulty component in an actual circuit.

Each experiment in *Computer Simulated Experiments for Electric Circuits using Electronics Workbench* includes a circuit diagram and parts list so that this manual can also be used in a hardwired laboratory environment. If this manual is used in a hardwired laboratory, wire the circuit from the circuit diagram and connect the instruments specified. If exact circuit component values are not available, then use component values as close as possible to those listed in the parts list. After the circuit is wired and checked, turn on the power, record the data in the space provided, and answer the questions. Due to component tolerances, real laboratory data will not be exactly the same as data obtained on the computer simulation. If a closer correlation between the computer simulation results and the hardwired laboratory results is desired, change the component values in your computer simulation circuit to match the measured component values in your hardwired circuit.

The experiments are designed to help reinforce the classroom theory learned in a circuits analysis course. By answering questions about the results of each experiment, students will develop a clearer understanding of the theory. Also, the interactive nature of these experiments encourages student participation, which leads to more effective learning and a longer retention of the theoretical concepts. Experiments that involve a wide range of difficulty have been included so that experiments appropriate for a particular level of instruction can be selected. Experiments 17, 22, 26–28, and 30 are more appropriate for more advanced students than most of the other experiments in this manual.

A series of troubleshooting problems is included at the end of many of the experiments to help students develop troubleshooting skills. In each troubleshooting problem, the parts bin has been removed to force the student to find a fault or component value by making a series of circuit measurements using only the instruments provided. A solutions manual showing measured and calculated data, answers to the questions, and answers to the troubleshooting problems is available.

In order to perform the experiments in this manual on a computer, you need to install the educational version of Electronics Workbench onto your computer system. If Electronics Workbench is not available, it can be obtained from Interactive Image Technologies, Ltd., 111 Peter Street, Suite 801, Toronto, Ontario, Canada M5V2H1 (Tel: 1-800-263-5552, Fax: 416-977-1818).

The disk provided with this manual has all of the circuits needed to perform the experiments on Electronics Workbench version 4. If the experiments are performed on Electronics Workbench version 3, you will need to obtain the *Version 3 circuits disk* from the publisher at no cost. While using Electronics Workbench, make sure that you insert the disk included with the laboratory manual into your disk drive so that you can access the circuits, or you can build the circuits on the computer screen yourself from the figures provided with the experiments. This circuits disk is write protected; therefore, you will not be able to save circuit changes to the disk. (See the Appendix, Note 4.) The manual provided with the Electronics Workbench software will describe how to access your circuit files and how to use Electronics Workbench. Additional notes on using Electronics Workbench have been included in the Appendix at the end of this manual.


## Acknowledgments

I wish to thank Professors Vartan Vartanian, Jerry Bernardini, and Barbara Christe of the Community College of Rhode Island for testing the experiments with their students and for their valuable suggestions during the development of this project. I also wish to thank Dr. Walter Buchanan, Tennessee State University, Stephen C. Harsany, Mt. San Antonio College, and Marcus Rasco, DeVry Institute of Technology, Irving, Texas, whose valuable suggestions for my previous manual have led to many improvements in this manual. I especially appreciate the dedication and talent of the editorial staff of Prentice Hall for their guidance and patience throughout this project.

I also wish to thank Joe Koenig, President, Interactive Image Technologies, and his technical staff for developing Electronics Workbench and giving me valuable technical assistance.

R. H. Berube

# Contents

PART

# I Direct Current (DC) Circuits

The experiments in Part I involve the analysis of dc circuits. You will review Ohm's law and the concept of resistance, Kirchhoff's voltage law and resistors in series, Kirchhoff's current law and resistors in parallel, series-parallel resistance networks, the voltage and current divider rules, the concept of electrical power and the difference between power and energy, the nodal voltage and mesh current methods of circuit analysis, and Thevenin and Norton equivalent circuits.

The circuits for the experiments in Part I can be found on the enclosed disk in the PART1 subdirectory.

Name ______________________________

Date ______________________________

EXPERIMENT

# 1 Voltage and Current in DC Circuits

**Objectives:**

1. Investigate how to use a voltmeter to measure the voltage across a circuit component.
2. Investigate how to use an ammeter to measure the current flow in a circuit component.
3. Investigate how to use the multimeter to measure voltage and current.
4. Demonstrate the two conditions necessary to allow a flow of electric charge in an electric circuit.
5. Investigate the relationship between the voltage applied to an electric circuit and the current flowing in an electric circuit.

## Materials:

One dc power supply (battery)
One dc 0–20 V voltmeter
One dc 0–100 mA milliammeter
One multimeter
One10 V, 1 W lamp

## Preparation:

An electric current (I) is the net flow of electric charge past a point in an electric circuit over a given period of time. An electric current of one ampere is the rate of flow of an electric charge of one coulomb passing a point in an electric circuit in one second. The two conditions necessary for an electric current to exist are a completely closed path and a source of electrical potential (voltage).

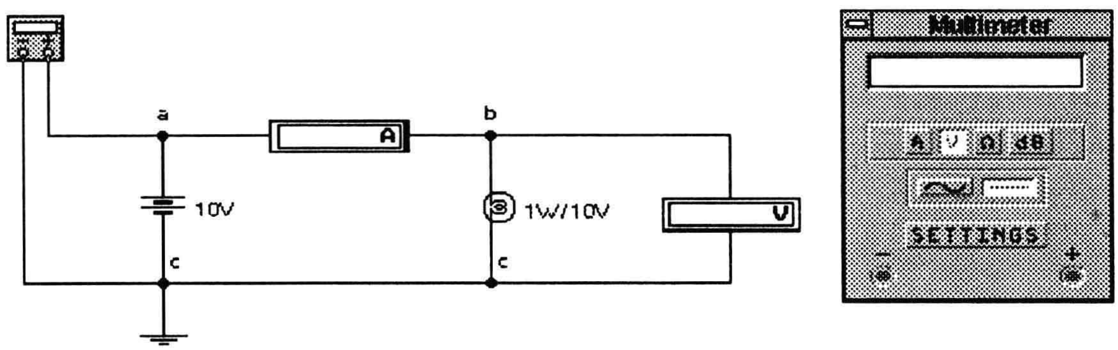
An electric current is measured with an ammeter. To determine the value of an electric current, an ammeter must be connected in the path of the electric current, as shown in Figure 1-1. **Never connect an ammeter across a circuit element, as this will damage the instrument.**

Voltage (V) is the potential to do work by moving an electric charge between two points. An electrical potential of one volt between two points in an electric circuit will produce one joule of electrical energy (work) when moving a charge of one coulomb between the two points. The value of the electric current (I) flowing in a circuit element is a function of the voltage (V) across the terminals of the circuit element. An electric charge does not have to be in motion in order for an electrical potential (voltage) to exist.

Electrical potential (voltage) is measured with a voltmeter and voltage is always measured between two points. A voltmeter is always connected across an electric circuit element, as shown in Figure 1-1.

> *Note*: The measured bulb voltage and current in a hardwired laboratory environment will not be exactly the same as the measured bulb voltage and current on the computer simulated circuit. Real light bulb voltage-current characteristics are nonlinear, while the bulb model in Electronics Workbench is a linear model.

**Figure 1-1 Measuring DC Voltage and Current**




## Procedure:

1. Pull down the File menu and open FIG1-1. Click the On-Off switch and verify that the battery voltage is 10 V as measured by the multimeter. Record the voltage across the lamp terminals (Vbc) and the lamp current (I).

   Vbc = _________ I = _________

**Question:** How did the voltage across the lamp (Vbc) compare with the dc source (battery) voltage? Explain.

2. Disconnect the lamp and the voltmeter from node b. Click the On-Off switch to run the analysis. Record the ammeter current reading (I).

   I = _________

**Question:** What happened to the current reading when the lamp was disconnected at node b? Explain.

3. Reconnect the voltmeter to node b. Record the voltage between nodes b-c (Vbc).

   Vbc = __________

**Question**: What happened to the voltage reading (Vbc) when the lamp was disconnected at node b? Explain.

4. Reconnect the lamp to node b. Change the dc supply (battery) voltage to 0 V. Click the On-Off switch to run the analysis. Record the current (I) reading.

   I = __________

**Question:** What happened to the current (I) when the dc source (battery) voltage was reduced to zero? Explain.

5. Change the dc supply (battery) voltage to 6 V. Run the analysis again. Record the new current reading.

   I = __________

**Question:** What happened to the current reading when the dc source (battery) voltage was changed to 6 V? How did the current reading in Step 5 compare with the current reading in Step 1?* Explain.

6. Disconnect the dc source (battery) from the circuit and rotate it until it is upside down. Reconnect the battery to the circuit at nodes a-c. Change the voltage to 10 V. Click the On-Off switch to run the analysis. Record the current (I) and lamp voltage (Vbc).

   Vbc = ________ I = ________

**Question:** What happened to the current and voltage readings when the dc source (battery) leads were reversed? How did the current and voltage readings in Step 6 compare with the readings in Step 1? Explain.

7. Remove the ammeter from the circuit and replace it with the multimeter, connecting the positive multimeter lead to node a and the negative lead to node b. Set the multimeter controls to measure dc current ( ——— and A). Click the On-Off switch to run the analysis. Record the current (I) reading on the multimeter.

   I = ________

**Question:** How did the ammeter current reading in Step 6 compare with the multimeter current reading in Step 7?

8. Reverse the multimeter leads between nodes a-b. Run the analysis again. Record the new multimeter current reading.

   I = ________

---

*The numbered procedures are referred to as Step 1, Step 2, etc., throughout the book.

**Questions:** What happened to the multimeter current reading when the multimeter terminals were reversed? Compare the reading in Step 8 to the reading in Step 7.

Describe the difference between the way to connect a voltmeter to a circuit and the way to connect an ammeter to a circuit. What precaution must be taken when connecting an ammeter to a circuit? Explain.

Name ____________________
Date ____________________

EXPERIMENT

# 2 Ohm's Law—Resistance

## Objectives:

1. Learn how to use the multimeter to measure resistance.
2. Verify the validity of Ohm's law.
3. Use Ohm's law to determine the resistance of a resistor.
4. Determine the relationship between current and resistance for a constant voltage.
5. Determine the relationship between current and voltage for a constant resistance.
6. Determine the relationship between linear resistance and the slope of the V-I characteristic curve.

## Materials:

One dc variable voltage power supply
One multimeter
One 1–10 mA milliammeter
Assorted resistors

## Preparation:

Ohm's law gives the relationship between the voltage across a linear resistance element and the current through it. Ohm's law states that the voltage across a linear resistance element is proportional to the current, and the proportionality constant is the resistance of the resistance element. An electric circuit element has a resistance of one ohm when a current of one ampere causes a voltage drop of one volt across the element. Ohm's law can be expressed mathematically as follows:

$$V = (R)(I)$$

where R is the resistance of the resistance element in ohms, I is the current through the resistance element in amperes, and V is the voltage across the resistance element in volts.

Ohm's law can also be expressed as $I = V/R$. This relationship shows that the current is inversely proportional to the resistance of the resistance element. This means that a higher resistance produces more opposition to the flow of an electrical current.

If you plot a graph of the current in a resistance element as a function of the voltage across it (V-I characteristic curve), you can determine whether the resistance of the element is linear or nonlinear. If the graph plots as a straight line, the resistance is linear; otherwise it is nonlinear. If a resistance element is linear, the resistance is equal to the inverse of the slope of the line because

$$\text{slope} = \frac{\Delta I}{\Delta V}$$

and

$$R = \frac{V}{I} = \frac{\Delta V}{\Delta I} = \frac{1}{\text{slope}}$$

The circuit in Figure 2-1 shows how to measure the resistance of a resistance element using the multimeter. The circuit in Figure 2-2 will be used to verify Ohm's law.

**Figure 2-1 Measuring Resistance**

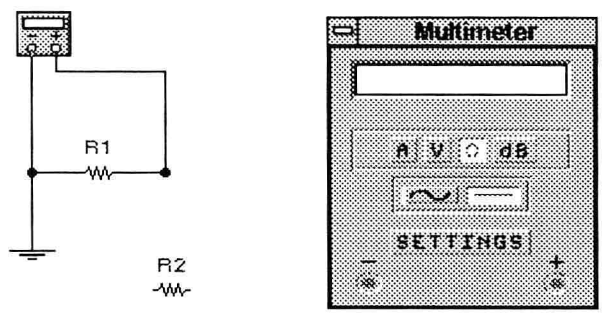
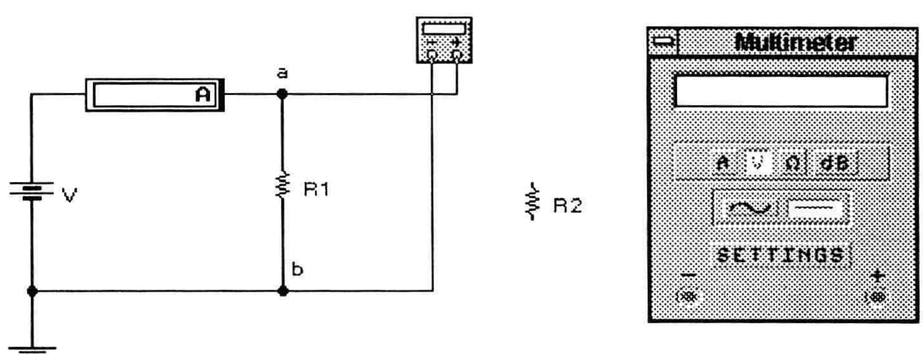



**Figure 2-2 Ohm's Law—Resistance**




## Procedure:

1. Pull down the File menu and open FIG2-1. This circuit shows how to connect the multimeter to a resistor to measure the resistance. Notice the settings selected on the multimeter. Click the On-Off switch to run the analysis. Record the resistance of R1. Next, remove R1 and replace it with resistor R2. Run the analysis again. Record the resistance of R2.

   R1 = ________ R2 = ________

2. Pull down the File menu and open FIG2-2. Click the On-Off switch to run the analysis. Record the voltage across resistor R1 (Vab) and the current through resistor R1 (Iab).

   Vab = __________ Iab = __________

3. Based on the measured values for Vab and Iab, and the value for R1 measured in Step 1, verify Ohm's law for a linear resistance, V = RI.

4. Replace R1 with R2. Run the analysis again. Record Vab and Iab. Calculate the value of R2 using Ohm's law.

   Vab = __________ Iab = __________

**Question:** How did the calculated value of R2 compare with the value of R2 measured in step 1? For a constant voltage in Steps 2–4, what happened to the current (Iab) when the resistance was increased? Explain.