

EE 101	Fall 2007	Date:	Lab Section #:
Lab #2		Name:	
Ohm's and Kirchhoff's Circuit Laws		Partner:	

Abstract

Electrical circuits can be described with mathematical expressions. In fact, it is possible to calculate the currents and voltages in a circuit by solving a set of equations, and this is one reason why advanced mathematics is so important in the field of electrical engineering. The circuit equations can be determined using Ohm's Law, which gives the relationship between voltage and current in a resistor ($V=IR$), and Kirchhoff's Current and Voltage Laws, which govern the currents entering and exiting a circuit node and the sum of voltages around a circuit loop, respectively.

After completing this experiment you should:

- (1) Be able to draw the equivalent circuit of simple series and parallel resistor circuits and to calculate the current in such circuits,
- (2) Be able to construct simple series and parallel resistor circuits on your prototype board and to apply power to your circuit using the bench power supply,
- (3) Be able to use the DMM to measure voltage and current at various parts of a given circuit.

Introduction and Theory

An electrical circuit can contain voltage sources (bench power supply or battery) and one or more additional components, such as the resistors that were used in Lab #1. A point in the circuit where two or more components connect together is called a circuit *node*. A path from one node to another is known as a circuit *branch*. A closed path through the circuit that starts at a particular node and passes through a sequence of components before arriving back at the starting node without the path crossing itself is called a circuit *loop*. All circuits have at least two nodes and at least one loop. It is possible to have several loops in a circuit, and the various loops may partially overlap each other.

One of the fundamental rules for electrical engineers is Ohm's Law, named for Georg Simon Ohm (1789-1854). Ohm discovered a linear relationship between voltage and current in many circuit elements:

$$V = I R$$

where **V** is voltage (volts), **I** is current (amps), and **R** is the resistance of the circuit element that we now measure in the unit of ohms. Another way of interpreting Ohm's Law is that the resistance R is the voltage across the component divided by the current through it: $R = V / I$.

Two other very important rules for understanding electrical circuits are Kirchhoff's Laws, named after Gustav Robert Kirchhoff (1824-1887), who did experiments with electricity in the mid-1800s.

Kirchhoff's voltage law: the sum of the voltages around a circuit loop must equal zero, when following a consistent measurement direction of voltages for each element around the loop. In other words, the total of the voltage steps as you go around a circuit loop must end up back where you started.

Kirchhoff's current law: the sum of all currents into a circuit node must equal zero. In other words, the total current flowing into a node must equal the current flowing out of that node.

Voltage and current measurements use two wires from the multimeter. Voltage can be measured by connecting one of the multimeter wires to one circuit node and the other multimeter wire to a different node: the meter will indicate the relative potential difference—the voltage—between the two nodes. Current is a little more difficult to measure because the meter must actually be connected in series with one of the circuit branches. This means that you have to disconnect part of the circuit, insert the meter, and then take the measurement: the meter will indicate the amount of current passing through it.

Both current and voltage measurements will have a polarity: either positive or negative. A positive voltage indicates that the positive terminal on the meter is connected to a node in the circuit that is at a higher potential than the negative (or common) terminal. Conversely, if the meter displays a negative number, it indicates that the positive meter terminal is connected to a node that is at a lower electrical potential than the meter's common terminal. Similarly, a positive current means that the branch current is flowing into the positive terminal on the meter and out of the negative terminal, while if the meter displays a negative number it means that current is entering the negative meter terminal and exiting via the positive terminal.

Since there are two wires from the multimeter, there are two choices of how the wires are connected in a circuit (black wire here, or red wire here?). Exchanging the meter wires changes the relative polarity of the measurement, so the meter display will switch from positive to negative, or vice versa. Being attentive to the connections and the meter terminal labels allows you to figure out the correct polarity for a given measurement. It helps to be consistent: you are encouraged always to connect the red wire to the meter's positive terminal and the black wire to the negative (or reference) terminal. The color of the wire obviously doesn't change the electrical properties, but it does provide a good visual cue to make it easier to recognize what is going on.

Engineers and technicians frequently use circuit diagrams to show how components and voltage sources are interconnected. Understanding circuit diagrams that others have written, and writing your own circuit diagrams so that others may understand them, is clearly an essential skill for communicating specific technical information in electrical and computer engineering. This lab will provide you a chance to begin to develop your skills in this area.

Prelab

PL1. Consider the circuit shown in Figure 1 in which $R_1 = 470\ \Omega$ and $R_2 = 1\ \text{k}\Omega$. To the right of the figure and inside the box provided, draw the single-resistor equivalent circuit and include the value of the equivalent resistance.

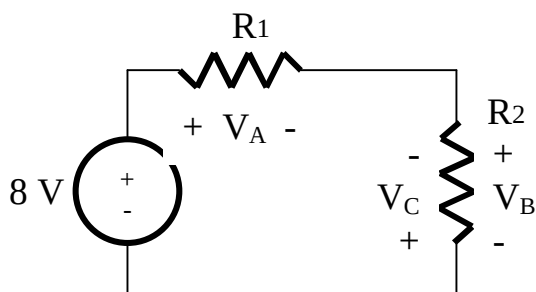


Figure 1: A series circuit

Single Resistor Equivalent Circuit

Calculate the expected current in the series circuit of Figure 1. Show your work below and box your answer.

Instructor's initials_____

PL2. Consider the circuit shown in Figure 2 in which $R_3 = 10\text{ k}\Omega$ and $R_4 = 1\text{ k}\Omega$. To the right of the figure and inside the box provided, draw the single-resistor equivalent circuit and include the value of the equivalent resistance.

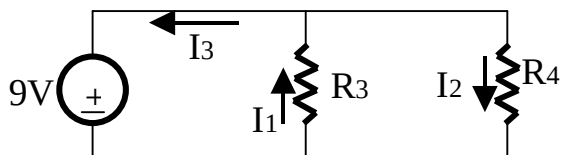


Figure 2: A parallel circuit

Single Resistor Equivalent Circuit

Calculate the expected current flowing in your single-resistor equivalent circuit. Show your work below and box your answer.

Instructor's initials_____

Equipment

Your circuit prototype board, your lab kit (containing resistors, resistor color code chart, potentiometer, and alligator clips), and the bench power supply, multimeter, and banana cables furnished in the lab.

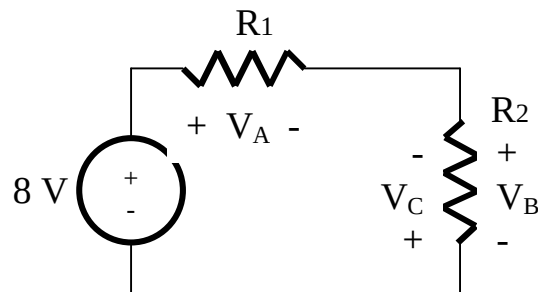
Procedures

P1. → Construct the circuit shown in Figure 1 of the prelab ($R_1 = 470\ \Omega$, $R_2 = 1\ \text{k}\Omega$) on your prototype board. Use the bench DC power supply for the voltage source, using the multimeter to set the supply voltage accurately to 8 volts.

→ Measure voltages V_A , V_B , and V_C and record them in the table below (pay strict attention to the proper polarities).

V_A	V_B	V_C

→ For V_A and V_C , show clearly on the figure below where the red and black wires from the multimeter were connected for your measurements.



P2. Using the voltages you measured in P1, show two example expressions demonstrating Kirchhoff's voltage law: one expression using your measurements for V_A , V_B , and the 8 V power supply, and another expression using your measurements for V_A , V_C , and the 8 V power supply. Provide explanations as to any discrepancy between theory and your measurements.

The P1 circuit is called a *voltage divider*, since the 8 V supply voltage is divided across R_1 and R_2 . Circuit theory can be used to predict the following relationships:

$$V_B = \left(\frac{R_2}{R_1 + R_2} \right) \cdot V_{\text{supply}} \quad \text{and} \quad V_A = \left(\frac{R_1}{R_1 + R_2} \right) \cdot V_{\text{supply}}$$

Using the nominal (labeled) resistor values for R_1 and R_2 and 8 volts for V_{supply} , do the equations match what you measured? Why might your measurements differ?

P3. → Using your prototype board, construct the circuit shown in Figure 2 of the prelab ($R_3 = 10 \text{ k}\Omega$, $R_4 = 1 \text{ k}\Omega$). Use the lab power supply for the voltage source and use the multimeter to set the voltage accurately to 9 volts.

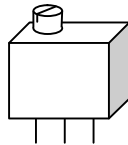
→ Measure currents I_1 , I_2 , and I_3 following the polarities shown in the figure and record your measurements in the table below. Remember that when measuring current you must place the meter *into* the circuit: you can't just touch the meter leads to the nodes the way you can when measuring voltage. This means you have to think carefully about how to separate the desired branch and place the meter *in series* with the branch. ALSO remember that the red lead must be moved from the voltage terminal to the current terminal on the DMM.

I_1	I_2	I_3

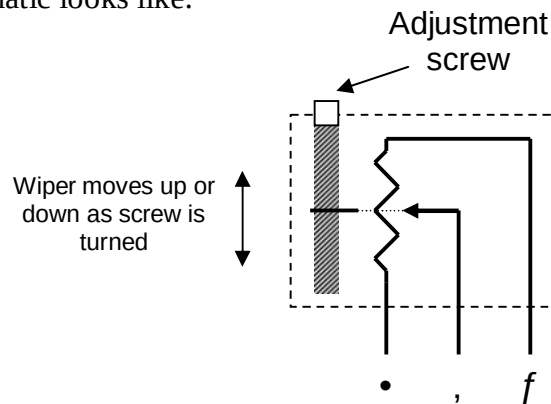
→ Redraw the circuit of Figure 2, indicating on the figure where you inserted the multimeter, including identifying clearly where the red and black wires were attached, when you measured I_1 .

P4. Using the currents you measured in P3, show an expression involving I_1 , I_2 , and I_3 that demonstrates Kirchhoff's current law for one of the circuit nodes and explain how this law relates to your measured currents.

P5. It is sometimes useful to have a way to change the resistance in a circuit without swapping out the resistors. One way to do this is to use a variable resistor, known as a *potentiometer*, and to tweak the resistance setting with a screw or thumbwheel. Find the potentiometer in your lab kit. It should look something like:



The potentiometer (or just 'pot' for short) contains a sliding conductive wiper inside the plastic case that can be moved gradually from one end of the internal resistor to the other by turning the control screw. The internal schematic looks like:



The resistance from terminal 1 to terminal 3 (50 k Ω for the pot in your kit) is fixed, while the resistance from terminal 1 to terminal 2 (and terminal 2 to terminal 3) can be varied from about zero to nearly the resistance between terminals 1 and 3 as the adjustment screw moves the wiper from one extreme to the other.

→ Start with the adjustment screw turned completely clockwise: *note* that the potentiometer in your lab kit takes about 19 full turns to move the wiper from one end to the other, so you may need to turn the screw quite a few times to make sure you are at the end (the screw will *not* stop, but you may hear a 'click-click-click' when you turn the screw once the wiper has reached the end).

→ Now use the DMM to measure the resistance between terminal 1 and terminal 2 for the several screw positions listed in the table below. One *full turn* means 360 degrees of rotation.

<i>Screw position</i>	<i>Measured Resistance between • and , (in ohms)</i>
Fully clockwise	
After rotating 5 full turns counterclockwise	
Rotating another 5 full turns counterclockwise	
Rotating another 5 full turns counterclockwise	
Rotated fully counterclockwise	

Using this information, do you think it would be possible to predict the measured change in resistance for an arbitrary number of screw rotations? What do you estimate to be the "ohms per turn" for this potentiometer? Test a few predictions yourself, and explain your reasoning using complete sentences.