Lab. 03: Electric Current and Voltage

- *I-V* curves of resistor, Zener Diode,
Light Emitting Diodes (LEDs), and Light bulb element

1. Objectives

The purpose of this lab will be to investigate the three variables involved in a mathematical relationship known as Ohm's Law. This experiment is to investigate the relationship between current (I) and voltage (V) in Ohmic and non-Ohmic materials, such as Resistors, Zener diode, light-emitting diodes (LEDs), and light bulb element.

2. Theory

The **I-V Characteristics Curves**, which is short for **Current-Voltage Characteristics Curves** or simply **I-V curves** of an electrical device or component, are a set of graphical curves which define its operation. These I-V characteristics curves show the relationship between the current flowing through an electrical or electronic device and the applied voltage across its terminals. *I-V characteristics curves* are generally used as a tool to determine and understand the basic parameters of a device and can also be used to mathematically model its behavior in an electrical circuit. For example, the “current-voltage characteristics” of an ideal resistor are reasonably constant within certain ranges of current, voltage and power as it is a linear or ohmic device. There are however, resistive elements (such as LDR’s, thermistors, varistors, etc) whose I-V characteristic curves are not straight or linear lines but instead are curved or shaped and are therefore called nonlinear devices because their resistances are nonlinear resistances. Consider the circuit below.

I-V Characteristic Curve of an Ideal Resistor

Suppose above that a current i in amperes flows through the resistance R when an electrical supply with an electromotive force of V volts is connected across its terminals. This current can be characterized as: $I = V/R$, and is one of Ohm’s Law equations which most people are familiar with. We know from Ohm’s Law that as the voltage across the resistor increases so too does the current flowing through it. If the voltage and current are positive in nature the I-V characteristics curve will be positive in quadrant Ⅰ, if the voltage and therefore the current are negative in nature then the curve will be displayed in quadrant Ⅲ as shown.

In a pure resistance this relation is linear and constant at a constant temperature, such that the current (i) is proportional to the potential difference V times the constant of proportionality 1/R giving $i = (1/R) \times V$. Then the current through the resistor is a function of the applied voltage and we can demonstrate this visually using an I-V characteristics curve. In this simple example, the current i against the potential difference V, is a straight line with constant slope 1/R as the relation is linear and ohmic. But there are many electronic components and devices which have non-linear characteristics, that is their V/I ratio is not constant. So, while the resistance at a particular voltage and current can be obtained using Ohm’s Law, it will vary as the voltage and current vary.

I-V Characteristic Curves of Semiconductors

Semiconductor devices such as diodes and transistors are constructed using semiconductor P-N junctions. For example, the primary function of a semiconductor diode is rectification. When a diode is forward biased (the higher potential is connected to its Anode), it will pass current. When the diode is reverse biased (the higher potential is connected to its Cathode), the current is blocked. Then a P-N junction needs a bias voltage of a certain polarity and amplitude to control the flow of electrons through it. This bias voltage controls the resistance of the junction and therefore the flow of current through it. Consider the diode circuit below.

I-V Characteristic Curve of a Diode

When the diode is forward biased, anode positive with respect to the cathode, a forward or positive current passes through the diode and operates in the top right quadrant of its I-V characteristics curves as shown. Starting at the zero intersection, the curve increases gradually into the forward quadrant but the forward current and voltage are extremely small. When the forward voltage exceeds the diodes P-N junctions internal barrier voltage, which for silicon is about 0.7 volts, avalanche occurs and the forward current increases rapidly for a very small increase in voltage producing a non-linear curve. The “knee” point on the forward curve.

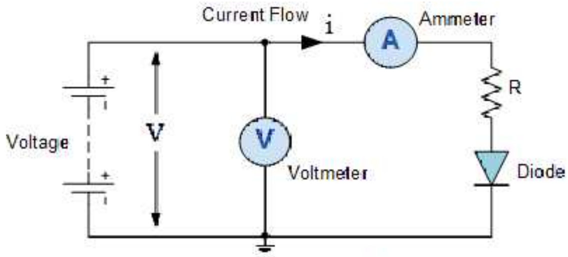
Likewise, when the diode is reversed biased, cathode positive with respect to the anode, the diode blocks current except for an extremely small leakage current, and operates in the lower left quadrant of its I-V characteristics curves. The diode continues to block current flow through it until the reverse voltage across the diode becomes greater than its breakdown voltage point resulting in a sudden increase in reverse current producing a fairly straight line downward curve as the voltage losses control. This reverse breakdown point is used to good effect in zener diodes.

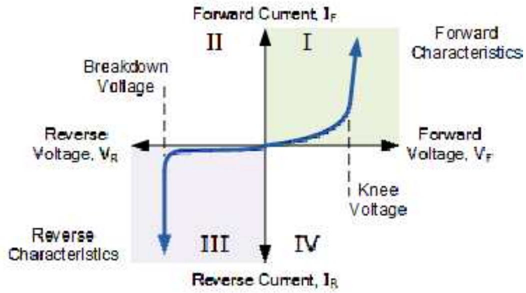
Then we can see that the **I-V Characteristic Curves** for a silicon diode are non-linear and very different to that of the previous resistors linear I-V curves as their electrical characteristics are different. Current-Voltage characteristics curves can be used to plot the operation of any electrical or electronic component from resistors, to amplifiers, to semiconductors and solar cells. They are a useful tool in determining the operating characteristics of a device by showing its possible combinations of current and voltage, and as a graphical aid can help visually understand better what is happening.

I-V Characteristic Curve of a light bulb

For a light bulb, the resistance of the filament will change as it heats up and cools down. At high AC frequencies, the filament doesn't have time to cool down, so it remains at a nearly constant temperature and the resistance stays relatively constant. At low AC frequencies (e.g., less than one Hertz), the filament has time to change temperature. As a consequence, the resistance of the filament changes dramatically and the resulting change in current through the filament is interesting to watch.

In the first part of this activity, you will investigate a ten ohm (Ω) resistor. In the second part, you will investigate the filament of a small light bulb.



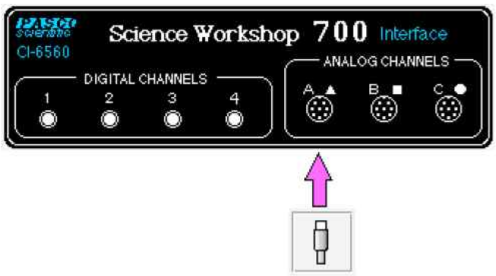


EQUIPMENT NEEDED:

- Computer and Science Workshop™ Interface
- Power Amplifier (CI-6552A)
- AC/DC Electronics Lab Board (EM-8656): 10 W resistor, 3 V light bulb, and wire leads
- (2) banana plug patch cords (such as SE-9750)

3. PROCEDURES

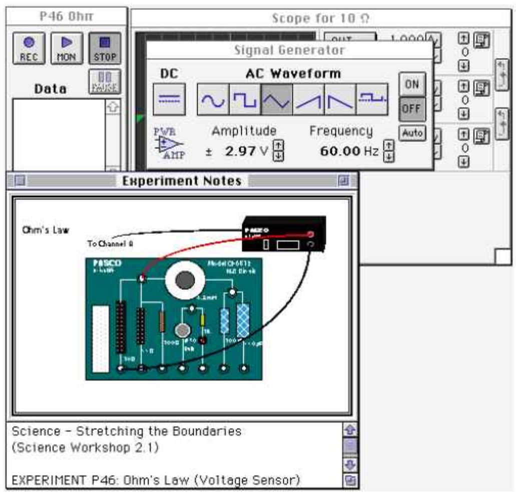
Part A: Resistance in a circuits



(1) Choose one of the resistors that you have been given. Using the resistor chart on Appendix, decode the resistance value and record that value in the first column of Table 3.1.

(2) MEASURING CURRENT: Construct the circuit shown in Figure 3.1a (*connect the red lead to the mA input*) by pressing the leads of the resistor into two of the springs in the Experimental Section on the Circuits Experiment Board.

(3) Set the Multimeter to the 200 mA range, noting any special connections needed for measuring current. Connect the circuit and read the current that is flowing through the resistor. Record this value in the second column of Table 3.1.



(4) Remove the resistor and choose another. Record its resistance value in Table 3.1 then measure and record the current as in steps 2 and 3. Continue this process until you have completed all of the resistors you have been given. As you have more than one resistor with the same value, keep them in order as you will use them again in the next steps.

(5) MEASURING VOLTAGE: Disconnect the Multimeter and connect a wire from the positive lead (spring) of the battery directly to the first resistor you used as shown in Figure 3.1b. Change the Multimeter to the 2 VDC scale and connect the leads as shown also in Figure 3.1b (*connect the red lead to the V input*). Measure the voltage across the resistor and record it in Table 3.1.

(6) Remove the resistor and choose the next one you used. Record its voltage in Table 3.1 as in step 5. Continue this process until you have completed all of the resistors.

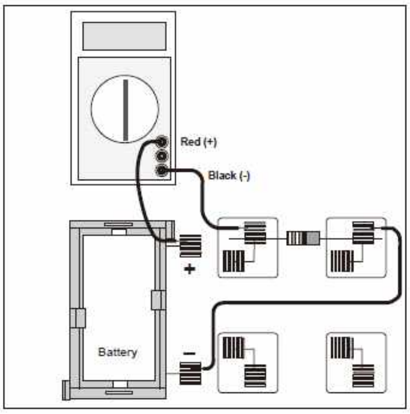


Figure 3.1a

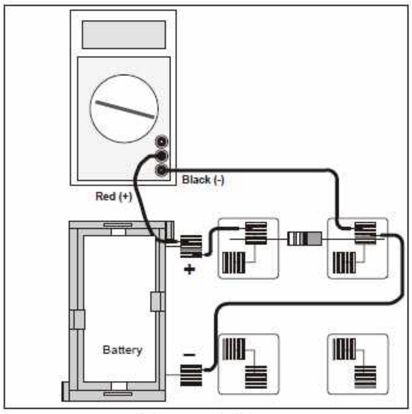


Figure 3.1b

Part B: I-V curves of resistor, Zener diode, and light emitting diodes (LEDs)

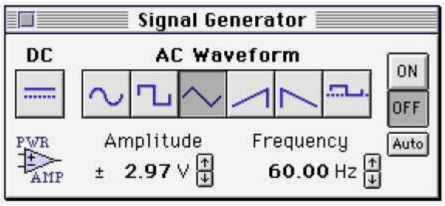
Computer Setup

(1) Connect the Science Workshop interface to the computer, turn on the interface, and turn on the computer.

(2) Plug the Power Amplifier into Analog Channel A. Plug the power cord into the back of the Power Amplifier and connect the power cord to an appropriate electrical receptacle

(3) The document opens with a Scope (oscilloscope) display of Current (I) *versus* Voltage (V), and the Signal Generator window which controls the Power Amplifier.

NOTE: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the "Zoom" box or the Restore button in the upper right hand corner of that window.



(4) The "Sampling Options……" for this experiment are: Periodic Samples = Fast at 4,000 Hz (set in the Scope display using the Sweep Speed control).

(5) The Signal Generator is set to output 3.00 V, triangle AC waveform, at 60.00 Hz.

(6) The Scope is set to show Output Voltage on the vertical axis at 1.00 V/div and Current (Analog A) on the horizontal axis at 0.100 V/div.

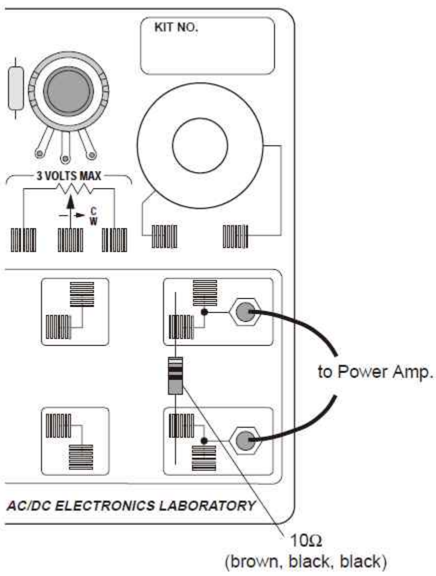
(7) Arrange the Scope display and the Signal Generator window so you can see both of them.

Sensor Calibration and Equipment Setup

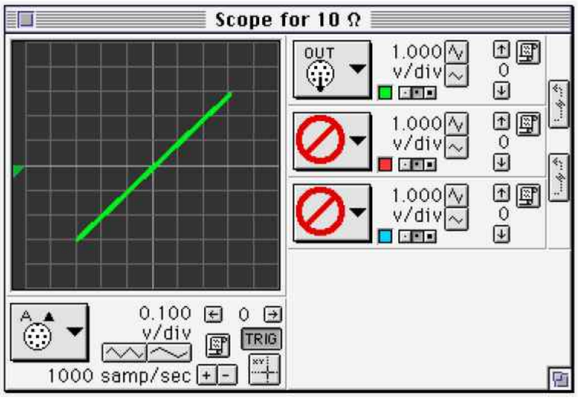
• You do not need to calibrate the Power Amplifier.

(1) Place a 10 ohm (Ω) resistor in the pair of component springs nearest to the banana jacks at the lower right corner of the AC/DC Electronics Lab Board.

(2) Connect banana plug patch cords from the output of the Power Amplifier to the banana jacks on the AC/DC Electronics Lab Board.



(3) Turn on the power switch on the back of the Power amplifier.

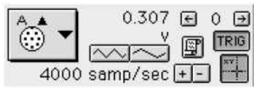


Data Recording – Resistor (10 Ω)

(1) Click the “ON” button () in the Signal Generator window.

(2) Click the “MON” button () in the Experiment Setup window to start monitoring data. Observe the Scope display of Voltage and Current. Wait a few seconds, then click the “STOP” button ().

(3) Click the “OFF” button () in the Signal Generator window. Turn off the power switch on the back of the Power Amplifier.



(4) Select the Scope display.

Analyzing the Data – Resistor

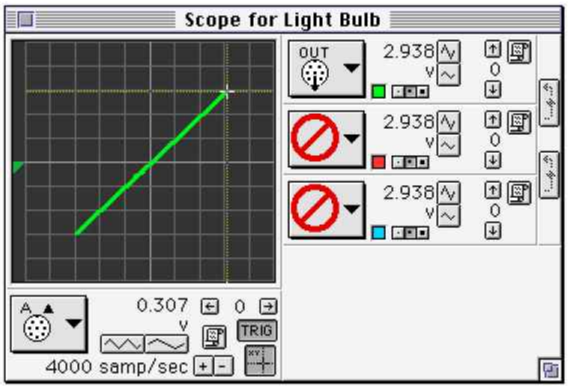
(1) Click the “Smart Cursor” button () in the Scope. The cursor changes to a cross-hair. Move the cursor into the display area of the Scope.

• The Y-coordinate of the cursor/cross-hair is shown next to the Vertical Axis Input button.

• The X-coordinate of the cursor/cross-hair is shown next to the Horizontal Axis Input button.

(2) Use the coordinates of a point on the trace on the Scope display to determine the slope of the trace on the Scope.

(3) Repeat the experiments for 100 Ω, 1 kΩ, 10 kΩ.



Additional works (Similar substitutions of Zener diode and LEDs for resistor is possible)

(1) Connect the 10 Ω resistor in series with the LEDs.

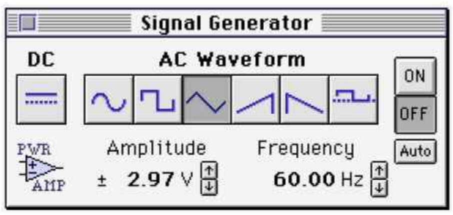
(2) Click the "Increase Sweep Speed" button () in the Scope display to change the sensitivity of the horizontal axis to 0.010 V/div.

(3) Repeat (2) for the 10 Ω resistor in series with the diodes and Zener diode.

(3) Repeat the (2)-(3) experiments for 100 Ω, 1 kΩ, 10 kΩ.

Part C – Light Bulb Filament

Computer Setup for Light Bulb Filament



For this part of the activity you will use the filament of a light bulb as the resistor. In the Computer Setup you will change the Amplitude and Frequency of the output AC waveform. You will also change some of the settings on the Scope display.

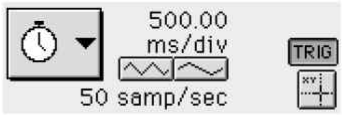
(1) Click the Signal Generator window to make it active.

(2) Click on the Amplitude value to highlight it. Type in "2.5" as the new value. Press the "enter" key.

(3) Click on the Frequency value to highlight it. Type in "0.30" as the new value. Press the "enter" key.

(4) Click the Scope display to make it active.

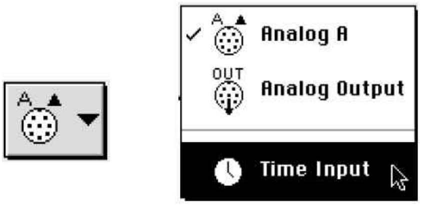
• You will change the rate at which the scope is sampling data.

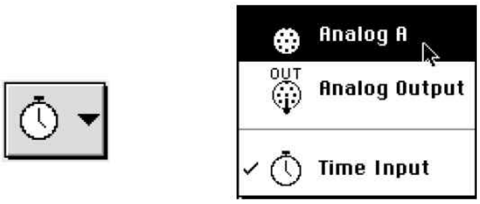


(5) Click the “"Horizontal Input”" button. Use the Horizontal Input menu to select "Time Input" (at the bottom of the list).

(6) Repeatedly click the "Decrease Sweep Speed" button () until the Sweep Speed is 500.00 ms/div.

Horizontal Input button with Horizontal Input menu Horizontal Output button with Horizontal Output menu





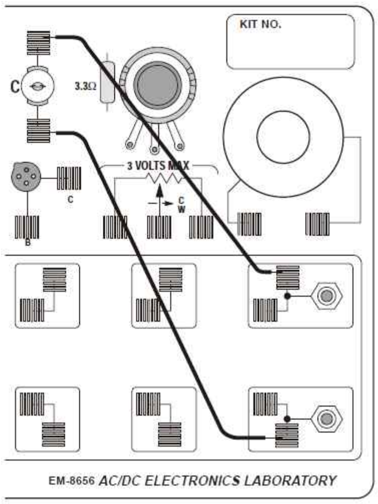
(7) Click the “Horizontal Input” button again. Use the Horizontal Input menu to select "Analog A" (at the top of the list).

• After making changes, the Scope display should be similar to the figure for the Resistor measurement.

Equipment Setup for Light Bulb Filament

(1) Remove the resistor from the component springs on the AC/DC Electronics Lab Board.

(2) Use two of the 10" wire leads to connect between the component springs near the banana jacks and the component springs above and below 3 VOLT BULB "C".



Data Recording – Light Bulb Filament

(1) Turn on the switch on the back of the Power Amplifier.

(2) Click the "ON" button in the Signal Generator window.

(3) Click the "MON" button in the Experiment Setup window to begin monitoring data. Observe the Scope display of Voltage versus Current for the light bulb filament.

(4) Wait a few seconds, then click the "STOP" button.

(5) Click the "OFF" button in the Signal Generator window. Turn off the power switch on the back of the Power Amplifier.

[Appendix]

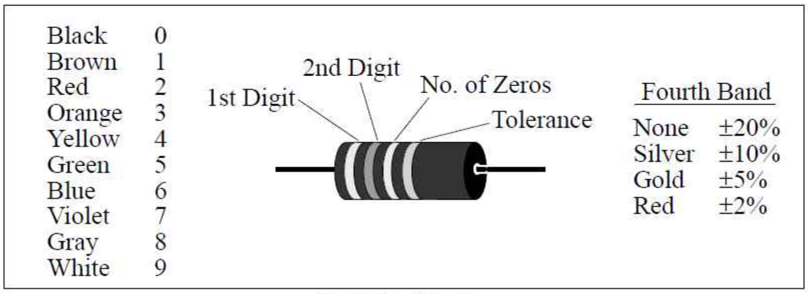
Getting Started

① Store the components in the Ziplock bag until needed. Keep track of, and return the components to the Ziplock bag after the experiment is completed.

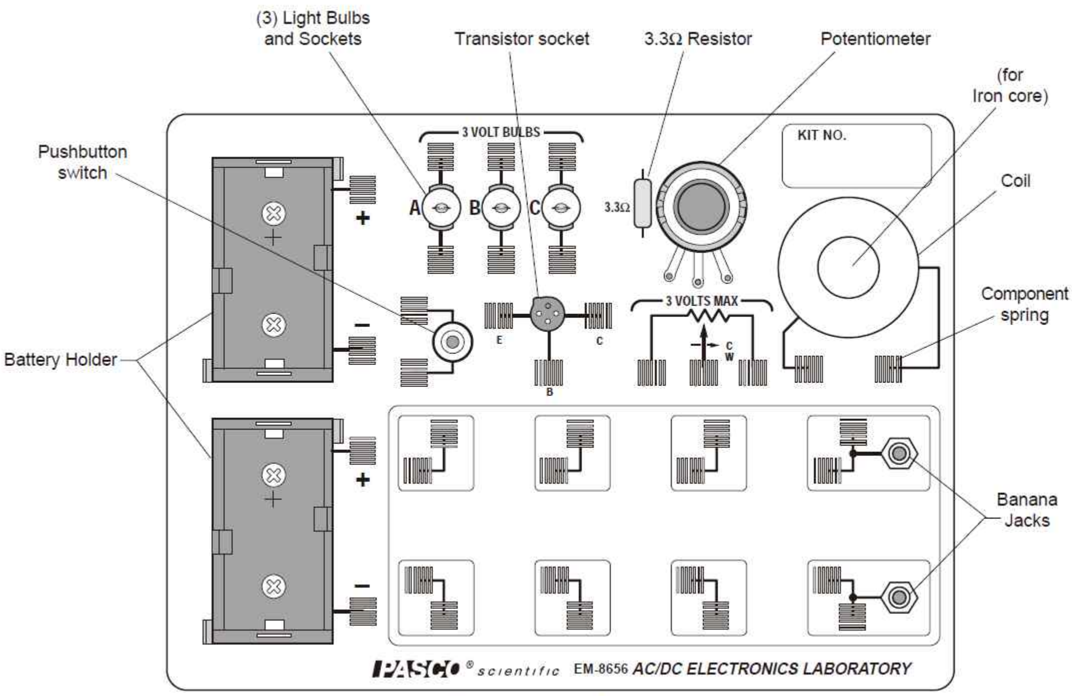
② Identify the resistor value required for the individual experiments with the help of the following chart.

③ Familiarize yourself with the board layout, as shown.

④ Students will need to use the same component layout from one experiment to another. Labeling of the boards and your meters will enable students to more easily have continuity in their work. Using removable labels or using a permanent marker are two alternatives for marking the board.



Resistor Chart



Board Layout

Worksheet 03: Electric Current and Voltage

- *I-V* curves of resistor, Zener Diode,

Light Emitting Diodes (LEDs), and Light bulb element

요약문 (Abstract)

실험 분반	( ) 학년 ( ) 분반	
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제출일	년 월 일	
( ) 조	학번	이름
제출자		
공동 실험자		

Results

Part A: Resistance in a circuits

(1) Construct a graph of Current (vertical axis) vs Resistance with changing resistors.

(2) For each of your sets of data, calculate the ratio of Voltage/Resistance in the Table 3.1. Compare the values you calculate with the measured values of the current.

Table 3.1. Measure current vs Voltage wi different resistors

Color codes	Resistance (Ω)	Current (mA)	Voltage (V)	Voltage/Current

Part B: I-V curves of resistor, Zener diode, and light emitting diodes (LEDs)

(1) Compare the I-V curve for various resistors (10 Ω, 100 Ω, 1 kΩ, and 10 kΩ). Make the graph as a log I versus log V curve, if needed.

(2) Compare the I-V curves for various resistors (10 Ω, 100 Ω, 1 kΩ, and 10 kΩ) in series with various diodes such as normal siode, LEDs (red, green and blue LEDs), and Zener diode. Explain the graph for the scope.

Part C – Light Bulb Filament

(1) Compare the I-V curve by showing the Scopes of light bulb element with varying frequency from 0.1 Hz to 10 Hz. Explain the graph for the scope.

Discussions

(1) Compare the slopes of the resistors (10 Ω, 100 Ω, 1 kΩ, and 10 kΩ) as shown in the Scope to the "official" value of resistance. In other words, how close is the value of slope to the value of resistance?

(2) Does the diodes have a constant resistance? Why or why not?

(3) Does the slope of the light bulb trace change? Why or why not?

(4) The slope of the graph for the light bulb is not symmetric. Why is the slope of the current trace different when the filament is heating up compared to the trace of current when the filament is cooling down?