WICHITA STATE UNIVERSITY

CS 194 – Lab Manual
Digital system design

Department of Electrical Engineering and Computer Science

Wichita State University

Contents

Laboratory Safety Rules

The major hazards associated with electricity are electrical shock and fire. Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is wet or dry. Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin. The effect of the shock may range from a slight tingle to severe burns to cardiac arrest. When you are shocked by electricity, your muscles contract, if the lungs are involved in the path of the circuit, voluntary respiration can be halted. If the heart is involved, fibrillation can occur resulting in heart failure. As little as 50 milliamperes can cause death. It is important to realize that an electrical shock may not be strong enough to cause a fatality but it could cause you to fall or jolt to dangerous surroundings. The chart below shows the general relationship between the degree of injury and amount of current of shock. While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes of current flow.

	Milliamperes (Thousandths of an ampere)	
Body Effect	**DC Voltage**	**AC Voltage 60 hz**
No sensation on hand	0.6 - 1	0.3 - 0.4
Slight tingling	3.5 - 5.2	0.7 - 1.1
Non-painful shock, muscular control not lost	6 - 9	1.2 - 1.8
Painful shock, muscular control not lost	41 - 62	6 - 9
Severe shock, muscular control lost, difficult breathing	60 - 90	15 - 23
Fibrillation from shock, 3 second duration	500	100

To Avoid Injury in the Circuits I lab:

1. Avoid contact with energized electrical circuits. Never touch even one wire of a circuit; it may be energized with respect to the ground you are standing on.
2. Do not work alone on energized electrical equipment.
3. Always turn the power off to a circuit before working on it, and always verify for yourself that the power is off. Don't take someone else's word for it.
4. Never modify a circuit while the power is on.
5. Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
6. If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt. Call 911 immediately, giving the location of the lab: room 330/331 Wallace Hall, 3rd floor, Wichita State campus.
7. Remove all jewelry on hands and arms and dangling necklaces in the lab. Wearing Metal jewelry can be hazardous in an electrical laboratory since such items make good electrodes for the human body.

8. Never lunge for a falling part of a live circuit such as leads or measuring instruments.
9. If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
10. Never use water on an electrical fire. If possible first switch laboratory power off, then use a CO_2 or dry type extinguisher. Identify the location of all extinguishers in or near the lab.
11. Before turning on the power to a circuit:
    a. If possible, have someone who did not wire the circuit check that it is correct.
    b. Always check for short circuits between power and ground – do this by using the digital multimeter, set on resistance (ohms) mode, to measure the resistance between the power bus and the ground bus. Use ohm's law to calculate the current that should flow. If it is greater than 500 mA (0.5 A) then something is wrong with your circuit. Rewire and recheck it before turning the power on.
12. If you apply power to a circuit and see sparks or smell something burning, immediately remove power from the circuit by unplugging the Elvis board from the wall outlet. Never attempt to handle the faulty circuit or remove components from the board.
13. Don't run, throw things, or play practical jokes in the lab.
14. Never eat or drink in the lab.
15. Remember that when using a multimeter to measure current, the meter acts as a short circuit. If the current flow through the meter exceeds a certain value, you will blow the fuse or damage the multimeter.
16. Avoid heat dissipating surfaces of high wattage resistors and loads because they can cause severe burns.
17. When using a voltmeter or ammeter, begin with the highest range and work your way down to a suitable range.
18. When using an ohmmeter, never measure resistance in a live circuit.
19. Report defective equipment and blown fuses to the instructor. Do not attempt to repair it yourself. There are no penalties for accidental damage to equipment, but it can present a hazard to the next person who tried to use it.

Sources:

Princeton University, Laboratory Safety Manual, web.princeton.edu/sites/ehs/labsafetymanual/sec7g.htm, August 18, 2011

Lab Safety Supply, Electrical Safety, www.labsafety.com/refinfo/ezfacts/ezf266.htm, August 18, 2011

Carnegie Mellon University, ECE348 Lab Safety Guidelines, www.ece.cmu.edu/~ece348/labs/docs/lab_safety_guidelines.pdf. August 18, 2011

Western Michigan University, ECE 2100 Circuit Analysis Laboratory: Safety and Rules, homepages.wmich.edu/~miller/ECE2100/laboratory/ECE2100LaboratorySafetyAndRules.pdf, August 18, 2011

After each laboratory class, a lab report should be prepared by each student. These reports are the primary sources to show your laboratory instructor that you have understood the objective and gained sufficient knowledge about the material. Remember as an engineer you should be able to communicate your findings, results and conclusions in a meaningful manner. These reports are intended to give you an exposure to technical writing.

All laboratory reports should be clear and concise. The reports can be either handwritten or typed. The use of tables, diagrams, and plots is strongly encouraged. Every laboratory report should consist of a short conclusion. The conclusion shall be your final judgment from the conducted experiment and necessary calculations.

Every student shall produce their own laboratory report, even if the students worked in groups. Sharing any information other than the recorded measurements will be considered academic dishonesty.

Contact your Lab Instructor if you have any questions about the report format. The necessary components of a lab report are:

a) **Front Cover:** Front cover shall contain
   a. Name
   b. myWSU ID
   c. Lab Partners
   d. Date (Lab performed)
   e. CS 194 – Morning /Evening (with day and time)
   f. Course Instructors' name
b) **Objective:** Clearly state the objective of the laboratory in your own words.
c) **Pre-Lab:** All the pre-lab questions and simulation results should be attached.
d) **Equipment Used:** Write down all the equipment used to conduct the experiment. Include the ratings and model numbers.
e) **Procedure:** Provide a brief summary of the procedure used in the lab. Do not copy the procedure from the lab manual. Any change in the procedure while conducting the lab to the procedure given in the lab manual should be noted
f) **Recorded Data:** Whenever possible use tables and figures to provide all the recorded data. The lab instructor may request that a student repeat the lab if any of the required data are missing.
g) **Post Lab:** If post lab questions are given they must be answered in this section. These shall be answered after the lab is over.
h) **Conclusion:** A brief conclusion shall be presented by the student. The conclusion should be based on the observations and recorded data.
i) **Signature:** Every lab report shall be signed by the student. The following statement should be included "I did not use any unauthorized material in producing this lab report. This includes collaboration with anyone other than the Lab Instructor or Course Instructor"

Introduction to NI ELVIS

Objective: By the end of this laboratory students should be able to build circuits using the Prototype Board and connect them to the NI ELVIS.

Pre Lab: None

Introduction: In the Circuits I lab we use a set of virtual PC based instruments called the National Instruments Educational Laboratory Virtual Instrumentation Suite (NI ELVIS). The NI ELVIS II provides a prototyping board for building electrical circuitry and allows connections necessary to access signals for common applications. Figure 1.1 shows the prototype board.

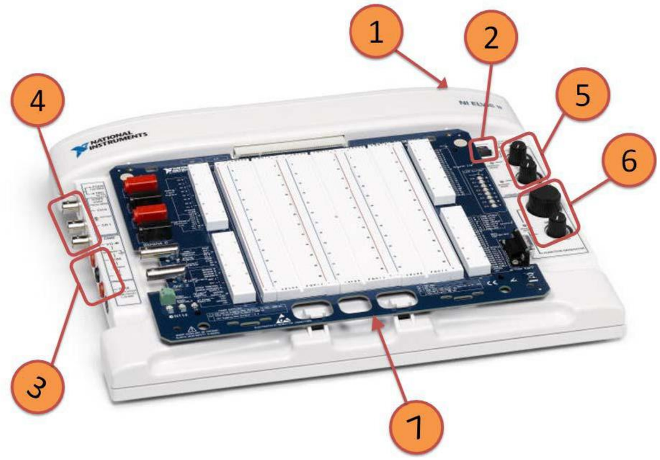


Figure 2.1: NI ELVIS

The NI ELVIS Prototype Board consists of the following components.

1. **Workstation Power Switch**: Located in the rear of the workstation.
2. **Prototyping Board Power Switch:** Controls power to NI ELVIS II prototyping board. The power LED lights up when the switch is turned ON. The Ready switch should be green or yellow when connected to host PC.
3. **Digital Multimeter (DMM) Connectors**: These are used to connect the prototyping boards. When the multimeter is used in current mode a different positive terminal is used. The connectors are enlarged and shown in Figure 1.2

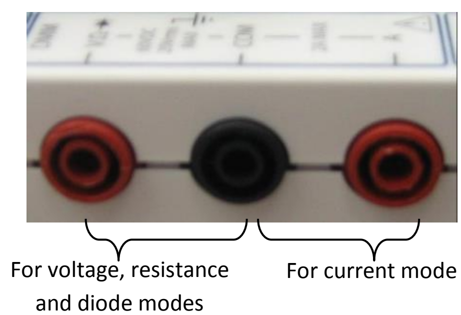


Figure 2.2: Zoomed in View of Digital Multimeter Connectors

a. Voltage, Resistance, and Diode Banana Jack (red): The positive input for digital multimeter in voltage resistance and diode modes.
b. Common Banana Jack (black): The common reference connection for digital multimeter voltage, current, resistance, and diode modes.
c. Current Banana Jack (red): The positive input for digital multimeter current modes.

(***Always connect Ammeter in series with bulb filament or filaments and Voltmeter in parallel***)

4. **Oscilloscope Connectors and Function Generator Outputs/Digital Trigger Input:** Out of the three BNC connectors (Bayonet Neill–Concelman) one is used for triggering. Figure 1.3 shows the zoomed in view of all the BNC connectors.

Figure 2.3: Zoomed in View of BNC connectors

   a. *Oscilloscope (Scope) Connectors (Input)*
      i. CH 0 BNC Connector: The input for channel 0 of the oscilloscope.
      ii. CH 1 BNC Connector: The input for channel 1 of the oscilloscope.

5. **Variable Power Supply Manual Controls:** This allows the user to set the voltage from the power supply to the required level. Figure 1.4 shows the two variable power supplies.

Figure 2.4: Zoomed in View of Variable Power Supplies

   - *Supply+* can supply between 0 and +12V
   - *Supply–* can supply between 0 and -12V
   - Knobs are active only when the associated power supply is in manual mode.
   - LED next to each knob lights up when associated power supply is in manual mode.

6. **Function Generator Manual Control:** These knobs allow the user to manually adjust the frequency and amplitude for a function generator output waveform. The Manual Mode LED lights up when the function generator is in manual mode.

Figure 2.5: Zoomed in View of Function Generator

7. **NI ELVIS II series Prototyping Board** – Provides an area for building circuitry and has necessary connections to access signals for common applications.

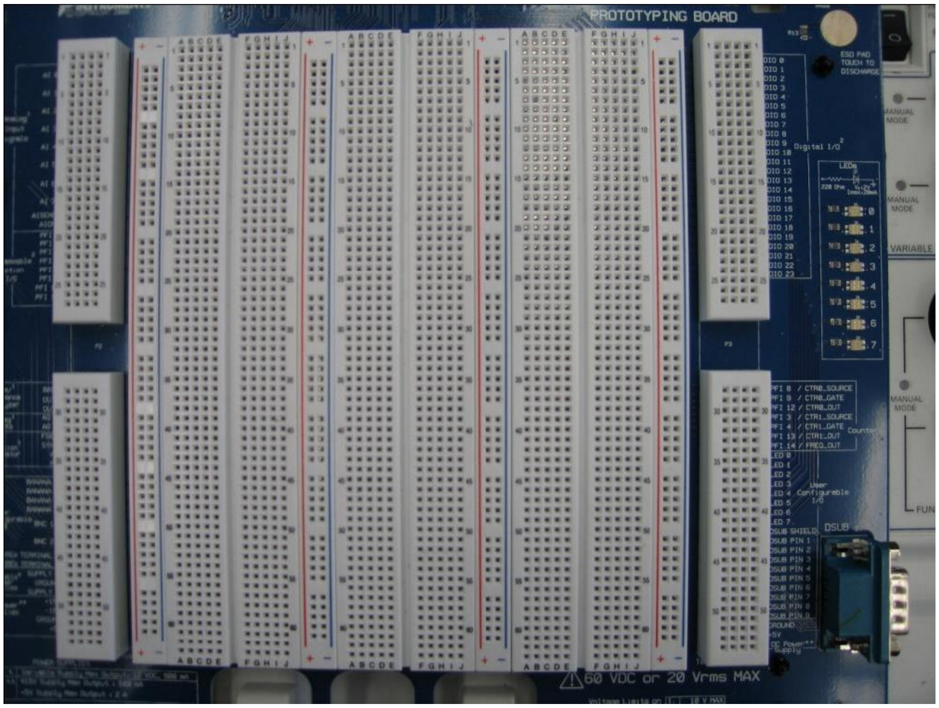


Figure 2.5: Prototyping Board

The layout of the Prototyping Board is shown in Figure 2.6. Adjacent terminals of the same color are connected together. For example, a component inserted in 1A is connected directly to components inserted in 1B, 1C, 1D, and 1E. The terminals that are not colored follow the same pattern.

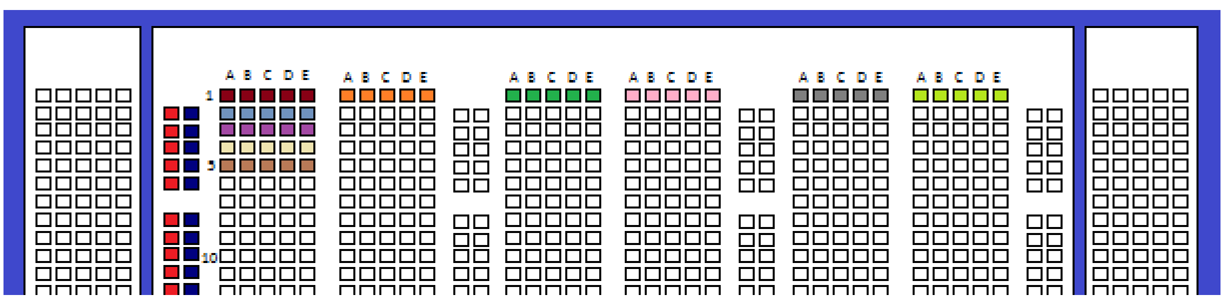


Figure 2.6: Prototyping board layout

NI ELVIS Instrument Launcher

All the controls can be performed using NI ELVIS software. To access this software, go to start, then all programs, then NI ELVIS, and then instrument launcher. Once the NI ELVIS Instrument Launcher is opened all the tools will appear as shown in Figure 2.7. Commonly used instruments are shown.

Figure 2.7: NI ELVIS Instrument Launcher

Digital Multimeter (DMM): The DMM is used to measure AC and DC voltages and currents, values of resistance, capacitance and inductance.

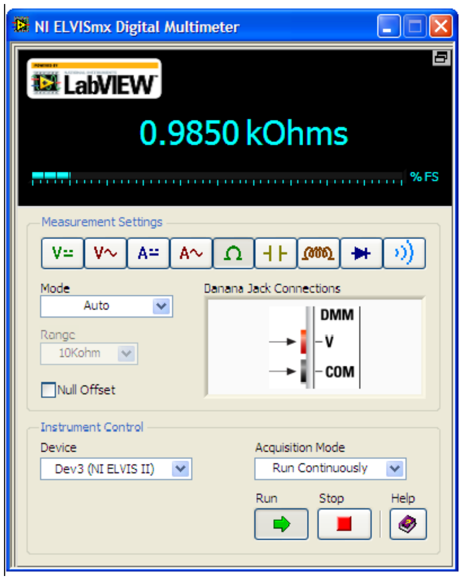


Figure 2.8: Screenshot of NI ELVISmx Digital Multimeter

Oscilloscope (Scope): Measures voltage waveforms on two different channels. Connect the black lead to the ground and the red lead to the voltage to be measured. The separate controls for channel A and channel B are identical. There are also time and trigger controls that apply to both channels. Figure 2.9 shows the NI ELVIS Oscilloscope with the most used tabs shown in red boxes.

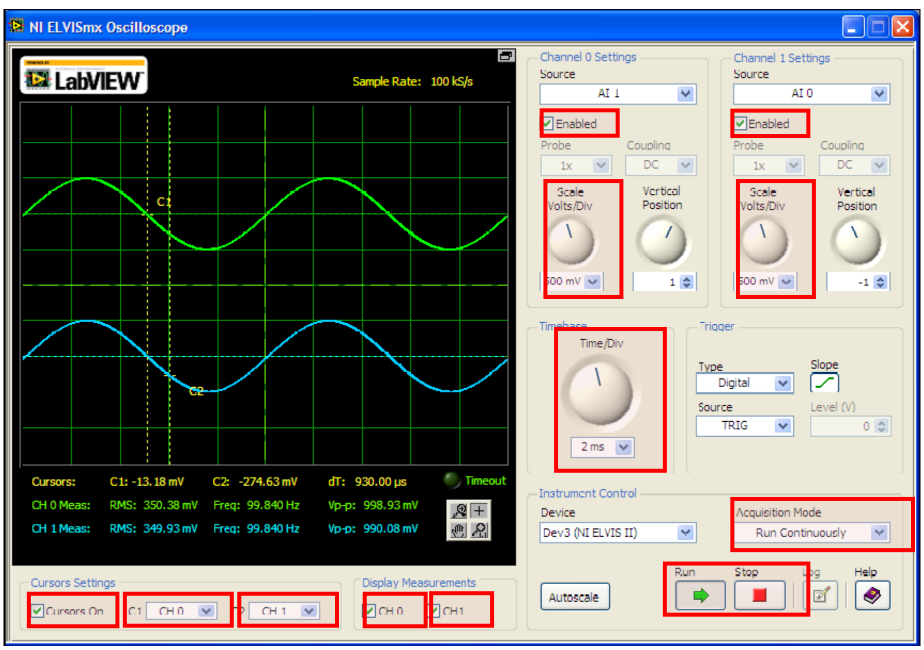


Figure 2.9: Screenshot of NI ELVISmx Oscilloscope

Function Generator (FGEN): Used to produce simple sinusoidal, square and triangle waveform voltages. The output of the function generator is between the FUNC_OUT terminal and ground. There are manual controls on the front of the workstation. They duplicated parts of the software controls, but have less functionality

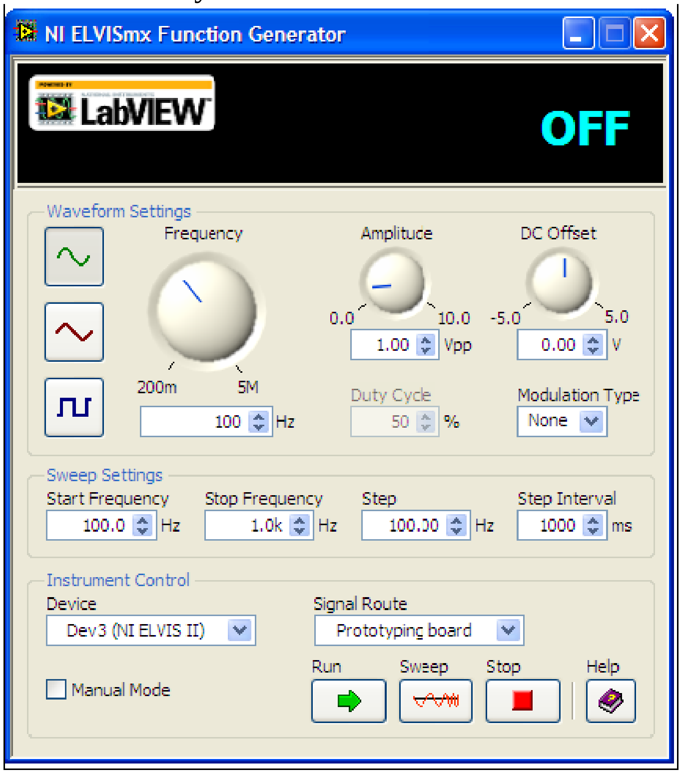


Figure 2.10: Screenshot of NI ELVISmx Function Generator

Variable Power Supply (VPS): The variable power supply consists of two channels that supply adjustable output voltages from 0 to +12V on the SUPPLY+ channel and 0 to -12V on the SUPPLY- channel. The output voltages are referenced to GROUND.

Procedure:

a) Equipment Needed
   i. NI ELVIS Workstation
   ii. Digital Multimeter
   iii. 1.0 $k\Omega$ resistor

b) With the NI Elvis board power “off,” make the connections shown in fig. 2.a on the NI-ELVIS prototyping board. “S” is the positive variable voltage source. “A” is the NI ELVIS ammeter. “V” is the dc voltmeter on the external DMM.

c) Turning on NI ELVIS
   i. Turn on the Computer
   ii. Turn on the NI-ELVIS workstation
   iii. Turn on the NI-ELVIS prototyping board
   iv. Launch NI-ELVIS Instrument Launcher
   v. Launch NI-ELVIS DMM instrument and set it to measure DC voltages.
   vi. Launch NI-ELVIS VPS instrument
   vii. Launch NI-ELVIS FGEN instrument
   viii. Launch NI-ELVIS Scope instrument

d) Set the variable source voltage to 10 V. For each connection, measure and record the currents from the NI-ELVIS DMM and measure the voltage from the digital multimeter in Table 2.1.

e) Turn the NI-ELVIS power off when changing circuit connections. Repeat b-d for the circuits shown in figs. 2.b through 2.g.

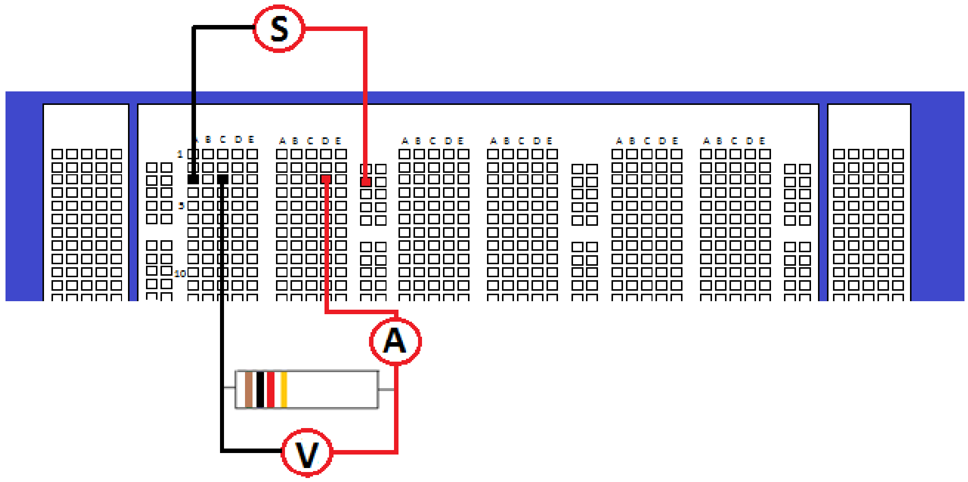


Figure 2.a: Test Circuit 1

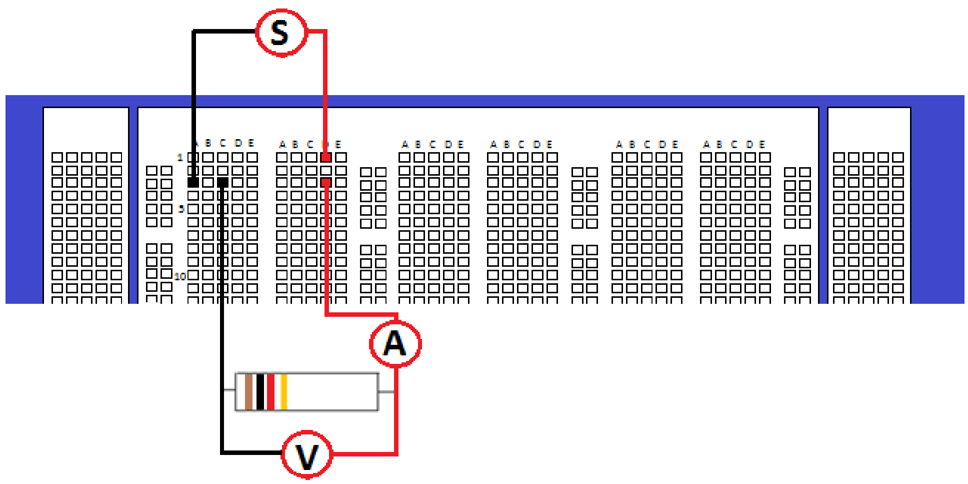


Figure 2.b: Test Circuit 2

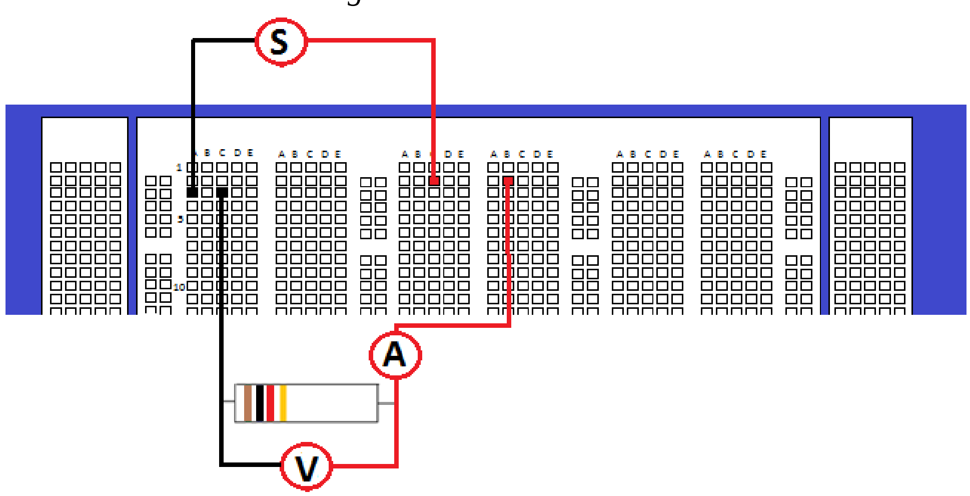


Figure 2.c: Test Circuit 3

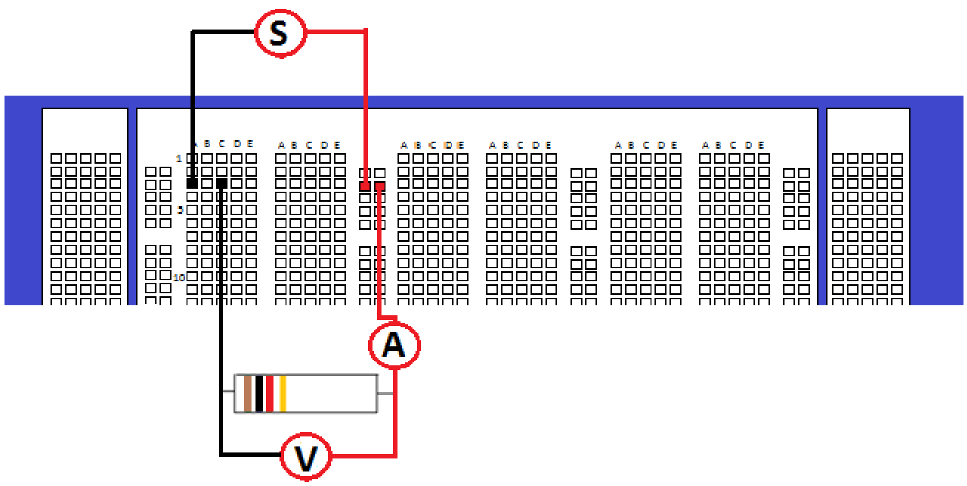


Figure 2.d: Test Circuit 4

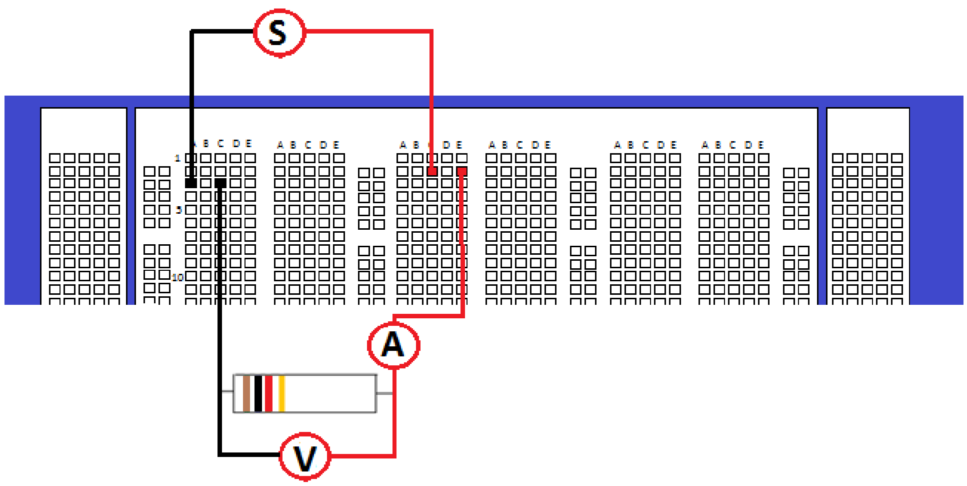


Figure 2.e: Test Circuit 5

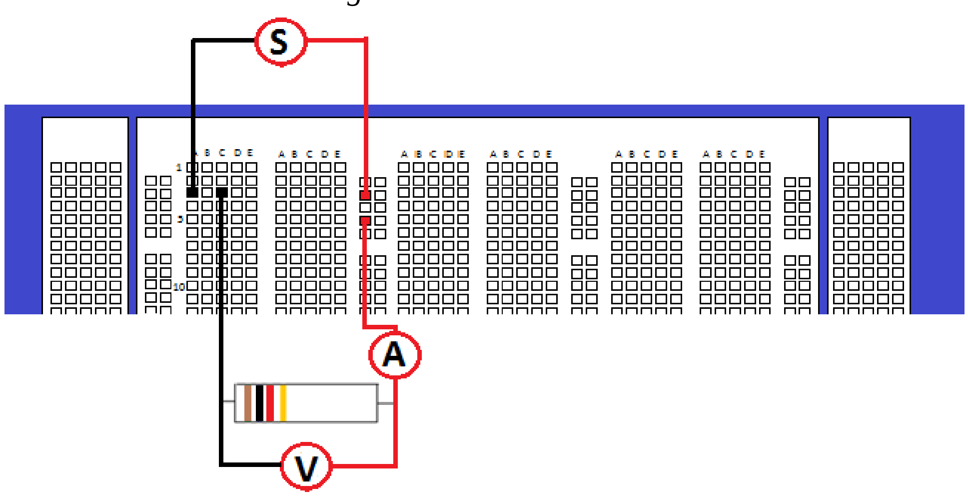


Figure 2.f: Test Circuit 6

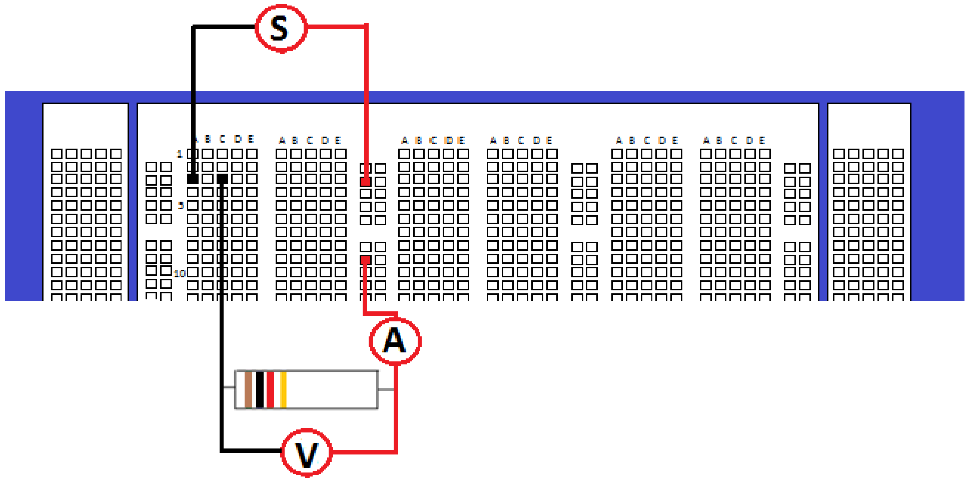


Figure 2.g: Test Circuit 7

Table 2.1: Current and Voltage Measurements

Circuit No	**Voltage across the resistor**	**Current through the resistor**	**Remarks (reasons for the reading)**
1			
2			
3			
4			
5			
6			
7			

Bonus: Sample Connections for this experiment

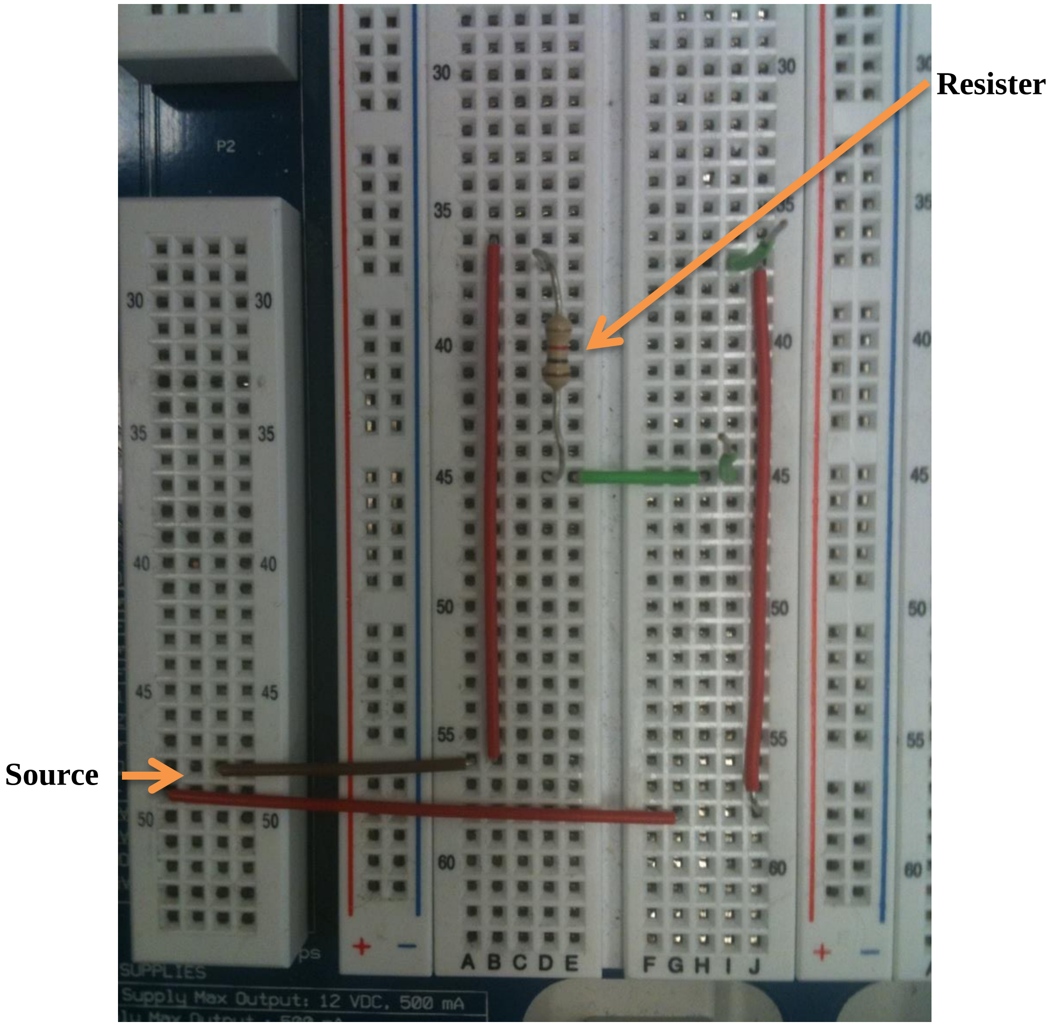


Figure 2.A.1: Connection of Resistor while leaving a provision for Ammeter

Figure 2.A.2: Voltmeter Connection (Connected Across the Resistor)

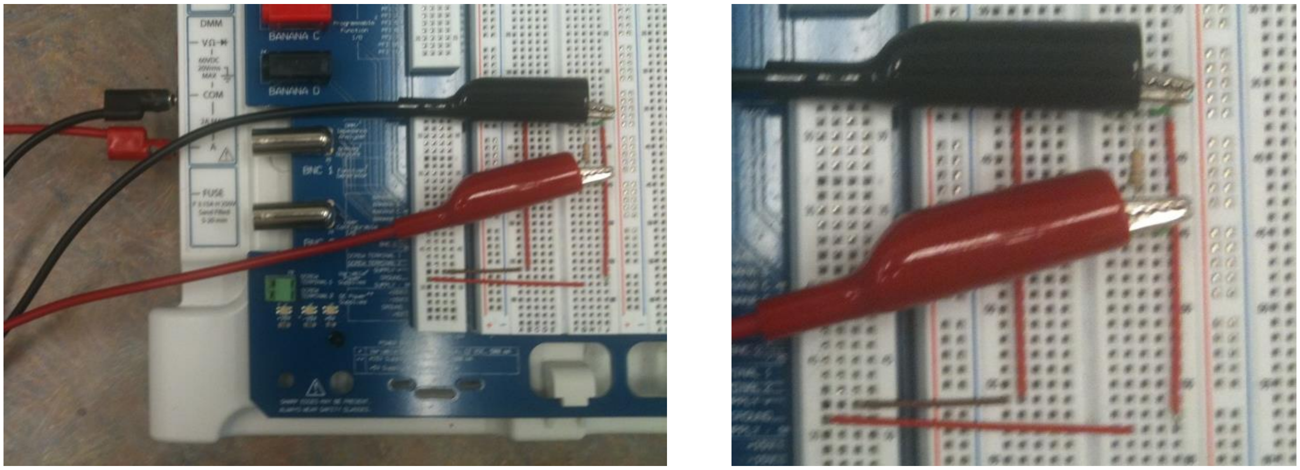


Figure 2.A.3: Ammeter Connection (Connected by breaking the line)

Introduction to Multisim™

(Further Reference: Multisim™ User Manual[1])

Objective: By the end of this laboratory students should be able to use Multisim™ software to analyze electrical circuits. Future 282 labs will require students to use Multisim for in Pre Labs.

Pre lab: None

Procedure:

1. By clicking on the following, Multisim™ will be launched. Figure 4.1 shows the shapshot of the Multisim™ Window.

   Start
   ↳ All Programs
   ↳ National Instruments
   ↳ Circuit Design Suite 10.0
   ↳ Multisim™

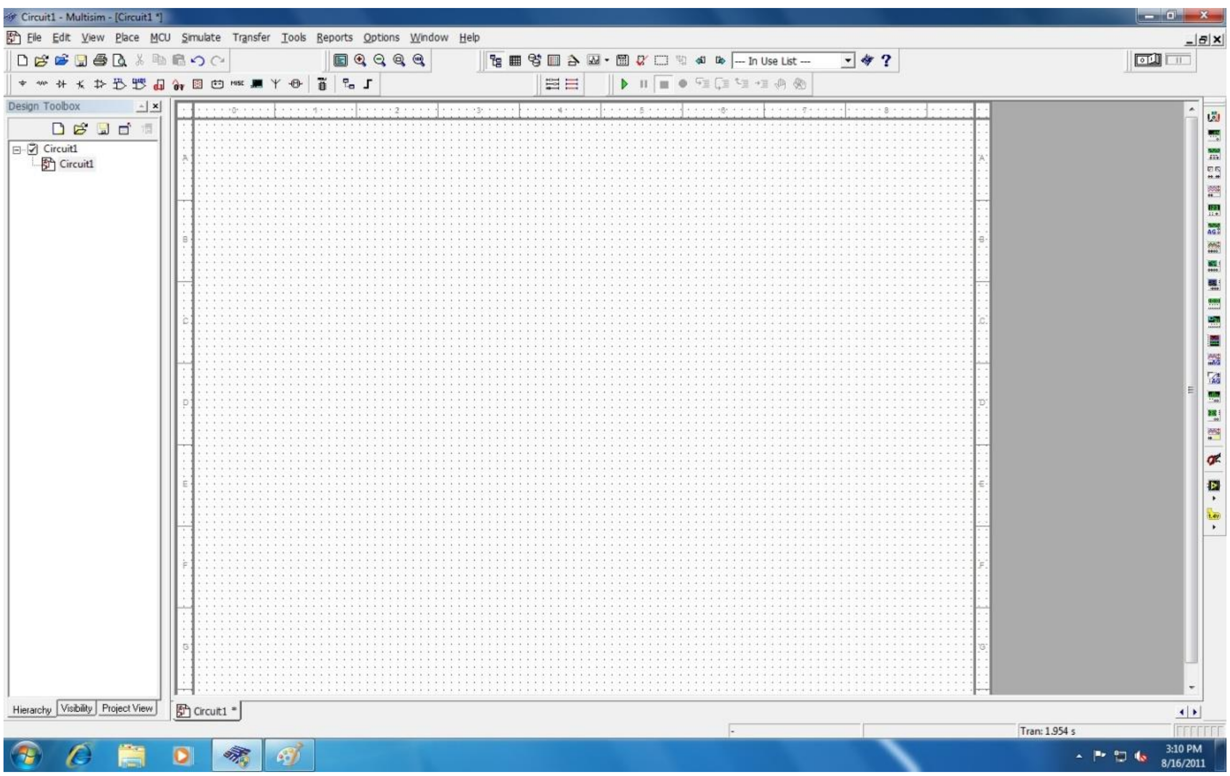


Figure 4.1: Snapshot of Multisim™

2. As the first step save the schematic window. To save the schematic, click on File and choose save option. Save the schematic as ‘lab_example’

[1] NI Multisim™ User Manual, National Instruments, Available: http://www.ni.com/pdf/manuals/374483c.pdf May 2008.

3. Add a Component (Resistor):

a. Identify the component toolbar. The component is shown in figure 4.2

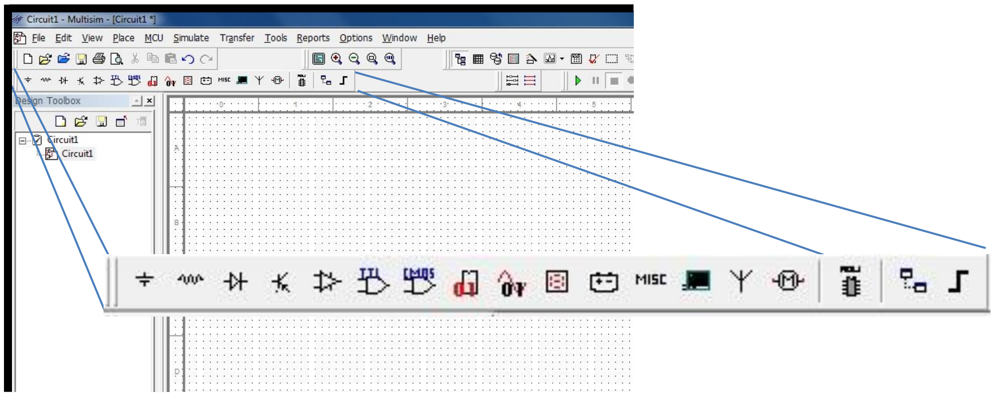


Figure 4.2: Component Tab Projected

b. Click on the second button, which is the basic component button, as shown in figure 4.3. When the arrow is above the second button, 'Place Basic' will appear.

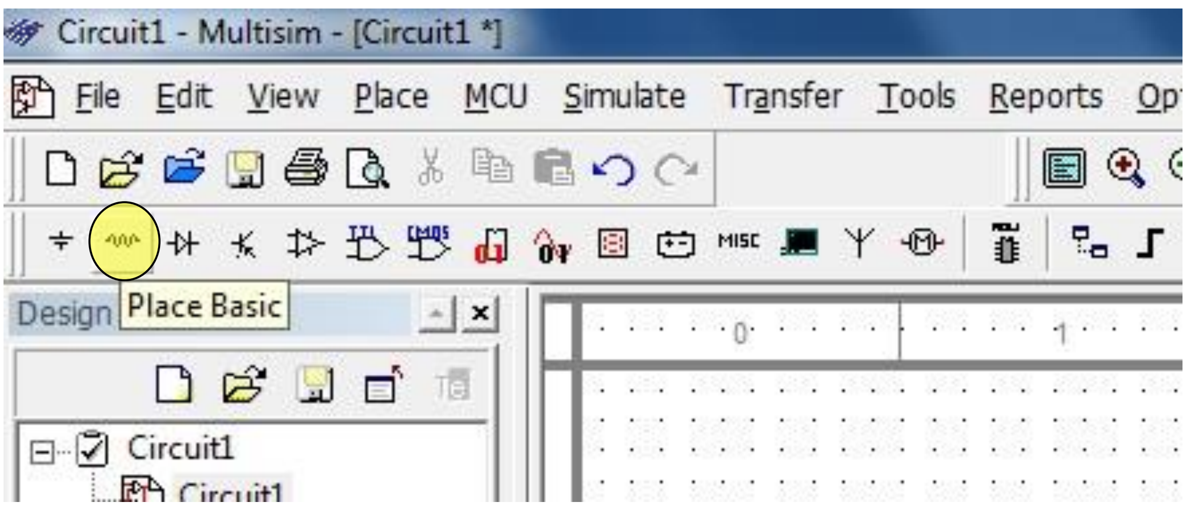


Figure 4.3: Place Basic Button

c. Once ‘Place Basic’ is clicked, a window, as shown in figure 4.4, will appear. Select the $1k\Omega$ resistor from the menu. Make sure the ‘Resistors’ from the first column is selected, and then select the $1\ k\Omega$. (In figure 4.4 both are highlighted)

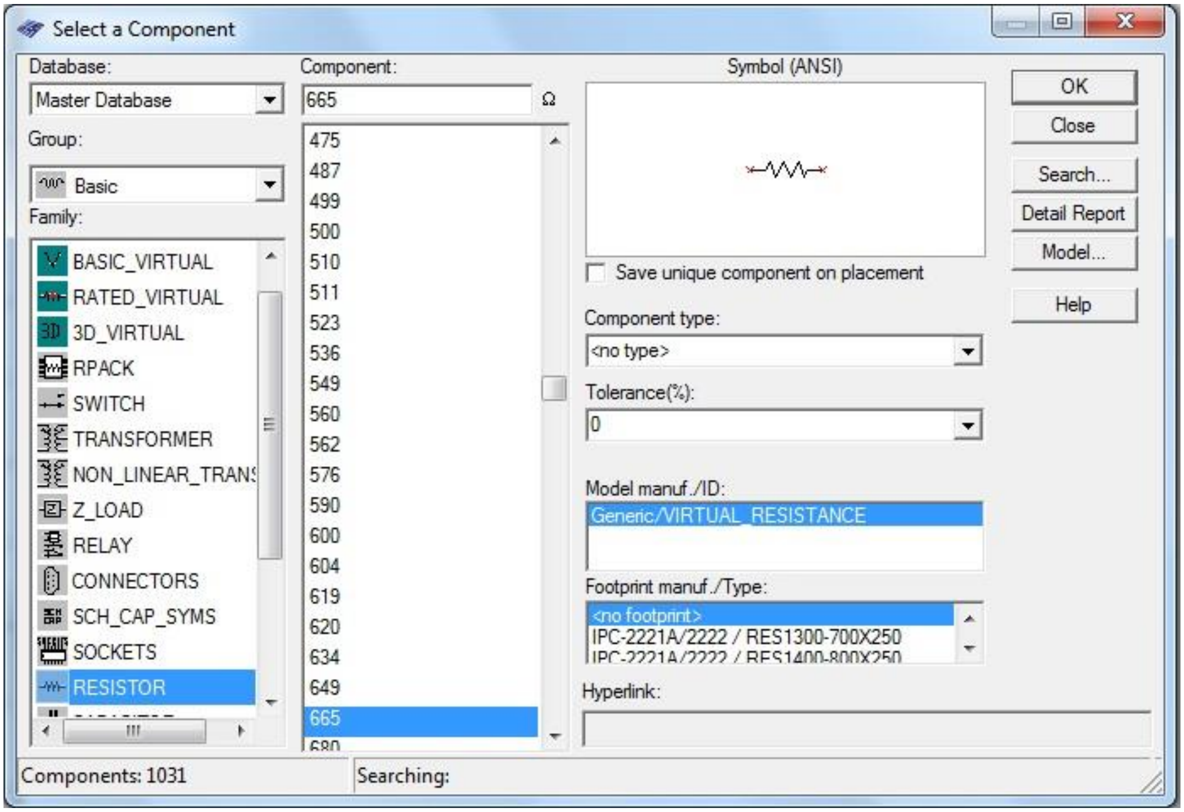


Figure 4.4: Selecting a Resistor

d. Place the resistor in the schematic window as shown in figure 4.5.

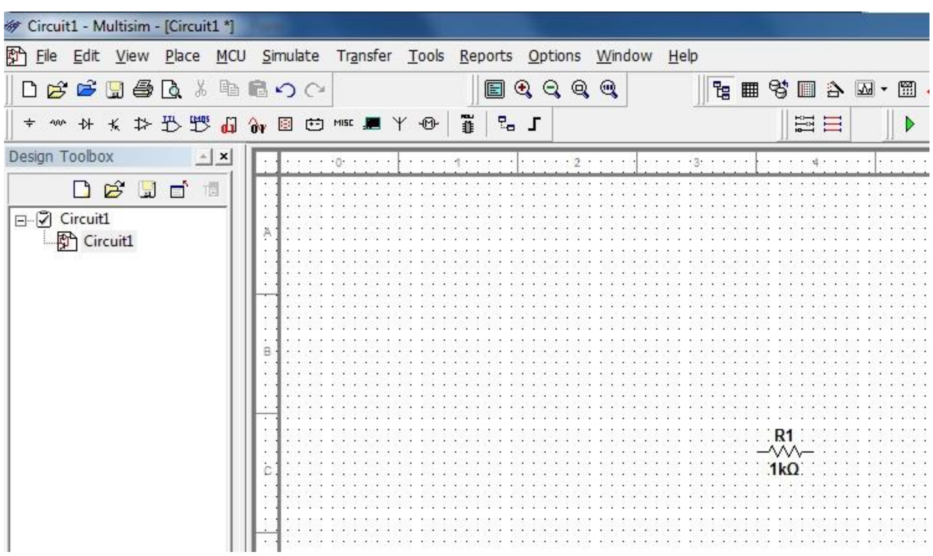


Figure 4.5: Placing the Resistor

e. If necessary rotate the resistor by first right clicking the mouse, while the resistor is highlighted (a blue box will appear around the resistor when its highlighted) and then use the rotation information as shown in figure 4.6

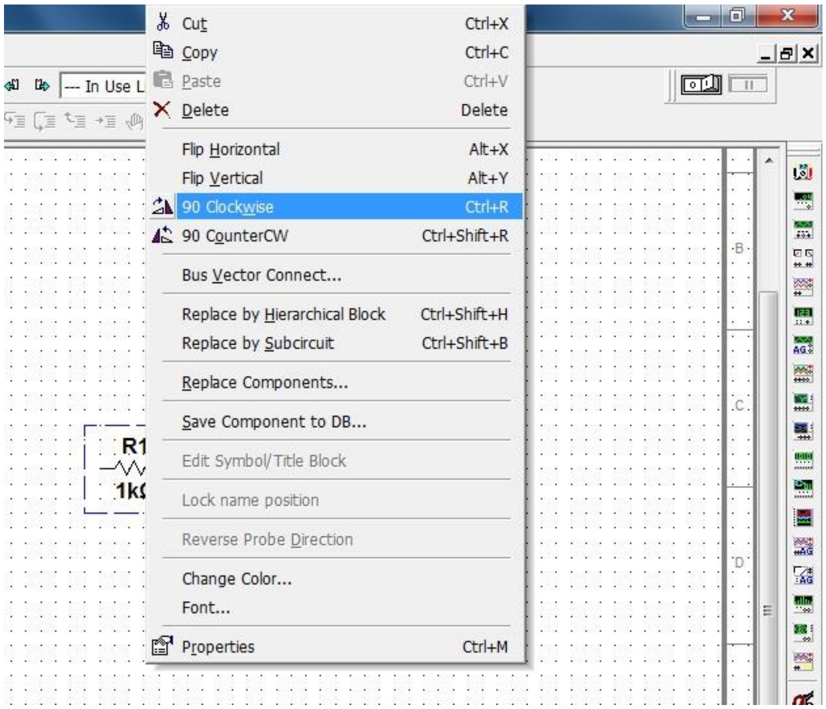


Figure 4.6: Rotating a Basic Component

f. Note: To change the resistor values, right click the mouse while the resistor is highlighted, and then choose the properties as shown in figure 4.7. The same window shown in figure 4.4 will appear.

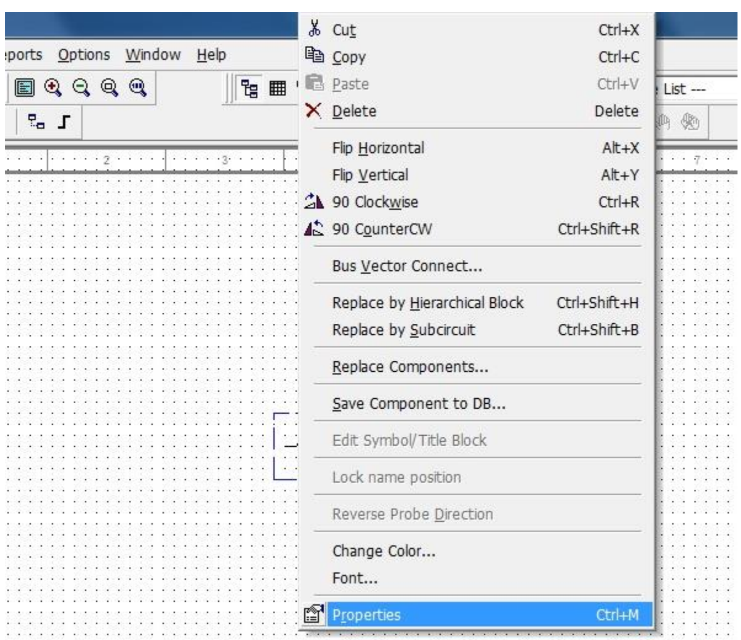


Figure 4.7: Changing the Resistance

4. **Add a Source:**
    a. On the component toolbar (shown in figure 4.2), click on the first button, which is the source button, as shown in figure 4.8. When the arrow is above the first button, 'Place Source' will appear.

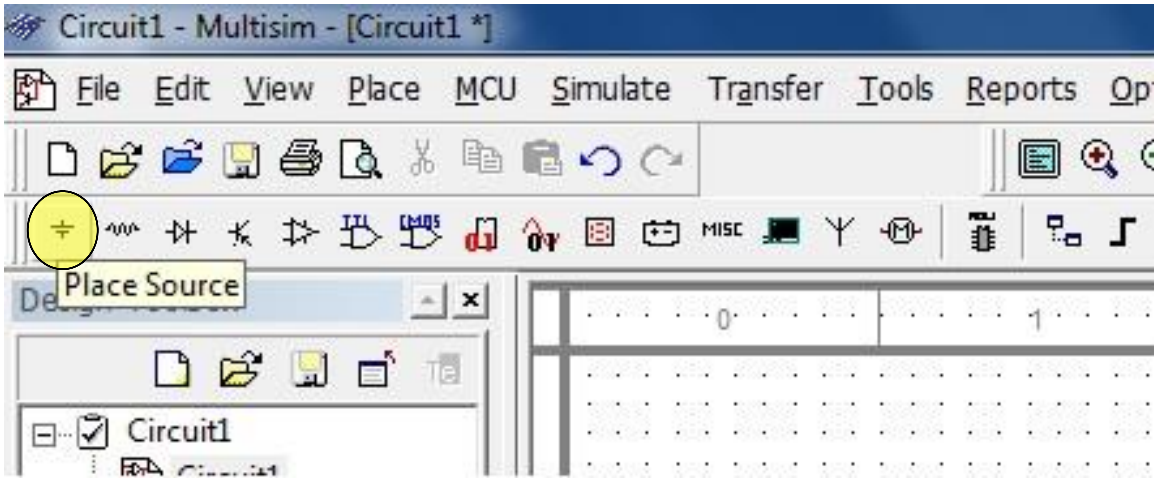


Figure 4.8: Place Source Button

    b. Once the 'Place Source' is clicked, a window, as shown in figure 4.9, would appear. Select the 'DC source' from the menu. Make sure the 'Power Sources' from the first column is selected, and then select the DC source. (In figure 4.5 both are highlighted)

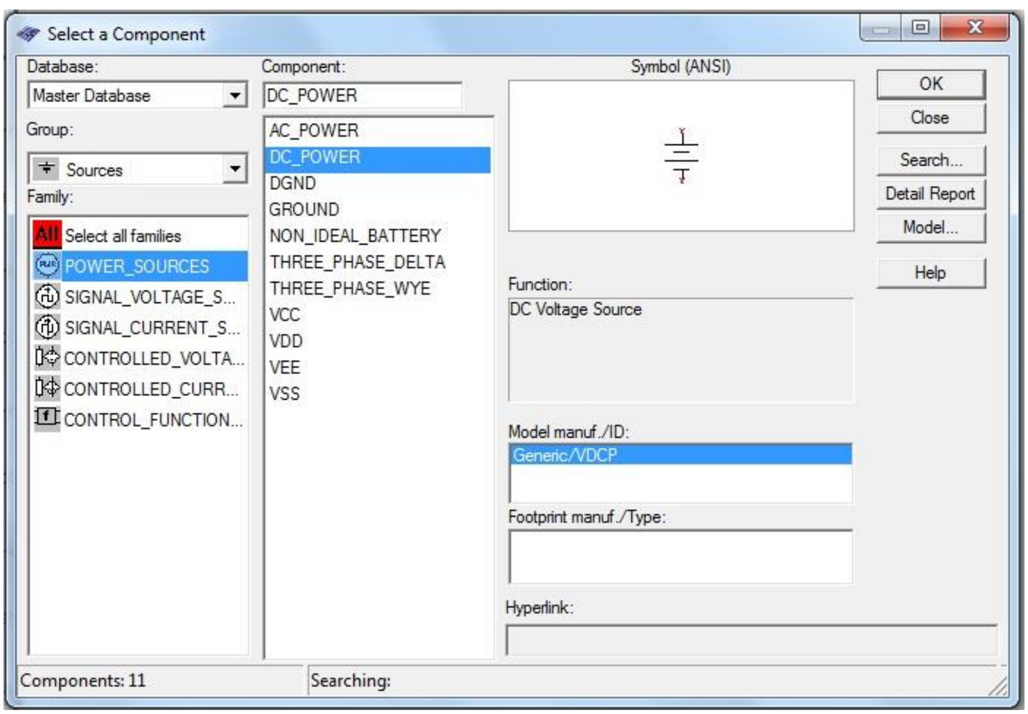


Figure 4.9: Selecting a Source

    c. Similar to the basic component place the source on the schematic.

5. To connect two components, left click on the terminal that should be connected to the other, without releasing move the mouse to the appropriate terminal of the other component. Figure 4.10 shown the components being connected. The mouse was pointed to the top of the source and left clicked. While the mouse is left clicked, it is being moved to the top of the resistor.

Figure 4.10: Connecting Two Components.

6. **Practice:** Complete the circuit as shown in Figure 4.11 by choosing two resistors.

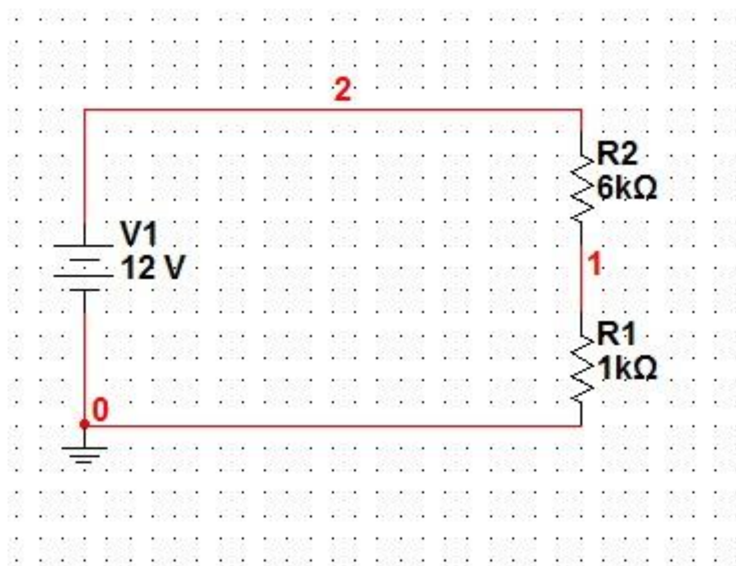


Figure 4.11: Completed Circuit with Two Resistors

7. To remove a component, from the schematic window, highlight the component and press the delete button on the keyboard. To remove a connection, highlight the connection and press the delete button on the keyboard.

8. Add Measuring Instruments and Simulating

a. The instruments toolbar is found on the right most corner of the window. Normally this would be a vertical toolbar as shown in figure 4.12.

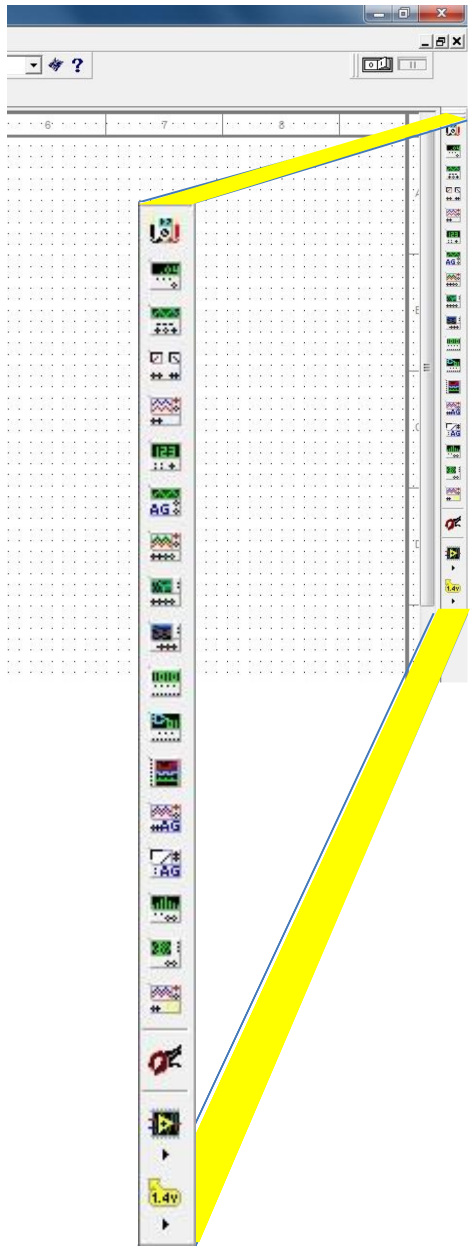
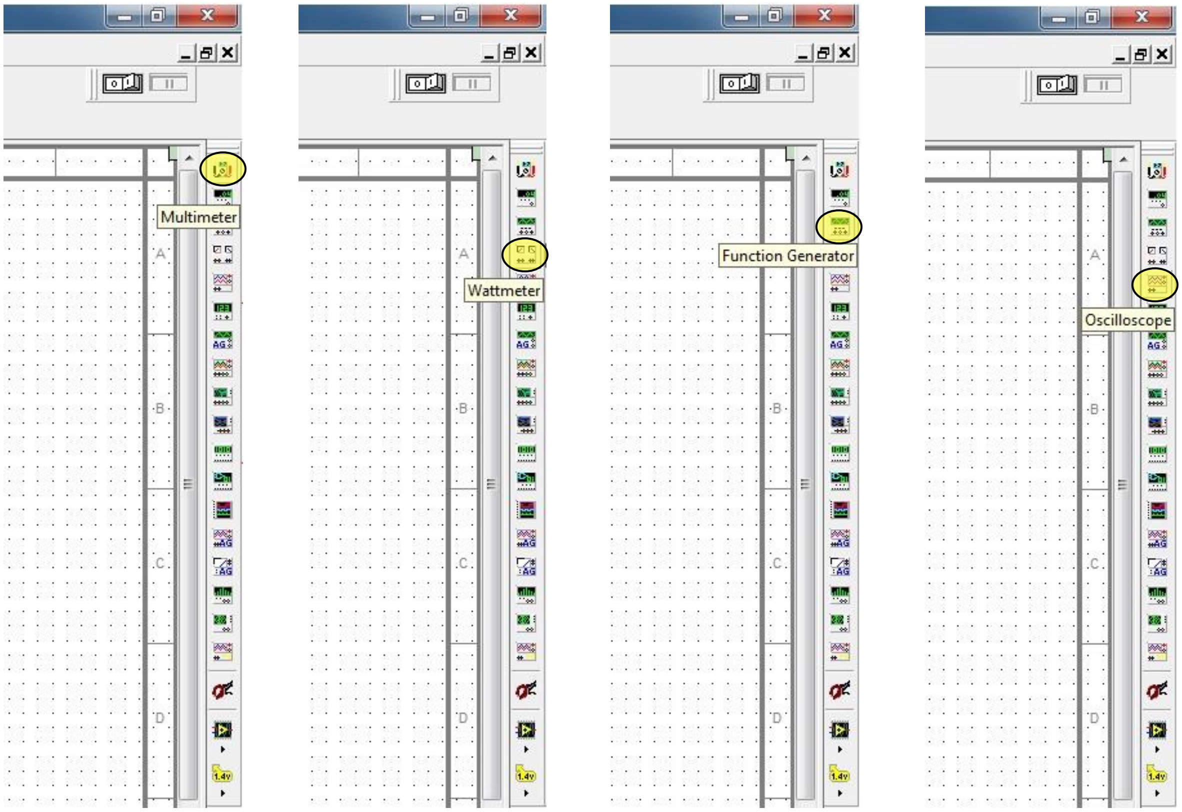


Figure 4.12: Measuring Instruments Tab

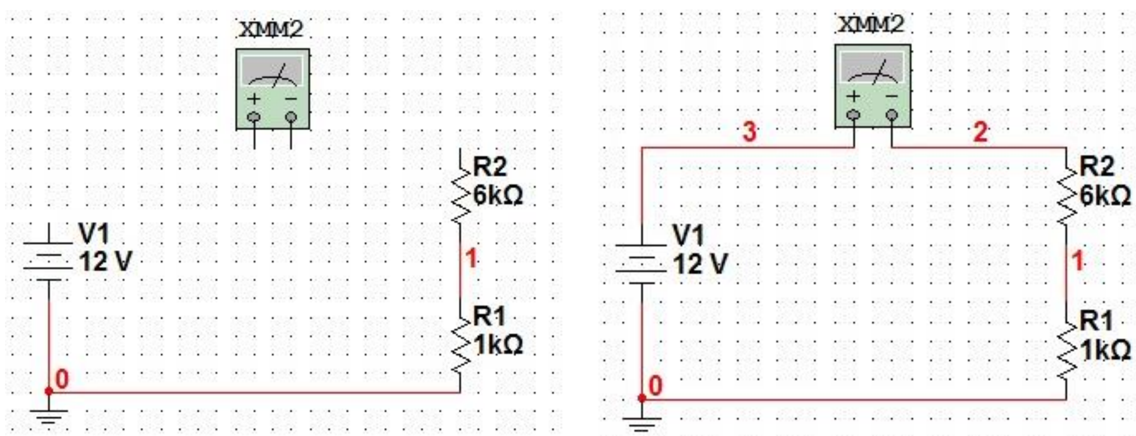
b. Figures 4.13a, 4.13b, 4.13c and 4.13d show the buttons to activate Multimeter, Wattmeter, Function Generator and Oscilloscope. By left clicking on the relevant instrument and dragging it while the mouse is being clicked the instrument can be placed. Note: Multimeter could be used as both Ammeter and Voltmeter. Note that when a current through a component is being measured multimeter should be connected in series to the component and when the voltage across a component is measured multimeter should be connected in parallel with the component. The Wattmeter consists of a Ammeter and Voltmeter.



(a) Multimeter *(b)Wattmeter* *(c) Function Generator* *(d) Oscilloscope*

Figure 4.13: Selecting Instrument Buttons

c. **Multimeter as an Ammeter:** Remove the connection from which the current measurement should be taken and place the multimeter as shown in figure 4.14a. To complete the circuit multimeter should be connected in series as shown figure 4.14b.



(a) Place the Multimeter *(b) Connect the Multimeter*

Figure 4.14: Placing the Multimeter in the Schematic Window

Double click on the Ammeter, and a new window with a digital Ammeter will popup as shown in figure 4.15. Click on the DC measurements button and the button with “A”.

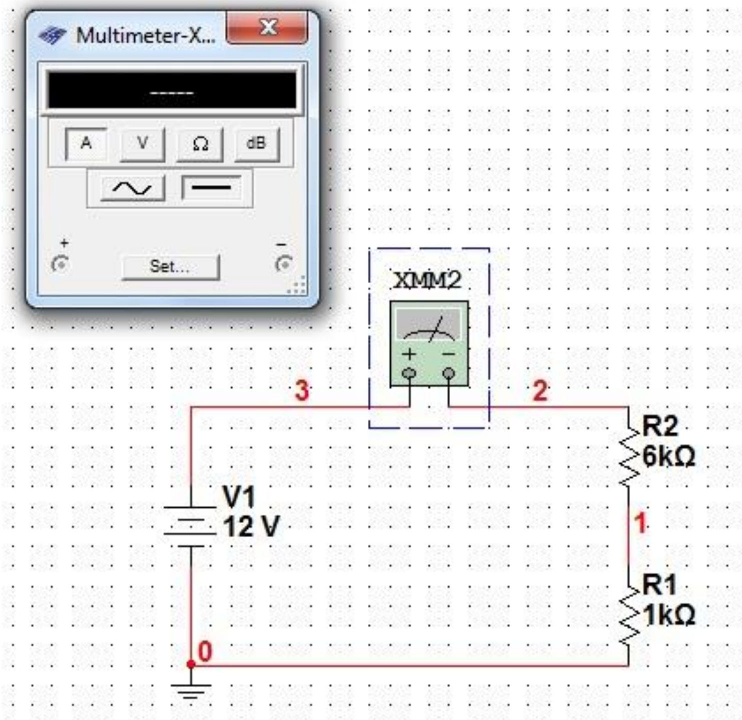


Figure 4.15: Ammeter Setup

d. **Multimeter as a Voltmeter:** Place a Multimeter in the schematic window and connect it in parallel to the component to be measured and complete the as shown in figure 4.16. Click on the Ammeter and select the ‘V’ button and the DC voltage button.

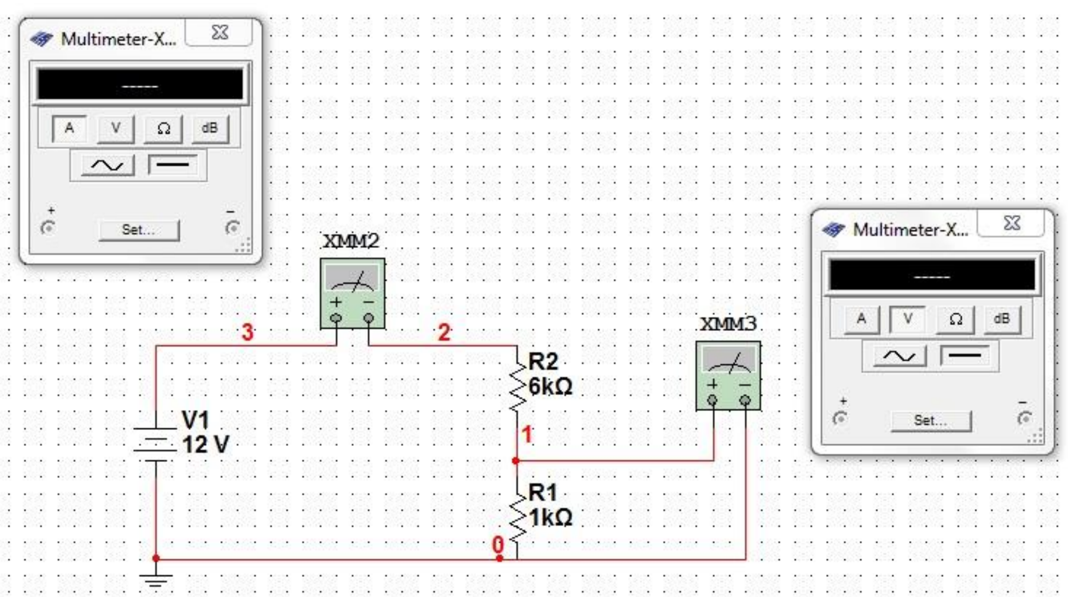


Figure 4.16: Voltmeter Setup

e. **Simulating the Circuit:** Locate simulation toolbar on main window and click on green triangle button. To stop simulation click on red square button as shown in figure 4.17.

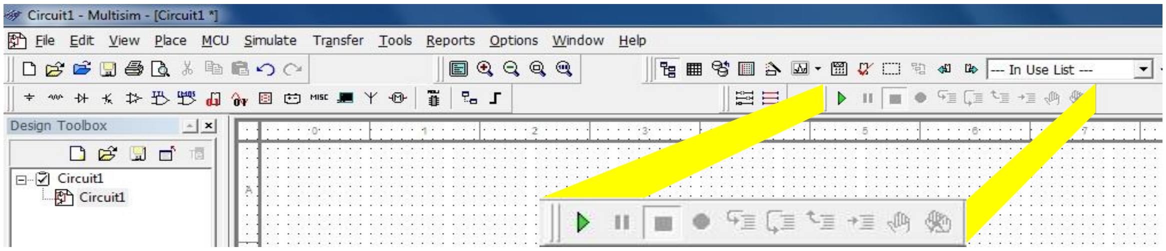


Figure 4.17: Simulation Tab

Once the start simulation button is clicked, the Multimeters would show the readings as shown figure 4.18.

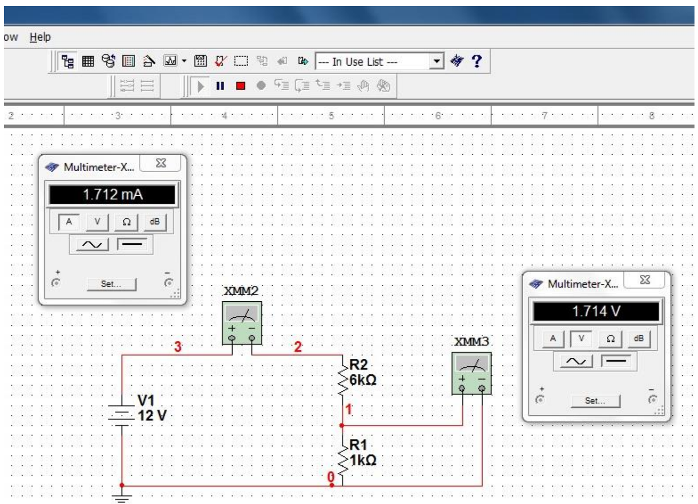


Figure 4.18: Simulated Circuit

a. **Connecting a Wattmeter:** Click and drag the Wattmeter to the appropriate location from the Instruments toolbar (fourth button from the top as shown in Figure 4.13). Connect the 'V' part in parallel and 'I' part in series to the component as shown in figure 4.19 and run the simulation.

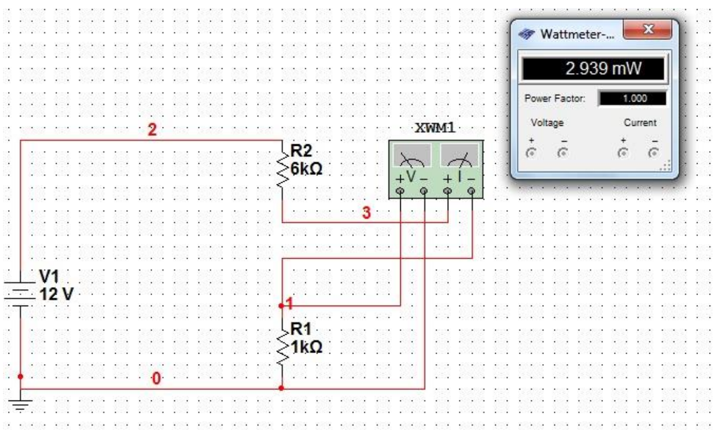
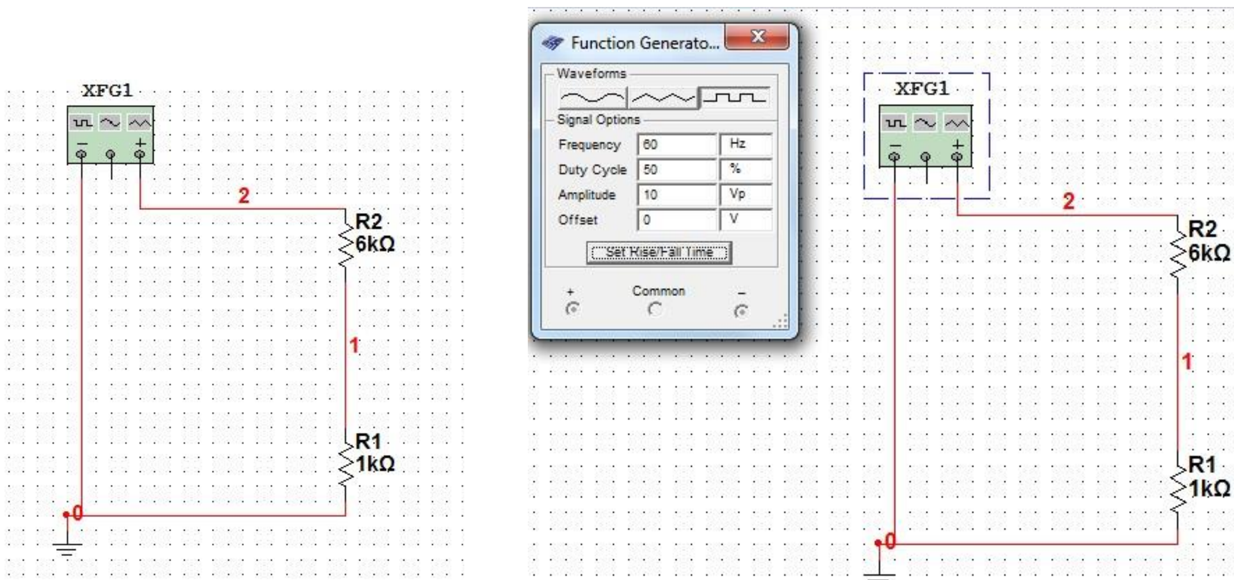


Figure 4.19: Wattmeter Connections

b. **Alternating Current Circuits:** In place of the DC source, use either the AC source (for sinusoidal signals) from the basic sources or function generator from the instruments toolbar. In this course function generator is used. Select the third button from the top of the instruments toolbar and place the function generator as shown in figure 4.20a. By double clicking the function generator, a new window will appear. Select the type of waveform, frequency, duty cycle and amplitude as shown in figure 4.20b. Simulate the circuit.



(a) Function Generator *(b) Function Generaor Window*

Figure 4.20: Placeing Function Generator

c. **Oscilloscope:** To measure and observe time varying waveforms the oscilloscope is used. A two channel oscilloscope similar to that of NI-ELVIS is available. Click on the fourth button on the instruments toolbar. Place the oscilloscope and connect it in parallel to the component as shown in figure 4.21.

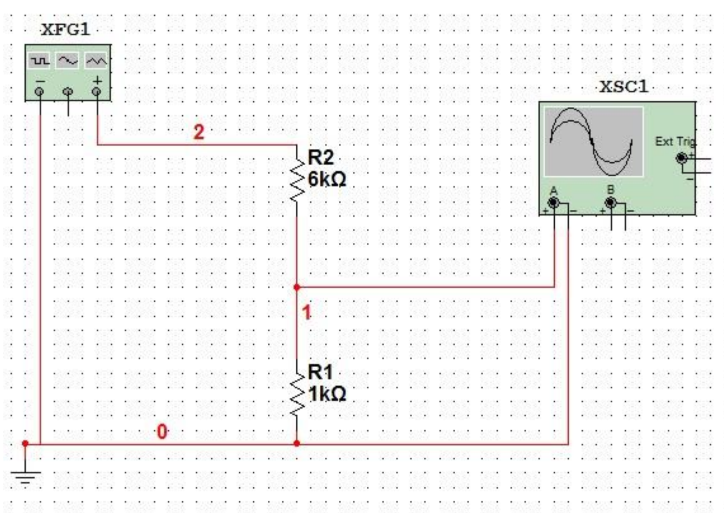


Figure 4.21: Placeing Oscilloscope

Double click on the oscilloscope and a new window will appear. When the simulation run button is clicked, then the voltage waveforms should be seen in the oscilloscope as shown in figure 4.22.

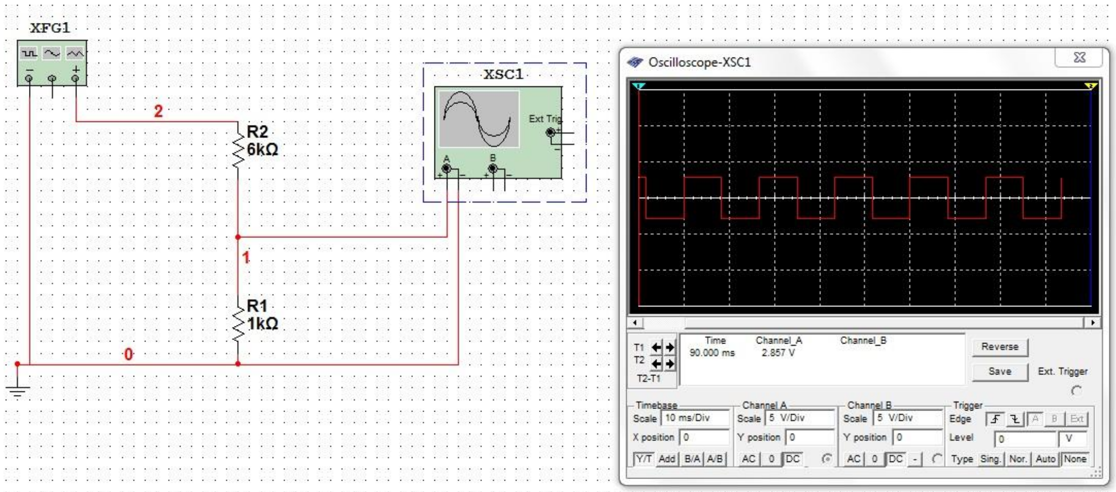


Figure 4.21: Simulating with Oscilloscope

Only voltage waveforms can be observed by the oscilloscope. To observe a current waveform, connect a small resistor in series with the current to be measured, then observe the voltage waveform across that resistor. The Amplitude should be divided by the resistance to determine the amplitude of the current waveform.