

Lab 2: Introduction to Electrical Circuits II

Objective

The objective is to build electrical circuits using a protoboard and a simulation software called Multisim. Another goal is to introduce the concept of Analog and Digital signals and conversion of one to the other.

Background

CdS (Cadmium Sulfide) Cell:

The CdS cell is in essence a resistor that changes its value with light intensity. The resistance of the CdS cell is lower in bright light and higher in low light. These cells are relatively cheap and commonly used as light sensors in applications where response time is not a design constraint.

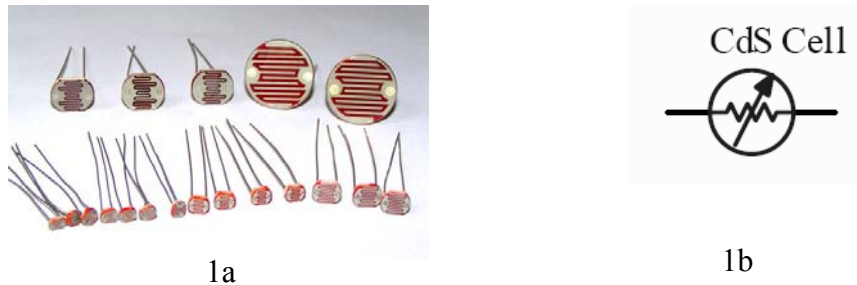


Figure 1 – CdS Cell Pictures (a) and Circuit Representation (b)

CdS cells come in different shapes and sizes as shown in Figure 1a. There is no hard convention in representing a CdS cell in circuit diagrams but the symbol that we will be using is shown in Figure 1b.

Protoboard or Bread Board:

A protoboard or breadboard allows construction of electric circuits. It is also known as the solderless breadboard because it does not require soldering. It is reusable, and thus can be used for temporary prototypes and experimenting with circuit design more easily.

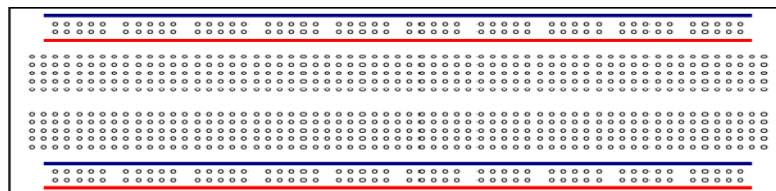


Figure 2 – Protoboard or Breadboard

Circuit Notation:

In almost all circuit diagrams, wires will have to cross at some point or another. It is often difficult to distinguish if they should actually be connected or should just pass over one another. The almost universal convention can be seen below. Figure 3a shows two crossing wires with a small loop at their intersection. This denotes that the wires cross over each other but do not connect. Figure 3b shows the two wires with a solid dot at their intersection. This denotes that they are connected.

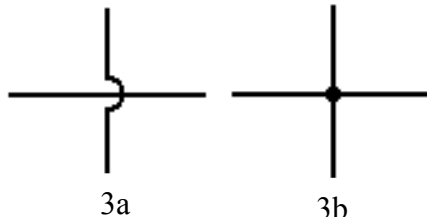


Figure 3 – Looped wires (a), Connected wires (b)

Light Emitting Diode (LED):

A LED is a low power light source found in many consumer electronics such as televisions, radios, DVD players, and video game console. Common uses of LEDs are indicator lights in electronic systems, displays (alarm clocks), and higher power applications like flashlights or household lighting. LEDs come in many different colors, shapes, sizes and power ratings. The most commonly used in academia and for hobbyists are the 5mm diameter red color LEDs (pictured shown in Figure 4a).

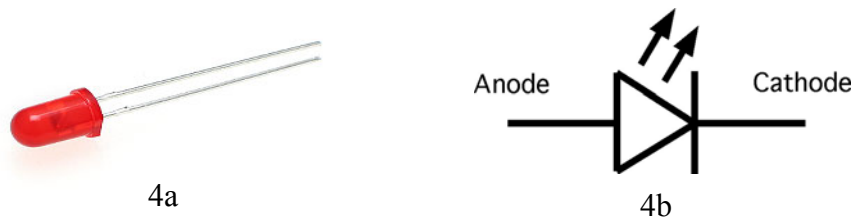


Figure 4 – LED Picture (a), circuit representation (b)

The circuit representation of an LED is shown in Figure 4b: the arrows indicate light being emitted. A regular diode has the same symbol without the arrows. The anode is the positive side of the LED - usually the longer of the two legs. However, a few manufacturers use the shorter leg as the anode. The user must make sure, which of the legs is the anode or risk burning out the LED. Current should only flow from the anode to the cathode and the voltage drop across the LED is referred to as the forward-biased voltage of the diode. LEDs are also rated for the recommended amount of current they can take. It is a common practice to use put a current limiting resistor in series with an LED.

HP34401A Digital Multimeter:

The digital multimeter used in this lab will be conceptually the same as the one used before but this will be a stationary model with more functionality. It is used in the same way as the portable DMM used before, the instructions for which are reposted here.

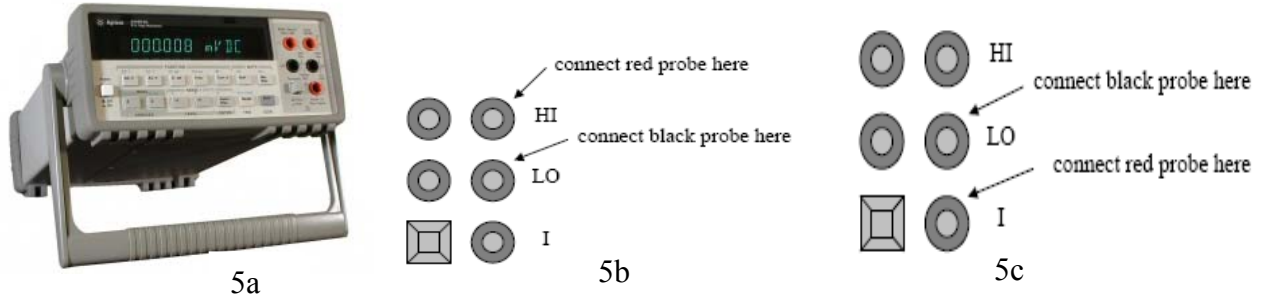


Figure 5: HP34401A Digital Multimeter(a), Measuring Voltage (b), Measuring Current(c)

We will be working with DC (direct current) voltage (V) and current (A). To measure the voltage, connect the leads as shown in Figure 5 (b). To measure current, connect the leads shown in Figure 5 (c) and then press the “Shift” key + “DC V” key. To measure resistance, use the same configuration for leads as measuring voltage; however press the 2W key on the DMM to change to measuring in resistance units.

HP E3631A Voltage Supply:

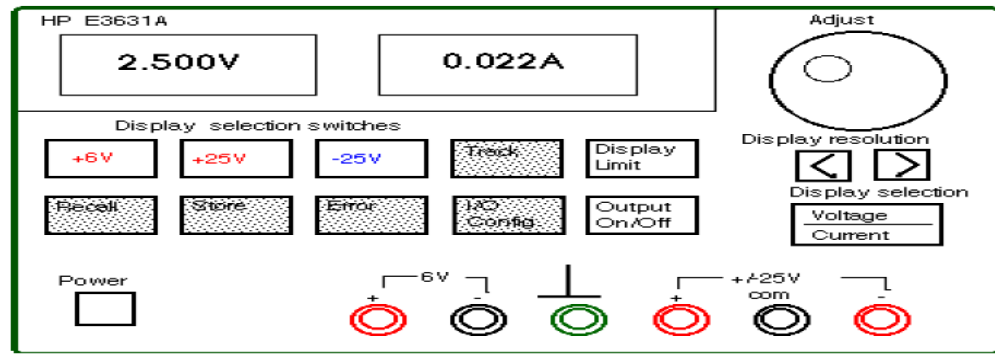


Figure 6: Hp E3631A Power Supply

The power supply has a triple output: 6V/5A, +25V/1A and -25V/1A. The outputs for these are located at the lower right-hand side of the front panel of the supply. The voltage supply also comes with earth ground (green concentric circle) which is connected to the chassis and earth for safety reasons. Choose the appropriate setting (this lab will only require +6V and +25V settings) for voltage and then use the knob on the top right corner to adjust the desired voltage. For range between 0-25V use the + and com labeled locations to connect the measurement leads/wires.

Multisim:

Multisim is a circuit simulation program created by National Instruments, in order to simplify the design and testing of analog circuits. It is based on software called SPICE (Simulation Program with Integrated Circuit Emphasis) developed in Berkley in the 1970s. This program was mainly intended for educational use, and it still remains the software of choice for many ESE classes. It is simple enough to be learned quickly, yet has enough depth to be useful for higher level classes.

Analog and Digital Signals:

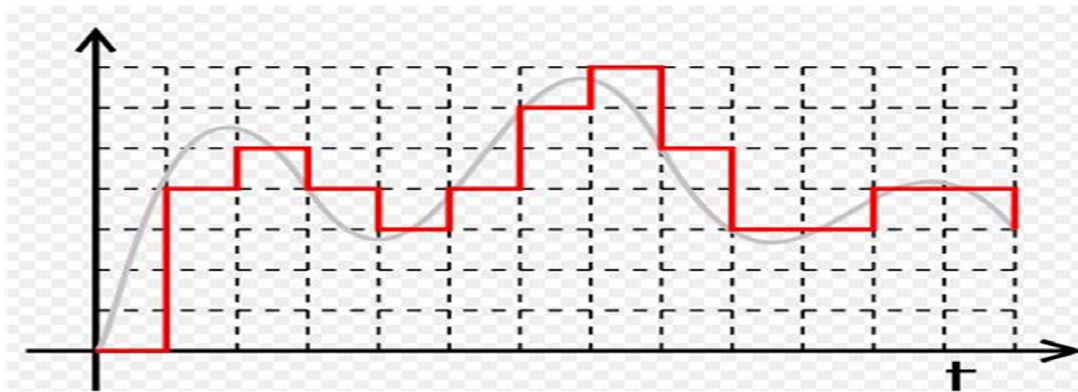
A signal is a measurable quantity through time or space. Daily we interact with signals from music, power lines, telephones, and cellular devices.

Analog Signal

Analog signal is signal that uses continuous range of values to represent information, e.g. a temperature at a given location with respect to time. The main advantage to an analog signal is that we can have infinite amount of data resolution.

Digital Signal

Digital signal is signal that uses discrete values to represent information (indicated by the red curve in Figure 7). The data is sampled version of continuous signal, therefore has less resolution.



Source: http://en.wikipedia.org/wiki/File:Digital_signal.svg

Figure 7: Analog vs. Digital Signal

ADC and DAC

Analog to Digital Converter (ADC) is a device which converts continuous signal to discrete values. The input to an ADC consists of a voltage that varies among a theoretically infinite number of values, e.g. is a sine waveforms representing human speech. Since most modern technology uses a digital computer of some sort (e.g. PDAs,

laptops etc.) to process information, the analog data must be converted into digital for the computer to make sense. Similarly, Digital to Analog Converter (DAC) is a device that converts digital signal to continuous values. A common DAC example is the processing done by a modem, taking computer data into audio-frequency (AF) tones that can be transmitted over a twisted pair telephone line.

LabVIEW:

LabVIEW stands for **L**aboratory **V**irtual **I**nstrumentation **E**ngineering **W**orkbench. It is a software program which allows the user to write programs of varying complexity using a graphical language known as G.

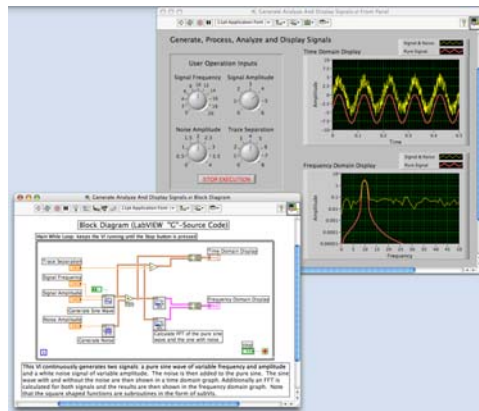


Figure 8: Sample LabVIEW

The most common uses for this software are data acquisition (which will be done in this lab) and control of instruments. One could, for example collect data from a physical circuit, perform some operations or conversions on it, and output the results back into this circuit as a voltage signal through the data acquisition board (DAQ).

DAQ Board:

A data acquisition board is a computer hardware add-on that allows the computer to receive signals from and send signals to physical circuits using a cable connected to the interface, which is connected to the computer. Thus a DAQ can do both AD/DA conversions.



Figure 9: Data Panel on Lab PCs

Materials

- Red LED
- Resistors
- Breadboard or Protoboard
- Voltage supplier (can supply 3V and 9V)
- DMM (use the workstation DMM)
- Computer with LabVIEW 6.1 software and DAQ Board
- Mutlisim software
- Connecting wires and leads

Pre-Lab Questions

1. Draw the circuit symbol for a photo resistor.
2. Look up the resistor code for 4-band resistor. Determine the value of a resistor given that the 4 bands are yellow (first band on the left), violet, brown and gold.
3. Search the web for information and explain with your own words how a protoboard is used and what the internal connections.
4. Calculate the value of current limiting resistor R1 given that the LED is rated at 2.2V, 20mA. That is the voltage drop across the LED is 2.2V and the recommended current is going through the LED is 20mA. *HINT: the current going through the LED is the same current that goes through R1.*

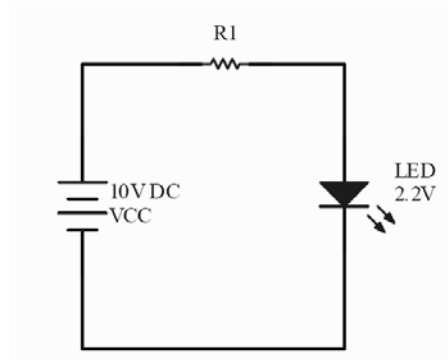


Figure 10: LED Circuit 1

5. Give one advantage and disadvantage of using simulation software as opposed to creating the circuit out of actual components on a bread board?

Lab Instructions

Part I: Circuit building on Protoboard

1. Measure the resistor values R2 and R3 in Figure 11 using HP DMM.
2. Build the resistor circuit in Figure 11 onto a protoboard.
 - a. Measure the voltage across R2 and R3.

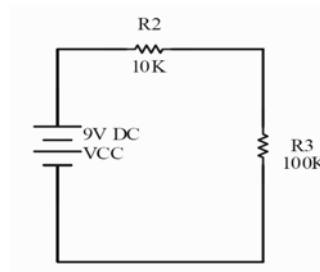


Figure 11: Resistor Circuit

- b. Now configure the circuit such that two resistors R2 and R3 are parallel with each other. Measure the total current through the circuit and through the individual resistors.
3. Calculate R1 and build the LED circuit shown in Figure 12. The exact value of the resistor calculated may not exist. Use the closest resistor value that you can find but be on the safe side. In other words, choose a resistor with value closest to the calculated resistance that will result in no more than 20mA current. Measure the voltage drop across the LED and R1 and the current through the circuit. Note: to measure the current, you need let the current pass through the multimeter.

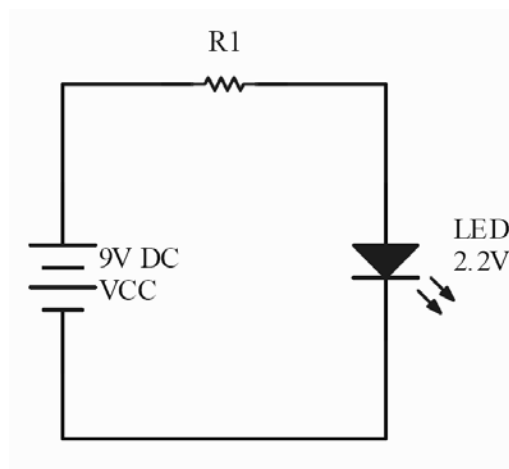


Figure 12: LED Circuit

Part II: Multisim

1. Open the Multisim software. Follow the arrows in the diagram below to create the circuit depicted in Figure 13. Save the file as ESE112_circuit1.ms7. Note: Change value on the components by double clicking on the individual component.

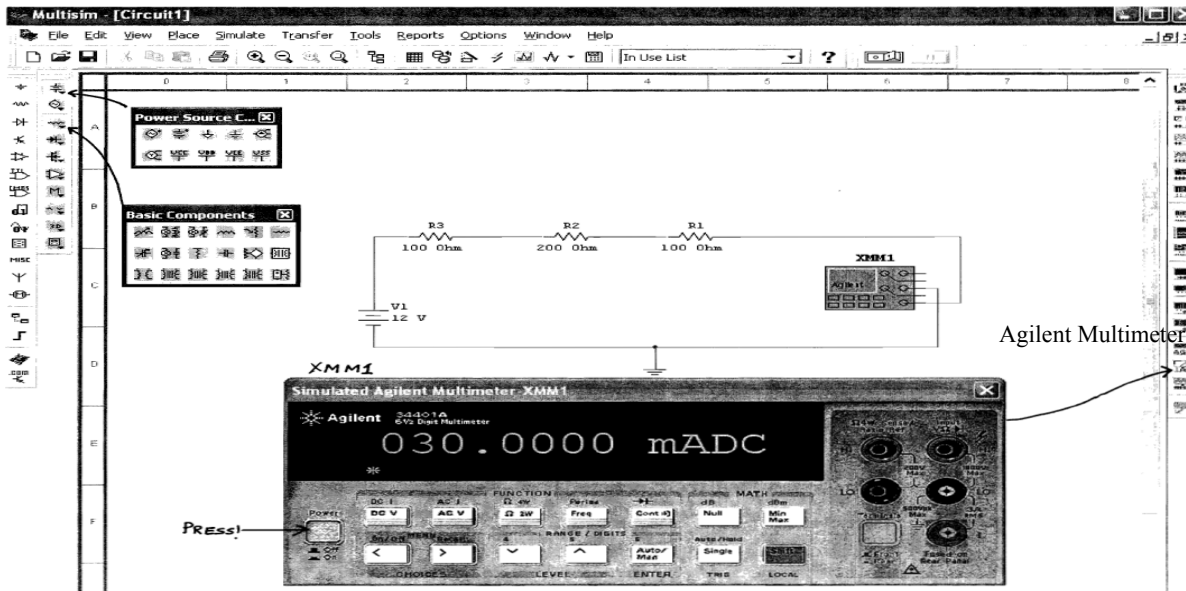


Figure 13: Circuit Simulation in Multisim

2. Use the virtual multimeter to measure the current running through the circuit (make sure to turn it on and set it to measure DC current). Then press the switch near the “?” icon or click on Simulate > Run (F5).
3. Change the values of the resistors to 200 Ω , 400 Ω , and 200 Ω and repeat the measurement. Save this circuit as ESE112_circuit2.ms7
4. Repeat the two measurements above by replacing the three resistors with one resistor of equivalent value (again the save the modified circuits as ESE112_circuit3.ms7 and ESE112_circuit4.ms7). Are the measurements consistent with what you had expected?
5. Now modify the circuit in step (1) (ESE112_circuit1.ms7) to have input voltage of 3V and measure current using virtual multimeter. Now build this circuit on the protoboard and measure the current using actual multimeter. Do you see in difference between the simulated current value and the measured current value from the circuit with actual components?

Note: There are two ways of capturing images of your circuits:

1. You can go to tools -> "capture screen area" in MultiSim and then paste it into a word document or image editor.
2. Using a software called Hypersnap that can capture the window of any program and save it as an image

Part III: ADC and DAC conversion

We will demonstrate working of sensor circuit that senses the light levels and if the light level is too dim then it indicates that by turning on a LED.

To measure the intensity of light we will use cadmium sulfide (CdS) photocell sensor. The change in resistance of the photocell can be converted to the change in voltage of a circuit. Using appropriate hardware and software we can read this change in voltage and generate software triggered output.

1. Calibrating a CdS Cell

In order to use the photocell, we will need to calibrate our instrument to its resistance value over the possible intensities of light it will be exposed to.

- To determine the resistance value, connect the probes of the DMM (use the DMMs on the workstation instead of the portable DMM you have been using) to the CdS.
- With the resistor covered and exposed to ambient light, measure the resistance value in ohms. This provides the range of possible values that a circuit including this CdS resistor will experience under varying light intensities.

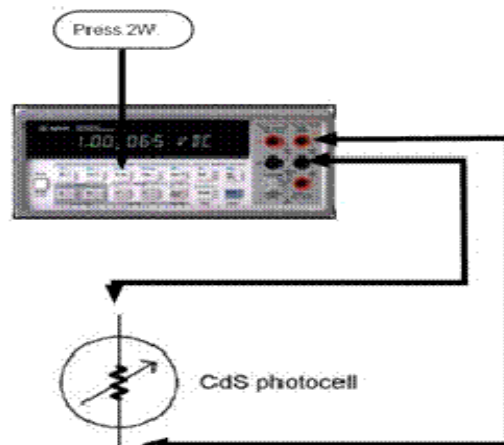


Figure 14: CdS photocell symbols and its resistance measurement

2. *Setting a Darkness Threshold Translating to Voltage*

In order to allow the computer to interpret the light conditions experienced by the CdS cell, we will need to find a way to convert the change in resistance of the cell into a change in voltage that the computer can read. This can be accomplished with a voltage divider circuit, which makes use of the proportional voltage drops over resistors in series to vary the voltage between two resistors as the one resistance varies.

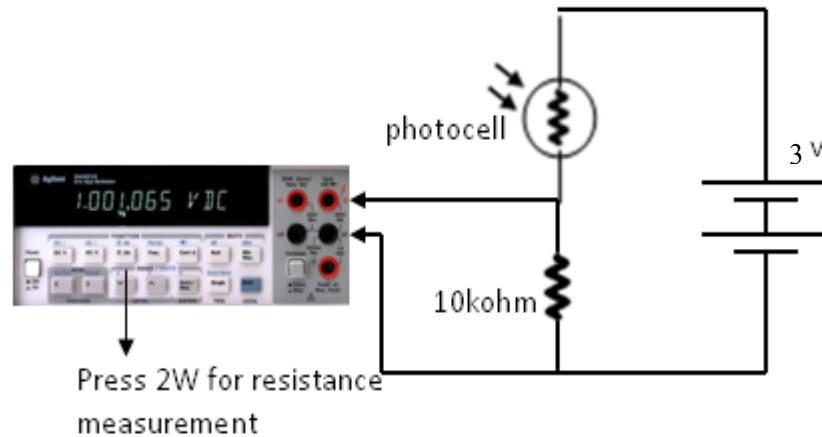


Figure 15: Converting the resistance of photocell to voltage

Build the above circuit on your protoboard, and then measure and record the voltage output when the photocell is exposed to ambient light. Repeat with your finger over the photocell and record the new voltage output to the DMM.

3. *Interfacing with the Computer*

Once you know the voltages at which the resistor will operate, you can connect the circuit to the computer and use the sensor as a form of digital control. The PCs in ESE Undergraduate Labs are equipped with boards that can read voltages. The boards are interfaced with software called LabVIEW, which has an easy-to-use interface to allow measurement and control of voltages. Refer to Figure 9 at this time.

- You will need one connector for CH 0 of 'Analog Input'. Connect the positive probe of the analog input to the voltage output of the voltage divider (where the DMM was connected earlier) and the negative probe to ground.
- Connect another connector to CH 0 of "Analog Output". Connect the positive probe to the positive end of an LED and the negative probe to ground. Also make sure the other lead of the LED is also connected to ground.
- From course website, download **Light_Intensity_08_Final.vi file**. Save this file and open it with LabVIEW 6.1 software (note this file will not work with newer version 8.6). Once you open the file, you should see the Light Intensity Indicator program as shown below in Figure 16.

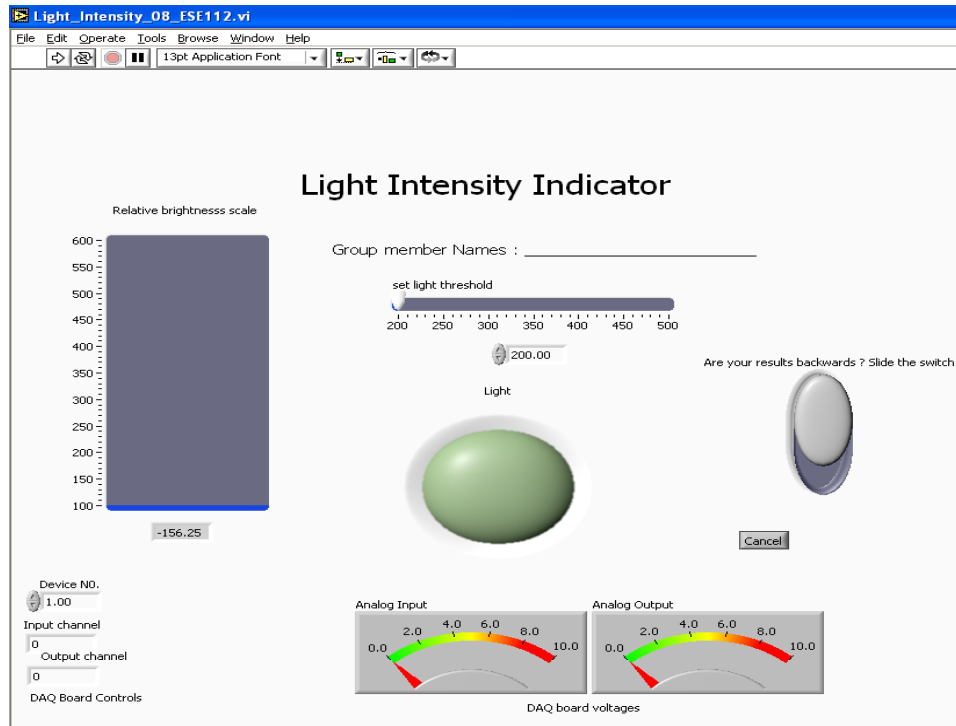


Figure 16: LabVIEW software front panel

- d. When you open the VI, you will be presented with this bar at the top of your screen. Press the ‘play’ button to start the simulation and begin receiving data.



Figure 17: Running the program in LabVIEW

- e. Cover the photo sensor with your finger and note the change in the measured voltage on the screen. The "relative darkness scale" indicator will vary proportional to light. Write down the numbers from the “relative darkness scale” for the maximum and minimum readings of the voltages measured from the photocell, based on the amount of ambient light the photocell is exposed to. Since the voltage is now converted into a digital number, the software can be set to control an indicator light that lights up when the ambient light level falls below a set threshold. You can adjust the threshold by dragging the slider. It is through these principles that computers can receive input from external sensors and dynamically set output to respond to changing conditions.

Post-Lab Questions

1. Part I
 - a. Questions 2
 - i. Tabulate the measured and calculated resistors values, and comment on the similarities and or differences of the values. Are the actual values within the tolerance specified by the resistor?
 - ii. Based the measurement of voltage across the battery and resistors R2 and R3, what is the value of the current flowing through the circuit?
 - iii. Based on your recorded measurements, is power conserved in the system for the circuit with series configuration of R2 and R3?
 - iv. With the current measurements for the parallel configuration of R2 and R3, does Kirchhoff's Current Law (KCL) hold true.
 - b. Question 3
 - i. Show your calculation for determining value of R1 in question 3.
 - ii. Based on your measured values, does Kirchhoff's Voltage Law (KVL) hold true?
2. For Part II
 - a. Answer the questions 4 and 5. Make sure you include all your Multisim circuit diagrams for each question.
 - b. Describe your experience with using circuit simulation software vs. building a circuit using actual components on a protoboard (lab activity Part I).
3. Part III
 - a. As the resistance of the photocell increases, what happens to the voltage over the resistor? Explain mathematically based on the basic electrical laws you have studied so far.
 - b. Describe carefully, the step by step operation of the system consisting of the photocell circuit, the LabVIEW virtual instrument, and the LED. You may also want use a diagram to explain operation to aid the reader visually.