University of California, Los Angeles

School of Engineering and Applied Science

Department of Electrical and Computer Engineering

ECE11L Lab Manual Winter 2023

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Experiment 1: Analog Discovery and Kirchhoff's Laws

Topics

- Introduction to Analog Discovery 2 (AD2) and basic instrumentation
- Kirchhoff's Laws

Objectives

- To become familiar with basic circuit construction, and operation of the AD2 device
- To learn how to measure voltage, and resistance with the voltmeter and the impedance analyzer on Analog Discovery 2
- To experimentally verify equivalent resistance and Kirchhoff's Laws

Background

i. Equivalent Resistance: The equivalent resistance of two or more resistors in series is given as:

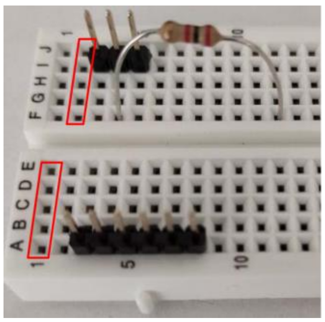
$$R_{eq} = R_1 + R_2 + \cdots$$

The equivalent resistance of two or more resistors in parallel can be found through:

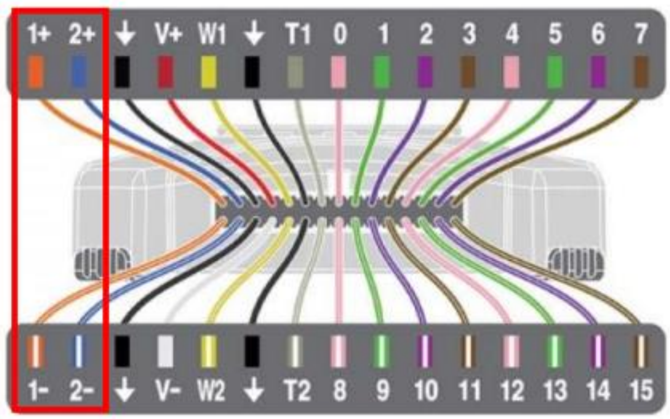
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

ii. Kirchhoff's Laws: Kirchhoff's Voltage Law (KVL) states that the sum of the voltages in a loop of a circuit must sum to zero. Kirchhoff's Current Law (KCL) states that the total current going into a node must equal the total current leaving the node.

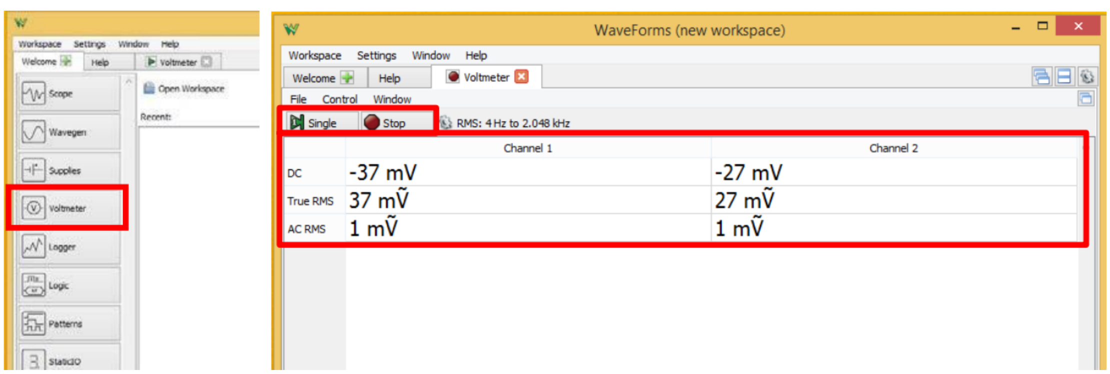
iii. Getting started with Analog Discovery 2 and the breadboard: Visit https://analogdiscovery.com/getting-started/, and follow all steps to ensure the hardware is properly interfacing with the software: WaveForms. The breadboard is where the components (resistors, capacitors, pin headers, etc.) are placed, and is usually configured in row/column-shorted fashion. For example, in the breadboard shown below, 1A through 1E are shorted and 2F through 2J are shorted as well.



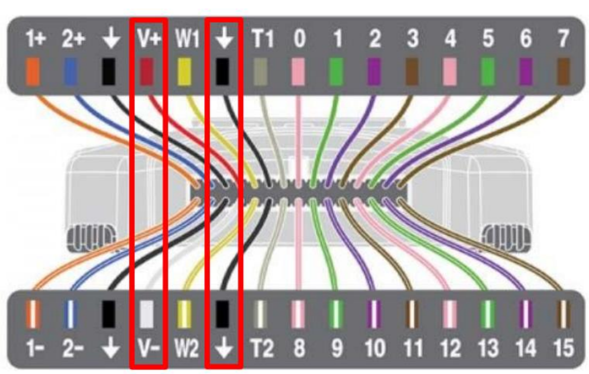
iv. The Voltmeter on Analog Discovery 2: There are two voltmeter channels on Analog Discovery 2 with pins 1+/1- as channel 1, and pins 2+/2- as channel 2. Jump wires are used to connect both channels to the breadboard and components.



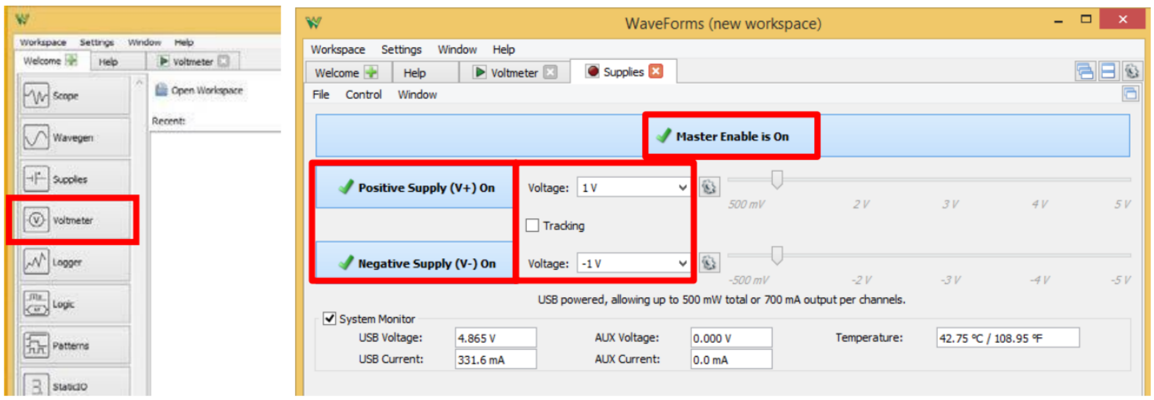
In the WaveForms software, open the Voltmeter applet from the left column and the DC voltages across 1+/1- and 2+/2- will be readily available when you click run.



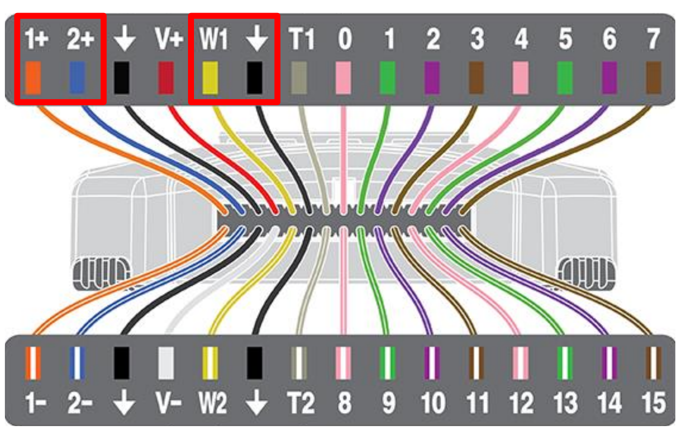
v. The power supplies and grounds: Analog Discovery 2 provides one positive and one negative programmable power supplies with pins V+/V-. The maximum available supply range is [-5V, +5V]. Ground pins are also available labelled as ↓.

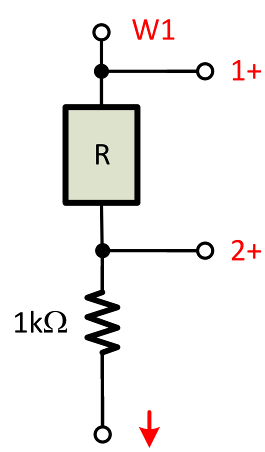


Do not forget to connect the grounds to the circuit to form a loop. Jump wires are used to connect both supplies and grounds to the breadboard and components. In the WaveForms software, open the Supplies applet from the left column and the supply voltages will be available when enabled.

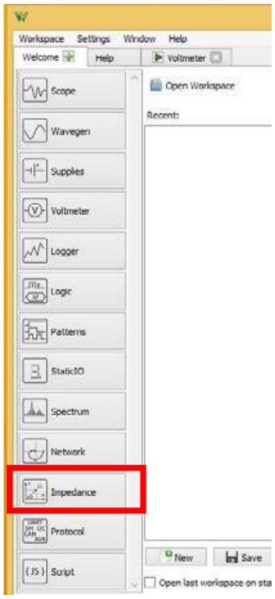


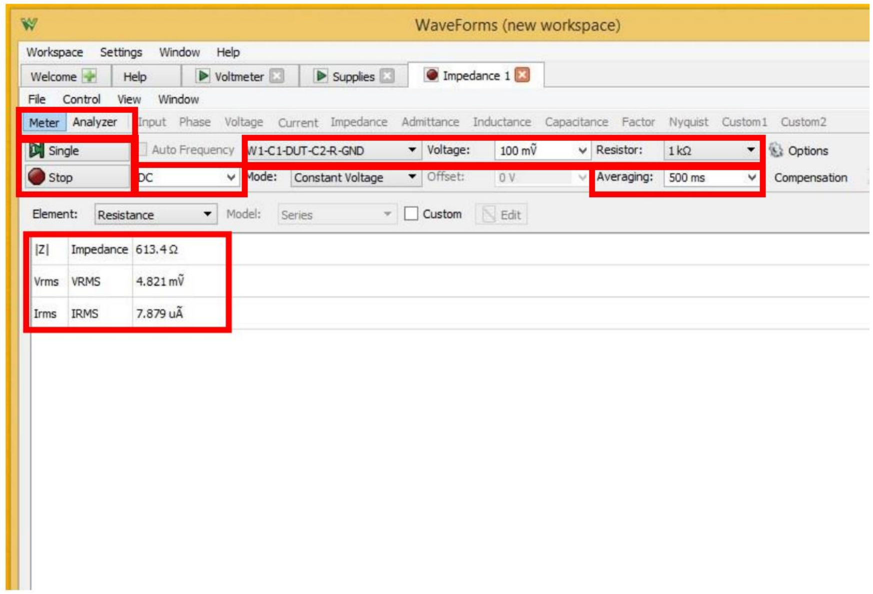
vi. The impedance analyzer: The impedance analyzer is used to measure the resistance/capacitance/inductance of a component. Within the scope of 11L, resistance measurement is of the most interest. The use of the impedance analyzer involves multiple pins and a reference resistor. The impedance analyzer requires the specific connection shown on the right. The box labelled R is the resistor to be measured. An additional $1k\Omega$ is also needed, connected between AD2 ground and 2+ pin.





To measure the resistance, in the WaveForms software, open the Impedance applet from the left column. Follow the settings shown below. The averaging time can be set longer if the impedance reading is jittery. Make sure $1k\Omega$ resistor is selected in the workspace.





For more information on the Voltmeter, power supplies or the impedance analyzer visit:

https://reference.digilentinc.com/learn/instrumentation/tutorials/start

Lab

1. Ohm's Law and Measuring Voltage and Current

Retrieve the following resistors: 680Ω, $1k\Omega$, and $2.2k\Omega$. Measure the resistance of each of the above resistors using the Impedance Analyzer and record the values. You will use them for your theoretical calculations ahead.

Build the circuit illustrated below on your breadboard using the previously obtained resistors. Set the voltage in the Impedance Analyzer to 1V and remember to include the $1k\Omega$ reference resistor in the connection. Note that due to the non-ideality of the impedance analyzer, the voltage across R to be measured may not be exactly equal to 1V.

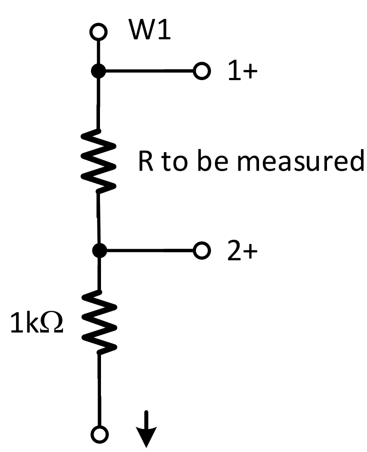


Figure 1: Setup for resistor measurement

Using the resistor values listed above, verify Ohm's Law by recording the voltage, current, and resistance in the circuit in each case from Analog Discovery 2. Record your experimental values in the table below.

Resistance (Ω)	**Voltage (V)**	**Current (A)**
680 Ω		
1 kΩ		
2.2 kΩ		

Discussion

- How did the values of resistance vary from their given values based on color code? Were they within the given variance?
- How does Ohm's Law hold for your experimental results?
- AD2 cannot measure the current directly. Based on your observation, how does AD2 impedance analyzer produce the values for the current and resistors?

2. Equivalent Resistance

Build the following resistive network shown in Figure 2. Once again, measure the values of resistance using the Impedance Analyzer (setup of Figure 1) before performing analysis. $R_1 = 680\Omega$, $R_2 = 1.2k\Omega$, $R_3 = 5.6k\Omega$.

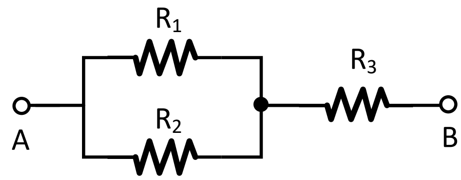


Figure 2: A simple resistive network

Calculate the equivalent resistance as measured across nodes A and B. Measure the resistance across A and B using the Impedance Analyzer. Does this agree with your theoretical equivalent resistance value? If not, why?

Take a resistor of value $1M\Omega$ or greater. Measure that resistance using the Impedance Analyzer but this time with reference resistor (the bottom resistor in Figure 1) of $1M\Omega$. Now, grip each lead of the resistance you just measured with your bare fingers as tightly as you can, hold long enough for the reading to settle, and read the new value of resistance. In this set-up, your "skin resistance" is in parallel with the resistor. From these measurements, calculate the value of your skin resistance.

Discussion

- Voltages of about 50V can cause an electric shock (assuming contact with dry hands, as in this experiment). Based on your experimental results, how much current would be going through your body with such a voltage?

3. Voltage and Current Dividers

Construct the voltage divider in Figure 3 with values: $R_1 = 100\Omega$, $R_2 = 470\Omega$. Use the V+ power supply in AD2 for the 5V voltage source.

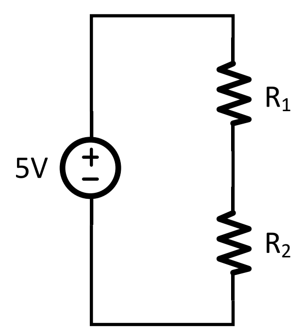


Figure 3: A voltage divider

Measure the voltage across each resistor with the voltmeter inside AD2 and compare with theoretical results. Next, construct the following current divider shown in Figure 4 with values: $R_1 = 100\Omega$, $R_2 = 470\Omega$, $R_3 = 1.2k\Omega$.

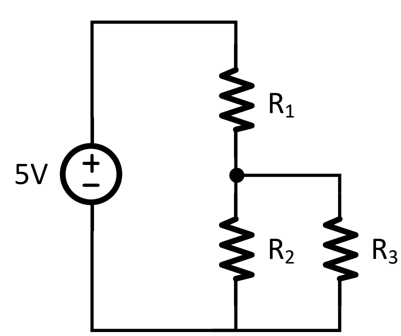


Figure 4: A current divider

Measure the voltage across each resistor with the voltmeter inside AD2, and compute the branch current using Ohm's Law.

Based on the voltage divider of Figure 3, you are now asked to design a sensor circuit which translates the lighting in the environment into a voltage value through the use of a photoresistor. A photoresistor's resistance changes based on the amount of light it is exposed to. Chose the resistor R_1 such that the output of the circuit, that is the voltage across the resistor R_2 (now replaced by the photoresistor), would be approximately 50% of the input voltage in standard room lighting, but roughly 5V in darkness. Use the 5V supply as the power source as in previous sections. Design this circuit, and measure the output both in normal lighting, and in darkness.

Discussion

- How did the voltage and current divider compare with theoretical expectations?
- How does the resistance of the photoresistor change as you alter the level of light?

4. Kirchhoff's Laws Analysis of Circuits

Build the circuit illustrated in Figure 5 with the following resistor values: $R_1 = 1k\Omega$, $R_2 = 680\Omega$, $R_3 = 3.3k\Omega$, $R_4 = 2.2k\Omega$, $R_5 = 470\Omega$.

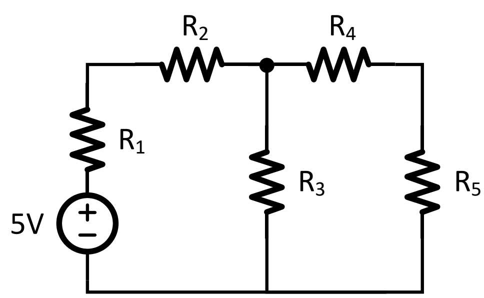


Figure 5: Kirchhoff's laws analysis

Using Kirchhoff's Voltage and Current Laws, find the theoretical values of the voltage and current across each resistor. Measure each of the voltages and compute the branch currents (using Ohm's law), and compare with the theoretical and experimental values.

Discussion

- Do your experimental results obey Kirchhoff's Laws?