EE 110
Introduction to Engineering & Laboratory Experience

Lab manual credit: Dr. Saeid Rahimi

Lab 2

Part-1: Introduction to Analog Discovery Scope

In part 1 we will use the Analog Discovery Scope (DS) instrument (instead of the laboratory instruments) to perform the same basic measurements you conducted in Lab 1. The functions of the DS which integrates all the traditional laboratory instruments into a small box will be described. Analog Discovery Scopes (DS) were purchased by the department so students could borrow and use them outside of the laboratory. The hardware is small enough to be placed in the students backpacks.

Introduction to Discovery Scope (DS)

The goal of this part of the lab is to become familiar with the Discovery Scope (DS) as a tool that functions as a DC power supply and multimeter. You will first need to download the DS software to your laptop computers. Your instructor will demonstrate the process of downloading the software from the Discovery Scope web site. For this part of the experiment you will need to connect the DS to your laptop through the USB port. Next, you will need to become familiar with the pin diagram of the DS. In the first glance, the number of DS wires could be overwhelming. However, they are conveniently color coded and you can identify each wire by referring to the ping diagram.
Experiment

Download the pin diagram of the DS by googling “Analog Discovery Scope”. Copy and paste the pin diagram in a document and later paste a hard copy of the diagram in your lab book. The pins are color coded. Two pairs of pins are used as the input of the oscilloscope. Two pins provide positive and negative 5 volts of DC voltage, and four pins are connected to the system’s ground. Two pins deliver AC waveforms and two pins are used for triggering purposes (not used in this lab). The remaining 16 pins are used for digital Input/output purposes.

Each student is assigned a DS box that in addition to the DS unit includes a set of colored wires with female end pins that are used to connect to the DS pins. Included in the box you will find a USB cable that connects the DS to a laptop. In addition to providing a screen for viewing the results and uploading and downloading codes, the laptop is also used to power up the DS.

Open the boxes and explore various parts of the DS and its pins. The pin diagram is described by the instructor. Prior to receiving the “numbered” DS boxes, students fill out forms and pledge to return the devices to the department at the end of the semester. For future reference paste a copy of the pin diagram in your lab book.

**Download DS Software**

Available in lab computers. When you use your own computer, you will need to download and install the software. The download takes a few minutes.
DC Measurement

In this section of the lab we will use the laboratory power supply as a variable source of voltage and the DS as a meter to test the output of the power supply. First connect the DS to your laptop and launch the DS application. Next, identify the output terminals of the power supply and the input pins of the DS (referred to as the I/O, or input/output pins). The DS has several I/O pins. Choose one of the sixteen I/O pins as your input port and connect the “high” output of the power supply to that pin. To create a return path for the current, connect the ground or “low” of the power supply to one of the ground pins of the DS (colored black). Choose the following voltages for the output of the power supply and check and confirm the values with your DS: 1 V, 2 V, 3 V, 4 V. Record the output readings of the power supply and the input readings of the DS in a table.

DS as a DC Power Supply and a Function Generator

In this section students use the DS as the source of DC and AC voltages. This part is the reverse of part 3. Use multimeters and the traditional laboratory instruments to measure the DC and AC output of the DS. The instructor describes the current, voltage, and frequency limitations of the DS compared to the standard laboratory instruments.

In this part of the experiment you will use your breadboard to power a simple circuit with the power supply feature of the DS. Connect a 300 Ohm resistor to a 1 k Ohm resistor in series as shown in the diagram below. In order to pass a current through these resistors we will use the DS as a source of power (battery). Note that the power output of the DS is limited and if you need large current and power output you will need to use a more powerful power supply. The DC output of the DS is limited to +/- 5 V and the current output of the DS through its I/O ports is limited to few tens of mA.

![Diagram](Image)

Apply 5 V to the circuit and use your multimeter to measure the voltages across each resistor. Record your measurements in a table in your lab books. Copy results to Lab 2: Results Report.

Confirm that the sum of the voltages across the two resistors is equal to 5 volts.

<table>
<thead>
<tr>
<th>R1</th>
<th>R2</th>
<th>V1</th>
<th>V_{AB}</th>
<th>V_{BC}</th>
<th>V_{AC}</th>
<th>I_{R1}</th>
<th>I_{R2}</th>
</tr>
</thead>
</table>

6
Part 2: DC Measurements I

Series and Parallel Resistor Combinations and Current Measurements
All circuit elements exhibit some resistance to passage of electric current through them. Resistors are specifically designed for the purpose of limiting current. When there is more than one element in the circuit, depending on the path of current, the resistance of the circuit elements combine to create an effective resistance for the combination. If the same current flows through two or more elements, they are said to be in series with each other. However, when the incoming current splits into branches the components are said to be in parallel. An electronic circuit usually includes both series and parallel combination of components. In this lab we will consider the following three resistor combinations:

(i) series
(ii) parallel
(iii) combination of series and parallel

Resistor Combinations
Your toolbox may include resistors with various resistances. Most tool boxes may include resistors with resistances ranging from a few Ohms to M Ohms. However, it is unlikely that any given toolbox would include all values of resistance. That would take an enormous amount of space! One of the goals of today’s experiment is to learn to use resistor combinations to create an effective resistance that does not exist in your toolbox. Of course, one can adjust a variable resistor called a potentiometer to the desired resistance. For instance a 10 kΩ potentiometer can be adjusted to have any resistance between zero (actually very small) and 10 kΩ. One can vary the resistance of a potentiometer by turning a screw located at the top of the device. But potentiometers are generally bulky and more costly than a fixed resistor. It is sometimes advantageous to combine fixed resistors to create a desired resistance. In this lab we will use both fixed resistors and potentiometers.

For example, consider the following three resistors: 300 Ω, 1 kΩ, and 10 kΩ potentiometer. Today, we will combine the 300 Ω and 1 kΩ resistors to create resistances that do not exist in your toolbox. In the last lab we described the color bands printed on each resistor and learned how to calculate the resistance corresponding to the color bands. We noticed that the last color band indicated the percentage of error that defines a range of resistances for any particular resistor. Therefore in order to pinpoint the exact resistance of a resistor, one needs to use a multimeter to measure the element’s resistance. Naturally one uses a color chart in the absence of a multimeter.

Resistors can be connected to each other (combined) to practically create any desired resistance. There are rules governing the combination of resistors. Today we will examine the series and
parallel resistor combinations. Capacitors may also be combined similarly, but their combination rules are different from resistors. Consider the following resistor combinations.

**Series Combinations**

The equivalent resistance of the parallel combination \( R_{\text{Eq}} \) is given by

\[
\frac{1}{R_{\text{Eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots
\]

\[ R_{\text{Eq}} = 0.545 \, \text{k}\Omega, \text{ which is smaller than any of the three resistors.} \]

Clearly in a series combination of resistors the same current goes through all resistors. The above formula can be easily obtained using Ohm's law. The derivation for the equivalent resistance of series and parallel combination of resistors can be found on the Internet, or in elementary physics and electronic text books.

**Parallel Combination**

The equivalent resistance of the parallel combination \( R_{\text{Eq}} \) is given by

\[
\frac{1}{R_{\text{Eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots
\]

\[ R_{\text{Eq}} = 0.545 \, \text{k}\Omega, \text{ which is smaller than any of the three resistors.} \]

Sometimes we may need to mix series and parallel resistor combinations to achieve a specific resistance. For cost reduction it is desired that we minimize the number of components in order to achieve a certain resistance. A mixed series and parallel combination of resistors is shown below.
Measurement 1

Select two resistors with values 200 Ω and 750 Ω. Verify the resistance of each resistor using the color chart. Using the last band of the resistors, indicate their percentage tolerance. Illustrate your method in your lab book. Next, use your multimeter to measure the resistance of each resistor. Present the expected values (from the color chart) and the measured values (using multimeter) in a chart. Are the measured values within the tolerance values of the resistors?

<table>
<thead>
<tr>
<th>R1 from color chart</th>
<th>R1 measured</th>
<th>R2 from color chart</th>
<th>R2 measured</th>
</tr>
</thead>
</table>

Measurement 2

Combine the two resistors from above in (1) series and (2) parallel and find the Equivalent. Describe and justify your method and calculate the expected value of the resulting resistance. Connect the resistors on your breadboard and use your multimeter to determine the equivalent values for each combination of resistors. Compare the measured values and the calculated values of each resistor combination, and make a note of the % error. Present your expected values (based on calculation) with measured values (using your multimeters).

<table>
<thead>
<tr>
<th>R1</th>
<th>R2</th>
<th>R_{\text{Eq}} \text{ calculated}</th>
<th>R_{\text{Eq}} \text{ measured}</th>
<th>% error</th>
</tr>
</thead>
</table>

Important note: When measuring the resistance of a resistor make sure that it is disconnected from your circuit or breadboard. You will be measuring the equivalent resistance of the entire circuit if you attempt to measure the resistance of a resistor while it is connected to the circuit.

Current Measurement

Electric current may be measured by your multimeter and other electronic instruments. However, in this lab we first measure voltage and then use Ohm's law to determine current: Measure the voltage across a resistor and divide by its resistance!

\[ I = \frac{V_{AB}}{R_1} \rightarrow I = 1 \text{ mA} \]

Measurement 3

Construct the circuit shown above on your breadboard. Use the laboratory power supply to provide the 5 V voltage to the circuit. Use the resistor bins in the laboratory if you do not have
the resistor values indicated in the circuit diagrams. Be sure to measure the resistances before inserting the resistor in the circuit. Also, be sure to measure the resistance values before placing the resistors back in the resistor bins in the lab. Other students will appreciate the care you exercise in not placing the resistors in the wrong bins. Measure the voltage $V_{AB}$ across resistor $R_1$ and use Ohm's law to calculate the current through the resistor.

<table>
<thead>
<tr>
<th>$R$ (measured)</th>
<th>$V_{AB}$ (measured)</th>
<th>$I$ (calculated)</th>
</tr>
</thead>
</table>

Note: Construct the circuits in Multisim (or a similar application) and use the multimeter within Multisim to find the expected voltage and current values!

**Measurement 4**

Next, add a second resistor in series with the first. Measure the voltage across each resistor ($V_{AB}$, $V_{BC}$) and calculate the current through $R_1$ and $R_2$. The two current values must be the same. Explain why! Call this current $I_{\text{measured}}$.

Calculation: Use the series resistor combination rule and calculate the equivalent resistance $R_{\text{Eq}}$ of the above series resistor combination. Redraw the circuit in your lab book and replace the two resistors with the equivalent resistor.

Use Ohm's law to calculate the current in the circuit and name it the expected current $I_{\text{exp}}$. 

\[ V_1 = 5V \]
\[ R_1 = 6.8 \, \text{k}\Omega \]
\[ R_2 = 1\, \text{k}\Omega \]
Measurement 5

Take the previous circuit apart and reconnect the resistors in parallel and apply the voltage as shown the figure below. Measure the current $I_1$ and $I_2$ through resistors $R_1$ and $R_2$, respectively. The total current supplied by the power supply is $I = I_1 + I_2$. Use the parallel resistor combination rule and calculate the equivalent resistance ($R_{Eq}$) of the two parallel resistors.

Redraw the circuit replacing the two resistors with $R_{Eq}$.

Use Ohm's law to calculate the current through $R_{Eq}$. Call this current $I_{exp}$ (should be the same as $I$). Note that the current $I$ branches out at point A and a portion of it flows through $R_1$ and the rest of it goes through $R_2$. The current in these two branches $I_1$ and $I_2$ recombine at point B and return to the negative terminal of the supply.
Measurement 6

In order to visually demonstrate the difference between series and parallel resistor combinations, consider first the series combination and then the parallel combination as shown below. Two identical LEDs are attached to each resistor so you can visually see the strength of the current in each resistor through the brightness of the LEDs. Construct each circuit and observe the LED brightness for each combination.