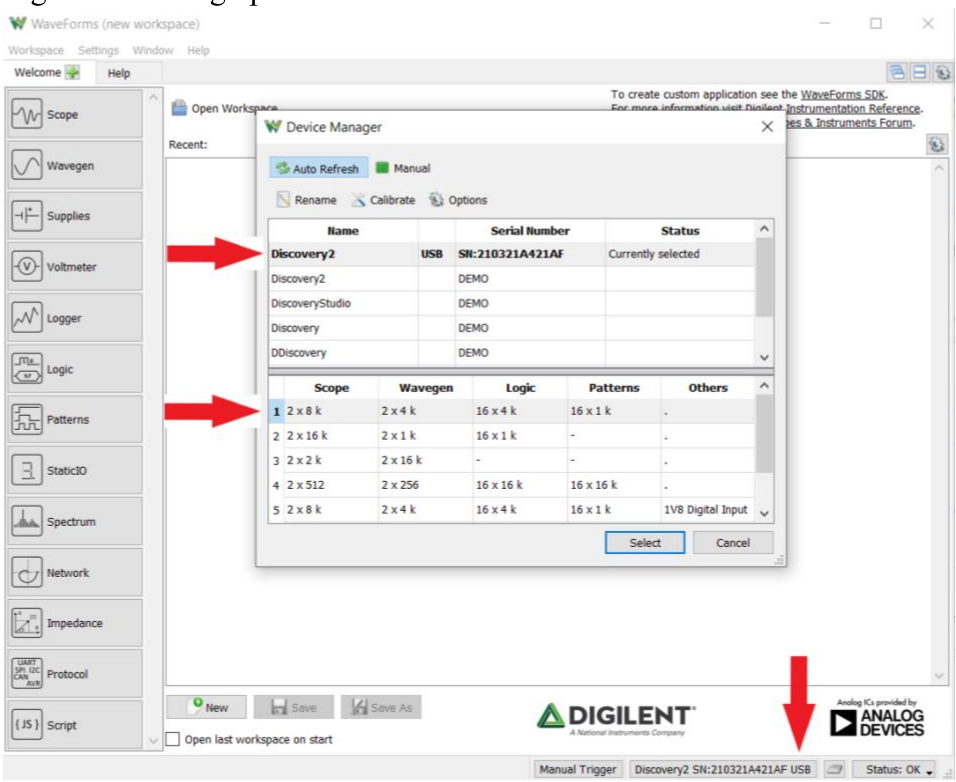
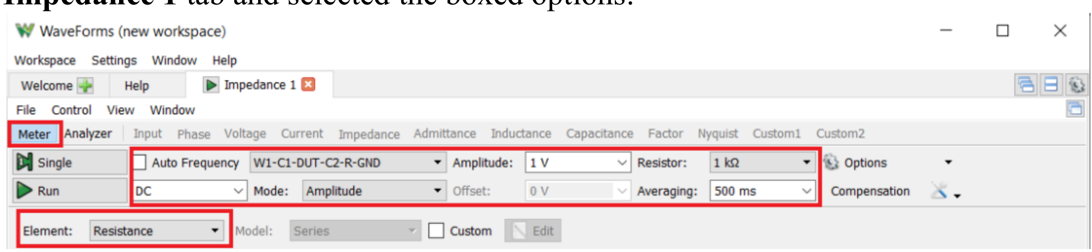
Using the AD2 Impedance Analyzer

In place of a DMM's ohmmeter, we will be using the AD2's Impedance Analyzer to measure resistor values.

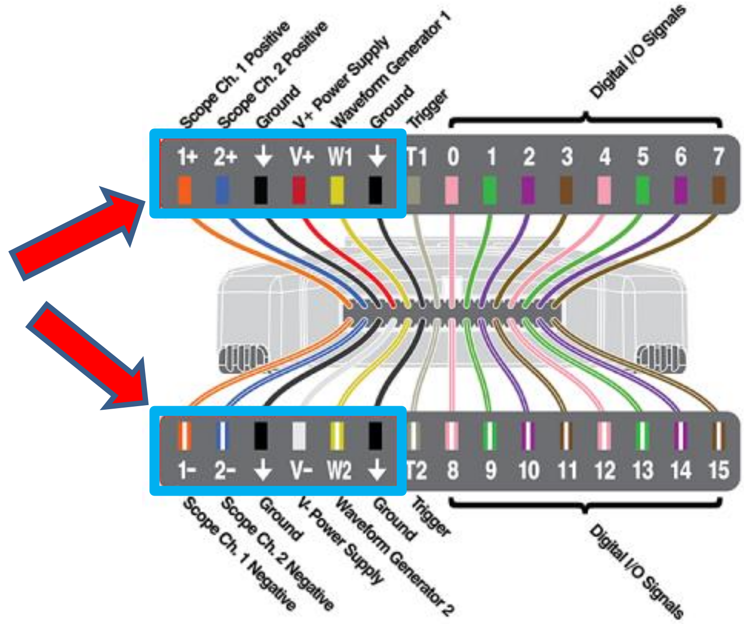
1. Launch the WaveForms software with the AD2 connected via USB. Ensure that you have the default settings selected in the Device Manager. This can be done by selecting the button in the bottom-right labeled "Discover2 SN:************ USB" and selecting the following options:



2. Select the Impedance Analyzer in the Welcome menu. Choose the **Meter** view in the **Impedance 1** tab and selected the boxed options:

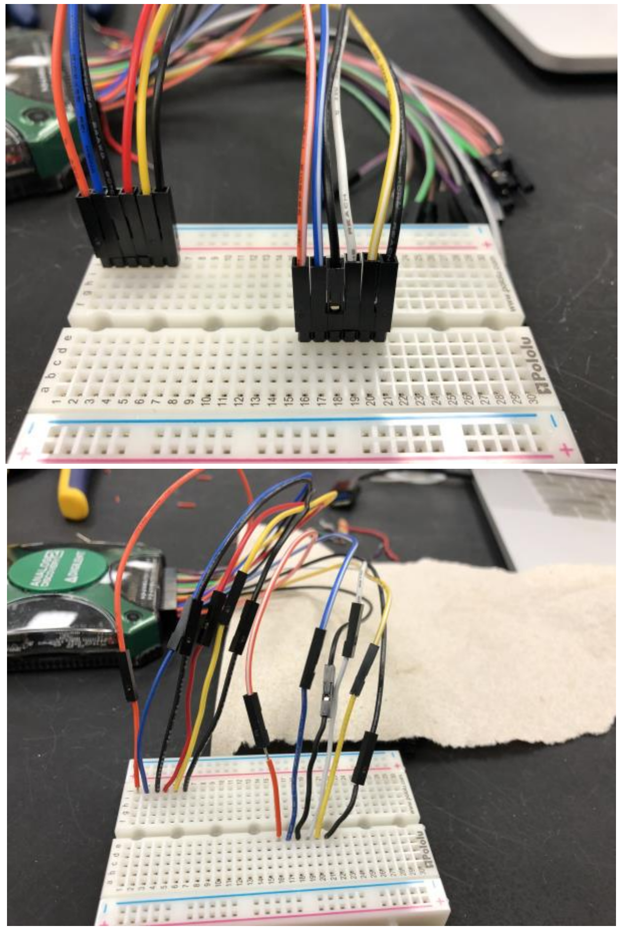


3. Now that you have the software setup, we look at the hardware. Here is a diagram (also included with your unit) of how the AD2's flywire cables are arranged:



https://reference.digilentinc.com/reference/instrumentation/analog-discovery-2/specifications

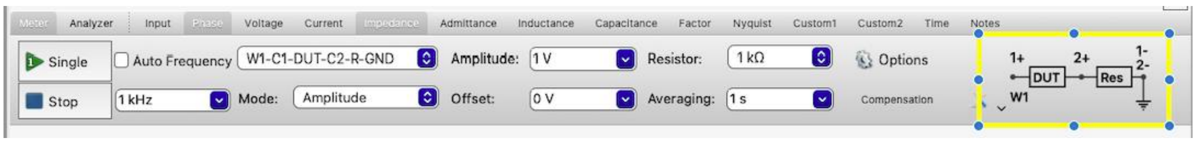
We only use the blue boxed left-most 2x6 cables.

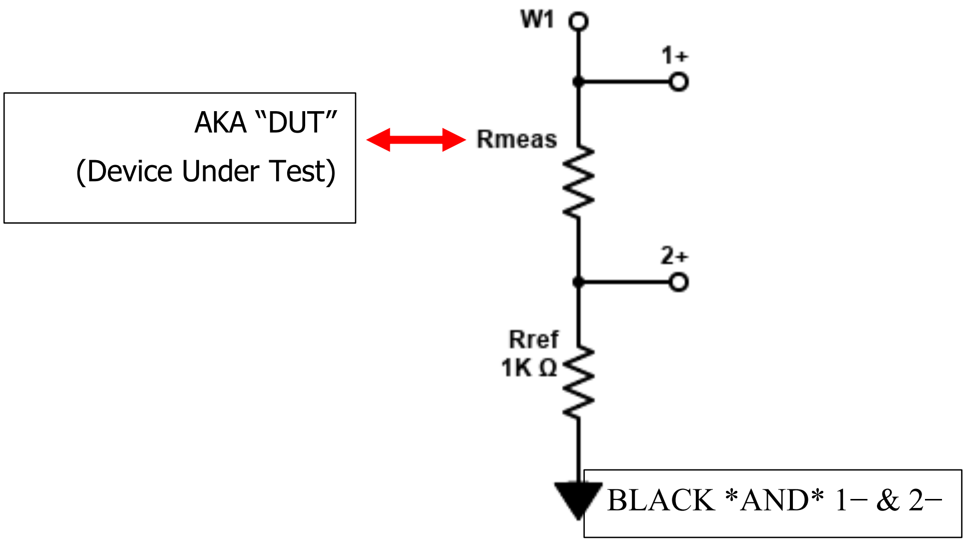


Two (organized) ways you might set up the AD2.
Use the rest of the board to place and connect components.

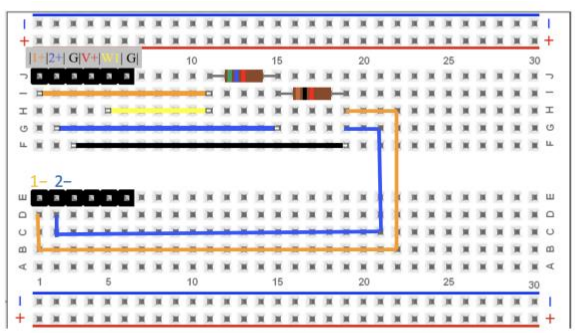
In this lab, we only use the boxed left-most 2x6 cables. It is suggested you connect these cables to your board in an organized manner. This will pay off when debugging your circuit.

4. Assemble the circuit below on your breadboard (you will find the breadboard diagram in the pre-lab helpful). Note that R_{meas} is the resistor you would like to measure and R_{ref} = 1K Ω is a reference resistor required for the Impedance Analyzer to function correctly. Ensure you have the AD2 pins connected correctly!





Circuit diagram

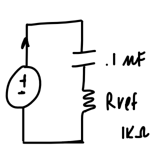


Example analyzer setup where R_{meas} = 5.6K Ω

5. When ready, click **Run** in the Impedance Analyzer and the resistance R_{meas} will appear.
6. Now, replace the DUT resistor with a 0.1μF capacitor. Change the Element from "Resistance" to "Capacitance". The capacitance measurement will appear.

The Impedance Analyzer works by the voltage divider principle (look at the pre-lab for a clue to what this principle is).

voltage divider



The AD2's Impedance Analyzer has a source of error we do not account for here (one that is not present when using a DMM). What is this error and what information do we need to minimize it?

ANSWER HERE:

To record its resistance, Rmeas is in series with Rref. The AD2 does not account for the additional source of error coming from Rref's own tolerance % when measuring Rmeas. Knowing the resistance and tolerance of Rref will help minimize this error.

Note: For the remainder of this lab, disregard this error (i.e. treat the Impedance Analyzer's measurements as truth).

Resistor Standard Values vs Tolerance (use a DMM for this!)

1. Pick 3 resistors with different color codes. If your resistors have 5 bands, consider only the first four bands. Measure their values with your AD2. Compare their stated values and tolerances (color code) with your measured analyzer results. (Do not differ from R_{ref} by a factor of 10)

WORK SHEET HERE:

$$\frac{\text{MEASURED-MARKED}}{\text{MARKED}}(100\%)$$

Resistor #	Marked	DMM Measured	% Deviation from Marked
R_1	.510 kΩ ± 2%	.509 kΩ	.2%
R_2	51 kΩ ± 5%	50.9 kΩ	.2%
R_3	2.2 kΩ ± 2%	2.159 kΩ	1.9%

Is the % Deviation greater or less than the indicated tolerance?

ANSWER HERE:

The % deviation is less than the indicated tolerance.

2. If you look at a standard list of 20% resistors available, you will see 1000 ohms and 1500 ohms but not 1200 ohms. Why? If you look at 5% resistors, would the results be different? Why? [An explanation of resistor values can be found at this site. Be sure to watch the video. Also, here.] Hint: Think about what tolerance means and how it differs from measurement error.

ANSWER HERE:

To manufacture resistors of every possible value would be impractical. A 1000 ohms resistor having a +/-20% tolerance might be any value between 800-1200 ohms. A 1500 ohms resistor having a +/-20% tolerance might be any value between 1200-1800 ohms. Therefore, making a 1200 ohms resistor would not be useful if it's covered by the ranges of the 1000 and 1500 ohms resistors

3. Pick two resistors that are approximately two orders of magnitude different e.g. 22 Ω and 2,200 (See Figures 1-2, 1-3, and 1-4. Do not exceed R_{ref} by a factor of 10)
   a. Measure them carefully. Note their actual values rather than the color code indicated value.
   b. Measure them in series and parallel connections.

WORK SHEET HERE:

R_1 Measured Value: 22.04 kΩ

R_2 Measured Value: .2243 kΩ

R_{Series} Value: 22.27kΩ

$R_{Parallel}$ Value: .2221 kΩ

   c. Compare R_{series} to the two individual resistors. Then compare $R_{parallel}$ to the two individual resistors.
   d. In the series connection, which resistor dominates the resistance measurement and why? Try to explain without using the equation.
   e. In the parallel connection, which resistor dominates the resistance measurement and why? Try to explain without using the equation.

ANSWERS HERE:

d. In the series connection, R1 dominates the resistance measurement. When electrical components are in series, they share the same current. Therefore, the equivalent resistance of 2 resistors in series is the sum of the resistances. R1 is two orders of magnitude larger than R2, so R1 dominates.

e. In the parallel connection, R2 dominates the resistance measurement. When electrical components are in parallel, they share the same voltage. R1 has a smaller current than R2, therefore R2 dominates.

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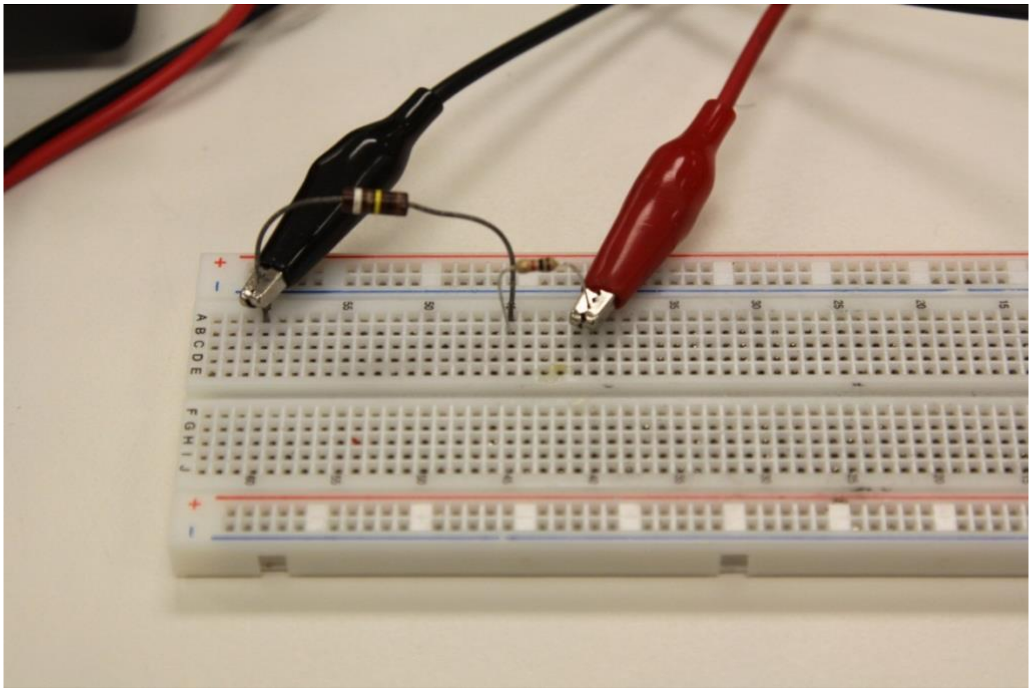


FIGURE 1-2. RESISTORS CONNECTED IN SERIES ON PROTO-BOARD

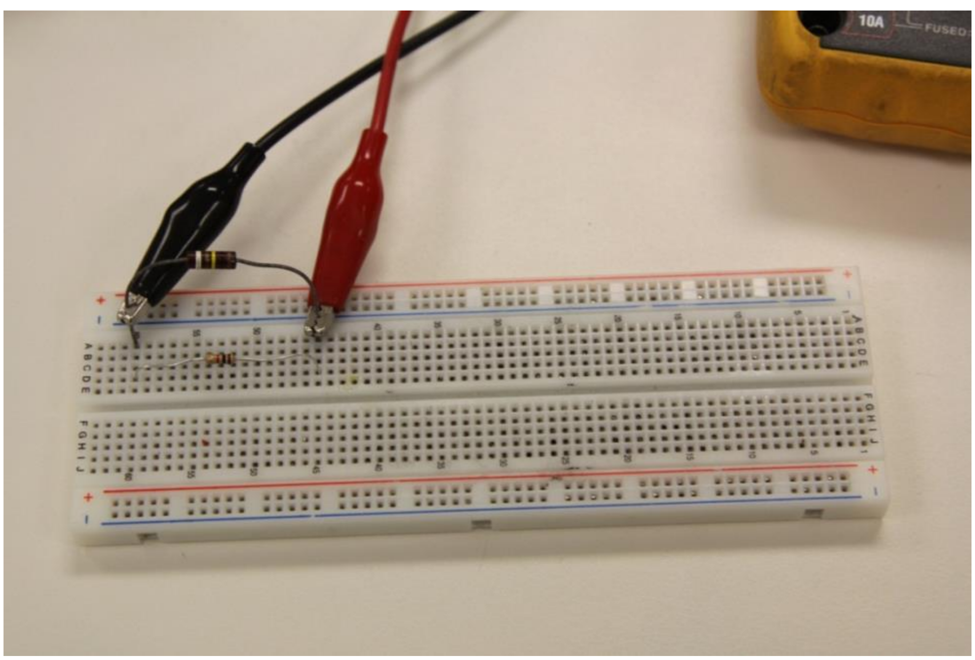


FIGURE 1-3. RESISTORS CONNECTED IN PARALLEL ON PROTOBOARD

Unloaded and Loaded Voltage Dividers

We will investigate the effect that loading has on a voltage divider circuit. Loading, as you recall from lecture, is the demand for current from a voltage source. That demanded current has an effect on the performance of the circuit. We will be measuring the amount of that performance change.

You will need the following components:

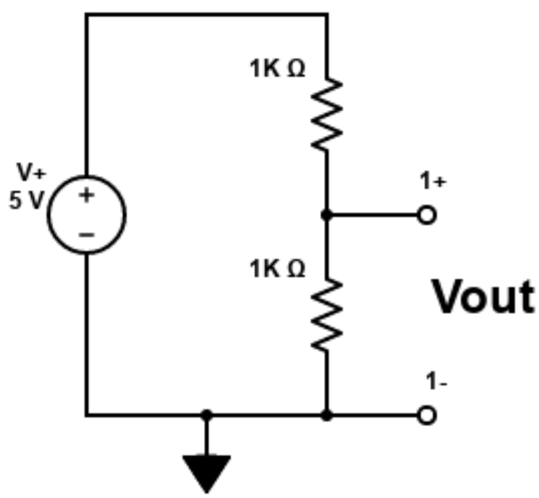
1 KΩ resistors (2)

3.3 KΩ resistor

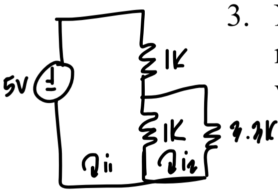
Breadboard

AD2

1. Construct the voltage divider circuit as shown below. This is an unloaded voltage divider.

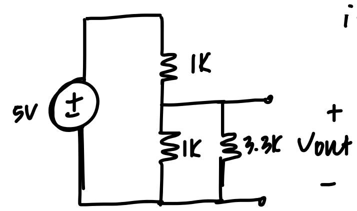


2. Using the Voltmeter Instrument, measure V_{out} at Channel 1 as shown. Record the value here __2.5V__ .



3. Now <u>load</u> the circuit by attaching the 3.3 KΩ load resistor across the lower 1 KΩ resistor, as shown below. The 3.3 KΩ resistor is now demanding current from the voltage divider.

$i = \frac{V}{R} = \frac{5}{1000}$



$5 = 1K\,i_1 + 1K(i_1 - i_2)$

$5 = 2Ki_1 - 1Ki_2$

$0 = 3.3Ki_2 + 1K(i_2 - i_1)$

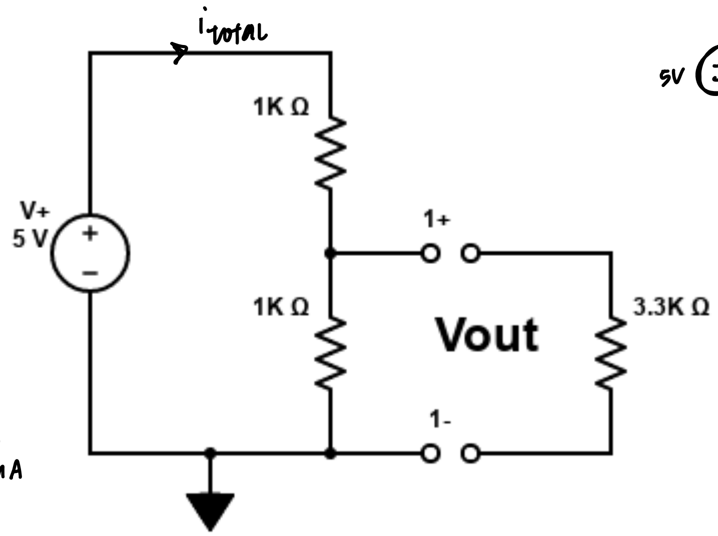
$0 = 4.3Ki_2 - 1Ki_1$

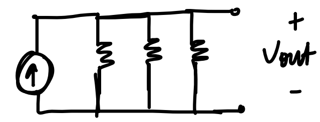
$i_1 = 4.3i_2$

$5 = 7.6Ki_2$

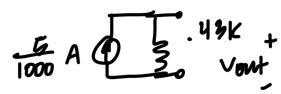
$i_2 = .66\ mA$

$i_1 = 2.83\ mA$





$.5K \parallel 3.3K$



Vout = 2.17V

4. Measure the new V_{out} as in Step 2. Record the value here: 2.17 V

5. Fill out the following table:

$I_{tot} = \frac{5}{2K} = .25mA$

	UNLOADED VOLTAGE DIVIDER	LOADED VOLTAGE DIVIDER
V_{out} (measurement)	2.5 V	2.17 V
$V_{upper1K}$ (calculation)	2.5V	2.83 V
I_{total} (calculation)	2.5 mA	2.83 mA

Why does an increase in total current result in lower output voltage of the loaded voltage divider circuit when compared to the unloaded circuit?

The 3.3K Ω resistor (RL) is in parallel with R2 in the loaded voltage divider. This reduces the overall resistance of the circuit. Following Ohm's law, a decrease in resistance results in an increase in circuit current (I = V/R) and decrease in output voltage (V = IR). This is different compared to the unloaded circuit where the input voltage is split equally between the two 1K Ω resistors.