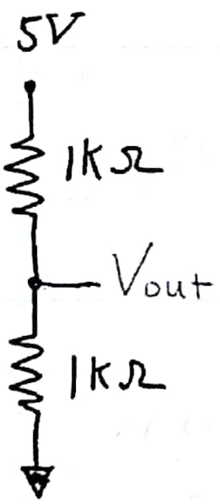
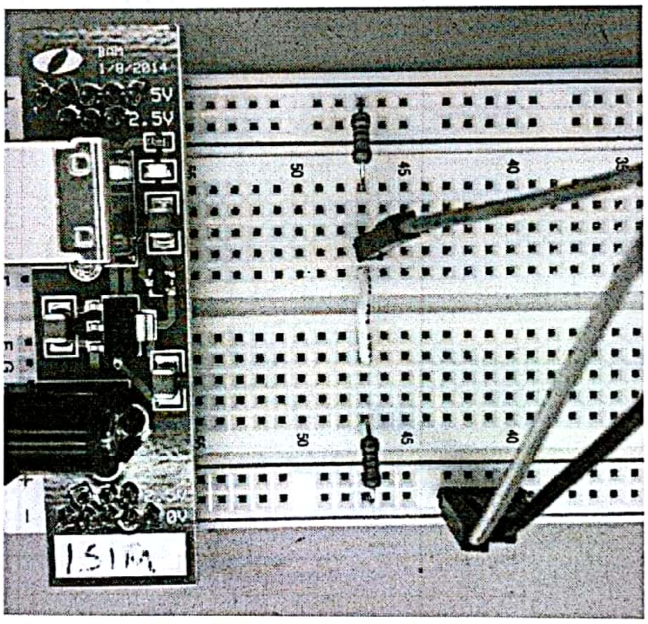
# Problem set : Resistors in series and parallel

To get started this week, let's use our breadboard and conduct a few very simple experiments with resistors. You should have watched the tutorial video on using the solderless breadboard that helped explain how some the basic connections work. But watching a video is no substitute for doing. If you have never worked with a breadboard, it will take some time and practice to get used to it.

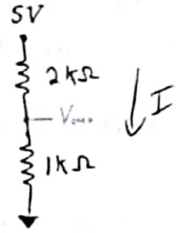
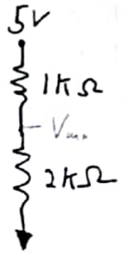
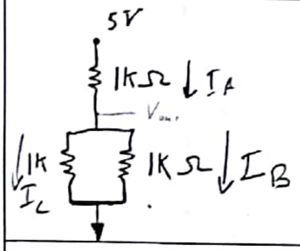
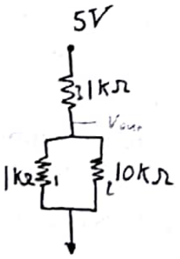
To get you familiar with the breadboard, below we show two equal resistors in series across 5 volts. The measurement, $V_{out}$, is at the midpoint of the resistors and is being done with channel 1 of the Analog Discovery. Below, we show the schematic and an actual implementation on the breadboard. In this case we are using your brand new power supply to provide the constant 5 V.




Your first test will be to create the circuit above, and confirm that with two 1 K resistors in series, that you in fact measure 2.5 volts at $V_{out}$. Depending on how carefully you look at your experiment, you will notice that you don't measure exactly 2.5 volts. One source of error is that you are not supplying exactly 5 volts. You can measure what the actual supply voltage (I measure 5.09 V on my setup) is and take half of that number and see if your measurement is closer to expectation. Another source of error is that the resistors are only specified to within 1% of their target value.

Now that you have the basic idea, analyze and construct each circuit in Table 1 and record the measured and expected voltage in the Table. Fill out the table:

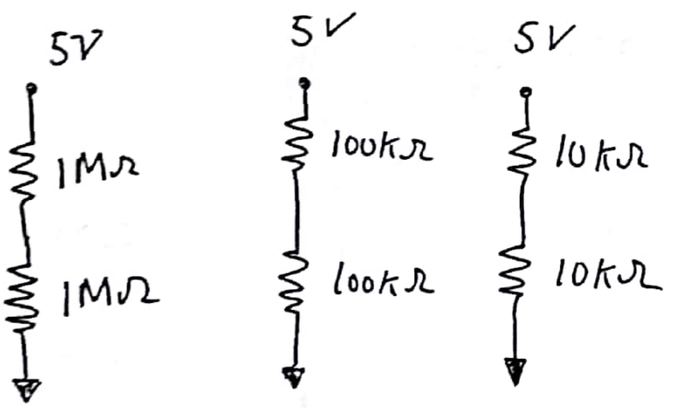
| Circuit | Expected voltage (include a short calculation) | Measured voltage |
| --- | --- | --- |
|   2/3 3.3 <br> 1/3 | $5 = I(3)$ <br> $\frac{5}{3} = I$ <br> $\frac{5}{3}\cdot 1 = 1.66$ | 1.73 V |
|   | $V = IR$ <br> $5 = I(3)$ <br> $I = 5/3$ <br> $V = IR$ <br> $V = 5/3 \cdot 2 \approx 3.33$ | 3.45 V |
|   | $R = \frac{1}{\frac{1}{1k} + \frac{1}{1k}}$ <br> $500\Omega + 1k\Omega$ <br> $5V = 1.5\Omega \cdot I$ <br> $I = 3.33$ <br> $5 - 3.33 = 1.66$ | 1.72 V |
|   | $1M\Omega >> 1K\Omega$ <br> $\therefore V_{out} \approx 5V$ <br> Nearly all energy is lost in second resistor | 5.18 V |
|   | $R_{п} = \frac{1}{\frac{1}{1k} + \frac{1}{10k}}$ $\frac{10K}{10+1}$ <br> $\approx 1k\Omega$ <br> $\approx .9k\Omega$ <br> $\therefore V_{out} > 2.5V$ <br> $\approx 2.4V$ | 2.47V |

1K 2k

1M 10k

Once you have the table complete, construct the following three voltage dividers. All are the same basic circuit and in theory should give the same measured voltage - only the overall value of the resistor is changing. Notice that while you might expect that all circuits would have the same voltage between the two resistors, this is not what you measure. The reason for the departure is that the measurement device has an input impedance (see section 2.4 of the course book for an explanation). Make the three measurements below and see if you can infer the value of the Analog Discovery's input impedance. Include your calculation and measurements.

What value of input impedance for the Analog Discovery best explains your data?




| Circuit | Measured voltage between resistors |
|---|---|
| 1M resistor | 1.74 |
| 100K resistor | 2.45 |
| 10 K resistor | 2.56 |

**Value of Analog Discovery input impedance (resistance):** 1144 736 Ω

**Deliverables:**

For these type of assignments you do not need to write a lab report. You should write your numbers in the tables and spaces provided. If you have any supporting hand calculations you should include those. These assignments are only checked for completeness – not fully corrected. While anything you turn in should be neat and any analysis should be clear, you do not need to type anything up. You can just scan your hand written assignment. Also, many weeks you might not complete all questions as there is something you don't understand. That is perfect. Just complete as much as you can, turn that in, and then come to next class with questions. These assignments are mean to be a bridge from the course content on circuits to the lab experiments. You can always go back and complete and re-submit any of these assignments.

$V_{out} =$

$\Delta V = IR$ $\qquad$ $V_{out} - 0 = IR_2$

$\frac{V_{in} - 0}{R_1 + R_2} = I$ $\qquad$ $\frac{V_{out}}{R_2} = I$

$$\frac{V_{in}}{V_{out}} = \frac{R_1 + R_2}{R_1}$$

$$V_{in}\left(\frac{R_1}{R_1 + R_2}\right) = V_{out}$$

$\Delta V = IR$

$\Delta V_{in} - 0 = I\left(R + \frac{1}{\frac{1}{R} + \frac{1}{R_I}}\right)$ $\qquad$ $\Delta V_{out} = IR\left(\frac{1}{\frac{1}{R} + \frac{1}{R_I}}\right)$

$\Delta V_{in} = I\left(R + \frac{R}{1 + R/R_I}\right)$ $\qquad$ $\Delta V_{out} = I\left(\frac{R}{1 + R/R_I}\right)$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R}{1 + R/R_I}}{R + \frac{R}{1 + R/R_I}} = \frac{1}{1 + 1 + R/R_I} = \frac{1}{2 + R/R_I}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2 + R/R_I}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2 + R/R_I}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2 + R/R_I}$$

$$\frac{V_{in}}{V_{out}} = 2 + R/R_I$$

$$\frac{V_{in}}{V_{out}} - 2 = R/R_I$$

$$R_I = \frac{R}{\frac{V_{in}}{V_{out}} - 2} \qquad R_I \quad \frac{1M}{\frac{5V}{1.74} - 2} = 1144736\ \Omega$$