Workshop 9: First steps in electronics

1 Getting Started

Make sure you have everything you need to complete this lab:

- Arduino for power supply
- breadboard
- black, red and blue jumper cable
- Multimeter with a red and black test lead cable
- potentiometer
- button switch
- LED

2 Introduction to electronics

This week you will switch from LEGO Mindstorms to basic electronics, and build the sensors yourself. First you need to learn the concept of basic electronics, how to use the multimeter, or how to measure voltage.

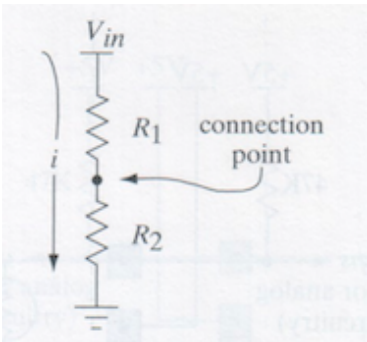
2.1 Ohm's Law

- The law stating that the direct current flowing in a conductor is directly proportional to the potential difference between its ends. Mathematically it is formulated as,

$$I = \frac{V}{R}$$

  where **V** is the **potential difference, or voltage (in units of volts)**, **I** is the **current (in amperes)**, and **R** is the **resistance of the conductor (in units of ohms)**.

- Now if we consider a series of resistance circuit, we can calculate the voltage drop across each resistor



The voltage drop across R_2 is i*R_2 volts, and the voltage drop across R_1 is i*R_1 (just by simply using Ohm's Law). This is just another way of saying that if we were to measure the voltage between ground and the connection point between two resistors.

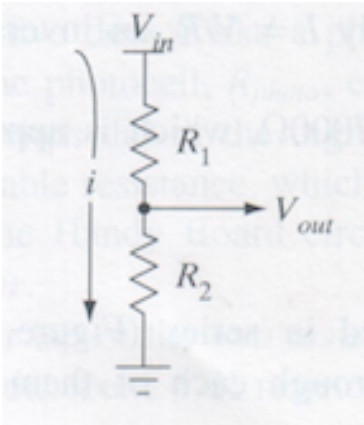
- **Voltages in a circuit must add up**, that is, the voltage drop across R_1 and R_2 must be equal V_{in} (input voltage from the power supply). Or mathematical way of describing this:

$$V_{in} = i * R_1 + i * R_2 = i * (R_1 + R_2)$$

Because series voltages add up, **series resistances add up too**.

2.2 The Voltage Divider

- **The Voltage divider** circuit is used in the photocell - and many other - sensor applications.



In the **Voltage divider** circuit, an input voltage V_{in} is dropped across two resistors (R_1 and R_2), with an output voltage V_{sens} tapped between the resistors.

- The V_{sens} voltage is a **function of the ratio of the two resistances and the V_{in} voltage**. We can calculate the current running through the resistors as

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

because the **two series resistances add**. Then the voltage drop across R_2 - the output voltage - is the product of this current and R_2:

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

- This relation shows how the voltage divider works. For example, if R_1 and R_2 **are equal the output formula reduces to**:

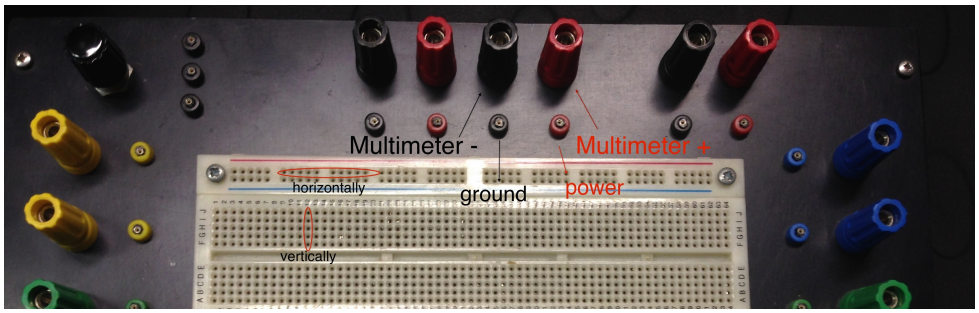
$$V_{sens} = \frac{1}{2} V_{in}$$

- Intuitively, if R_1 **is smaller than** R_2 - **it provides less resistance** - then the **output voltage will be closer to the input voltage** than to the zero volt ground.
- Conversely, if R_2 **is smaller**, the output will be **closer to zero volts.**

3 How to use the breadboard

First of all, before you start using the breadboard and any electronic equipment, please **read this section carefully!**

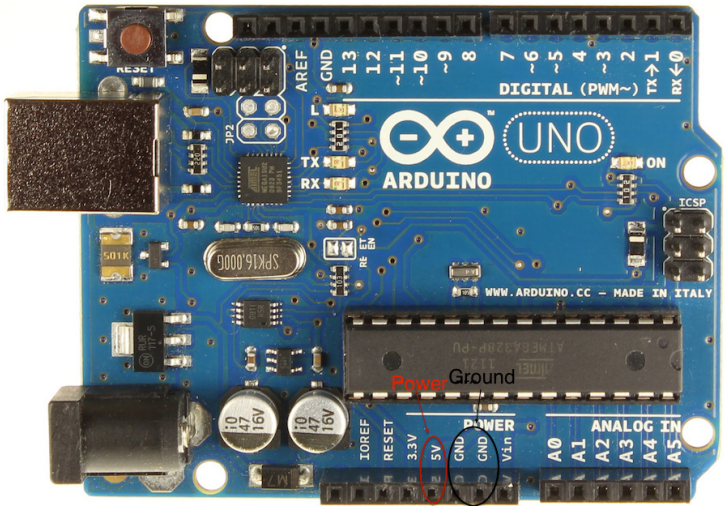
1. This is a breadboard in the image below, **keep in mind that any connection made by jumper cables or resistors need to be FULLY connected.** The upper part of the breadboard is **horizontally connected**, **marked with a red line, called supply voltage**, while the lower row, **marked with blue line, called ground**. Everything else, marked with letters, **is connected vertically**.



2. To measure the voltage across the connections use a **multimeter!** For this you will need to connect the **ground and the supply voltage** to the multimeter's hole, using jumper cables. Then the **red** test lead cable goes to the **multimeter + hole** and the **black** goes to the **multimeter - hole**

3. When **you measuring voltage, use the 20V option**, or when you **measuring the resistance, use the 2K ohm option on the multimeter.** Don not forget to **TURN OFF** the multimeter when not using it!

4. To connect the supply voltage and ground to the breadboard use an **Arduino board**. Connect the **voltage (5V) to the supply voltage row** on the breadboard, and the **ground (GND) to the ground row**.

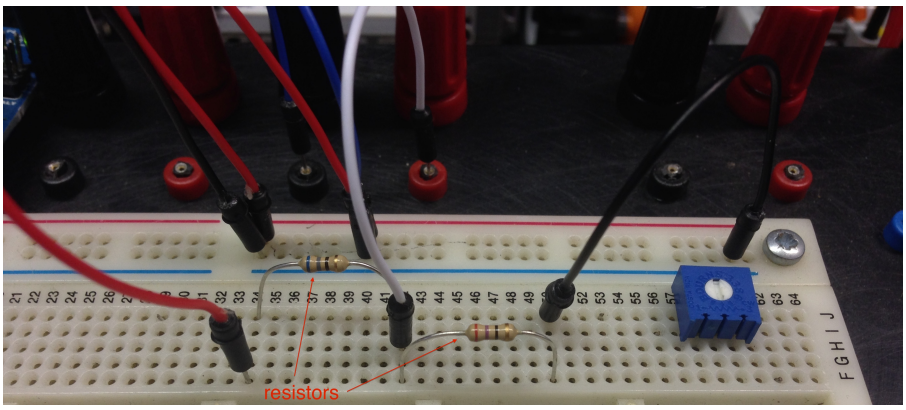


5. A good concept is to use **red jumper cable for the voltage connections** and **black for the ground connections**.

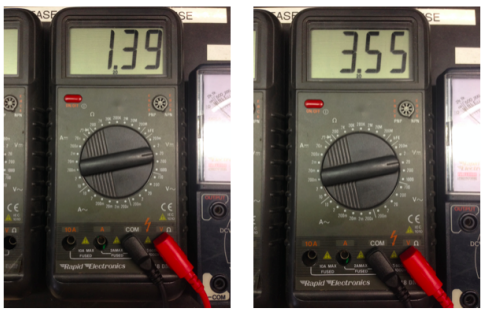
4 Build a Voltage Divider

In this section we are going to a build a basic voltage divider, using resistors and then a potentiometer.

- As you can see in the image below, the **connections are fully connected**. To measure the voltage across the resistors **connect the ground to the multimeter's ground hole**. And the white jumper cable is the **voltage across the resistors, this should be connected to the multimeter's voltage hole**.



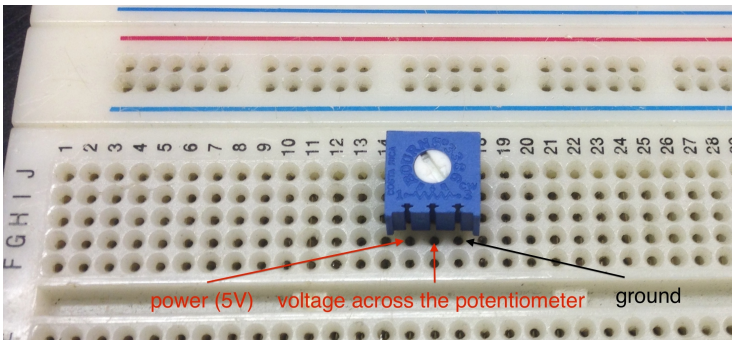
1. We are going to use the Arduino as the voltage input. The Arduino connected to the computer has a **5V** voltage. The DC current for the 5V Pin is **50mA**. **Calculate the resistance of the Arduino!**
2. Create a **Voltage Divider** which has a 2.5V output(V_{sens}) voltage. What is the **resistance of the resistors** that you need to use for this?
3. Modify the basic Voltage Divider to get a **1.4V** and then a **3.5V** output, like on the image below!



5 Voltage Divider, using a potentiometer

A potentiometer is a **three-terminal resistor** with a **sliding or rotating contact** that forms an adjustable voltage divider:

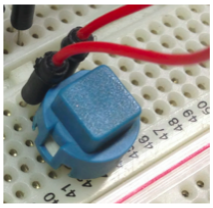
1. For this exercise you will need to do the same connections that you did above, but now using a **potentiometer** to measure the voltage across it.

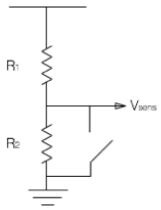


2. Once you have connected the supply voltage, ground and the multimeter,**measure the voltage across the potentiometer**.
3. **Rotate the contact on the potentiometer to adjust the voltage divider.**

6 Touch Sensor

Now you have learnt the basic concept of electronics. It's time to build a **Touch sensor**. Use the button below and **connect it to the resistors** that we built in section 4. The multimeter should show **5V when the the button is released** and a different voltage (based on the voltage divider, resistors you are using) when it's pressed.

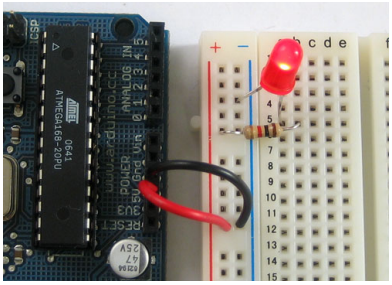




HINT: The button is connected horizontally, so it has a parallel connection. It connects two columns together on the breadboard. As you can see on the image above it goes in at **line 42** and comes out at **line 44**. It's a good idea to keep the button pressed to see the voltage difference.

7 Touch Sensor with LED

Well done, you just built a **touch sensor**, the one we used in LEGO Mindstorms. In this challenge, modify the **Touch Sensor** by connect an LED to it. The **LED should turn on when you connect the breadboard to the supply voltage** and **turn off when you press the button**. An LED has **two leads, a negative and a positive**. The positive lead is a **slightly longer lead, this should be connected to a resistor**, while the **negative lead should be connected to the ground**.



HINT: To turn off the LED you will need to create a voltage divider with two resistors, where the V_{sens} output should be close to zero volts. So when you press the button there won't be any voltage across the resistors, so the LED should turn off.