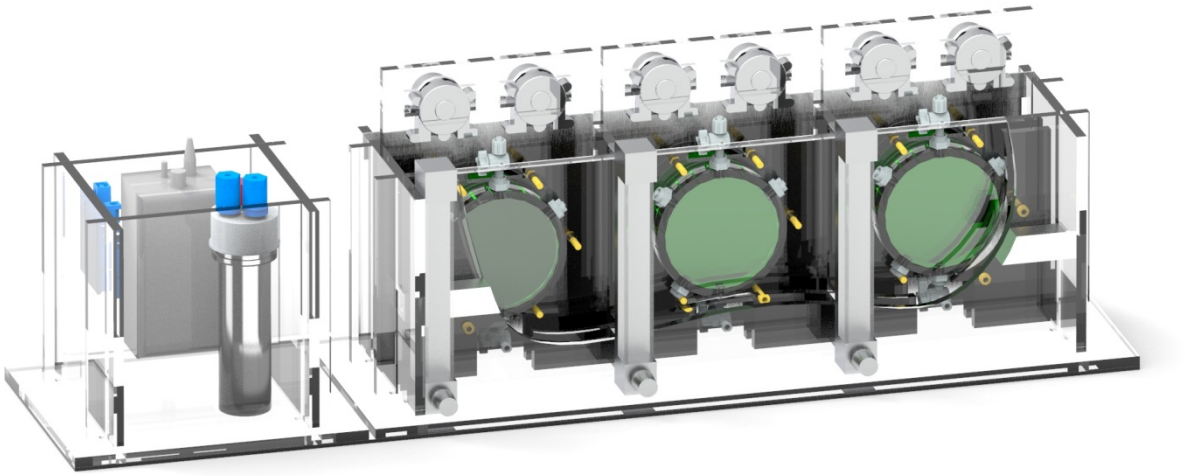
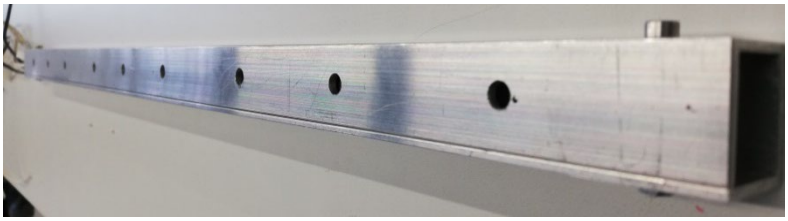


Sensor system (openPBR)

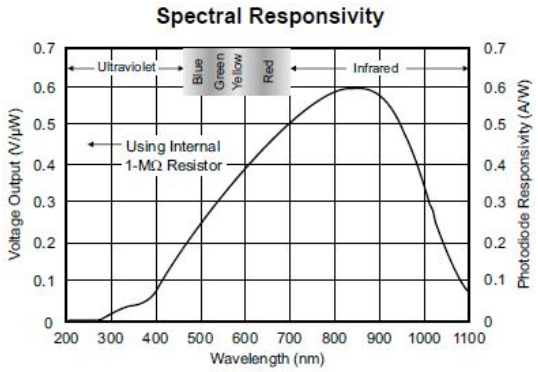
The sensory system of the openPBR consist of up to nine Opt 101 Monolithic linear voltage sensors and nine 680 nm LED's. It is possible to use any LED in the linear area of the sensor thus measurements from 450 nm to 750 nm. And a temperature sensor to measure the water bath temperature.

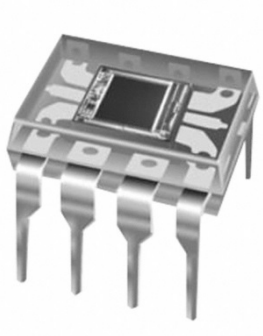
1. Sensor rail
2. Opt 101
3. 680 nm LED
4. Calibration
5. Thermometer



Sensor rail of the openPBR

Opt101:





Partlist:

- Monolithic linear ambient light sensor Opt101, 4,97

https://www.amazon.de/gp/product/B07WHTF4S9/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1

- x3 – x9LED 680 nm (or else in visible light), 3,89 Euro

http://www.roithner-laser.com/datasheets/led_div/led680-series.pdf

- Two 527 x 20 x 20 mm Aluminum angle rails 4,29 Euro

https://www.amazon.de/GAH-Alberts-473631-Winkelprofil-Aluminium-silberfarbig/dp/B002TYLFAE/ref=sr_1_3?__mk_de_DE=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=aluminium+winkel&qid=1571517375&s=diy&sr=1-3

- DS18B20 digital temperature sensor 3,99 Euro

https://www.amazon.de/DS18b20-Wasserdichter-Temperatursensor-Thermometer-Temperaturf%C3%BChler/dp/B01G1F2172/ref=sr_1_22?__mk_de_DE=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=DS18B20+digital+temperature+sensor&qid=1570473194&s=garden&sr=1-22

-
- x3 - x9 standard cuvettes (generic lab stuff)
- 3-9 x 1kohm, 3x 10ohm resistors (optional potentiometer), (part of Arduino starter kit)
- 6 pin Cables (part of Arduino starter kit)
- 2x M3 30 mm long screws and nuts. ~ 1Euro

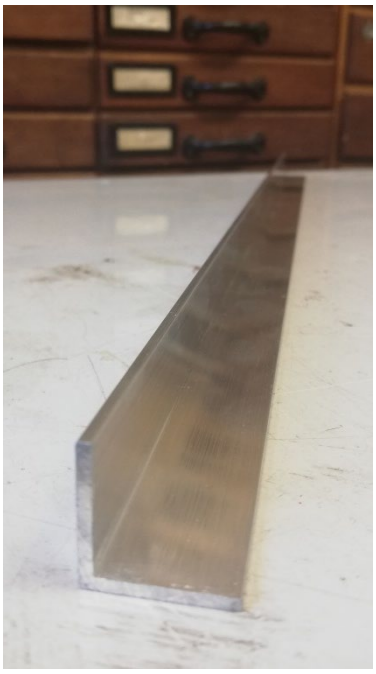
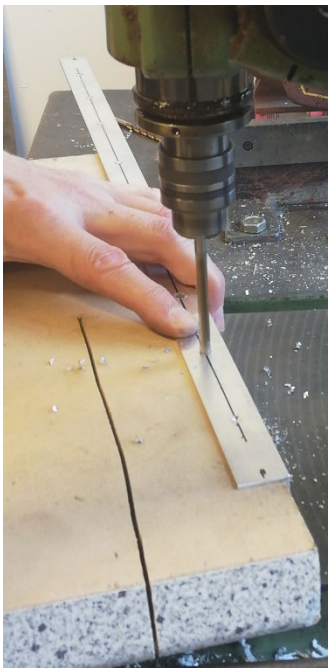
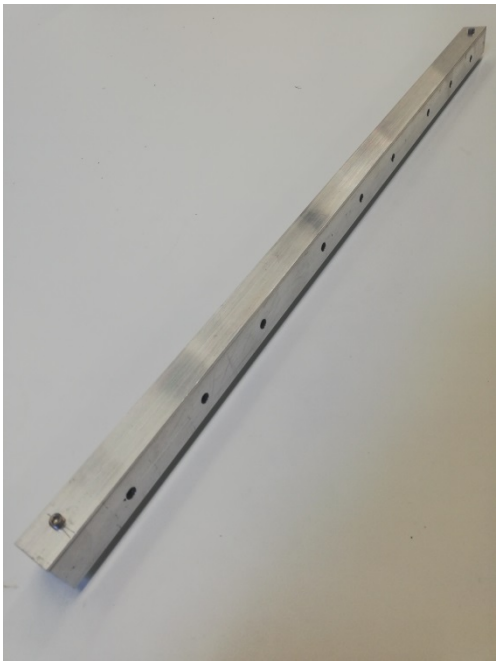
Total for 3 sensors units: <u>35.87 Euro</u>

Total for 9 sensors units: <u>83,69 Euro</u>

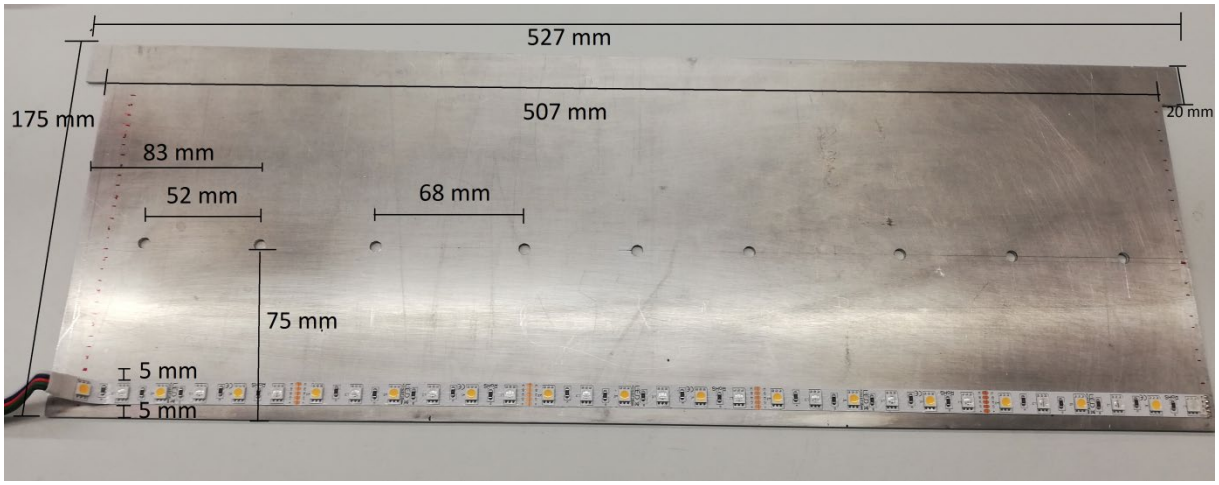
Step by step Tutorial:

Step 1: Sensor rail:

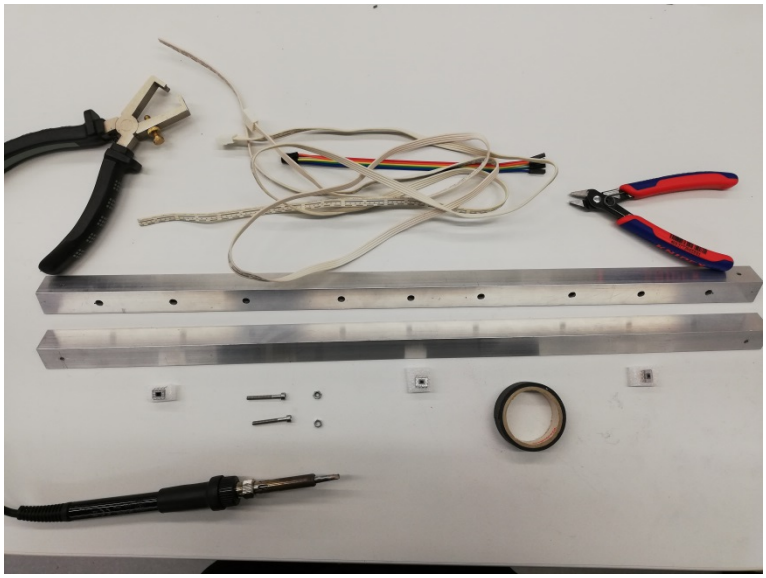
- Take two 527 x 20 x 20 mm long Aluminum angle rails and drill nine 5 mm holes in one of them. A longer rail is also possible up to 600 mm.
- The distance between the holes is similar to the hole position of the holes in the LED panel. 52 mm between the three holes of one chamber and 68 mm to the next chamber
- Drill two M3 holes in to the opposite side of the alu rail and two holes in to the remaining alu rail so that they can be connected with a M3 screw.

LED Aluminum plate:



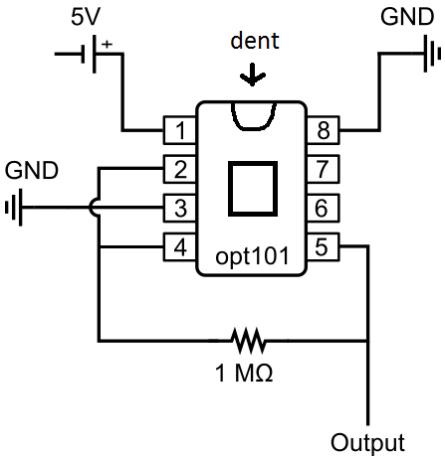
Step 2: Assembly of Opt101 and Aluminum rail:



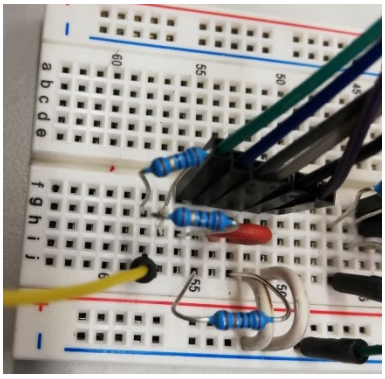
Wiring of the Opt101 to the Arduino.

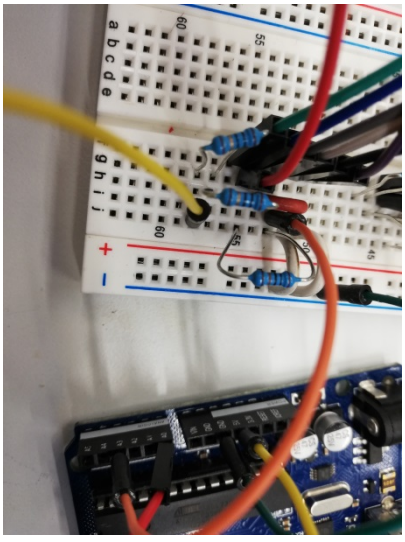
Connect the cables to the Opt101 as following:

- 1: Connect green 5/3,3V (VCC)
- 3: black to GND
- 2: blue, 4: grey, 5: white over a 1M ohm resistor to Output
- 8: violet to GND
- 6 and 7 to nothing.

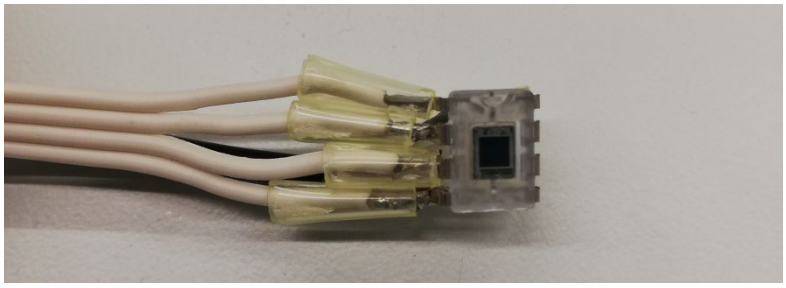


- The sensor has a dent on one side this shows the orientation.
- Connect the Output (orange) and a cable to monitor the current
- Connect (red) to an analog pin (A0, A3) as well as the 5V (yellow) to the Arduino.
- Connect a the black to GND.



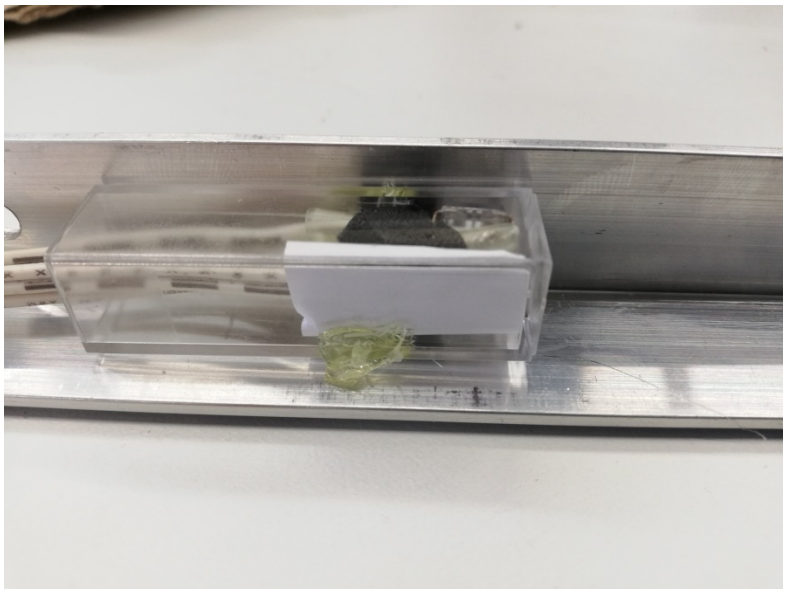


- Solder the Opt 101 as seen below to a six pin cable.

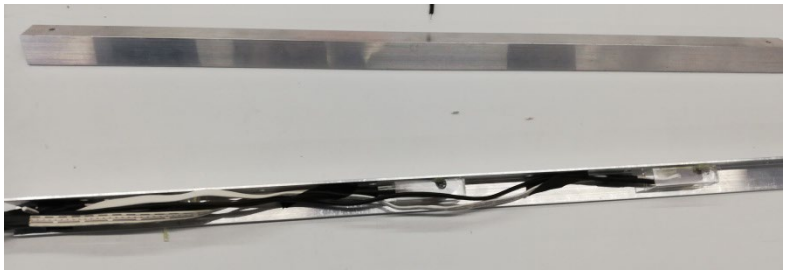


- Stick the Opt101 in to a standard cuvette and make sure the sensor is lying flat on the inner surface. Adjust its position with a folded piece of paper.

- Use hot glue to fix the cuvette in the aluminum rail. It is crucial that the sensor sits exactly in the center of the hole on the rail.

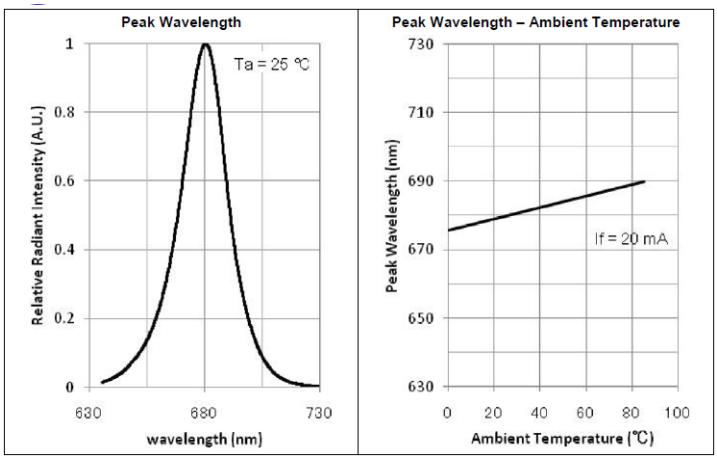


- Fit all cables into the rail and close it with the two screws and nuts.



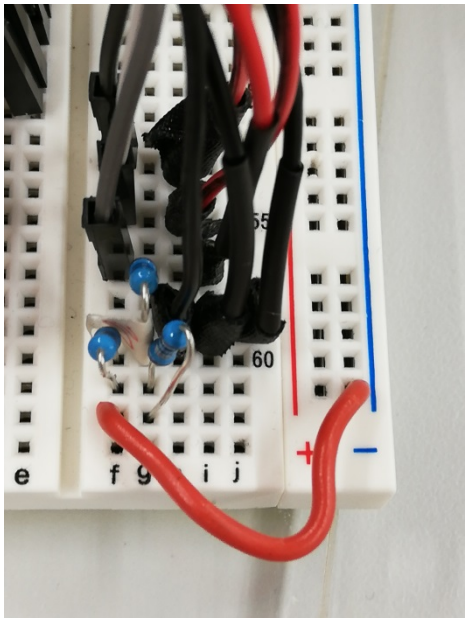
Step 3: 680 nm LED

- Solder cable to the LEDs put them into the holes of



- Connect the 680 nm LED ground cable to ground with three 10 ohm resistors in row to 5V (-).

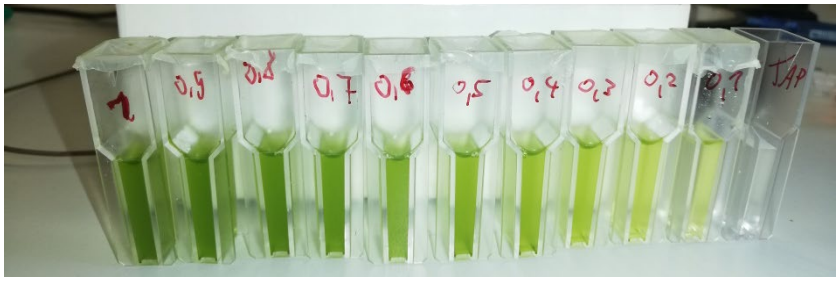
- Connect the (+) cables of the LEDs to a digital Pin of the Arduino.



Software for the sensors is in the openPBR control Software.

Step 4: Calibration of the Opt101

Prepare a dilution series of your Algae in this case *C. reinhardtii.* And measure it with a at 680 nm photometer.



1. To calibrate the sensors set up a decadal dilution series of a given OD (from a reference photometer) from OD 2.5 down do OD 0.1.
2. Set the interval in the openPBR_control to 30 seconds
3. Start PuTTY and measure a single data point for each step of the dilution.
4. Include the data in to a excel file.

In order to get a net voltage, you need to subtract the output value from the input value. Subtract the V_{out} values from the V_{in} values and plot them against the reference OD from your photometer. Then perform a logarithmic fit (Fig. 1)

Your equation should look something like this: $\Delta V = a * \log(OD) + b$

In our example we got *a = 0.496* and *b = 4.389*.

In this case, y is the voltage ΔV and x the OD.

To get the OD from your measured values, solve your equation for x:

$$x = e^{\frac{\Delta V - b}{a}}$$

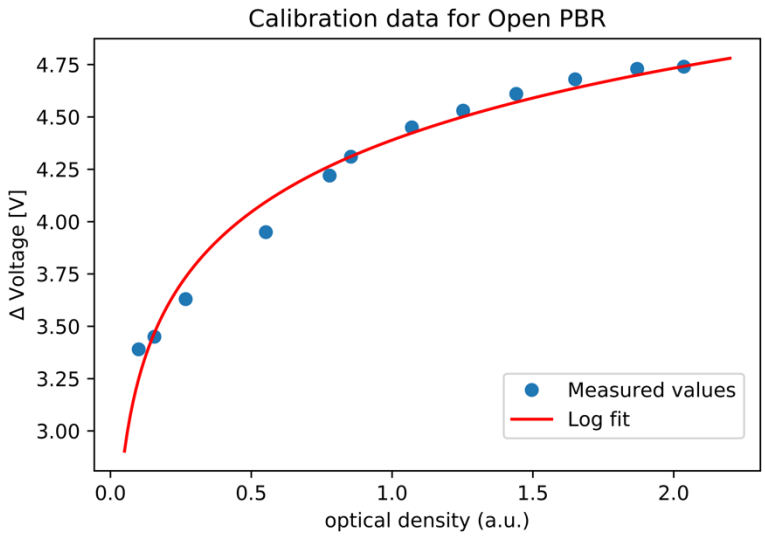


Image 1:Measured OD with reference photometer against measured ΔV with openPBR

After the calibration, we measured other random samples both with our reference photometer (Expected OD) and with openPBR (Figure 2).

We also plotted the “ideal correlation”, meaning expected = measured, in order to get an idea of how good the openPBR measurements are.

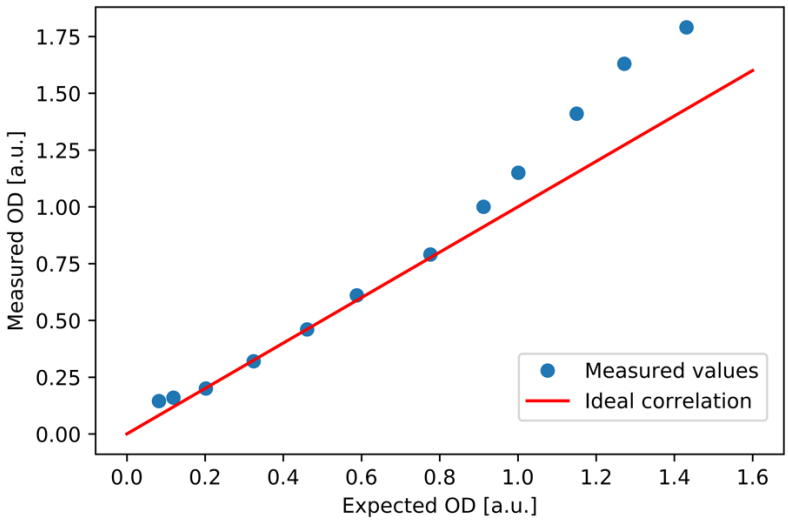


Figure 2: Expected OD values from reference photometer plotted against openPBR measurements with an “ideal correlation” of x = y

From this we can conclude that, while the openPBR measurements between OD = 0 and OD = 1 are quite reliable, further calibrating points are needed in order to improve the range beyond OD = 1.

Step 5: Thermometer:

Monitoring temperature can be very important for a lot of applications. Here we present a short do it yourself tutorial for a; low cost, online measurements.

Wiring:

- Connect GND to GND
- Connect DQ to 5V(+)
- Connect VDD to digital pin 13
- Bridge DQ and VDD with a 1x 5 kohm resistor