Final report

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1 Introduction

As part of the course II2302 sensor based system, we formed a team of three students to make a project in relation with sensors. After brainstorming, we chose to make an auto regulated hydroponic farm. This allows us to use different type of sensors and learn how they works. In this final report, we will explain how we proceed to conduct this project.

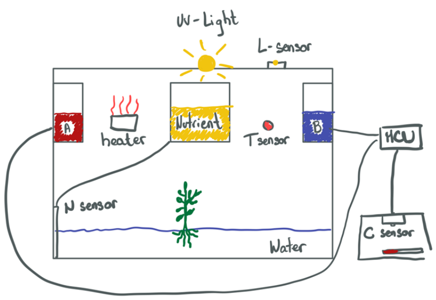


Figure 1: Drawing of the concept

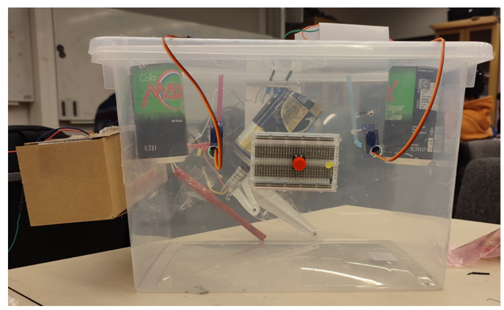


Figure 2: Photo of the prototype

2 General description of the system

Light Sensor:

For a plant getting a certain light intensity is very important for the growth of a plant. However we still want the plan to be exposed to sunlight during the day.

Therefore we chose to do a sensor capable of detecting the intensity of the light shining on our plant which will then activate a growth light if the intensity is lower than a certain set point determined by the plant that we want to grow. This will enable us to have the light turned off when the sun is shining on the plant and to get the light turned on towards the end of the day when the intensity of the sun begins to fade.

Temperature sensor

The plant need to be in an environment at a specific temperature range to guarantee maximal growth. for most plants the best temperature range is 20°-25°. Thus we choose to to put a temperature sensor in our greenhouse that will monitor the temperature and heat resistances if the temperature in the greenhouse is lower than 20° and stop heating when the temperature is above 25°.

Nutrient regulation system

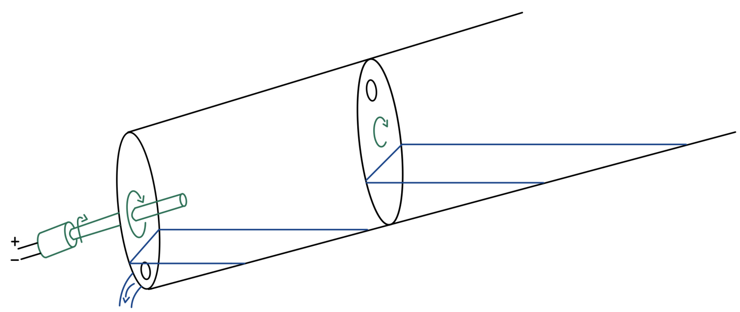
The quantity of nutrients in the water is an important parameter when we try to grow a plant in a hydroponic farm, then we decided to make a nutrient regulation system. The aim of this system is to measure the nutrient concentration in the farm and regulate this nutrient concentration by adding some nutrient solution when it is needed. The user of the system can put the nutrient composition that is the best adapted to its plant and put it in the nutrient tank.

The nutrient regulation is made of different parts:

- A nutrient measurement sensor
- A trigger system which is calibrated on the right nutrient concentration value
- A nutrient release system

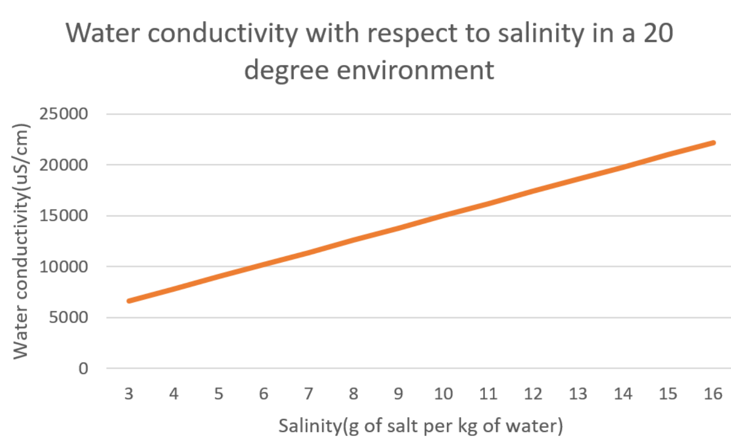
The first step is to measure the nutrient concentration of the tank using a sensor. We first tried to find a commercial nutrient sensor but it appears that this kind of sensor is very expensive, then we decided to make our own nutrient sensor. Nutriments are mainly contained in the salts of the water which changes its resistance. So we can measure the nutrient in the water by measuring the electric current in it, it means that we need a conductivity sensor. The construction details of our home made conductivity sensor will be discussed in the hardware description section and the way we characterized it in the data analysis section.

The nutrient release system is composed of a DC motor and a nutrient releasing structure. The nutrients are released though a nutrient solution and following researches, it is better if this solution is mixed before we send it in our tank. It permits that the nutrients spread everywhere and uniformly in the solution. This is the reason we decided to use a rotary motor that will mix the nutrient solution. We first tried to make our own electro-magnet motor using copper wire and metal. Unfortunately it appears that the numbers of loop to do was too important to have a reasonable strength from the electro magnet. We then decided to use a commercial DC motor to release the nutrient solution. The nutrient realising system works this way:



The nutrient solution (in blue) pass through the two holes separated by a 180º angle. This system mimics the endless crew concept to mix and release the nutrient solution. We use old cans for the cylinder structure for economical/ecological reasons and because they perform the same task.

After several hydroponic researches, we realized that the best nutrient concentration for the majority of plants growth's corresponds to a conductivity between 10 000 us/cm and 19 000 us/cm. In a 20 degrees environment, it corresponds to a water salinity between 5.84 and 13.33 grams of salt by water kilogram as we can see on this graphic.



Our nutrient regulation system will take care of regulating the salinity of the farm water between 5.84 grams of salt by water kilogram and 13.33 grams of salt by water kilogram, this range will allow a good development of the user's plant.

PH regulation system

When we grow a plant in hydroponics, the plant grows directly in the water and it will absorb and release chemical component directly in it. However, those phenomena of exchange from the plant to the water may cause the pH in the water to progressively change and became either more acid or more basic. The problem with it is that a plant need to be maintain in a proper range of pH to grow efficiently and if the pH change to much compare to the value the plant need it can become dangerous for the plant and in the end it can completely kill it slowly. That's why we need to come with a mechanism that can allow the system to regulate the pH inside the main tank, where the plant grows.

In this purpose, we imagined a pH control and regulation system for our machine that will take care of the pH inside the main solution to ensure that the pH stays at 6 (usually that's the pH that most of the plant that you can grow in hydroponics need) the whole time the the plant is growing.

This system is composed of :

- A color sensor
- An Arduino
- Two servo motors
- One tank full of acid and one tank full of Base

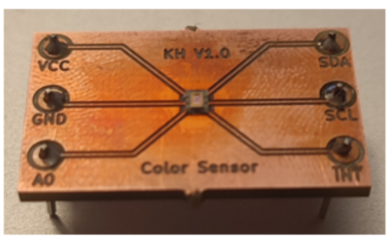


Photo of the color sensor

Tank with the servo motor

The idea behind this system is that the user will use a pH paper to measure the pH is the solution, then he will need to put it under the color sensor that will sense the color of the pH paper. Then the color sensor will send this measure to the arduino by I2c, the arduino will then know the pH of the solution and will activate the different servo motor to regulate the pH by putting more acid or more base.

You may wonder at this point why we used this little trick with the color sensor and a pH paper, that is not fully automatic, and why we don't use directly a pH sensor.

The answer to that is just that a regular electronic pH sensor is really expensive, fragile, and hard to find. That's why we choosed this solution.

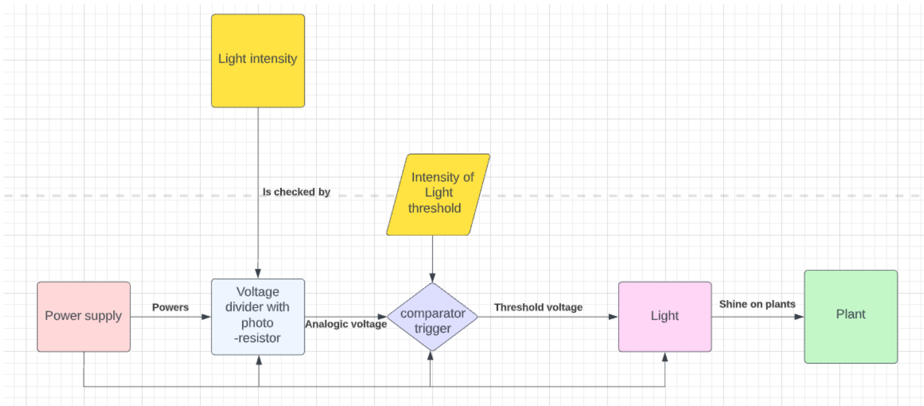
In the next section, we will now detail more how this regulation system work from the hardware and software point of view.

3 Hardware and software description

Each of the regulation system works independently, so we will present the software and hardware detail of each regulation mechanism in separated section

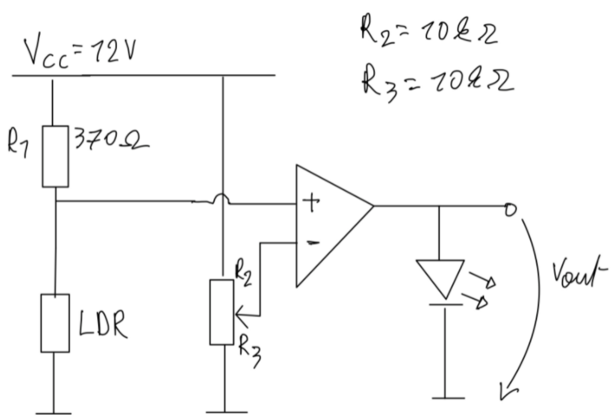
Light Sensor

The light sensor is composed of a power supply, a photo-resistor, a comparator trigger that enable us to turn on the light. We sum up all these tasks in the block diagram below:



List of elements that fulfill these functions :

- Power supply: 12V DC voltage source
- comparator trigger: OP amp branch as non-invertible comparator.
- Light : LED's.

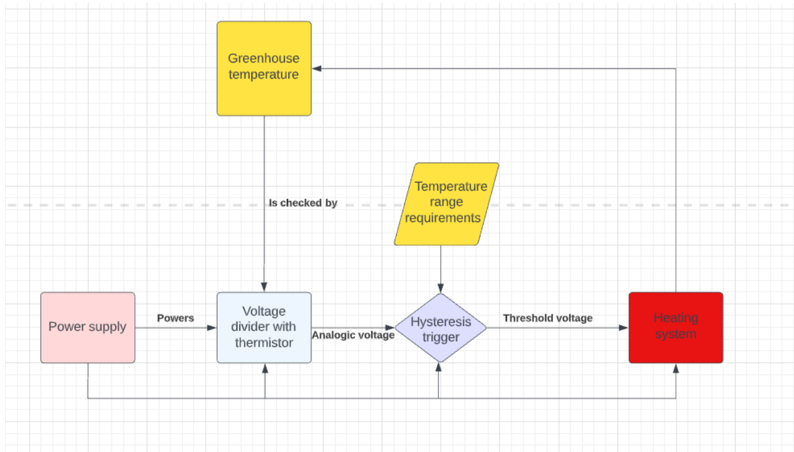


From our circuit we see that V- = 6V (This value is chosen by the potentiometer thus by shifting this value we can easily change the threshold for which the light is turned ON)
then when the LDR <370 Ω then the light is turned OFF (Vout =0V)
When the LDR > 370 Ω then the light is turned ON (Vout = 12V)

Note : We will see in the data chapter that when the LDR = 370 Ω this corresponds to around 10 000 Lux.

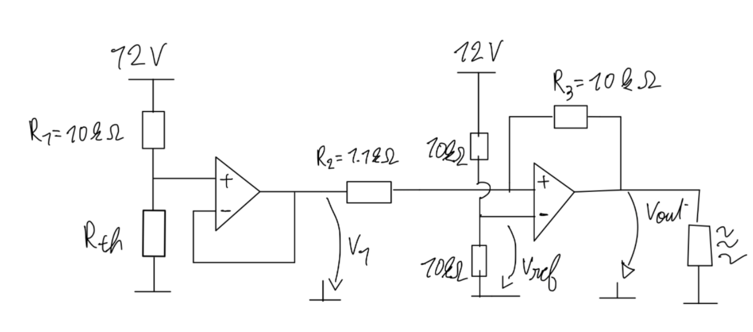
Temperature Sensor

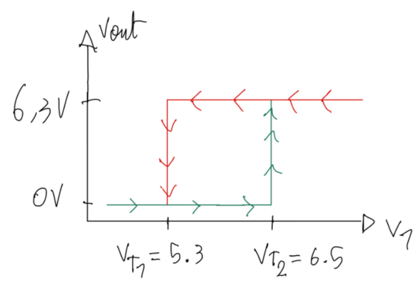
The Temperature sensor is composed of a power supply, a thermistor, a hysteresis trigger calibrated for our temperature range that enable us to turn a heater. We sum up all these tasks in the block diagram below:



List of elements that fulfill these functions :

- Power supply: 12V DC voltage source
- Hysteresis trigger: OP amp branch as non-invertible schmitt
- Heating system : made by heating resistances





Note : First we have a voltage follower to control V1. Then we have Vref that is given by a voltage divider and is worth 6V but this value is adjustable if we want to shift the hysteresis up or down (Which will also shift the temperature range for which the heater is activated).

Then we can calculate theoretical values of VT1 and VT2 as:

$$V'_{ref} = V_{ref} \frac{R_2 + R_3}{R_2} = 6 \times \frac{1.1 + 10}{10} = 6.66$$

$$VT_2 = V'_{ref} - V_L \frac{R_2}{R_3} = 6.66V$$

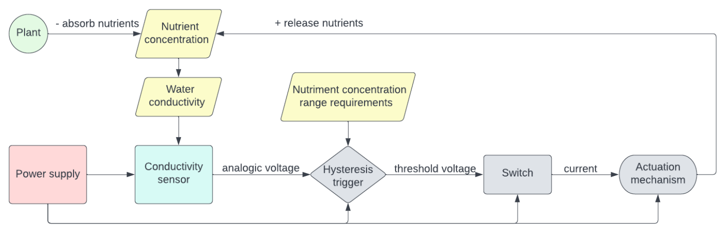
$$VT_1 = V'_{ref} - V_H \frac{R_2}{R_3} = 6.66 - 1.32 = 5.34$$

This is closed to the actual values that are :
$VT_1 = 6.5V$ and $VT_2 = 5.33$ Then when $V1 = VT_1$ we have $Rth1 = 11K\Omega$
Then when $V1 = VT_2$ we have $Rth2 = 8K\Omega$

Note : We will see that in the data part that the thermistor value is $9K\Omega$ for a temperature of 25 degrees and $12K\Omega$ for a temperature of 20 degrees.

Nutrient regulation circuit

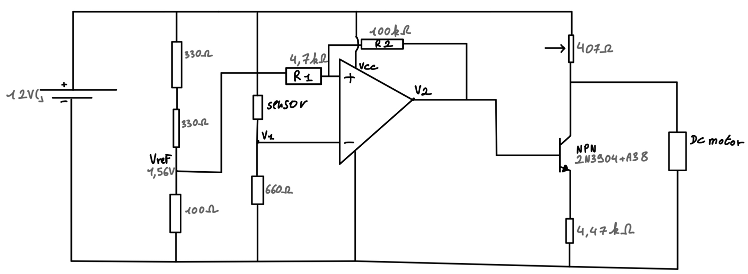
The nutrient system is composed of a power supply, a conductivity sensor that measures the nutrient concentration of the water, an hysteresis trigger calibrated on our requirements in terms of concentrations, a switch and a actuation mechanism that release the nutrients. We sum up all these tasks in the block diagram below:



List of elements that fulfill these functions :

- Power supply: 12V DC voltage source
- Hysteresis trigger: Shmitt trigger, OPAMP with resistances
- Switch : NPN transistor
- Actuation mechanism: DC motor with release system shown before

These elements are connected to each other in this circuit:

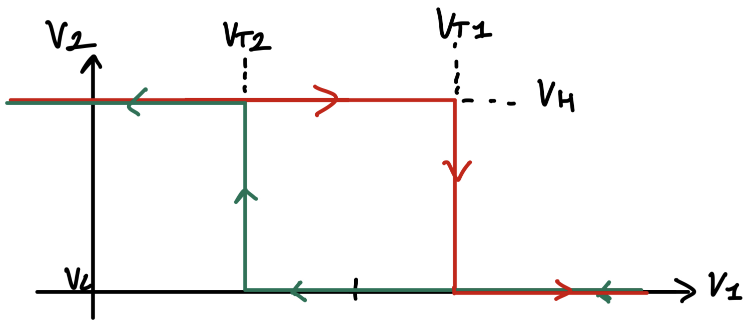


Our home made conductivity sensor is made this way:

- Black : Isolated structure (wood pen)
- Grey : Nichrome wire
- Orange: Copper wire
- Red : Isolated layer (isolated tape)

The sensor is immersed in the water, the current go from one nichrome wire to the other one through the salts of the water. More precisely through the small nichrome wire area that is in contact with the water. The amount of nutrients modify the conductivity of the water and then the resistance of our sensor. It changes the V1 voltage given to the Shmitt trigger. The nichrome area in contact with the water is about one millimeter of wire, the material used is nichrome to avoid oxidation.

In the first part we computed that the correct salinity level is between 5.84 and 13.33 grams of salt by water kilogram, after plotting it on our sensor characteristic graphic (next section), we deduce that it corresponds to a V1 voltage between 1.5V and 2V. In order to respect this range of voltage, we needed to implement a trigger that will set a high voltage when the input is too low and a low voltage when the input is too high (to control the motor and release nutrients). The objective nutrient concentration isn't a single value but a range, then we don't want a trigger that activate the motor very often because the voltage is too low. We need to implement an hysteresis in this trigger that respects this range. The OPAMP is then used as a Schmitt trigger following this curve :



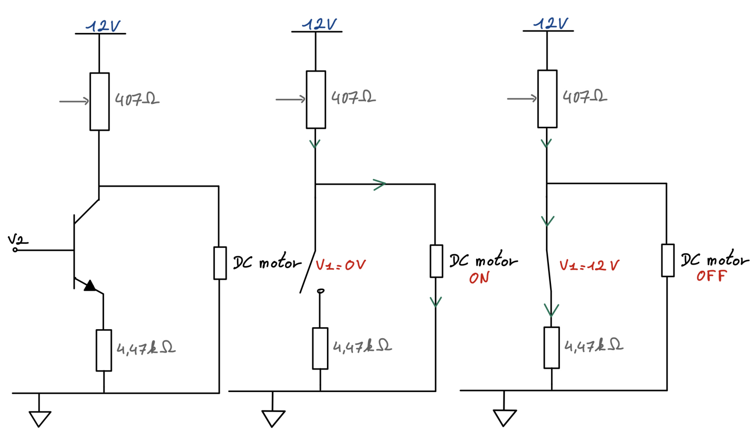
After some current/voltage calculus, we obtained these two analytics values for V_{T1} and V_{T2}:

$$V_{T1} = V_{ref}\frac{R_2}{R_1+R_2} + V_H\frac{R_1}{R_1+R_2}$$
$$V_{T2} = V_{ref}\frac{R_2}{R_1+R_2} + V_L\frac{R_1}{R_1+R_2}$$

We choose $R_1 = 4.7\cdot 10^3\ \Omega$, $R_2 = 100\cdot 10^3\ \Omega$, $V_H = 12V$ and $V_L = 0V$ to obtain the wanted V_{T1} and V_{T2}

$$V_{T1} = 1.60\frac{100\cdot 10^3}{4.7\cdot 10^3+100\cdot 10^3} + 12\frac{4.7\cdot 10^3}{4.7\cdot 10^3+100\cdot 10^3}$$
$$V_{T2} = 1.60\frac{100\cdot 10^3}{4.7\cdot 10^3+100\cdot 10^3} + 0\frac{4.7\cdot 10^3}{4.7\cdot 10^3+100\cdot 10^3}$$
$$V_{T1} = 2.05V\ \ V_{T2} = 1.51V$$

The final step of the nutrient regulation system is to power the motor using this output voltage. After different tries, we realised that the Opamp is unable to give a sufficient output current to activate the motor. Then we implemented a switch using a NPN transistor, this switch permits to directly take the voltage from the source and amplify the current to power the motor.



With this system the source provides enough current to turn the motor on.

PH regulation

As we said before, to measure the pH we use a color sensor linked to an arduino board : the color sensor will measure the color of a pH paper and the arduino will deduce the pH from the color he receive from the sensor.

The color sensor that we use is the MAX44008. This sensor is composed by a matrix of clear, red, green and blue photo receptors (you can see that in the figure below) that allow the sensor to measure the intensity in lux of the light that the all the different photo receptors sense. Then with those measure in lux of the red, green and blue intensity sense by the sensor we can deduce an RGB value that we can compare to the RGB value reference for the pH paper that give us the pH corresponding to each color.

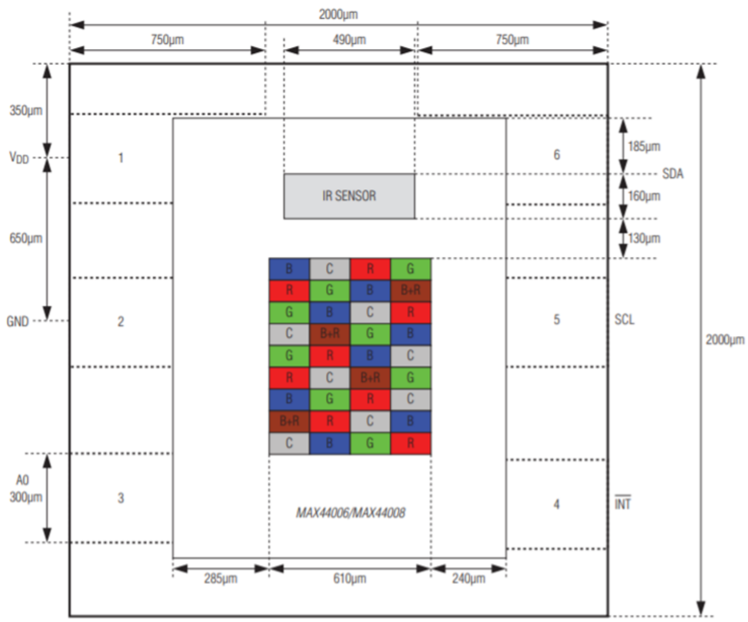


Figure 3: MAX44008 color sensor

This sensor is perfect for our application because it can be used really easily with an arduino : the sensor communicate following the protocol I2C, the arduino include also a I2C interface, and the sensor need to work on a tension between 2.7V and 5.5V, the arduino can give us 3.3V and 5V.

General functioning :

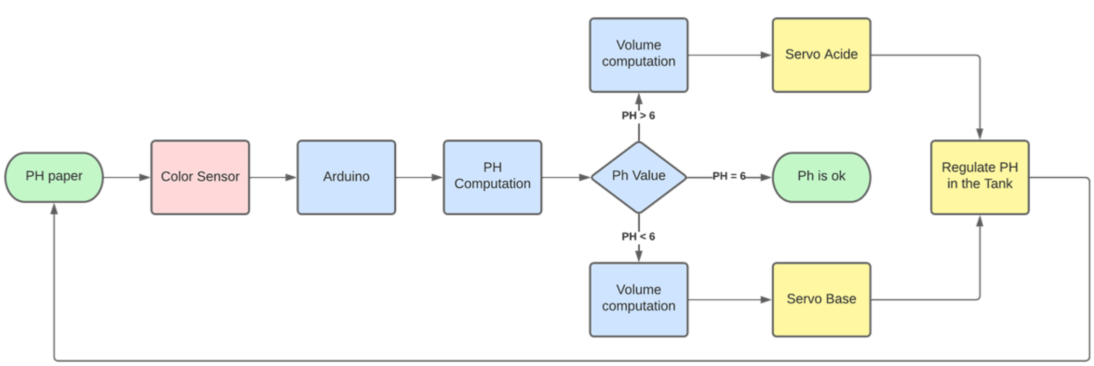


Figure 4: Flowchart of the pH regulation system

On the figure above, we summarize the general functioning of the pH regulation system. We will not detail again the way it works, and you can see it with more detail on this flowchart. However, there is still two point that we will clarify : the way we deduce the pH in the solution from the color the sensor send to the arduino, and the way that we compute how much volume of solution we need to put in the solution to regulate it.

First of all, we gonna see how do the arduino deduce the pH from the data that the color sensor send. The pH paper gives us a reference where we can see the corresponding between the color on the paper and the pH values in the solution (the figure below represent the scale that we had, it's not exactly the same because our pH paper had a 0.5 pH resolution).

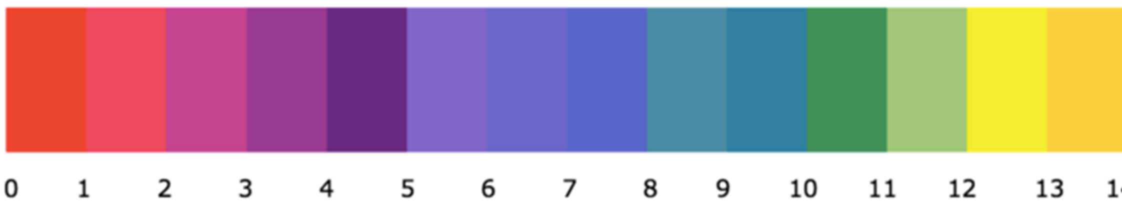


Figure 5: pH color reference

The idea that we used is basically to put this reference in the arduino so the arduino just have to compare the color it received from the color sensor to the color that it knows and after it just have to take the color, and so the pH value linked to this color, that is the closest from the color that it's sense.

Once we know the pH in the solution we need to compute the volume to add of the different acid or base to regulate the pH to the value that we want. To do so, we need to know before the pH of the acid solution and the basic solution that we gonna use and compute with a simple calculation formula the volume that we need to add.

To find the formula that we use and that the arduino board use to compute this, we applied the model of the acido-basic reaction :

we want a solution at 6 Ph and we have :

$$[H_3o^+] \text{ in tank : } 10^{-PHtank} \cdot V_{tank} \tag{1}$$

$$[H_3o^+] \text{ in Acide/Base : } 10^{-PHAcide/Base} \cdot V_{Acide/Base} \tag{2}$$

$$10^{-6} = \frac{10^{-PHtank} \cdot V_{tank} + 10^{-PHAcide/Base} \cdot V_{Acide/Base}}{V_{tank}} \tag{3}$$

$$\Rightarrow V_{Acide/Base} = \frac{10^{-6} - 10^{-PHtank}}{10^{-PHAcide/Base}} \cdot V_{tank} \tag{4}$$

However this is the model for strong acid and base reaction because we assume the fact that all the amount of reagent added in the solution is totally transformed and reacts completely, but it's not the case because we can't use strong acid or base, it can hurt the plant. In the case of weak acid and base, the reagent not react completely, so the formula above is not totally true but for small regulation, like it is in our case this not a big problem and we can use this approximation.

Finally, now that we have a way to compute the volume we need to add in the solution, we just have to find the relation between the time that we can put the servo motor, that control the output of the acid/base tank, in the release position, and the volume that goes out during this time so after with simple proportionality we can compute how much time we need to put the servo in the release position to add the desired amount of acid/base. With that method we found out that we need to use this formula to compute the time :

$$\frac{12V_{regul}}{100} - 2 \tag{5}$$

To finish, we don't want the system to be on all the time because it can create a regulation that we don't want if the color sensor detect a color when there is nothing under.

To solve this problem, we just add a button and a led to the final circuit that will allow the user to control when he want to start a regulation procedure : when he has the paper, under the color sensor and that everything is ready, he just have to press the button and a led will then start to shine to indicate that the procedure is in progress. This will just allow the arduino to start the regulation process.

You can see below the final circuit schematic.

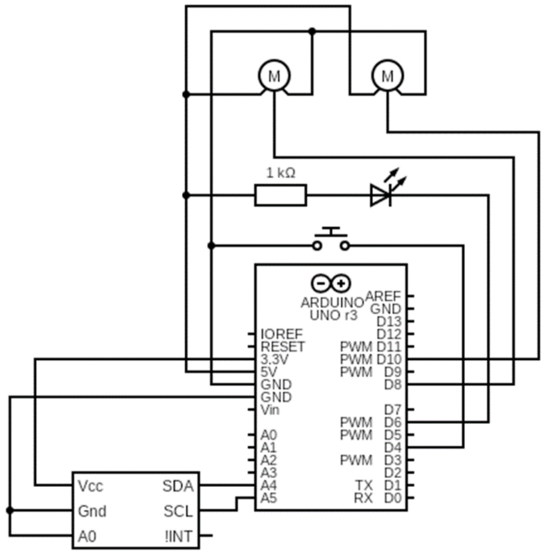


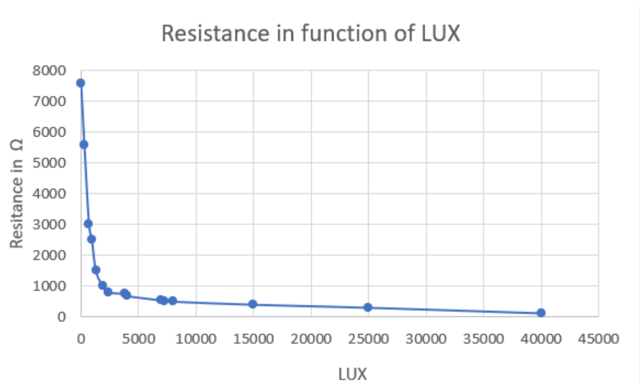
Figure 6: Circuit schematic of the pH regulation system

4 Data analysis

Light regulation system :

We didn't have the datasheet of the photoresistor so we decided to characterize ourselves our light sensor.

To do that we borrowed a Lux meter in the mentor space and plotted the value of resistance of the photoresistor for different value of LUX.



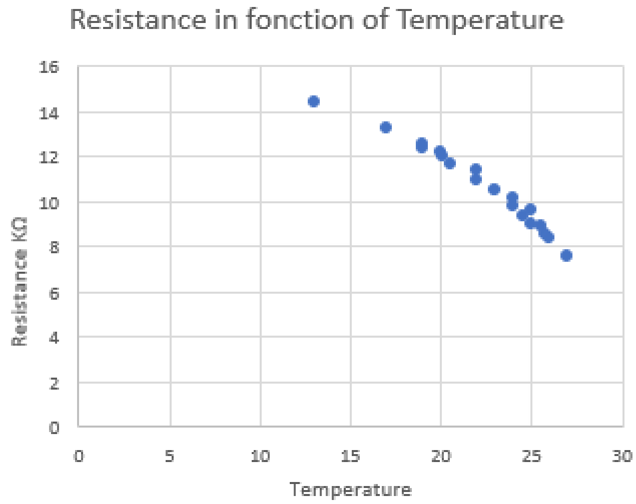
From the graphic we saw that for a value of resistor equal to 370 Ω we indeed have around 10 000 Lux .

For the worst case scenario :

- **Accuracy :** 500 LUX, based on the difference in resistance for the predicted value in LUX. (The predicted value is calculate as the mean of the different resistance for the same value of LUX)
- **Precision :** 1000 LUX, based on the maximum difference between 2 measurements of resistance for a same temperature.
- **Resolution:** 10 LUX, same resolution as the LUX meter because the light sensor reacted to each variation in Lux nearly instantly.

Temperature regulation system

We also didn't have the datasheet of the thermistor so we decided to characterize it ourselves. To do that I used a kitchen thermometer that could reliably indicate the temperature in a precise spot, then we plotted the resistance in function of the temperature.



Then form the graphiw we see that for Rth1 = 12khomn correspond to a temperature of 20 deg. and Rth2 = 9 khomn correspond to a temperature of 25 deg. We then see that our system does turn the heatingf for a temperature of 20 deg and switch is it off for a temperature of 25 deg.

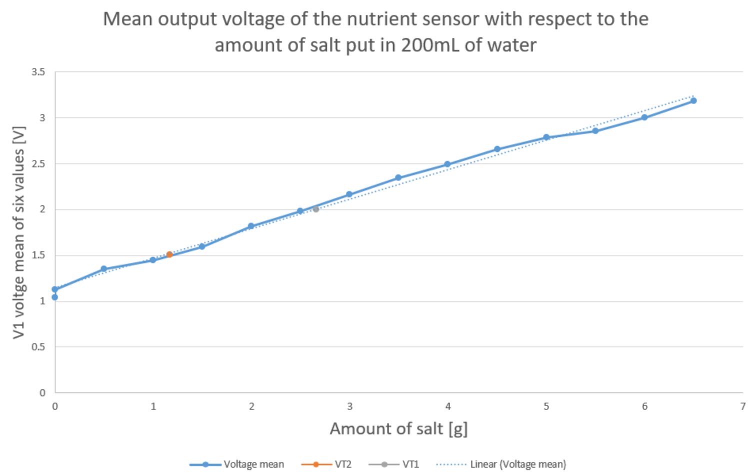
For the worst case scenario :

- **Precision :** 1.2 degree, based on the maximum difference of temperature between 2 measurements of resistance.
- **Accuracy :** 0.6 degree, based on the maximum difference between our predictive value and a voltage measurement for an amount of salt
- **Resolution:** 0.1 degree, analogic voltage output of the measure

Nutrient regulation system

After several tests we can plot the characterization curve of the nutrient sensor. We characterized it by measuring the output voltage V1 with respect to the amount of salt we put in the water. In this first graph, we took 6 series of measurement:

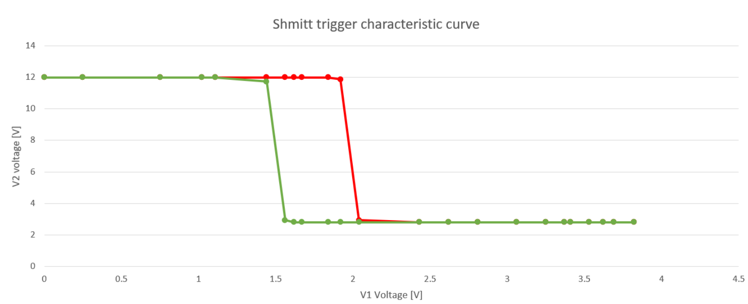
The correct salinity range (between 5.84 and 13.33 grams of salts by kg of water) corresponds to 1.17 to 2.66 grams of salt for 200 mL of water. These are the quantities we took on the characterization curve of the nutrient sensor because we did our experiments in 200 mL of water. Our final sensor characterization curve is the trend line of the mean of these measurements.



It is from this curve that we realised that our requirement $5.84g < m(salt) < 13.33g$ corresponds to $1.51V < V1 < 2.00V$ and then that we need a Schmitt trigger that implement an hysteresis with $V_{T1} = 2V$ and $V_{T2} = 1.5V$. The final step to fully characterize the sensor is to compute its main characteristics.

- **Precision :** 0.37 V, based on the maximum difference between 2 measurements voltage for the same amount of salt
- **Accuracy :** 90.013 %, based on the maximum difference between our predictive value and a voltage measurement for an amount of salt
- **Resolution:** mV, analogic voltage output of the measure

Regarding the Shmitt trigger, we first designed it theoretically and then tested it to verify its performances. Here is its characterization curve:



The Shmitt trigger corresponds approximately to the theoretical values, except for $V_L = 2.8V \neq 0V$ but the voltage difference between 12V and 2.8 V is enough to switch the DC motor. This error comes from the fact that we use a too high voltage for this OPAMP. We realised it at the end of the project.

PH sensor :

Concerning the data analysis of the pH sensor, we need to start by saying that we had a big problem with the color sensor when we were using it to harvest some data to analyze : the sensor burnt (You can see the image below, it was one day before the presentation, so we didn't have the time to change it). The problem with this situation is that we have only few data to characterize the sensor, so we gonna do the analysis as good as we can with the data that we have, it will however not be as representative as it should.

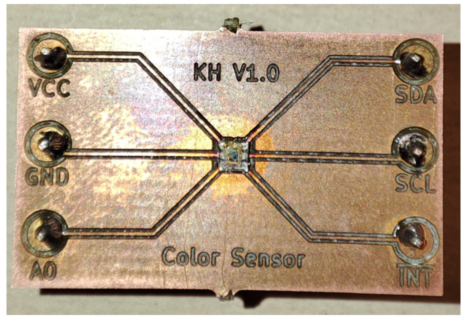
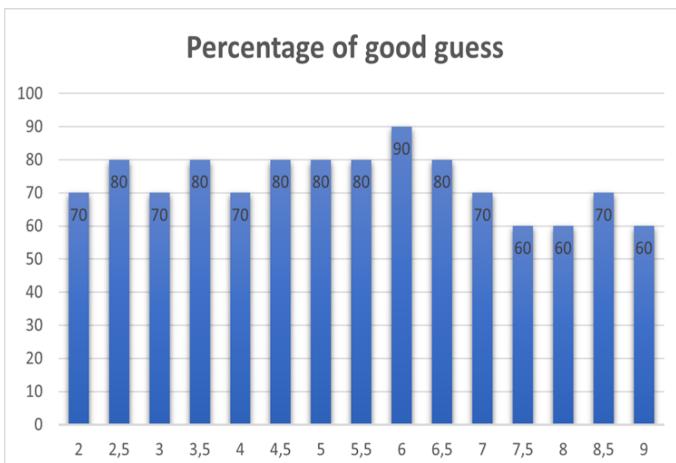


Figure 7: Color sensor burnt

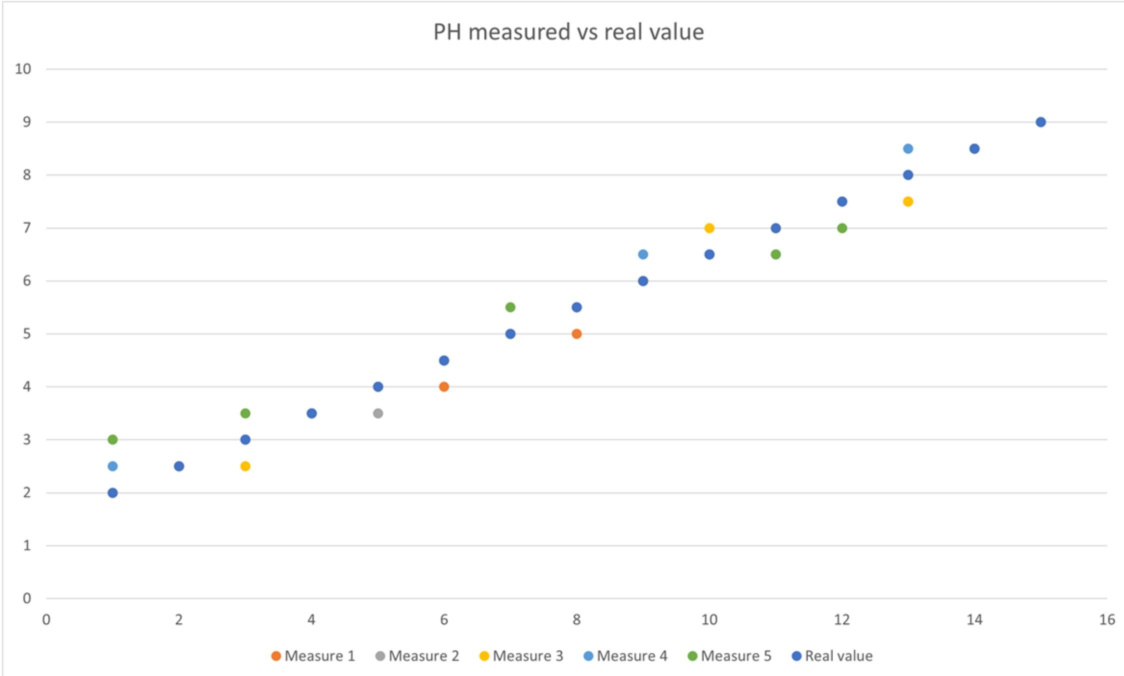
The first we did was to take some a lot of different solution with a pH that we know (had this time we had a little electronic pH-meter to know the real pH value) and we were putting the paper inside those solution, then under the color sensor and we were looking what is the pH that the arduino was giving us. We did that 10 times for each solution of each pH and it's all the data that we have.

To begin the analysis of those data, we start by plotting the percentage of good guess (when the arduino give us the rigth pH) that we had on ten repetition for each pH value :



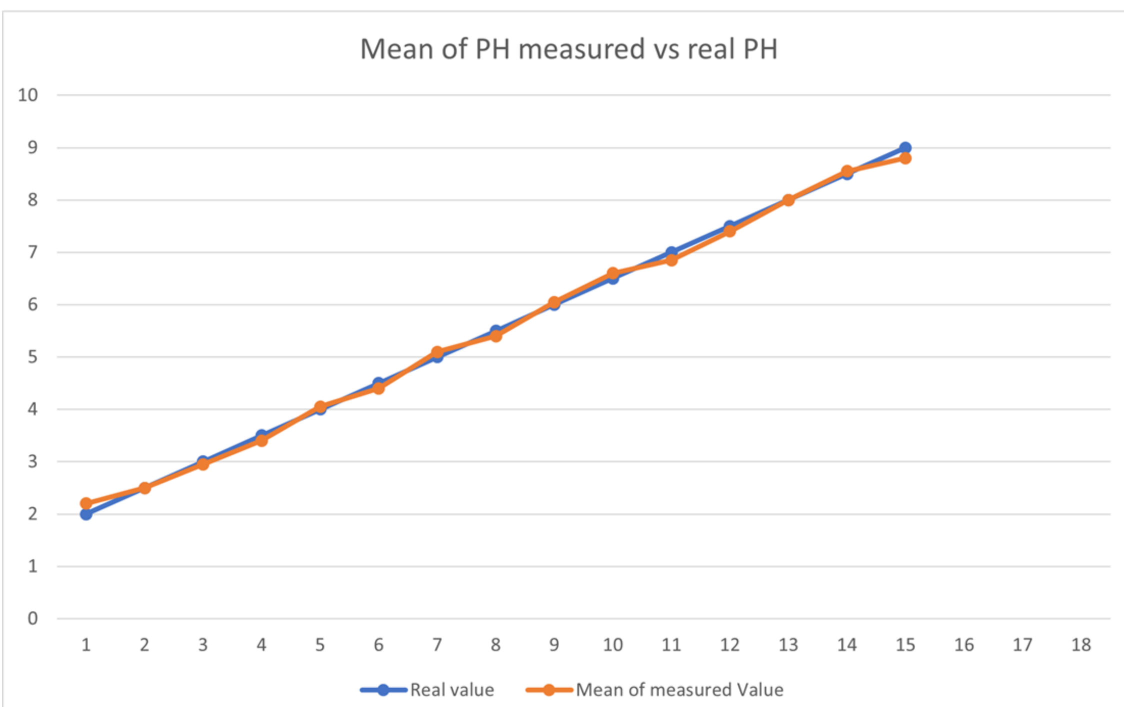
On this graph we can see that the percentage of good guess is not that good, especially for the high values of pH, we can explain that by the fact that the MAX44008 struggle more to detect the blue and it different shades, it's what we can saw by analyzing the datasheet of the sensor, and because of the fact that the high values of pH are represented by blue and violet shade, the sensor can't distinguish well the difference between them.

After that, we plotted the measure series that we had. For each pH value that we can detect, we plotted the measured value vs the real value to see how accurate and precise were the pH sensor :



we can see on this graph that the precision (1 ph) and the accuracy (75%) of our sensor are not that good. There is a lot of variance and error compare to the value that we want to have so we need to find a way to improve that. We can explain the bad precision that we have by the fact that the sensor is really sensible to the ambient light. Even if we put it in a closed black box to protect it from the exterior, still the measurement really depend and the luminosity in the room.

The idea now to improve the accuracy and the precision of the sensor is, instead of taking directly the raw data, we gonna do a certain number of measure of the same paper, apply a color and so a pH to each one of them as we where doing before and then take the mean of this pH as the value of the pH in the solution. We did that and then plot what we have :



We can see that the pH measurement with this method gives us a way more accurate measure. It's a simple thing to do and it has also the advantage to increase the resolution of the system : normally the pH paper have a resolution of 0.5 ph so the whole system will in the best case have a resolution of 0.5. But the color of the reagent on the pH paper change continuously, it's not a discrete mechanism so sometimes we can see a color between two reference color so we, human being, know that it's a value between the both that the reference give us. In the way we were modelling our system before, it was impossible to find a value between two reference value. Now it's possible and if a color is not exactly the same as one of the reference value, the arduino will assign it sometime one of the reference color that's is the closest, and sometimes because of the bad precision, it will assign another but then when we take the mean it will give us a ponderate mean of the two color the closest to the color we measure and so the pH will then be a value between the 2 reference value. That's a very interesting result four our system.

5 Tasks distribution

The task distribution was really easy in this project, we worked together and help each other when we were trying to solve common problems but most of the work was quite individual. We divided the workload fairly between the three members of the group.

- Killian: PH regulation system
- William: Heat and light regulation systems
- Kelyan: Nutrient regulation system

We finally all work together for building the prototype.

6 Results interpretation

William Oh

I'll will write the conclusion on the Light sensor and Temperature sensor:
First of all the systems work as intended as they cover the appropriate range of values, have a sufficient accuracy, precision and resolution for our demands. Moreover the light sensor and temperature sensor where cheap to implement as we didn't need to overly characterized them and could be made with simple circuit and a thermistor and photoresistor. Therefore saving a lot of money which might have been spend in an overqualified LUX meter or thermometer which would have produce the same result for our application but would've had unnecessarily performance. One of the draw back is that we didn't manage to produce a complete system capable of growing a plant. Because as we only wanted basic prototype of our system we didn't buy a strong grow light which would've been expensive but we replaced it by 3 LED's. Similarly for the heater we didn't have enough power to heat enough resistance for the size of our tank we chose to only heat a few resistance to create more of a symbolic heater. Furthermore we could also improve the precision, accuracy of our sensor if we wanted to grow a specific type of plant optimally which we could do by trying different type of circuit, taking more measurement, using more photoresistors and thermistors etc...

In this class I have discovered how to apply my electronics theory to create sensors which certain standards. And how to characterize those sensors by regards to LSB, precision, accuracy and Resolution (For example before this course I didn't know precisely the difference between accuracy and precision and why it is so important). I also enjoyed the liberty accorded to us to find the idea and create it from A to Z as we had to make our own schedule and be more rigorous. Finally I think the mentorspace is a beautiful place where with a bit of imagination and the components at our disposition you can really create incredible stuff. Plus you can easily ask for help if you have any problems or doubt on how to do things. So I really thank this course to have showed us this place where you can work on learning and creating as time flies by.

Kelyan Hangard

I will write a conclusion about the nutrient regulation system since this is the part of the project I worked on and wrote in the report. The main drawbacks of the system are the DC motor and the nutrient sensor. First, the system is very sensitive because of the DC motor. The current needed for its activation is very dependent of its inertia. In other words, we need a very low current to activate the motor if it is already moving a little but a very large current if we want to switch it on when the motor isn't moving at all. This is the reason we put a potentiometer between the motor and the voltage source, the voltage difference between the two switches of the motor can depend on a few ohm difference on the potentiometer. The second drawback is the precision of the nutrient sensor. The precision is just good enough for our application but is very bad for other potential applications that would need more precision such as growing a more demanding plant. The accuracy of the sensor is fine. The whole system use 12V, we put this voltage to power on the motor but we should use a lower voltage to control the system. It would be better in terms of power consumption and better adapted for using the OPAMP. The whole system is really cheap except for the Arduino which is too expensive, the next time we should buy a cheaper MCU. I think that people could buy this type of system, obviously if we want to sell it we should radically change the prototype and improve it. Here the prototype was only a way of describing our ideas and we should make a finish product (smaller box, integrated circuit better hidden, interface...) to sell it, but if we achieve to do it I think people may buy it because it is a useful system really easy to use. By matching market prices, we could sell the final system between 1200 and 1500 SEK. To summarize what I explained before, I would improve our design by:

- Use a smaller voltage
- Improve the sensor precision
- Use a more accurate motor (with less inertia)
- Use a cheaper MCU
- Improve the prototype

But the most important goal has been achieved: the nutrient system works and is able to regulate the nutrient concentration in the farm. I learned a lot of new things in this course. I will remember the important concepts of resolution, precision and accuracy regarding the sensors. In general I learned interesting things about how companies can we use sensors to collect some data and I will be more curious about that in the future. I liked the fact that we sometimes focus on technologies I didn't know like RFID, fingerprints, iris detector ... I discovered how to deal with noise in electronics and I think that it will be an important skill later. I never took a course that allows me to really construct a system before so I learned a lot of practical things by doing the project. I learned how to weld cleanly, how to create a circuit that I designed before on paper, how to make a PCB by seeing Killian doing it, how to construct a sensor from nothing and characterize it. I also learned softer skills like how to share the tasks of a project between members of a team to be efficient. I also learned that in reality electronics doesn't always works the way I drew it on my paper and that I have to do a lot of tries and tests to make a system works. I think that the mentor space is a nice place to learn all these new practical skills since there are always students more experienced ready to help each other.

Killian Hinard :

In this section I will do my personal conclusion on the project the part I did and what I learned through this course.

First of all, since it's me that did this part of the project, we gonna do a short conclusion on how well the pH-regulation work, is it satisfying for our application, and what should be improve for the next times.

We saw trough the data analysis that the raw data of our pH-sensor was not good, not precise nor accurate and only have a resolution of 0.5. But when I use the mean method I obtain really good measure, with a better accuracy and resolution so it's clearly good enough to regulate the pH of a plant, that don't need a really high quality regulation the important is more that it's staying between 5.5 and 6.5 of pH. I think personally that we can be satisfy by this system, of course we should have more data to really do a representative conclusion on how well the mechanism work but it's still a beginning and for a first approach and concept the test are satisfying.

An interesting part was also to find a build and idea for the regulation mechanism. In the end we were really enchanted of the way it works and it was reliable enough for ensure a good regulation.

Now let's interest ourselves at the price of the design and how much people would buy it.

The prototype that we build was really cheap, every thing that we used was recycling, even when we look at the electronic part, there is just the MCU that maybe cost a bit but we can change it to something less powerful that just have the functionalities that we need, the arduino was a bit overkill maybe for the application, but was still a good choice I think, it was really adapted to our application when we look about all the library that we can use, the I2C interface, and the fact it make the production faster because we didn't need to design a PCB to use it nor learn a lot on it before using it.

Of course if we want to produce those product at a commercial scale, we need to use better materials, that will cost a bit more, we need to put some effort and money on the design to improve it and make something that look good and attractive for the client and maybe improve the power consumption that is not even very high now.

When we look on what is made now on the market, what price they sell it, and if we plan to put some common user interface improvement on the machine like maybe a link with a mobile phone app to regulate every parameter the user want, stuff like that, we can imagine the first model to cost around 1500 SEK - 2000 SEK, that is a price a bit higher than the other hydroponics farm. Why higher ? Because our farm is fully automatic, it will really open the world of botany to a large amount of people, the client will be able to grow a plant everywhere, without needed to take care of it, we can imagine that those product can interest a big amount of people. Today, we loose more and more time, everything goes really fast and the human are increasingly removed from nature, this product can really be a way for everyone to have fresh and healthy vegetables, aromatic herbs or decorative plant at home.

The design as it is today is far from being a really good design and a lot of thing can be improve. For the moment it's impossible for the user to interact with the machine more than start the pH-regulation. He cannot decide the configure precisely every parameters and that's a problem if you want to fit the system to different type of plant. We can also maybe think the improve the box of the color sensor to really make something totally hermetic to the environment luminosity. We can also build to tank totally hermetic to really keep the temperature inside as the right level without consuming too much, and we can then add a oxygen/CO2 regulation system. That will permit to the user to really use the design in hostile environment.

In conclusion, this course was a really good surprise, i took it without any special expectation, but more because it was a mandatory equivalence with a course in my bachelor, and I really don't regret it. In my home university we are not use to do a lot of practical stuff like that, and this course was for me a very formative course in which I learned a lot of things. Trough the development of our project and idea I had to always search to solve the different problem we had, I had to learn a lot about how you do the practical stuff, such as designing making and using PCB, learn how to solder, etc. On that point the mentorspace was also a great discover, a place where you have every thing in free access, to learn and to build whatever you want, it's really a incredible tools for learn how to do stuff by yourself. There is always more experiment people that can help you and gives you some advice, that's a really rewarding experience.

Speaking about the sensor, the course was really a good introduction to that very interesting world that is the world of sensor, or how giving a way to your machine to recognize and be aware of the environment. I really liked the course format, i there is just a thing to say it would be that maybe if the course was more in canvas it could be good because on the other website you really have to seek for the information, but that's not that big of a problem in the end. I particularly enjoyed the part of the course on the bio-metrics sensors and the way they work. That was really interesting and useful to understand more about the everyday world.

To finish, if I had to recommend this course to someone else I would do it without any hesitation and I think it was one of the best course I had in KTH.