Scale +

Project Internet of Things
Connected Body Scale

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Introduction

Balance has existed for many years. Its style and use have developed over time with the arrival of new researches and technologies. This measuring instrument consists of evaluating masses of two objects in relation to each other.

In the earliest Antiquity, the weights of the scale were hung by a hook on the underside of the scale but with the invention of Robervalt, his idea came up to put the weights directly on the scale and not underneath. Later on, electronics revolutionized its use with the introduction of the Tare, digitalization made it possible to obtain an automatic scale with graduated dials and subsequently with a digital screen.

During the year of preparation for our Master 1 at Efrei Paris, we have a new course called Internet of Things co-teaching by Mr. Ali MODARESI and Aomar OSMANI. Over time, the term IoT, has evolved and now encompasses the whole ecosystem of connected objects. In a conceptual way, it represents connected physical objects with their own digital identity and capable of communicating by producing the massive exchange of data such as data storage and processing.
In a more technical way, IoT is the direct digital identification of a physical object through a communication system.

Nowadays, most objects become connected on the market, especially body scale. In fact, there are all sorts of them, but today in this project we are going to look at connected scales. Its use remains unchanged, the user steps onto the scale and can see his weight displayed. The new functionality allows the user to store his weight in an IoT platform called ThingSpeak, so that he can have a daily monitoring of his weight and avoid gaining weight too quickly.

Part 1 : Study of the project idea

A - Definitions of subject terms

Before we talk about Scale+, we thought it was necessary and indispensable to define the literature for our project. Whether we talk about scale or balance, we can't really see the difference since both objects do the same thing, measure the weight. In fact, it is by understanding how they both measure weights, that we will be able to understand how they differ from each other.

Balances are generally used in the application of very precise values. Their operation is based on the mechanism of restoring the force that opposes the force of the weight of the material on the scale and will allow the object to return to a force of zero. On a daily basis, the balance is used in the kitchen for recipes or in scientific laboratories where it is necessary to be extremely rigorous in weighing.

Image for a balance and a scale

Scales are generally used to measure weight as in our case. These scales use the weight formula to determine the weight of this object on Earth. There are different ways to obtain this value. The first one is using a spring to determine the weight, while others will place a sensor on it. However, in everyday life, its use is the most common, we find it at home, in our bathroom or even at the gym.

In this IoT project, we are going to focus on the definition of a Scale that has been presented above. So, we may wonder how the idea came to us and that's exactly what we're going to talk about in the next paragraph.

B - Issue and contexte

At first, we wanted to realize a music-related project but its content was missing a connected part essential to the IoT project. Thus, our teacher suggested another project like the "Plant Watering System", but we were not very excited about this one. Then, we searched for another idea and came up with something. Unfortunately another group had already a similar project in terms of content. Lastly, we picked one of the two other projects proposed by our teacher : the Connected Body Scale.

This project could be very useful to keep track of your own weight evolution. Whether you are an athlete, or a food lover, you will see the increase or the loss of weight in a small or larger interval of time.

C- Study of art

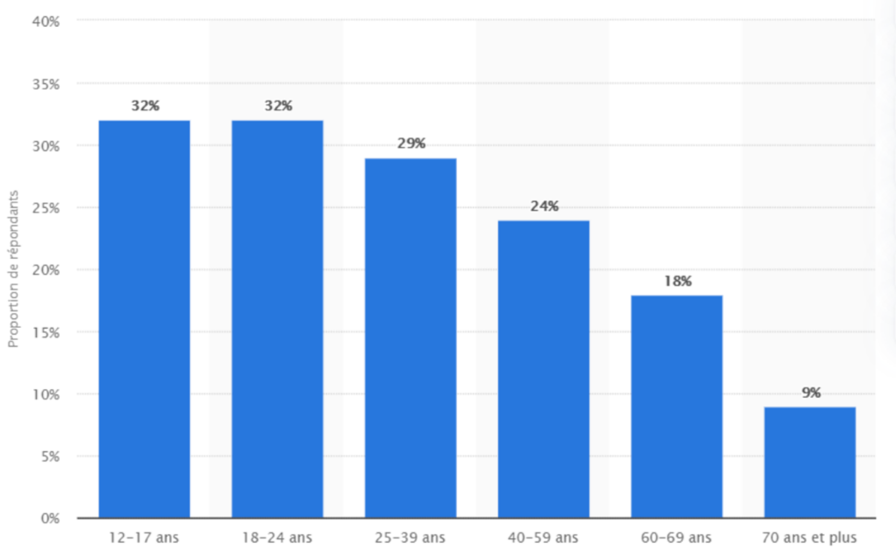
In society, the weight of a person has always been a complex subject. Social networks and media show us every day, photos of models with a perfect appearance without knowing that most of them are retouched. The objective would be for everyone to look like them, have a healthy diet and do a lot of sport. Yet very few people manage to keep this balance. In reality, a person's weight is not just the single number on the scale, in fact, it is thanks to a lot of indicators that help to determine weight.

1- A bit of statistics...

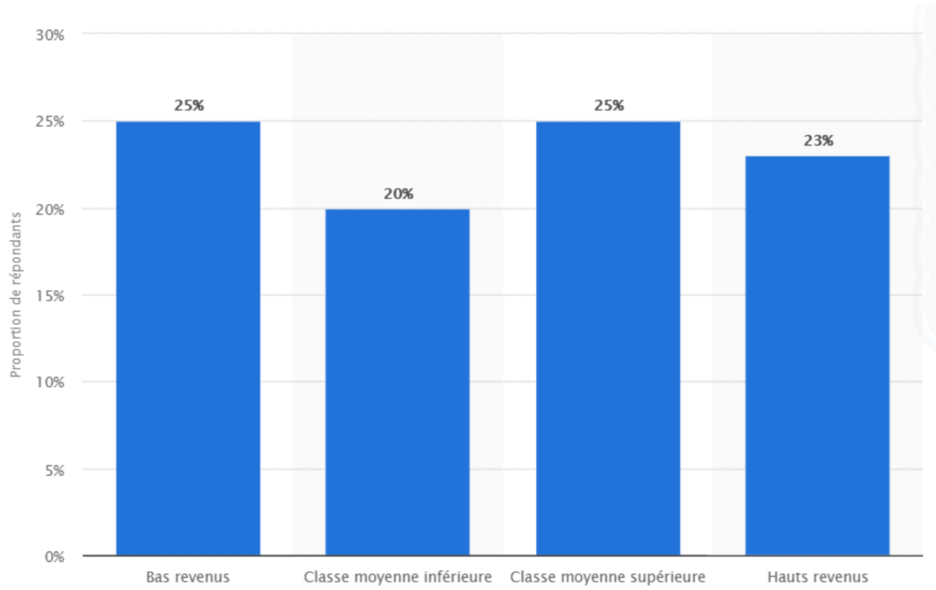
The question that can be asked is to see if a connected scale is really better than a simple scale, but above all, what more will it bring to your daily life ?

According to the website "Statistica", this graph shows the proportion of people who are interested in using a connected scale classified by ages. We can notice, obviously, that the youngest are the most interested in particular those from 12 to 25 years old. This graph has been realized in 2015 that's why this statistic can evolve with the rise of connected objects.

Graph of percentage of people interested using a connected scale



Graph of percentage of people interested using a connected scale depending on financial situation



However, owning this kind of connected object is quite expensive and not everybody can afford it. Prices evolve according to the functionalities offered but remain unaffordable for some people.

The second graph presented below shows the low-income class and upper middle class are the most interested by having a connected scale. They represent 25% which is quite high but most impressively, this graph demonstrates that price doesn’t matter. In fact, the four classes have almost the same percentage.

2 - What's already on the market

On the market there are several varieties of connected scales which are suitable for all types of person.

- **FitTrack**

The most popular one is FitTrack. This connected scale can analyze all parts of the body with 17 specific indicators such as: body hydration rate, percentage of fat mass, muscle or bone mass and many others. It is particularly well known because a lot of influencers promote it on social networks and offer promotional codes for the purchase of this scale, that is worth 84,90€

- **FitBit Aria Air**

FitBit Aria air is a smart scale that syncs with the FitBit app in which you can view BMI, as well as graphes to see your weight evolution over time. It is easy to use but costs 59,00€.

- **QardioBase 2**

QardioBase 2 is a smart scale that syncs with the Qardio app which gives you information about your weight, BMI, but also full composition of your body (body fat percentage, muscle, water, and bone mass). With a beautiful design, it has a pregnancy mode as well. This connected scale is specific to professional sportsmen, who need a precise and constant monitoring of their body. This one is more expensive and cost 149,99€.

Partie 2 : Technical development

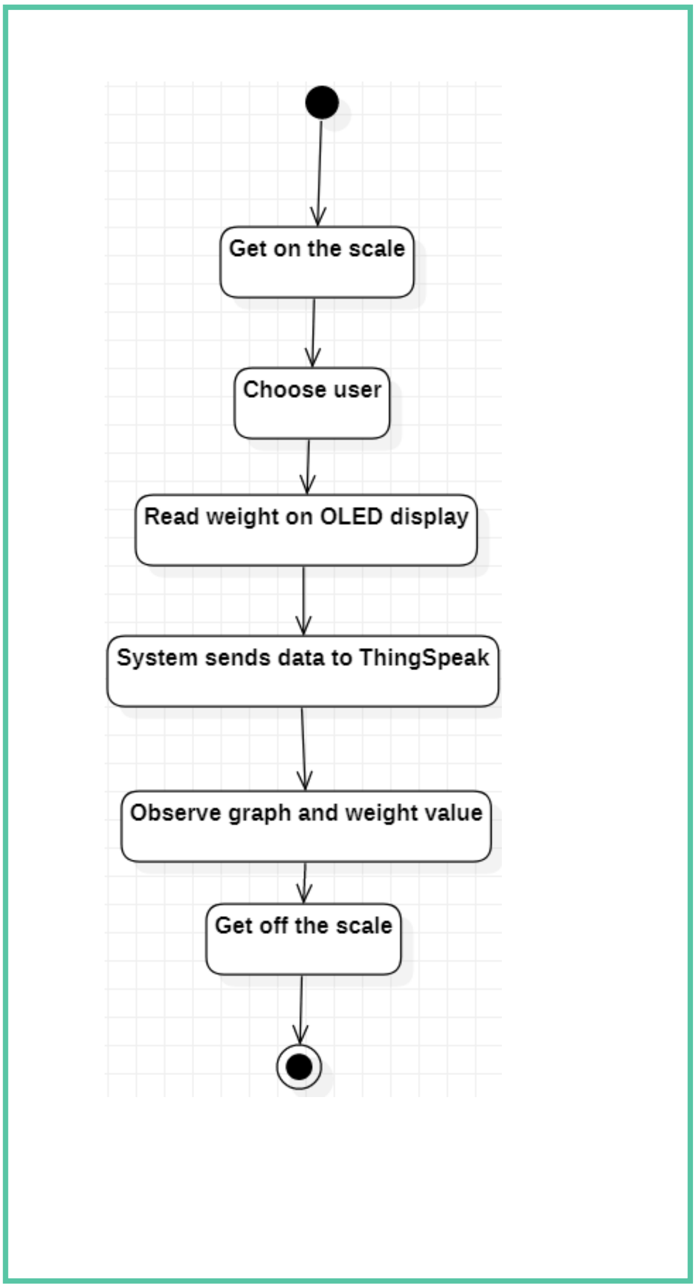
A - Project description

Scale+ is a connected scale that reads the weight using sensors. This scale is connected through a Wi-Fi network from a smartphone for example. From the ThingSpeak platform, the user will be able to see their weight directly on the dedicated dashboard and will be able to follow the evolution of their weight thanks to a graph according to days, weeks and months.

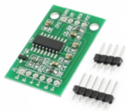
B - Functional aspects of the project

In order to see how the scale project works, we will see below an activity diagram of the situation.

Activity diagram of Scale+



C - List of all components used for this project

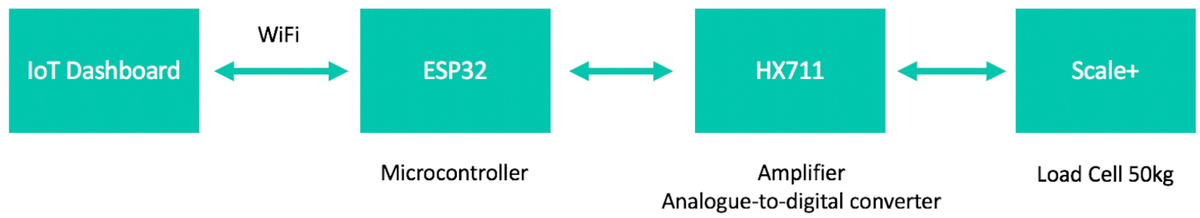
A wooden plank	
Load cell sensor 50kg	
HX711 Amplifier	
Breadboard	
Double face scotch	
ESP32	
Oled	
Wires	
Foot end fixture	
Soldering iron	
White adhesive roll	

D - Technical presentation

1- Description of the main components used

Scale+ project involves a few components as we showed above. First, we will see their functionality and how they are working together. Afterwards, we will discuss steps that help us to implement this project and issues we encountered. All the parts will be illustrated with schematics and photos taken during the scale construction.

Scale+ connected part



- ESP32

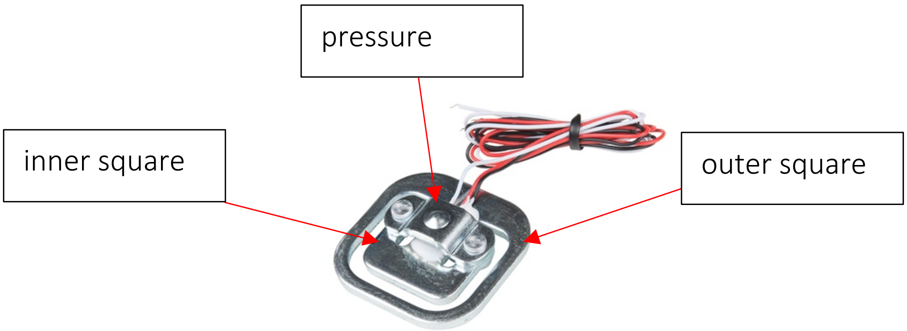
The microcontroller ESP32 is the first important component. In the lab four of IoT, we had the opportunity to work with this component which has an integrated Wi-Fi and dual-mode Bluetooth. This board is the most adapted for this project because we want to communicate by sending data's and provide an IoT dashboard for our scale.

ESP32 component

- Load Cell 50kg

For this project, we will need 4 load cells of 50kg each and set them on the four outer corners of the scale. A load cell is a metal force transducer that have strain gauges glue to them. A strain gauge is a potentiometer that can determine some pressure variance which is converted into the weight whether it is grams, kilograms or ounces depending on our unit of measurement.

Each of load cells have 3 wires: red, black and white to provide power, ground and sensor reading. The goal of the load cell is to measure weighting with the pressure of the weight placed on the scale.

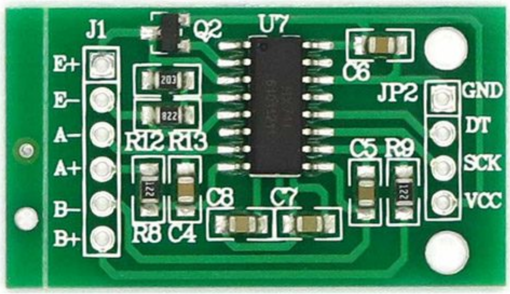


In the load cell's picture above, we can make a distinction between the inner square and the outer square. This part is an important one when building the scale because we need to set the load cell on a support so that the inner square can flex up and down inward. Otherwise, the scale won't read the weight properly. So, it is thanks to the pressure on this piece that the scale works.

- HX711

HX711 is an amplifier module for Wheatstone bridge force transducers based on an analogue-to-digital converter. It allows the reading of changes in resistance of the force transducers, which will give you accurate measurements after calibration. Its goal is to make the connection between the microcontroller and the scale. Moreover, we can use analog input of our microcontroller to read the weight directly from the load cell but the voltage inside the cell is very small and the sensitivity of the analog to digital converter in the ESP32 is not enough to do this, that's why HX711 amplifier is important for the reading.

HX711 Component



Now, let's have a look at the component. We can see two parts the left one and the right one.

The left part of the HX711 amplifier is used to make the connection with the load cells and the scale. E- and E+ represents the excitations pins and A+ and A- are the amplifier pins. For this project, we won't be able to use B+ or B- (shield) because theses pins act as an optional input which is not connected to the strain gauge but it is used for grounding and protection against external electromagnetic interference (EEI).

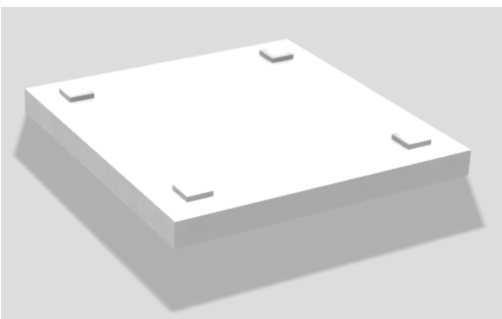
On the right side of the HX711 amplifier, those pins are used to connect with the micro-controller ESP32. We have ground and VCC supplied by the ESP32. On the ESP32 VCC is 3,3V and we will use any digital pin for DOUT and Clock.

2 - Realization and approaches

Step 1 : board construction

The first thing to realize is to build the scale. We went to Castorama and bought a wooden panel size 33x33 thick enough to support the weight of a human on it. We also decided to buy white adhesive rolls to recover the contours of wood that has been cut off.

Modelisation of our plank with Fusion360



Wooden plank

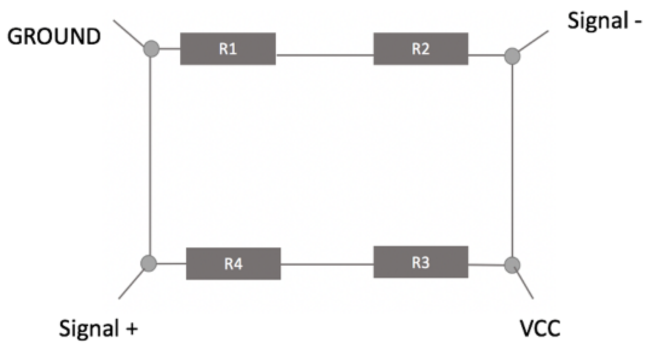
The next step of this first part is to set load cells sensors on the scale. As we saw on the component description, load cells use the Wheatstone bridge principle and our four load cells need to be set up in the following a specific order. A Wheatstone bridge is a bridge circuit used to measure electrical resistance depending on the strain pressure.

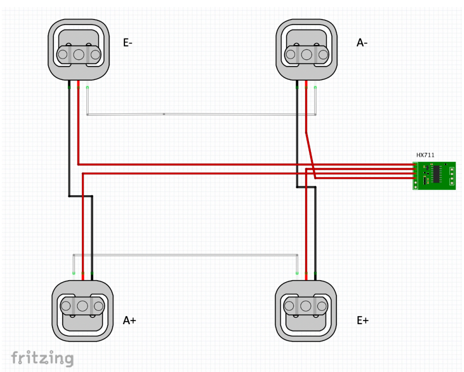
As we can see on the following schematic: we have four resistors for our four sensors.

The sensor E- is going to represent the excitation ground, the sensor E+ represents the VCC, the sensor A+ represents the sensor positive and A- represents the sensor negative.

Also, we need to connect the black wires together, from lower to upper and the white wires from the left to the right and we will use the red one to connect to the HX711.

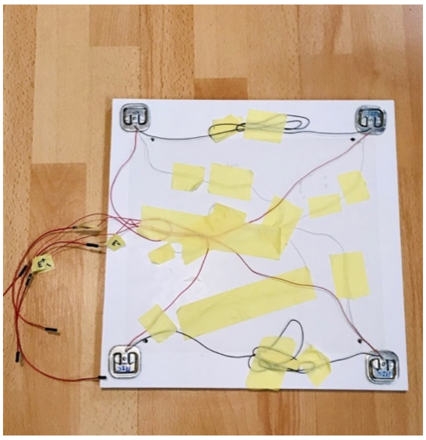
Wheatstone bridge





As we said earlier in the component description part, the inner square of the load cell needs some space between the scale and the ground to flex. It is for this reason we decided to drill a hole in the wooden plank.

Here is the result of our scale.



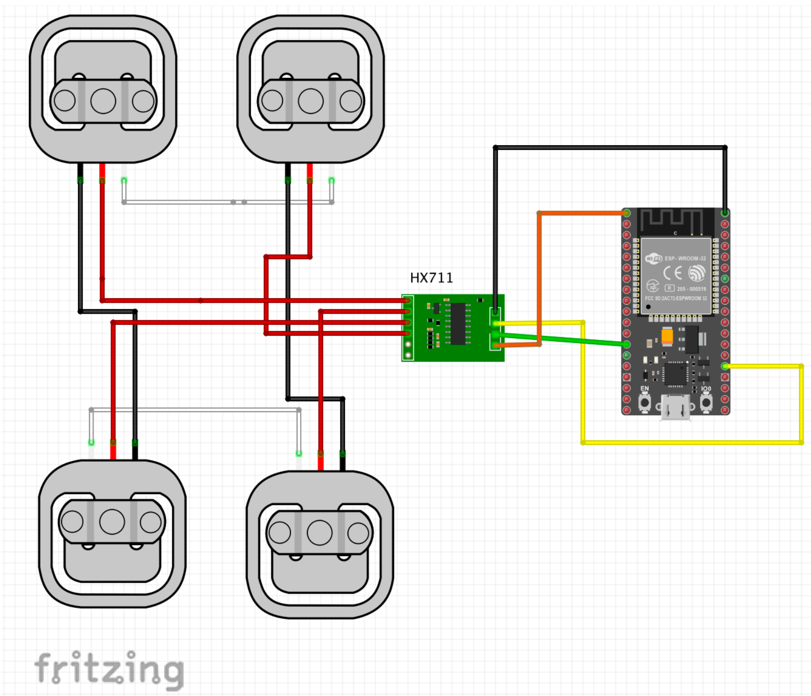
Step 2 : Connecting wires together

For this part we will be interested in how the other side of the HX711 is connected to the ESP32. As we can see here, HX711 has a Ground, Dout, Clock and VCC.
We will connect :

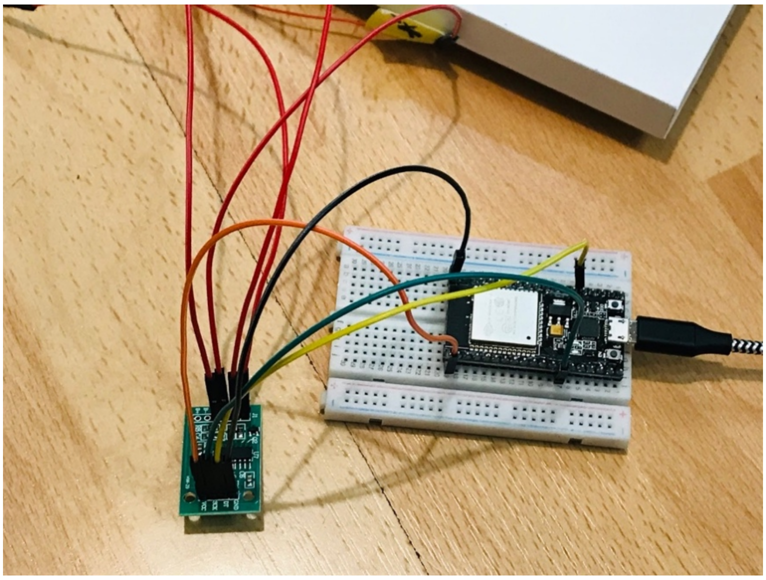
- HX711 Ground to ESP32 Ground
- HX711 VCC with ESP32 VCC which is 3,3V here.

Doout pin 2 and Clock pin 12 we choose a random pin to connect them to ESP32.

Schematic: Connection between the load cells, HX711 and ESP32



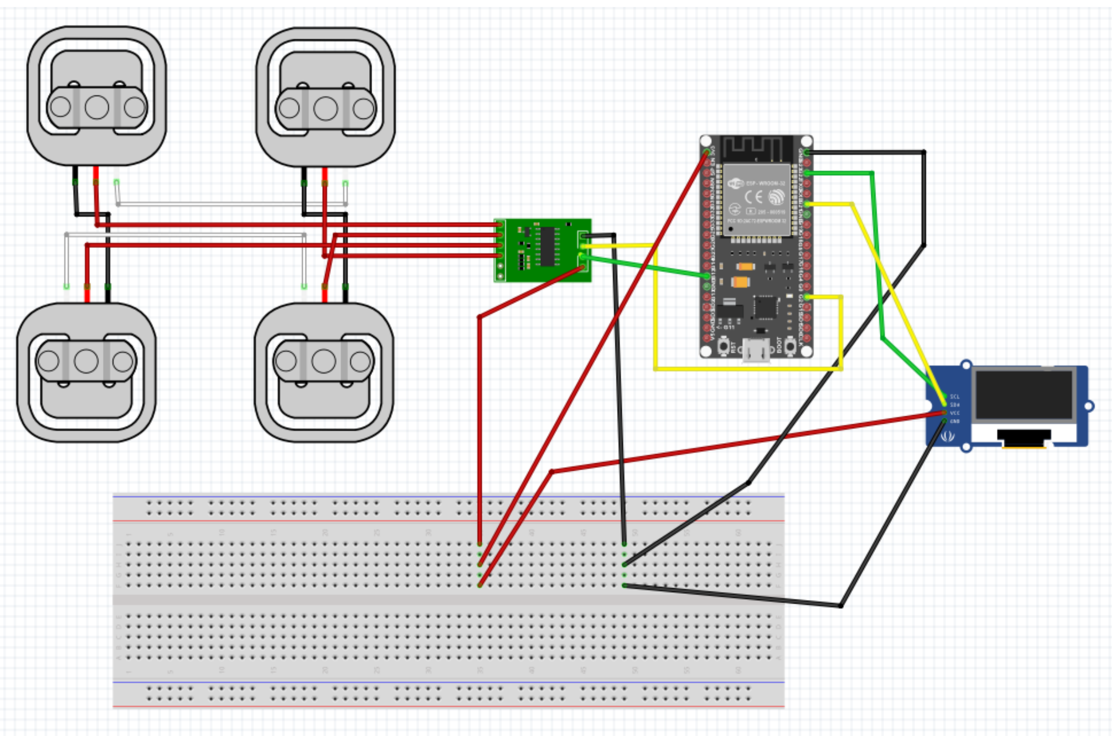
Board image : Connection between the load cells, HX711 and ESP32



Step 3 : Display weight on OLED screen

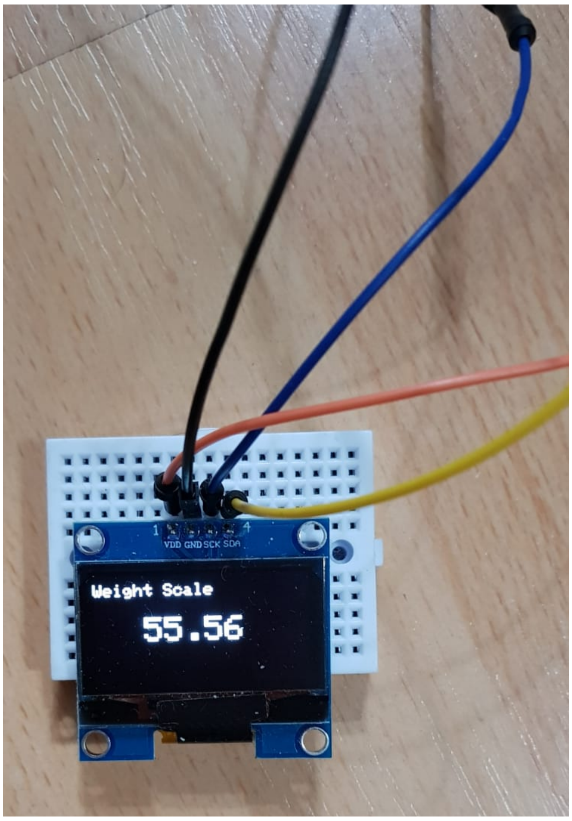
Now that the main steps are realized, it is the moment to see if everything works together. To do so, we want to display people's weight on an OLED screen. We use the Lab 4 to implement this part and we get this following schematic :

Schematic OLED display weight



SCK : pin 22
DOUT : pin 21

Board image OLED display weight



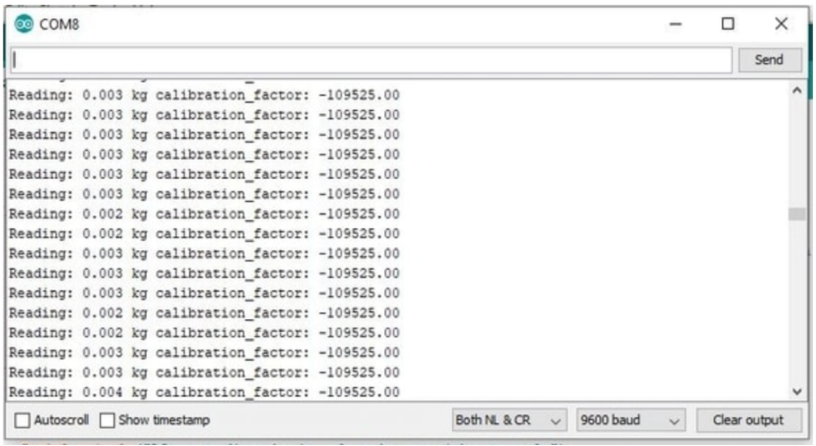
Step 4 : Scale calibration

After connecting all the wires together with the OLED, we will test our scale and see if it reads any weight. Before any manipulation, we first need to calibrate the scale. Calibrate the scale means that we need to set up the scale to 0kg without any weight on the scale.

To calibrate our scale, we will use a program we found.

1. Compile the code and look at the value on the serial
2. See a lot value close to zero but not the exact value
3. Adjust the value by increasing or decreasing the reading value to obtain 0.00kg.

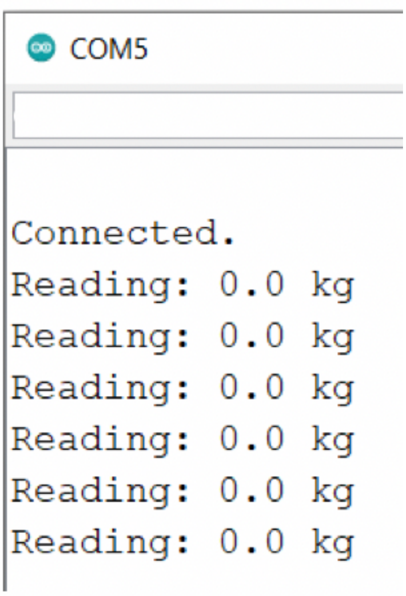
Serial monitor for scale calibration



When it is done, we will record the calibration factor and put it on the main code.

Now we have correctly calibrate our scale.

Serial monitor with good calibration



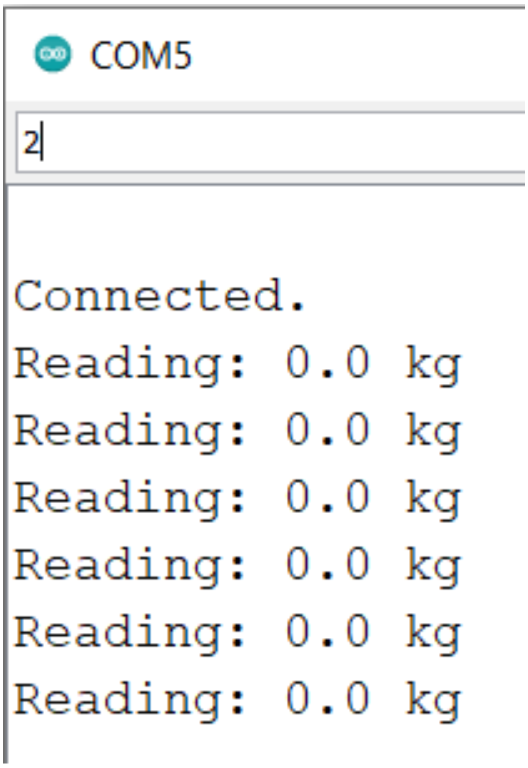
Step 5 : Connection with Thingspeak

The last step of this project is to send the data here is the weight of a person to a IoT platform. We decided to choose the Thingspeak dashboard to realize the record.

In the platform, we implement two user profiles for the two members of our group so we can check our own weight on a graph and another test profile for the demonstration in class.

To manage this functionality, we set up a number to send in the serial monitor for each user. For example if the user Pauline is getting on the scale, we have to wait two seconds until the weight is stabilized and then we will send the number 2 in the serial monitor as followed :

Serial monitor for user 2



After the input of the user number, the serial monitor will display the correct weight and the user can check on Thingspeak his graph and can analysis his body's evolution.

E – Issue encountered

In the last past week working on this project, we encountered a lot of issue related on the scale construction. At the beginning we used some double face scotch to fix the load cell on the scale as followed :

Fixation of the load cell 1

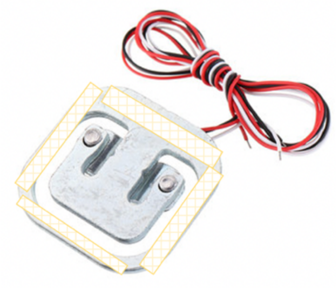
We continue the project without knowing that the construction was wrong. When we compile the code, the scale display 0.0 kg, even when we make a pressure. It is at this moment we realized something was wrong.

After a lot of research and documentation, we found that we've made a big mistake. In fact on the load cell we can see one outer square and one inner square. We realize putting scotch like this in the inner square will block the pressure and there will be no more space for the inner square to be flexible. Without this pressure, we won't be able to detect a weight. That's why it is really important to elevate the outer square in relation to the board to let the inner square flex. For this reason, we sur-elevate the outer square with a lot of layers of scotch tape as we can see on the following picture.

When compiling the code and doing the scale calibration again, the weight appears when we put a pressure. However, while the displayed weight must be at 50kg, the scale display 49-50-51-52kg which are obviously not correct.

With some reflection we realized that the non-exact value is due to a non-stable fixation of the load cells. Realizing the tape is making this variation, we decided to drill a hole in the wooden panel and fix the load cells with special resistant glue.

Fixation of the load cell 2



The second issue we have encountered is also the non-stable fixation of the HX711. In fact when we ordered the component, it came like this :

HX711 component

When using the component, we only put pins in the hole and assembling with wires. The variation of the weight is also caused by that. We realized we had to solder the pins to the HX711 to get a good value.

The final issue we encountered was working on the different user profiles. All along the project, we were working on Blynk IoT application however, Blynk app doesn't allow to have many user profiles. For this reason, we had no choice other than to change our dashboard and internet connection part.

We moved to Thingspeak which is a great because we can have many fields and visualizations for the different users. The only problem was changing the entire code with a very little time left.

Part 3 : Financial aspect

The last part of this project is about financial analysis and aspect.

Material	Price
Wooden panel	2.44
Load cells + HX711	11.99
Scotch tape double face	10.99
Adhesive rolls	10.99

TOTAL : 36.41€

Please find in annex invoice for the materials purchased for this project.

Finally, Scale+ is a scale that didn't cost us so much to produce compared with the connected body scale already on the market. There is a huge difference in price compared to ours. This is of course due to the aesthetics of the physical product but also to the design of the dashboard and the functionalities offered.

These are functionalities that we wanted to bring to our scale but due to a lack of time we were not able to realize them. However, we have seen that there is an impedance meter sensor module used in almost all connected scales that sends a very weak electric current through the body and allows us to determine about ten indicators such as the level of fat, body hydration and so on.

Conclusion

All along this project, we were able to learn a lot on the composition of a scale we didn't know about before, even though it is a tool we use every day. This allowed us to work as a team to look for solutions and how to achieve them. We spent a lot of time building the scale but we are proud of what we have achieved in such a short time. We obtained a prototype that works well and met our initial expectations. Finally, we would like to thank our teachers who supported us and answered our many questions.

Sources :

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Fitbit : https://www.fitbit.com/global/fr/products/scales/aria-air
Qardiobase : https://www.getqardio.com/fr/qardiobase-smart-scale-iphone-android/

Source for the coding part

https://www.youtube.com/watch?v=nodSjsUoWVA&t=470s

Source for the project in general

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