IoT Project : Wine storage

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***Project Aim*— Our Goal is to add an IOT project which can measure the surrounding parameters of a wine storage, to make sure the flavor and the contamination process is in a perfect condition.**

I. Introduction

Wine, a French heritage and proper tradition. Nearly every French region produces some sort of wine: red, white, rosé, champagne, and so on. But these delicacies need to be properly preserved to enjoy the best taste possible. And it is not an exact science, but enthusiasts have been making all kinds of experiments to try to pin down the ideal parameters to efficiently store wine. Temperature, humidity, light, or even vibrations are important factors to consider when storing your wine. Even though wine cabinets and fridge already exist, we wanted to apply that kind of monitoring to an entire room: an enclosed room in a house or an apartment, or a basement for example. And for measuring the parameters we use sensors and actuators for changing the physical output. Besides, we provide internet connectivity to share all the information of a storage compartment to the client. In order to illustrate what we are saying, here is our use case environment.

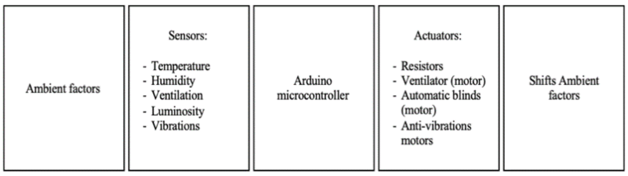


Fig. 1. Use case environment

For the scenario we'd like to develop an app, capable of controlling all our system: setting a temperature provided by the user, giving tips about wine conservation or even manage a list of all bottles stored and monitored by our system. It would include data visualization, environment settings, a storage map to know where your bottles are stored in the room, and a list of those bottles. The system, from the information it will get from the app, will be capable of adapting the temperature and humidity in the room to satisfy most efficiently all conservation parameters given for each type of wine stored in the room.

II. Technical System

A. Diagrams

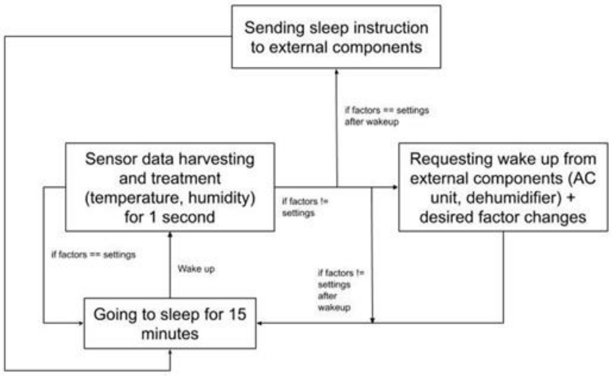


Fig. 2. Bloc diagram

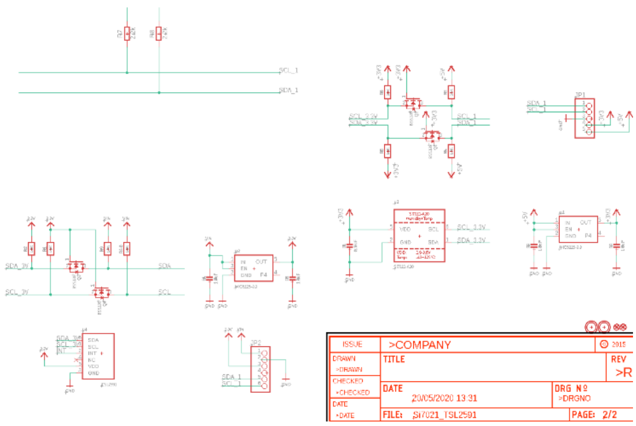


Fig. 3. Electrical diagram

B. Details

Here, the design which can control and monitor the cabinet storage conditions. We're going to use a network of between 6 to 10 (depending on the room size) digital humidity/temperature (ADA3251) and light (TSL2591) sensors packed into integrated chips communicating in

I²C with our microcontroller to obtain the most precise data possible (datasheet available). Getting the data is one thing, but we want to control our environment, hence influence and modify those parameters. The actuators we will use are “passive”: they will not be hardwired, but instead are going to be external objects, such as a dehumidifier or an AC unit controlled over the internet by our microcontroller.

The idea of a network of sensors would be to limit the systematic and the random error of each sensors. Having several sources at the same time for the same parameter will allow for a more precise result of the data harvesting. Obviously, the probability to get 3 or 4 false measurements at the same time is low, hence our decision to choose this format and the I²C protocol rather than the more resource-consuming SPI.

The system will be the most power-efficient possible, integrating a sleep mode: it should not exceed 250mW in sleep mode, or 1W during work. Bandwidth specifications will be low, not exceeding 1Mb/s. Referring to the technical diagram, you can see that our system would wake up only for a short amount of time every 15 minutes. After trying to influence external parameters, it would either disable or go back to sleep if external parameters respect the user’s presets for its room.

As mentioned earlier, our system would integrate a network of sensors connected to an I²C line. Obviously, all sensors should have a different address to avoid any addressing issue. Our current sensors’ variations do not support custom addressing or address switching, but the TSL2561 (same sensor, configurable address) does support such features. Our final system would therefore feature such addressable sensors rather than our current ones.

The control of external systems would be done through the local network of the house. Working on a custom link between all these systems would require some time and might need the integration of an infrared module to control those external objects rather than the local network. A network functionality would still be implemented along the mobile app.

In the next part, we will explain how these sensors work, their interface with the microcontroller as well as their relative precision.

III. Experiments and Results

This project has the prospect to be in any house. Therefore, each component and especially sensors must be tested on a prototype. In this part we are going to check both sensors with data we obtained.

1. The Temperature and humidity sensor: SI7021

A. *Measurements*

This part deals with 4 measurement of 100 samples. To notice, the accuracy is quite complicated to measure as the reference value is also measured by another biased sensor. We had no other humidity to compare with our data, only internet.

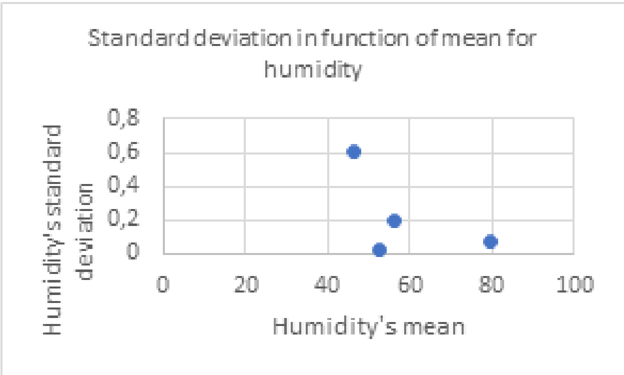
4 measurements of humidity and temperature are:

Sampling	**Localization**	**Relative humidity (%), source**	**Temperature (°C), source**
1st	Outdoor	44, (Météo France)	22, (Météo France)
2nd	Indoor	56, (SI7021)	20, (thermometer)
3rd	Indoor	80, (SI7021)	16, (thermometer)
4th	Freezer	37, (SI7021)	-16, (SI7021)

Fig. 4. Table of measurements

a) Description of the sensor : This active sensor has ± 3% relative humidity measurements with a range of 0–80% RH, and ±0.4 °C temperature accuracy at a range of -10 to +85 °C. It uses I2C for data transfer and work with a 3 or 5V powering.

b) Precision :



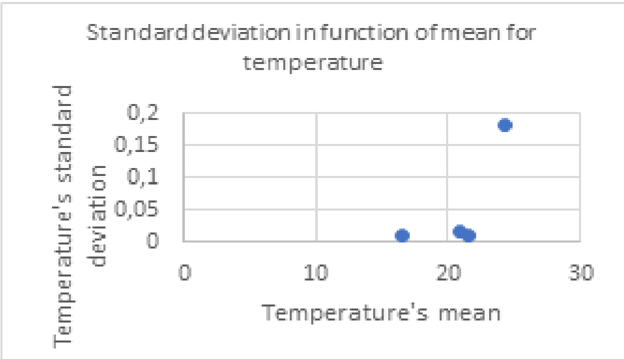


Fig. 5. Si7021 temperature’s precision

Here we can see that the precision standard deviation is enough small for humidity and temperature to our use.

c) Accuracy: For the first instance, Météo-France forecast has been used to know temperature and humidity of the region. We have found with our data a difference of 2,5% of relative humidity and 2,3°. For the second instance we compared our data with a mercury thermometer, but we did not have another humidity sensor to compare with. Then we have found on average 0,7° difference between thermometer and the SI7021.

d) Systematic error : Systematic error can be estimated for temperature between 0,47° and 0,95°.

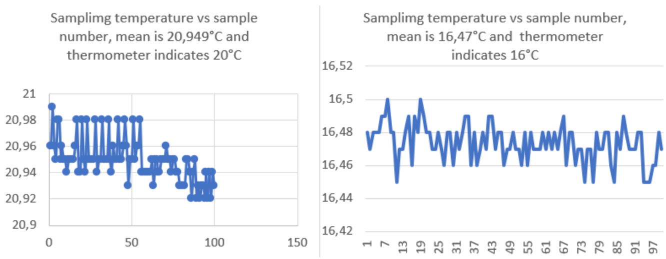


Fig. 6. Temperature measurments

Here the humidity's systematic error we have is about 2,50% when our data are compared with local humidity prevision:

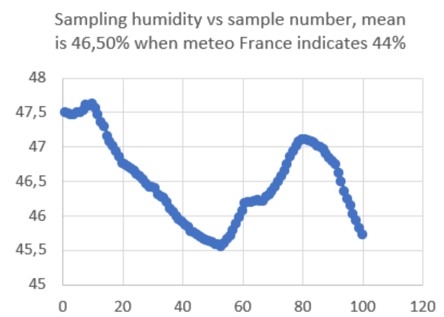


Fig. 7. Humidity measurements

e) Random error : The temperature's standard deviation of those 400 samples is on average less than 0,05°C but increases with temperature as shown on the graphic below.

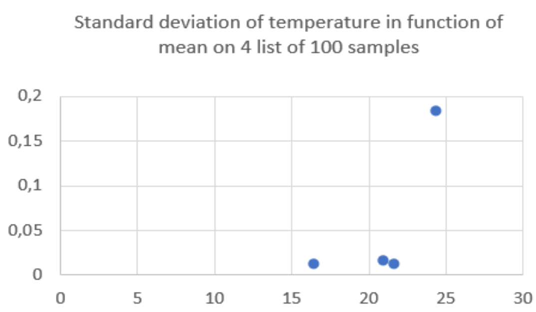


Fig. 8. Si7021 temperature random error

The humidity standard deviation is less than 0,6:

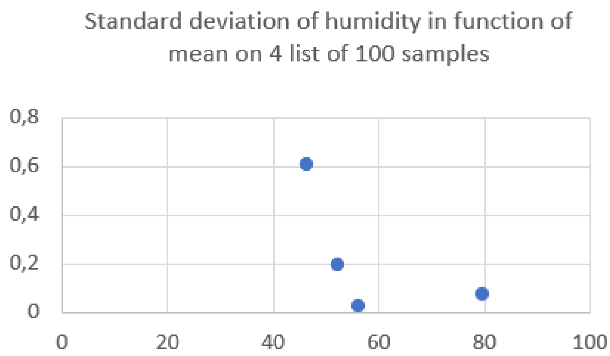


Fig. 9. Si7021 humidity random error

f) Response time : As there is a time delay of 10 ms, and all sampling begin at 103 ms. We can deduce that the response time is about 93 ms. Nevertheless, response time for each measure is configured to be 1s and all data samples are separated by 1043 ms.
Therefore, response time is 93 ms for the first data and 43 ms for other data.

g) Range measurement: To verify the capacity to work at extreme conditions we have put the sensor in a freezer during few minutes. It appears that it has worked. For extreme hot conditions it has worked in an oven. What we know is that lowest temperature was about -15°C and hottest temperature was about 50°C but we did not have the right material to measure it precisely.
For humidity we could not try in a dry environment and we did not have a control sensor to do it in a wet environment. Nevertheless, we tried in a cellar and the sensor measured 80% of relative humidity that seems to be correct but cannot be verified.

h) Power consumption : Data given at 20°C for 56% relative humidity:

	Voltage	**Current**	**Consumption**
Measuring	5 V	1,12 mA	5,6 mW
Measuring	3 V	1.25 mA	3.75 mW
Stand by	5 V	0.55 mA	2,75 mW
Stand by	3 V	0.7 mA	2.1 mW

Fig. 10. Si7021 power consumption

i) Physical Dimension :

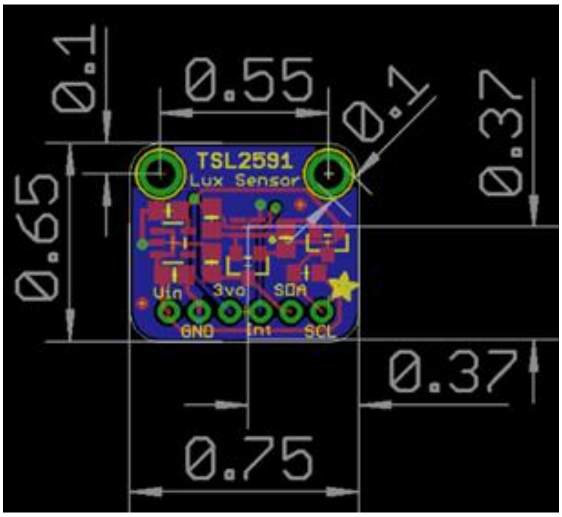


Fig. 11. Physical dimensions

Dimensions above can fit easily within any wine cellar.

j) Cost : This sensor costs about 6,95 $. The expedition costs 10 $. Nevertheless, price can be cut of if a significant number of sensors are bought.

2. The luminosity sensor: TSL2591

The same testing protocol has been implemented for the TSL2591, with obviously different parameters:

Sampling	**Localization**	**Lightning type**	**Additional parameters**
1^{st}	Indoor	Sunlight	Low
2^{nd}	Indoor	Artificial type	Low
3^{rd}	Indoor	Sunlight	Neutral
4^{th}	Indoor	Artificial light	Neutral
5^{th}	Outdoor	Sunlight	High
6^{th}	Outdoor	Artificial light	High

Fig. 12. Table of measurements

a) Description of the sensor : This active sensor has a 600M:1 dynamic resolution and has a range of 188uLux to over 88kLux, featuring two channels: one dedicated to the full spectrum and one to infrared light. It uses the I2C protocol for communicating.

b) Precision: Following schema is the measured precision of the sensor in a real-life environment

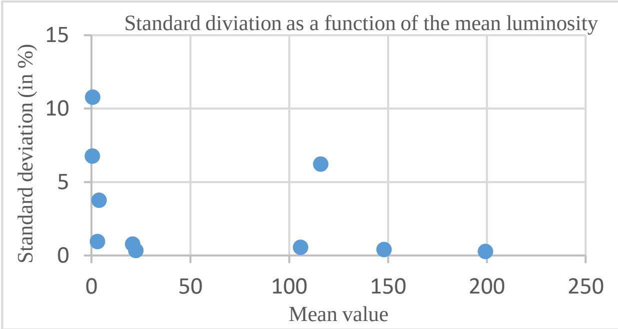


Fig. 13. TSL2591 precision

c) Accuracy: We used a smartphone's luminosity sensor while doing our measurements with the TSL2591. While we obtained a value interval coming from the smartphone, our sensor read values with a precision to the 2nd decimal value, far greater than what the smartphone returned us.

d) Systematic error: the systematic error is quite hard to measure for the luminosity because the illumination is going to be different from one place to another. We reckon it is quite accurate and does not present any significant systematic error. If so, the systematic error should be around ±1lux.

e) Random error: The standard deviation of those samples is increasing with luminosity as shown on the graphic below.

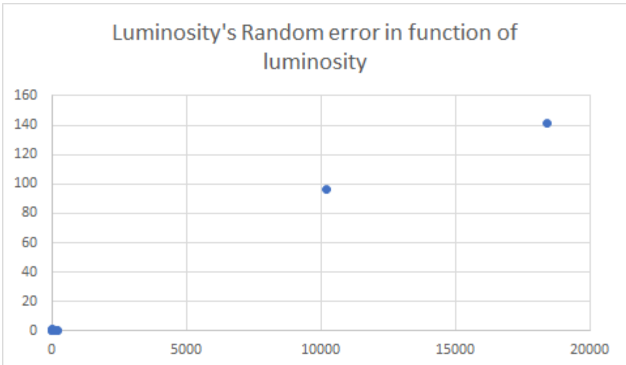


Fig. 14. TSL2591 random error in function of the illumination

An example of random error:

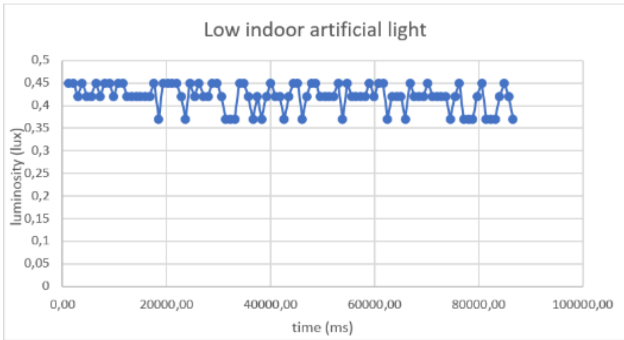


Fig. 15. TSL2591 random error example

f) Response time: For the first sample 1200 ms are required, there is a 500 ms delay beside a 300 ms of integration time. Then for each sample 863ms are required, that considers a 500 ms delay. Thereby, response time is about 400 ms for acquiring the first sample and 363 ms for others.

g) Range measurement: For the range measurement, we used the sun for the maxima of the sensor. It described on average 18400 lux. We did not get properly the 88uLux that datasheet deals with. Nevertheless, we have obtained 0,42 lux with an artificial light far from the sensor. We also powered at 3V and at 5V, that has worked. And even with bad atmosphere conditions as 80 percent of humidity and at -15°,40° it has worked too.

h) Power consumption:

	Voltage	Current	Consumption
Measuring	5 V	0.39 mA	1,95 mW
Measuring	3 V	0.5 mA	1.5 mW
Stand by	5 V	0.005 mA	0.025 mW
Stand by	3 V	0.002	0.006 mW

Fig. 16. TSL2591 power consumption

i) *Physical dimensions :*

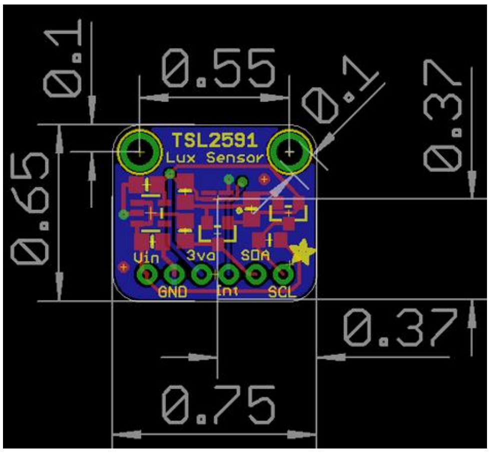


Fig. 17. Physical dimensions TSL2591

Dimensions above can fit easily within any wine cellar.

j) Cost: This sensor costs 7,25 $, the expedition costs 10 $.

IV. Conclusion

Finally, the sensors we used worked in many extreme cases. As our product is intended for private use, such extremes will rarely be reached. A certain margin of tolerance is necessary because damage due to installation and time can lead to accuracy problems and uncertainty. This margin makes recalibration easier.

This project has therefore enabled us to gather information in many domains:

- Realizing of a circuit to recover physical quantities while minimizing consumption
- Achieving a sustainable and acceptable transmission between the different poles
- Processing recovered digital data
- Tackling a subject unknown to some of us, that of wine conservation.

Currently all data sent by our sensors are received and decoded. The physical values vary slowly, and the samples are widely spaced (for energy concerns) with respect to the acquisition time and therefore are negligible although significant for this field.

Sensors are not perfect; it has been shown that errors are present, but these deviations are negligible. Indeed, the optimal rate of hygrometry is around 70-75%, If the sensor is correctly parameterized the errors can be included in the 5% error range. Darkness is also essential to preserve the wine, but only excess brightness leads to premature oxidation, moderate light exposure is not disturbing. So, the slight malfunctions of the sensor are not very serious.