Make CTD report

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Contents

1 Introduction

1.1 Objectives of the Oceanographic Tool

The first prototype of the CTD (Conductivity, Temperature, Depth) probe developed by Sailowtech was created by Alexandre Tellier as part of a Master's semester project. I have worked on this project as a member of the Sailowtech association and as an employee at the SENSE laboratory for one semester. My work will be articulated in two parts: first, the calibration of the different sensors with the first prototype of the Make CTD and the testing of these sensors; second, the reflection on improvements and the design and construction of the Make CTD v2.

Sailowtech is a student-driven association dedicated to promoting ocean conservation and advancing the understanding of marine ecosystems. The association enables students to contribute to the development of innovative and cost-effective scientific instruments for field measurements, particularly for studying the marine environment. The SENSE laboratory, supervised by Professor Jérôme Chappelaz, also plays a key role in providing research support and guidance for various projects related to oceanography and environmental sciences.

The objective of the CTD probe is to provide a flexible and modular tool for measuring key environmental parameters in the ocean, such as conductivity, temperature, dissolved oxygen, and depth. The Sailowtech/SENSE CTD prototype aims to offer a low-tech, open-source solution for oceanographic research. While CTD probes are widely used in marine studies, few open-source projects exist for building such instruments, making it difficult for small laboratories or associations to replicate them. The aim of this project is to make the CTD accessible to a broader scientific community, allowing researchers, laboratories, and organizations worldwide to reproduce and use the tool, regardless of location or resources.

Furthermore, the development of this tool emphasizes modularity, ensuring that additional sensors can be easily integrated, allowing for customization and adaptability to various research needs.

1.2 Overview of the Sensors Used

All the sensors integrated into the Make CTD probes communicate through the **I^{2}C protocol**, a widely used communication system in embedded electronics. I^{2}C (Inter-Integrated Circuit) is a **serial bus protocol** that allows multiple devices (sensors, memory modules, controllers, etc.) to share the same two communication lines:

- **SDA** (Serial Data) for transmitting data.
- **SCL** (Serial Clock) for synchronizing communication.

Each sensor connected to the I^{2}C bus is assigned a **unique 7-bit address**, which allows the microcontroller (the "master") to distinguish between different devices on the same bus. This feature enables multiple sensors to communicate over just two wires without interference.

Data transfer occurs in a **master-slave configuration**: the CTD's microcontroller initiates communication, selects a sensor by calling its address, and then either sends commands or reads back data from it. This architecture is particularly well suited to the Make CTD, since it allows the easy addition or replacement of sensors without modifying the wiring, simply by assigning or detecting a new address.

Overall, I^{2}C ensures a **lightweight, scalable, and modular system**, which is ideal for compact oceanographic instruments like the CTD probes developed in this project.

1.2.1 Sensors in Make CTD v1

- **Pressure:** Blue Robotics Bar30 high-resolution pressure sensor [1]. It measures absolute pressure using a piezoresistive MEMS sensor and converts it into depth.
- **Dissolved Oxygen & Temperature:** Atlas Scientific Industrial DO probe (Gen 3) with integrated RTD [2]. It is a galvanic probe where oxygen molecules diffuse through a membrane and react at electrodes, generating a voltage proportional to oxygen concentration.

- **Conductivity:** Atlas Scientific Mini Conductivity Probe K 1.0 (Gen 3) [3]. It measures conductivity by applying an AC voltage across two graphite electrodes and detecting the resulting ionic current.

1.2.2 Sensors in Make CTD v2

- **Pressure:** Same Blue Robotics Bar30 sensor. Operates identically as in v1, measuring pressure through a MEMS element and inferring depth [1].
- **Dissolved Oxygen:** Atlas Scientific Lab Grade DO probe (Gen 3) [4]. Similar galvanic principle as the industrial probe, but designed for higher accuracy in lab/field contexts with a PTFE membrane.
- **Temperature:** Dedicated Atlas Scientific PT-1000 Standard Temperature Probe [5]. A platinum resistance thermometer (RTD) where resistance varies linearly with temperature, providing high stability over a wide range.
- **Conductivity:** Same Atlas Scientific Mini Conductivity Probe K 1.0 (Gen 3) [3]. Uses the same AC excitation principle between graphite electrodes to measure ionic conductivity of water.

1.2.3 Comparison of Sensor Specifications

Sensor Type	Make CTD v1	Make CTD v2
Pressure	Blue Robotics Bar30 Range: 0–30 bar (300 m) Resolution: 2 mm Accuracy: ±4 °C (temp.)	Same Blue Robotics Bar30 Identical specs
Dissolved Oxygen	Atlas Scientific Industrial DO Probe (Gen 3) Range: 0–100 mg/L Accuracy: ±0.05 mg/L Depth: 212 m Temp. range: 1–99 °C Lifespan: 4 years	Atlas Scientific Lab Grade DO Probe (Gen 3) Range: 0–100 mg/L Accuracy: ±0.05 mg/L Depth: 352 m Lifespan: 4 years
Temperature	Integrated in Industrial DO probe (RTD sensor) Temp. range: 1–60 °C	Atlas Scientific PT-1000 Standard Probe Range: –50 °C to 200 °C Class B platinum RTD (PT-1000) Accuracy: ±(0.3 + 0.005·T) °C Lifespan: 15 years
Conductivity	Atlas Scientific Mini Conductivity Probe K 1.0 Range: 5–200,000 µS/cm Accuracy: ±2% Depth: 352 m Temp. range: 1–110 °C Lifespan: 10 years	Same Atlas Scientific Mini Conductivity Probe K 1.0 Identical specs

Table 1: Comparison of sensor specifications between Make CTD v1 and v2.

1.3 PCB Architecture

The PCB architecture of the Make CTD v1 is more extensively described in the semester project report of Alexandre Tellier [6]. In general, the internal architecture of the probe is organized as follows: dedicated

PCBs are used for the sensors, a specific PCB hosts the Raspberry Pi, and another PCB manages the battery system. The battery itself is composed of 8 cells (4S 4P)of 3.2V volts each. All these elements are vertically stacked inside the hermetically sealed housing of the CTD, ensuring both compactness and protection from the marine environment. The PCBs were designed using a professional PCB design software, allowing the integration of all components in an optimized layout. In the Figure 1, the position of the main components is indicated.

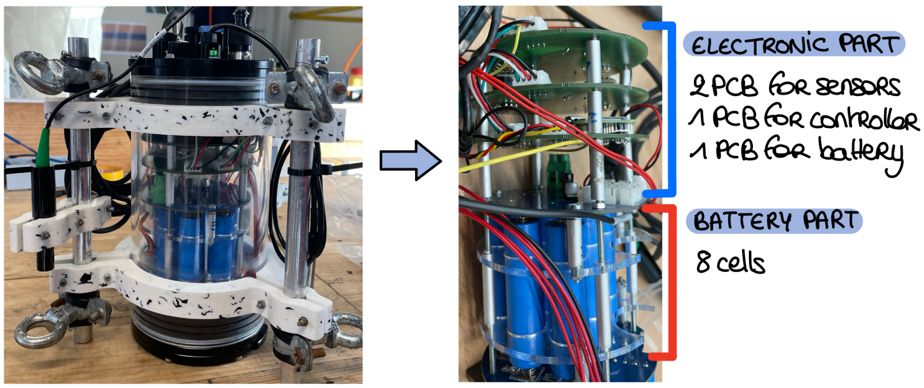


Figure 1: Picture of the inside arrangement of the make CTD v1

2 Calibration of CTD 1

Before performing the calibration of any sensor, the following steps must be carried out:

- Power on the CTD, connect your laptop to its Wi-Fi network, and establish an SSH connection through the terminal (see [10] for details).
- Once connected, navigate to the `Raspberry-pi-sample-code` directory. This package is normally pre-installed on the device; if not, it can be cloned from the official repository [11].
- Run the command: `python i2c.py` This will display the list of sensors correctly connected via the I^2C protocol together with their addresses. The sensor currently in communication will be marked with an arrow (`->`). Only this sensor will receive the commands you send, so make sure the arrow is set to the correct device before proceeding.
- Once the correct sensor is selected, you can enter the calibration commands described in the following sections.

2.1 Dissolved Oxygen Sensor

The calibration procedure of the dissolved oxygen (DO) sensor is essential to ensure accurate measurements. The Atlas Scientific EZO-DO circuit supports both a **two-point calibration** (0 mg/L and air-saturated water) and a **one-point calibration** (air-saturated water only). The calibration is performed by sending commands to the sensor through the terminal.

Preparation

- Make sure the probe is clean and has been soaked in water for at least 10 minutes before calibration.
- The commands are sent in text mode; type them into the terminal followed by the `Enter` key.

One-Point Calibration (Air-Saturated Water)

1. Place the probe in air-saturated water (e.g., water that has been vigorously stirred or aerated).
2. Type the following command in the terminal:

```
Cal
```

3. The sensor automatically uses the current barometric pressure to set the reference point. Wait for the `*OK` response.

Two-Point Calibration

For higher accuracy, both zero and air calibration are performed.

1. Place the probe in an oxygen-free solution (e.g., sodium sulfite solution).
2. Type the following command in the terminal:

```
Cal,0
```

3. Then, place the probe in air-saturated water.
4. Type the following command in the terminal:

```
Cal,100
```

   Wait for the `*OK` confirmation.

Useful Tips

- After calibration, type:

```
Cal,?
```

  to check the calibration status.
- To clear all previous calibration data, type:

```
Cal,clear
```

- Ensure stable readings before sending calibration commands.
- Always rinse the probe with clean water between calibration steps.

2.2 Temperature Sensor

The calibration of the temperature probe is performed with the Atlas Scientific EZO-RTD circuit. Calibration ensures accurate measurements of the platinum RTD sensor by removing offsets from the system. The process is straightforward: place the probe in a temperature-stable environment of known value (for example, a reference thermometer in a water bath). Once the reading has stabilized, type the following command in the terminal:

```
Cal,<temperature in °C>
```

where `<temperature in °C>` is the actual measured temperature of the environment. The circuit will return `*OK` to confirm calibration. If needed, multiple calibration points can be entered across the expected measurement range to improve accuracy. To clear all stored calibration data, use the command:

```
Cal,clear
```

This procedure aligns the EZO-RTD sensor output with a trusted reference thermometer, ensuring reliable measurements during CTD operations.

2.3 Conductivity Sensor

The conductivity sensor is calibrated through the Atlas Scientific EZO-EC circuit, which requires liquid calibration standards. The procedure begins by placing the probe in a conductivity calibration solution of known value (e.g., 12,880 µS/cm). Once the reading stabilizes, type the following command in the terminal:

```
Cal,<value>
```

where `<value>` is the conductivity of the reference solution in µS/cm. The circuit will return `*OK` to confirm calibration. For higher accuracy across the measurement range, additional calibration points can be performed with other standard solutions (e.g., 84 µS/cm for low range or 80,000 µS/cm for high range). To check the calibration status, use:

```
Cal,?
```

and to erase stored calibration data, use:

```
Cal,clear
```

It is important that the entire sensing surface of the probe is fully submerged during calibration and that air bubbles are removed by gently tapping the probe, as trapped bubbles can affect readings. Proper cleaning of the probe before calibration ensures reliable and accurate results. ‘

2.4 First Tests and Results after Calibration

To validate the calibration of our sensors, we carried out a series of tests aboard the Léxplore platform at different depths. In order to assess the accuracy of our measurements, we compared our CTD probe with an RBR CTD, a high-precision instrument widely used in oceanographic research. The RBR CTD, equipped with conductivity, temperature, and pressure sensors, is designed for long-term deployments and can reach depths of several thousand meters, making it a reliable reference for this comparison.

Data from both sensors were collected simultaneously and underwent the same post-processing steps: standardizing the units, filtering out invalid or missing values, and aligning the measurements to ensure both probes corresponded to the same depth. Since the positioning of the sensors on the probe may introduce slight disturbances during the ascent, only the data recorded during the descent were retained for analysis, as this phase provides the most consistent and reliable measurements.

2.4.1 Depth Comparison Results

The pressure data recorded during the descent are presented in Figures 2 and 3. As shown, the depth profiles from the two sensors (CTD in red, RBR in green) follow each other very closely throughout the test.

During the descent phase, the two curves are nearly superimposed, with only small deviations that can be attributed to differences in sampling frequency or sensor response time. At a maximum depth of approximately 35 m (Figure 2), both instruments stabilize and again display very similar readings. At 54 m (Figure 3), the depth difference between the two sensors is around 0.06 m. This small offset can be explained by the difference in the positioning of the sensors on the probe, particularly their height relative to one another. Since this difference remains consistent throughout the measurement, it can be easily corrected manually after data collection.

The decision to focus solely on the descent ensures that potential biases linked to sensor placement during the ascent do not affect the comparison. Overall, the strong agreement between the two datasets demonstrates that our calibration and post-processing methods were effective, and validates the use of our CTD probe under these testing conditions.

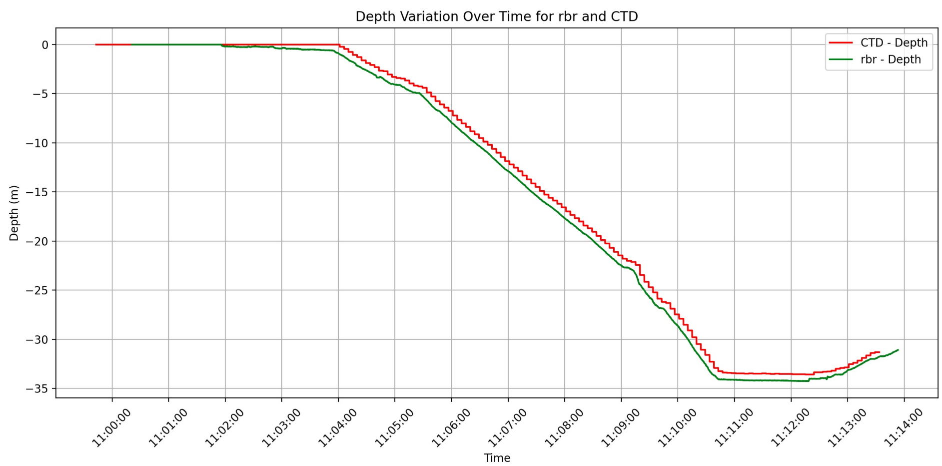


Figure 2: Depth variation over time measured by the CTD (red) and the RBR (green) during the descent at 35 m.

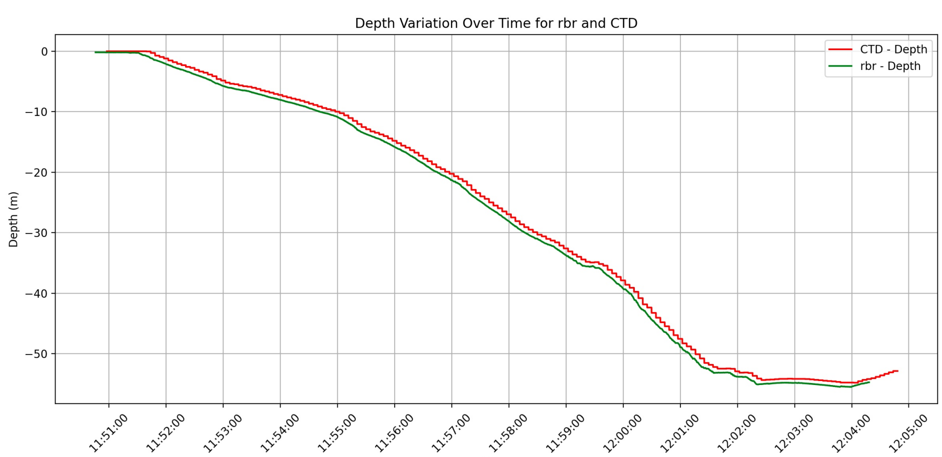


Figure 3: Depth variation over time measured by the CTD (red) and the RBR (green) during the descent at 54 m.

2.4.2 Conductivity Comparison Results

The conductivity data recorded during the descent are presented in Figures 4 and 5. As shown, the profiles from the two sensors (CTD in blue, RBR in orange) follow each other very closely throughout the measurement campaign.

During the descent phase, the two curves remain almost parallel, with a small but consistent difference of approximately 0.06 mS/cm. This offset can be easily corrected manually during post-processing if needed.

At 35 m (Figure 4) as well as at 55 m (Figure 5), both instruments display the same vertical structure, confirming that the conductivity variations are measured consistently by the two probes.

Overall, the strong agreement between the two datasets validates the performance of our conductivity sensors and confirms that the calibration and post-processing steps were successful.

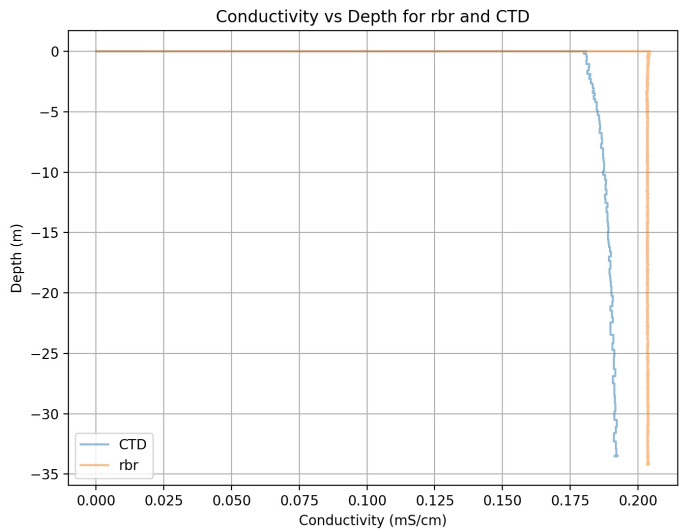


Figure 4: Conductivity variation with depth measured by the CTD (blue) and the RBR (orange) during the descent at 35 m.

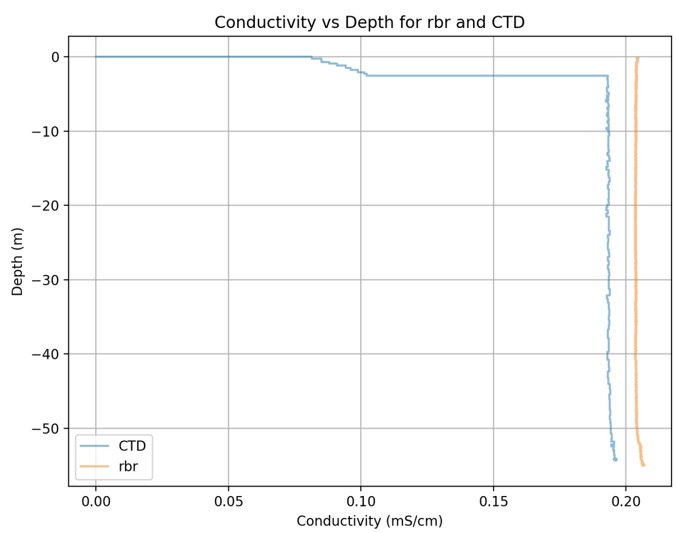


Figure 5: Conductivity variation with depth measured by the CTD (blue) and the RBR (orange) during the descent at 55 m.

2.4.3 Temperature Comparison Results

The temperature data recorded during the descent are presented in Figures 6 and 7. As shown, the profiles from the two sensors (CTD in blue, RBR in orange) remain close throughout the water column.

During the descent phase, the two curves display a nearly parallel evolution, with a small but consistent difference of approximately 0.05°C. The discrepancy remains almost constant across the depth range, which allows for straightforward correction during post-processing if higher accuracy is required.

At both 35 m and 55 m, the two instruments capture the same vertical temperature structure, showing no significant divergence in trends. This confirms that both sensors respond reliably to the natural thermal variations observed in the water column.

Overall, the strong agreement between the two datasets validates the performance of our temperature measurements and supports the effectiveness of the calibration and post-processing procedures applied.

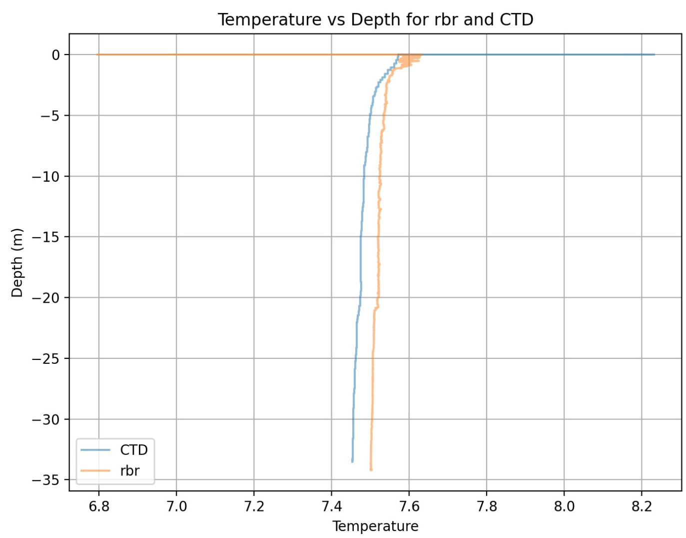


Figure 6: Temperature variation with depth measured by the CTD (blue) and the RBR (orange) during the descent at 35 m.

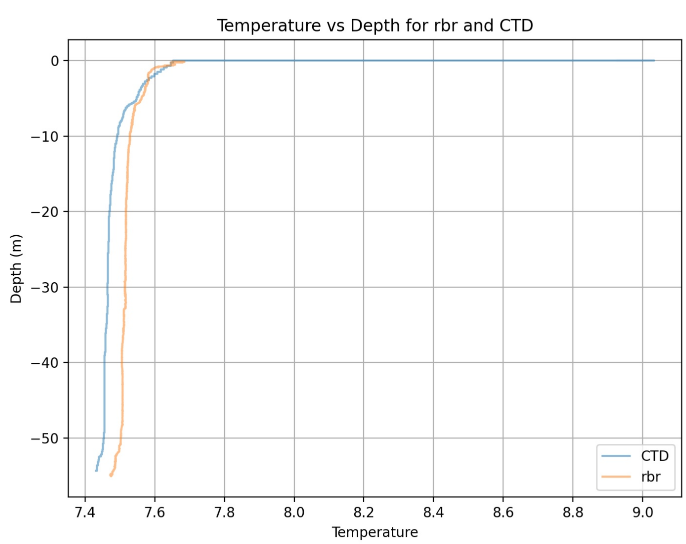


Figure 7: Temperature variation with depth measured by the CTD (blue) and the RBR (orange) during the descent at 55 m.

3 Development of CTD 2

3.1 Conceptual Reflections

The second version of the CTD aims to address several limitations of the first version while improving usability, safety, and reproducibility. Key improvements include:

- **Simplified internal architecture:** A rail-based system inside the watertight enclosure separates the electronics and control section from the battery compartment. This simplification facilitates maintenance and makes the system easier to reproduce. The rail system is a product of Bluerobotics ([12]) and perfectly matches the cap of the waterproof box that encapsulates the electronics of the probe, making it the preferred choice for version 2. The Figure 8 shows the rail system and its different parts.

Figure 8: Rail system of bluerobotics used for the version 2 of the make CTD

- **Electronics design:** Multiple PCBs will manage the sensors, with a dedicated PCB handling the Raspberry Pi and its I2C communication with the sensors. New stackable components from Atlas Scientific, capable of connecting three sensors each, will be used due to their simplicity, compactness, and compatibility with the Raspberry Pi ([13]). This component can also be easily connected to another carrier board, allowing additional sensors to be added in the future and making version 2 more modular. Figure 9 shows an image of the Atlas Scientific carrier board.

Figure 9: Carrier board of Atlas Scientific

- **Battery:** The 12-cell battery from version 1 is replaced with a commercially available battery with an integrated BMS, simplifying assembly and replacement.

- **Indicator light:** A power indicator will show when the CTD is turned on ([14]). It will be placed on the cap of the waterproof box.

- **Decompression valve:** This feature increases safety during deployment by regulating pressure as the CTD is submerged. Figure 10 illustrates the arrangement of the indicator light, decompression valve, pressure sensor, and on/off button on the CTD cap. The empty holes are reserved for the remaining sensors (conductivity, temperature, and dissolved oxygen) as well as for potential additional sensors that may be integrated in future versions.

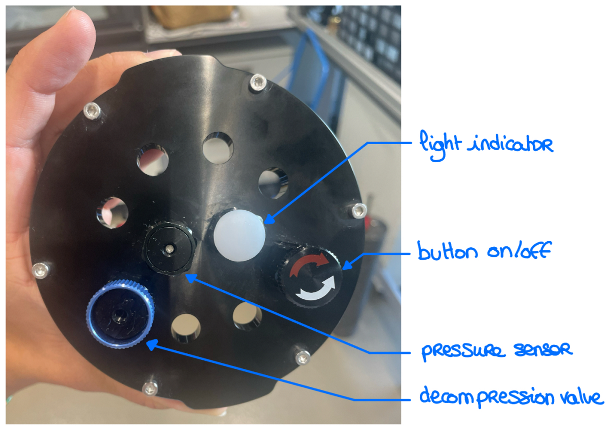


Figure 10: Arrangement of the different components placed onto the CTD cap

- **Protective cage:** A cage will allow secure mounting of the sensors and simplify deployment using a winch. The cage was built in the SPOT mechanical workshop using aluminum bars and stainless steel. The figure 11 shows the schematic with the dimensions of the completed cage. To secure each of the four vertical bars at the top and bottom with nuts, 8.5 mm diameter holes were drilled. The current dimensions represent a first prototype and can be modified in future iterations of the project. The mounting parts for the sensors have not yet been manufactured and will be added in later stages. In addition, a dedicated mounting component to hold the CTD will need to be 3D-printed in the future. A picture of the assembled cage is shown in Figure 11. Note that in this image the hook is mounted upside down; it will normally be oriented the other way to allow the cage to be directly attached to the winch during future tests with the CTD.

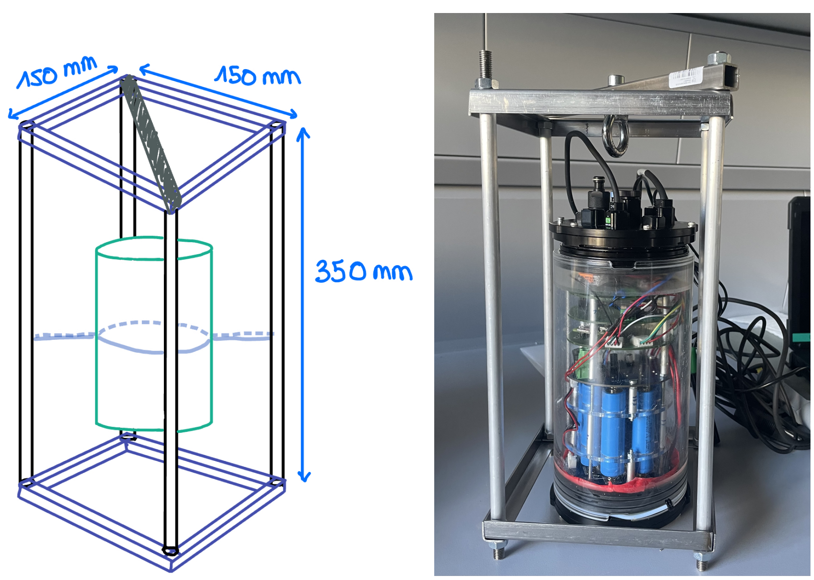


Figure 11: Schematic of the cage dimensions and the resulting assembled cage

3.2 New choice of Sensors

To select the most suitable sensors for the Make CTD v2, we carried out a new series of tests on the Léxplore platform. For each of the three parameters—dissolved oxygen, temperature, and conductivity—we compared two different sensors provided by Atlas Scientific. As in the first test campaign, every dive was accompanied by an RBR probe, used as a reference to assess the accuracy of the sensors.

3.2.1 Conductivity Sensor

Since the initial tests had already shown very close agreement with the reference data, we decided to keep the *Mini Conductivity Probe K 1.0* for the Make CTD v2.

3.2.2 Temperature Sensor

We evaluated the following two sensors:

- Atlas Scientific Standard PT-100 Probe ([5])
- Atlas Scientific Industrial PT-100 Probe ([15])

Figure 12 shows the three temperature profiles: the RBR probe (green dashed line), the Standard PT-100 (blue), and the Industrial PT-100 (orange). The results indicate that the Standard PT-100 follows the RBR data more closely. Consequently, this sensor was selected for integration in the Make CTD v2.

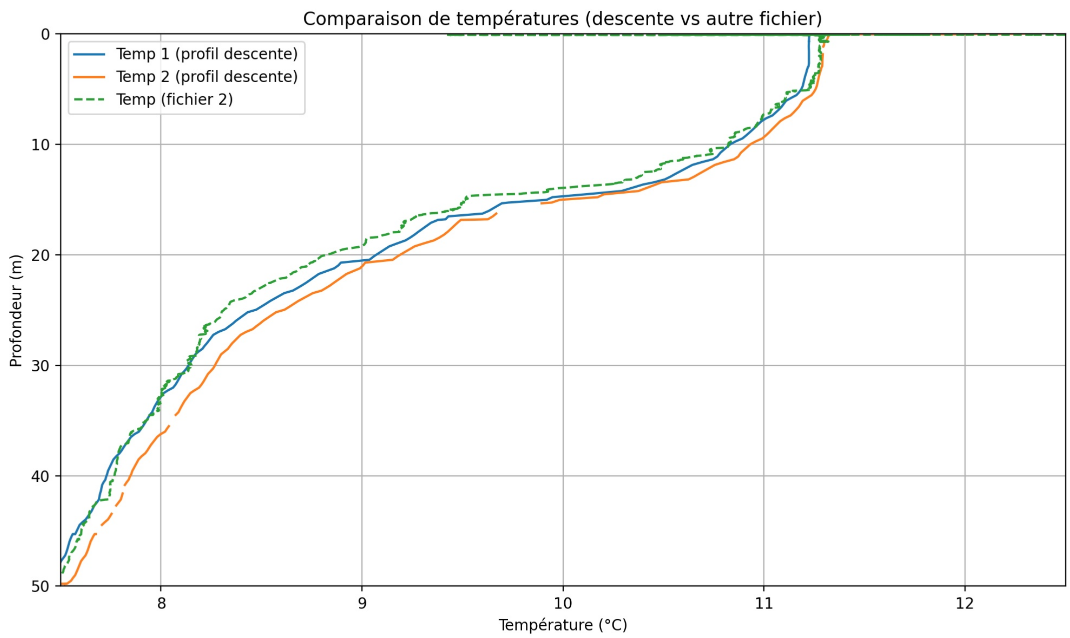


Figure 12: Temperature comparison between the RBR probe (green dashed line), the Standard PT-100 (blue), and the Industrial PT-100 (orange) as a function of depth

3.2.3 Dissolved Oxygen Sensor

We evaluated the following two sensors:

- Atlas Scientific Lab Grade DO Probe ([4])
- Atlas Scientific Industrial Dissolved Oxygen Probe ([2])

Figure 13 presents the dissolved oxygen measurements: the RBR probe (dashed line), the Lab Grade DO probe (purple), and the Industrial DO probe (orange). Dissolved oxygen sensors are highly sensitive and prone to larger error margins. Among the two, the Lab Grade DO probe showed the lowest error and was therefore chosen for the Make CTD v2.

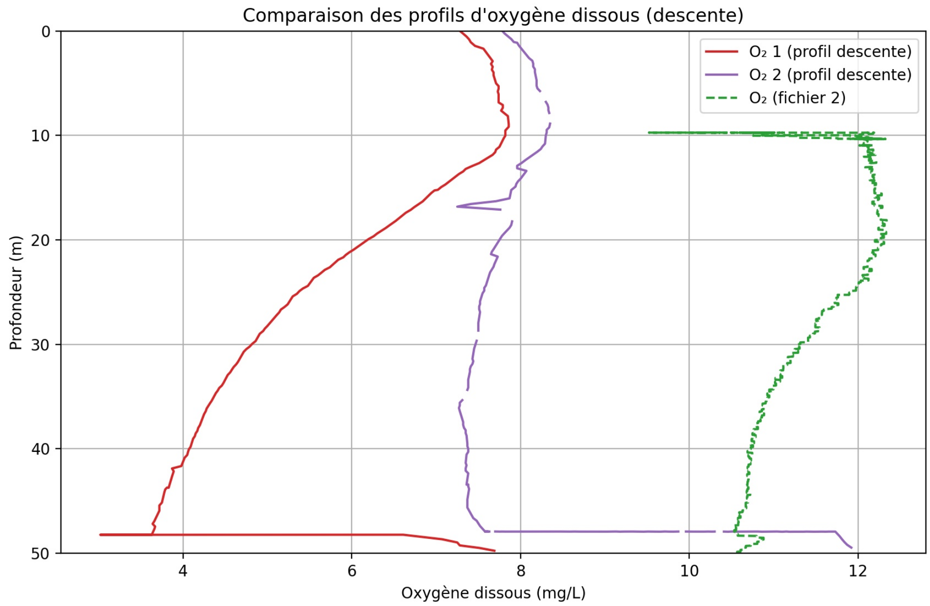


Figure 13: Dissolved Oxygen comparison between the RBR probe (green dashed line), the Standard PT-100 (blue), and the Industrial PT-100 (orange) as a function of depth

Overall, the selected sensors—the Standard PT-100 and the Lab Grade DO probe—are not only less expensive but also appeared more accurate in our tests. This can be explained by the intended application of the Make CTD: unlike advanced oceanographic instruments designed for great depths, our probe targets shallow-water environments (less than 100 m), where small and rapid variations in the measured parameters are more relevant. In this context, smaller sensors with faster response times often perform better.

For instance, the Industrial Dissolved Oxygen probe is larger and includes an integrated temperature sensor to automatically compensate the oxygen reading. However, the temperature compensation lags behind rapid changes, which introduces errors in dynamic environments. In contrast, the smaller Lab Grade DO probe reacts more quickly to variations, making it more suitable for the Make CTD v2.

3.3 Newly Designed PCBs

The organization of the PCBs will follow a stacking arrangement, as shown in Figure 14. The stacked PCBs will be mounted onto the rail system from Bluerobotics, ensuring a compact and organized integration inside the waterproof enclosure. We will use three different types of PCB components: one for battery management, one for controller management, and the Atlas Scientific carrier board. Figure14 shows the arrangement of these three PCBs within the electronic section of the CTD. The goal is to maximize space within the probe by using this stacking system, made possible by the use of the Atlas Scientific carrier board. This component fits directly above the PCB controller, connecting to the Raspberry Pi pins and allowing the connection of three sensors. Currently, we only require one such component, but future versions may use additional carrier boards (connected via flat cables) to enable the integration of new sensors. This solution is also chosen because all the sensors are from Atlas Scientific. The PCBs required for version 2 of the CTD were designed using EasyEDA, an online and open-source electronics design platform. Initially, the PCB schematics were drawn manually, then recreated using the software, and finally fabricated. Two PCBs were created: one for battery control and one for Raspberry Pi controller management.

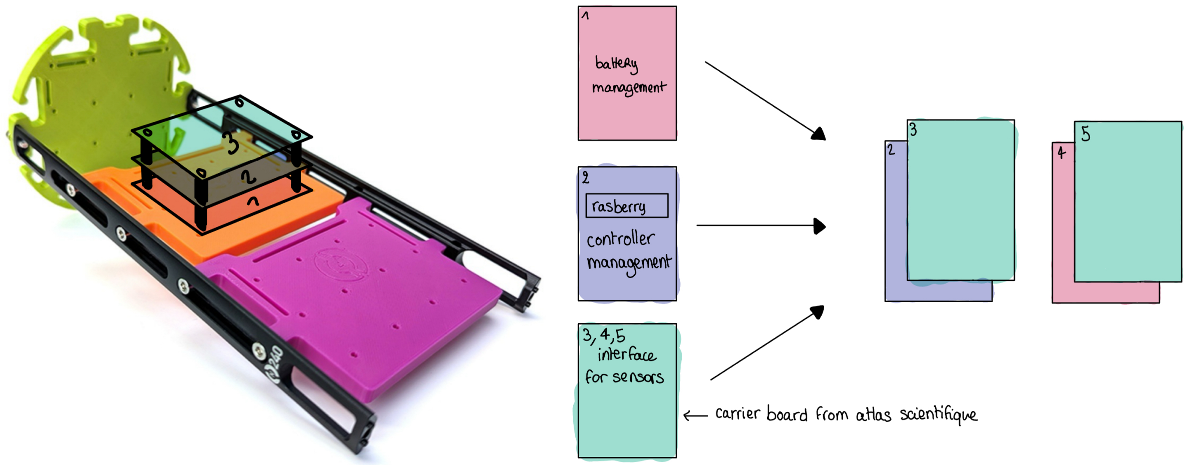


Figure 14: Schematic of the stacked PCBs mounted on the Bulerobotics rail system and their overall arrangement

3.3.1 PCB Battery

The battery PCB is composed of several components:

- A connector for directly connecting the battery (input voltage between 12V and 14V).
- A switch element that allows the CTD to be turned off by cutting power to all circuits (it is positioned at the very beginning of the circuit for this purpose).
- A first converter, the TSR25120, which steps down the input battery voltage to a stable 12V.
- A second converter, the TSR2450, which steps down the input battery voltage to a stable 5V.
- A third converter, the TSR2433, which steps down the input battery voltage to a stable 3.3V.
- A connector for the BlueRobotics LED indicator, placed immediately after the switch, to provide a visual indication when the device is powered on.
- Each of the converters is connected to a series of connectors, allowing for multiple outputs of 12V, 3.3V, and 5V respectively.

3.3.2 PCB Controller

The controller PCB consists of several components:

- A connector to receive the 5V input required to power the Raspberry Pi Mini.
- A connector for UART, which is connected to the Raspberry Pi for potential future use with the probe.
- Several connectors for potential future sensors, directly connected to the appropriate pins of the Raspberry Pi Mini (SCL, SDA, GND, and 5V).

In Figure 15, the left side shows the initial hand-drawn PCB drafts, while the right side shows the final PCBs designed using EasyEDA.

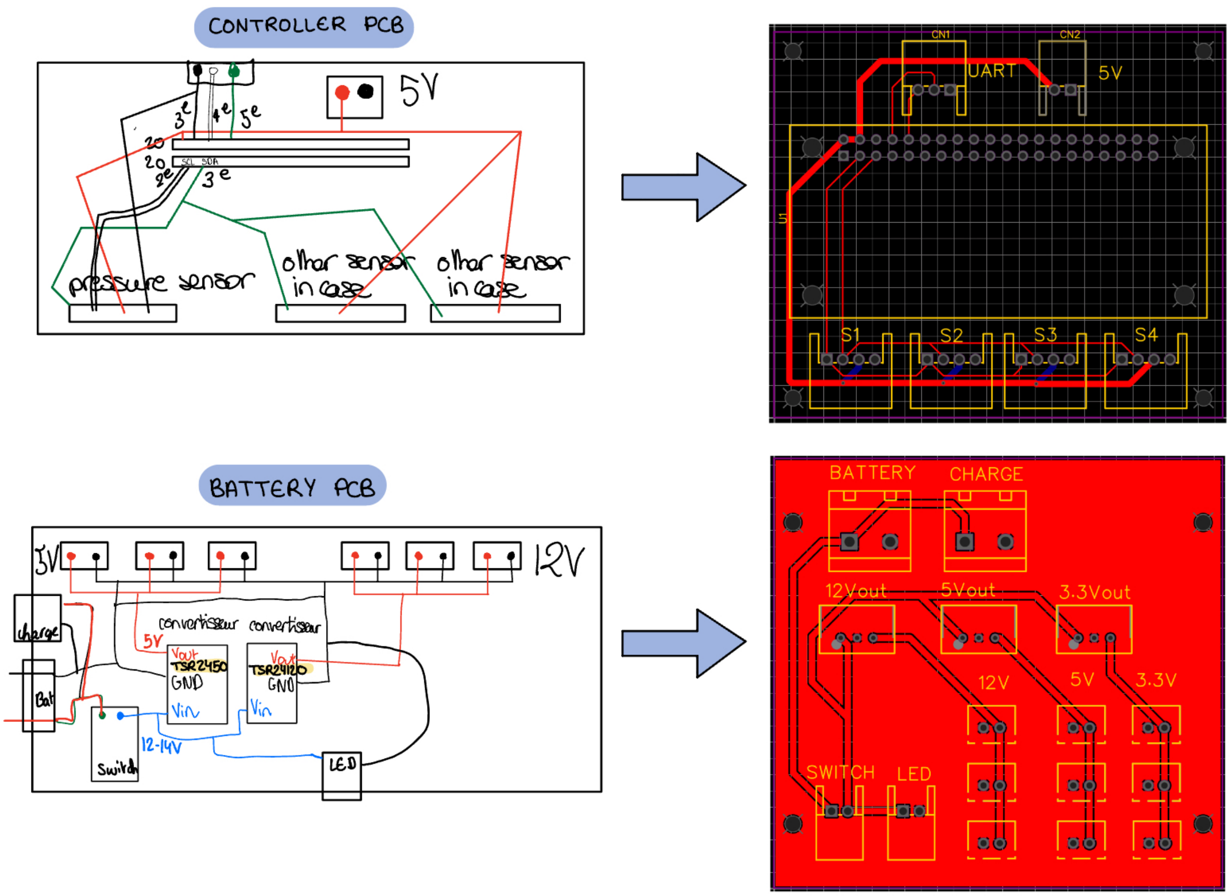


Figure 15: PCB schematics: from hand-drawn sketches to EasyEDA design platform

To properly mount the Atlas Scientific carrier board onto the Raspberry Pi Mini without causing imbalance, a small support was 3D-printed and glued directly onto the PCB using Loctite. The final result is shown in Figure 16.

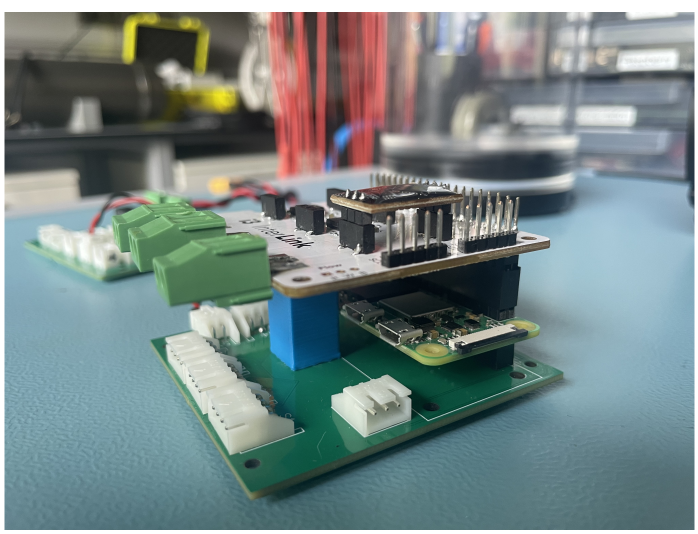


Figure 16: Atlas scientific carrier board properly mounted onto the Rasberry Pi Mini

The complete arrangement of the PCBs is also illustrated in Figure 17. As can be seen, the setup is divided into two sections, with the PCBs stacked on top of each other: on one side, the battery PCB provides the 5V required to power the Raspberry Pi, while on the other side, the controller PCB is topped with the Atlas Scientific carrier board.

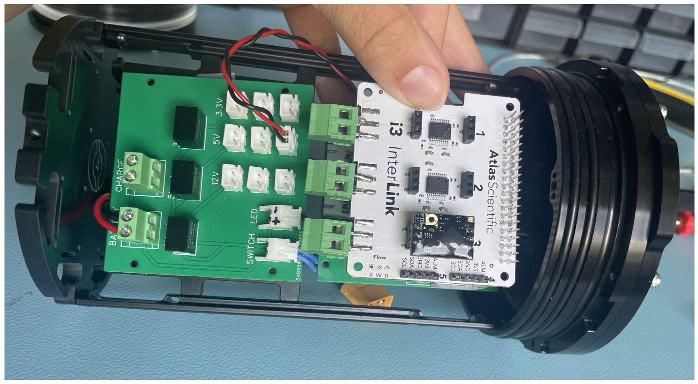
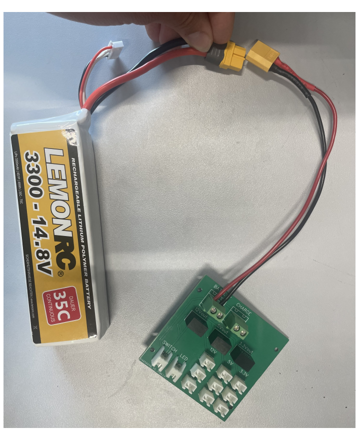


Figure 17: complete arrangement of the PCBs

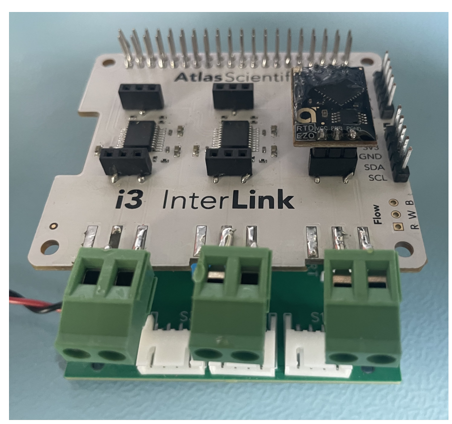
3.4 Sensor Installation

3.4.1 Installation

After designing the PCBs and receiving the new components from BlueRobotics and Atlas Scientific, the next step was to assemble everything and test the different modules. For this purpose, we used a battery available in the SENSE laboratory, although a similar model (see Figure 18a) could be ordered in the future. The battery PCB was first connected to the battery, which then supplied power to the controller PCB. The Atlas Scientific carrier board was directly mounted onto the Raspberry Pi located on the controller PCB. The sensors were then connected directly to the Atlas Scientific carrier board. To make this possible, we had to desolder the original connectors from the Atlas Scientific carrier board and replace them with new ones, as shown in Figure 18b. The original connectors could not be used because the corresponding sensor connectors were too large to fit through the cap of the BlueRobotics waterproof housing protecting the probe. We therefore also had to cut the male connectors from the sensor cables themselves, strip the wires, and connect them to the new green terminal blocks installed on the carrier board.



(a) Battery used for testing the Make CTD v2



(b) New connectors installed onto the Atlas Scientific carrier board

Figure 18: Battery and connectors used in the Make CTD v2 assembly.

3.4.2 Initial Tests

Preliminary measurements were carried out in the laboratory to verify that the sensors were functioning correctly with the new PCBs and electronic components. The tests confirmed proper operation—for instance, the temperature sensor responded consistently when held in the hand. These quick checks validated the integration of the sensors with the new electronic system and the battery. However, more extensive testing remains to be performed. Due to time constraints, it was not possible to fully assemble the electronics into the waterproof housing or to conduct in-depth tests of the CTD v2 probe. Nevertheless, the encouraging laboratory results suggest that only the final assembly steps are missing before achieving a fully functional and operational CTD v2.

4 Conclusion

This report presented the development of the Make CTD project, from the calibration and testing of the first prototype (v1) to the design and construction of the second version (v2). The work included sensor calibration, performance testing, PCB design, and the first stages of integration of the new electronic and mechanical components. These steps mark an important milestone in the effort to create an open-source, modular, and low-cost CTD probe that can be reproduced and used by a wide scientific community.

The first laboratory tests carried out with the Make CTD v2 confirmed the proper functioning of the sensors and electronics, demonstrating the feasibility of the design choices and the improvements implemented compared to the first prototype. However, these results remain preliminary, and real-world testing in aquatic conditions will be necessary to fully validate the system's performance and robustness.

Several aspects of the project are still ongoing. The protective cage requires further refinement to ensure optimal deployment and durability, and the integration of additional sensors remains a promising direction for future iterations of the probe.

In summary, while the Make CTD v2 is not yet fully operational in the field, the encouraging initial results indicate that the probe is close to being ready for deployment. The next stages of testing and development will be crucial in achieving a fully functional and reliable tool for oceanographic research.

5 Acknowledgements

I would like to sincerely thank Professor J. Chappellaz and the entire SENSE Lab team for their guidance and support. I am also grateful to the Sailowtech association, without whom this project would not have been possible. In particular, I would like to thank Sébastien, who provided invaluable help and advice throughout all stages of the project. Finally, I would like to thank the Explore team for enabling the practical tests, which were essential for the success of this work.

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