S.O.N.I.A. AUV Technical Design Report

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***Abstract*—S.O.N.I.A. is a student-run robotics team from École de Technologie Supérieure (ÉTS) in Montréal, participating in the RoboSub competition since 1999. This year marks a significant transition for the team with the introduction of AUVLite, a new lightweight prototype designed to operate in cooperation with AUV8.1. The team's competition strategy focuses on maximizing point acquisition through collaboration between the two AUVs, supported by contingency plans to address potential system failures. The design strategy emphasizes a watertight and lightweight hull, an optimized electrical architecture, and advanced software integration, including the adoption of ROS2 and SLAM-based mapping systems to improve autonomy and situational awareness. A comprehensive testing strategy has been developed to validate the mechanical, electrical, and software systems, ensuring overall reliability and performance. This report presents the competition approach, design methodology, and testing processes that aim to enhance the capabilities of S.O.N.I.A.'s AUVs for RoboSub 2025.**

I. Introduction

S.O.N.I.A.[1] AUV[2] is a student-run robotics club from École de Technologie Supérieure (ÉTS) in Montréal. The team was founded in 1999 and has been participating in the Robosub competition ever since.

This year marks a new era for the team. The oldest prototype of the S.O.N.I.A. AUV has been retired to make room for a new prototype: AUVLite. Paired with AUV8.1, both AUVs will cooperate to maximize the competition points.

The competition strategy, design strategy, and testing strategy will be described in this report. The competition strategy focuses on the point-scoring approach, while the design and testing strategies detail the work carried out to achieve those points. The last two sections are structured into three parts: mechanical, electrical, and software.

[1]Système d'Opération Nautique Intelligent et Autonome (Autonomous and Intelligent Nautical Operation System)

[2]Autonomous Underwater Vehicle

II. Competition Strategy

A. Overview

For the team's competition strategy, at the time of writing this report, it remains uncertain how our project will perform. To address this uncertainty, we have developed multiple contingency plans to prepare for various scenarios. **Plan A** will be described in detail, while **Plans B and C** will be discussed in terms of how they adapt to the different behaviors exhibited by our AUVs. If everything proceeds as expected, **Plan A** will be executed.

This plan involves both of our AUVs: **AUV8.1**, the 2020 prototype updated with 2024 modifications, and **AUVLite**, this year's new prototype. The strategy is to complete all tasks through the cooperation of both vehicles.

The critical components of our strategy are the **robotic arm**, the **mapping system**, the **inter-vehicle communication system** (IVC), and the **control system**. The robotic arm is mounted on AUV8.1, while the most critical control system is the one on AUVLite, due to differences in sensor configurations compared to AUV8.1.

B. Plan A

As previously mentioned, **Plan A** is to complete all tasks through the cooperation of both AUVs. First, both vehicles will perform the coin flip task and pass through the gate. Following this, AUV8.1 will execute the slalom task using its precise control system, while AUVLite will complete the style points task.

While AUV8.1 is performing the slalom, AUVLite will locate the bin and transmit its approximate position to AUV8.1. AUV8.1 will then proceed to the bin task. It may also interrupt its trajectory to complete the torpedo task if it is encountered beforehand; otherwise, the torpedoes will be completed after the bin.

After completing the bin task, AUV8.1 will search for the octagon task and proceed toward it. Meanwhile, AUVLite will return to the gate area while waiting for AUV8.1 to finish the octagon. Once the octagon task is completed, both AUVs will perform the return home task.

This strategy is designed to maximize point acquisition, with minor deductions expected due to the weight of AUV8.1, which exceeds the competition's optimal weight threshold.

C. Plan B

Plan B is designed to be used in the event that the IVC system is not functional. In this case, the same tasks will be performed by the same AUVs, but the key differences arise in the segments that require cooperation between the two vehicles.

First, AUV8.1 will need to locate the bin task independently, which may result in significant time loss. Additionally, due to the reduced data exchange, the mapping system is expected to be considerably less accurate, leading to further delays in locating tasks.

Finally, AUVLite will not wait for AUV8.1 to complete the octagon task before initiating the return home procedure. Instead, it will depart as soon as the style points task is completed.

D. Plan C

Plan C is intended for situations where AUVLite's control system proves to be unstable. Due to differences in the sensor configuration compared to AUV8.1, there is a possibility that AUVLite may exhibit reduced stability.

If the vehicle is unstable, its position becomes unreliable, making the mapping system unusable in conjunction with its vision system. In such a case, AUVLite will be unable to collect the style points or transmit the bin's location to AUV8.1. It will instead pass through the gate, remain idle while AUV8.1 completes all remaining tasks, and then perform the return home procedure.

This plan results in reduced mapping reliability and increased time loss.

E. Other perspectives

There remains a possibility that other systems on the AUVs may be non-functional by the time of the competition. However, these systems are generally easier to bypass.

For instance, if the robotic arm is not operational, the table portion of the octagon task will be excluded from the mission plan, while all other tasks will still be executed.

This same logic can be applied to any non-critical system on the AUVs.

F. Plan Comparison

Table I provides a succinct comparison of the three competition strategies, highlighting the key system requirements and expected outcomes for each plan.

TABLE I
PLAN COMPARISON

Criteria	**A**	**B**	**C**
Control system	Stable	Stable	Unstable
IVC	Functional	Non-functional	Functional
Mapping	Full	Reduced	No
AUVLite Tasks	Style points	Style points	Gate only
Bin Location	Lite transmits	8.1 searches	8.1 searches
Coordination	Full	Limited	Minimal
Performance	Max points	Time loss	Time & Point loss
Divergence Risk	Low	Medium	High

III. DESIGN STRATEGY

The design component of the S.O.N.I.A. AUV team's strategy is divided into three main sections. First, the **mechanical team** is responsible for the hull and all other physical subsystems of the AUV. Second, the **electrical team** designs the communication infrastructure between all components of the AUV using custom PCBs. Finally, the **software team** is in charge of integrating new systems into the existing codebase, while also maintaining and optimizing the software stack.

A. Mechanical Design

1) Hull Design: The main task of the mechanical team is to design the hull of the AUV. This is a significant responsibility, as it involves numerous considerations, all under high pressure since any hull failure would be catastrophic. Key factors to address include water-tightness, weight, controllability, and assembly complexity. This year, a completely new AUV is being developed, which allows the design team to control all of these aspects.

The most critical factor is water-tightness. Historically, the team has used O-rings because they can be easily integrated into the design. This year, a gasket seal was also considered. However, after conducting simulations and physical tests, it was concluded that too many screws would be required to securely tighten the hull's cap when using a gasket. As a result, O-rings remain the primary sealing solution for the AUV.

Weight is another important consideration. Since AUV8.1 is losing competition points due to its weight, the mass of AUVLite was minimized as much as possible. To achieve this, aluminum was selected for the hull material, and the hull thickness was reduced to save mass. Static simulations showed that a thickness of 5 mm is sufficient to safely withstand depths of at least 10 meters. The results of both simulations can be found in Figure 1.

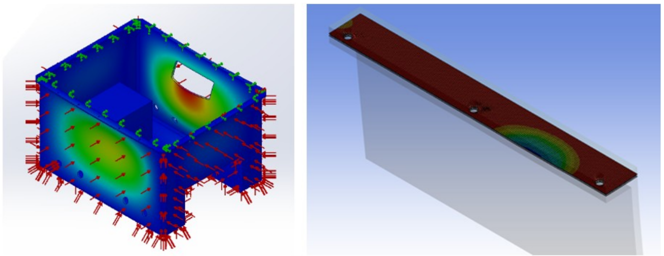

Fig. 1. Simulation results: (a) Hull thickness analysis; (b) Gasket water-tightness analysis.

Controllability has been a recurring issue in past designs. It was concluded that the weight must be centered and lowered as much as possible [1]. This is why the battery is positioned beneath the main hull. This configuration improves the stability of the AUV while maintaining the a small moment of inertia. The motors were also positioned following the configuration successfully used by the team for the past ten years, as it provides a favorable moment arm that enhances stability. As stated in Section II, controllability is particularly critical for AUVLite due to its reduced number of sensors. For this reason, all design aspects that influence controllability have been carefully optimized.

Assembly complexity was another challenge identified by the team. To address this, a top-mounted cap was designed to cover the entire upper section of the hull. This greatly facilitates maintenance for the electrical team, as it provides easy access to all PCBs and cables.

2) Buoyancy: Achieving proper buoyancy for the AUV has historically been a challenging task, often resolved in previous designs by adding foam floaters as a temporary solution. This year, the hull design team focused on developing an AUV that would inherently meet the minimum buoyancy requirement of 0.5% of the AUV's mass, as specified in the competition rules. [2].

To achieve this, a prismatic hull shape was selected to optimize the volume of water displaced. The weight was then adjusted through SolidWorks calculations to ensure positive buoyancy. A safety margin was also incorporated to prevent the AUV from sinking.

At the time of writing this report, buoyancy testing has not yet been completed, and further adjustments may still be required.

3) Manufacturing: Manufacturing is another important aspect of the hull design that must be taken into consideration. This year, the team set itself a major challenge: to build a completely new AUV in less than one year. This challenge was successfully met from a design perspective, although some financial challenges remain.

A significant portion of the budget was allocated to sensors, as high-quality control was essential for AUVLite. Consequently, the budget for manufacturing the hull had to be minimized. Instead of machining the hull from a large block of aluminum, it was divided into several smaller plates that were welded together. The design was therefore adapted to accommodate this approach.

Several team members also learned how to weld aluminum using the TIG method. Considerable practice, logistics, and effort were dedicated to welding the hull to ensure it would be strong, watertight, and visually appealing. The final results are considered a success by the team.

The welding process is shown in Figure 2.

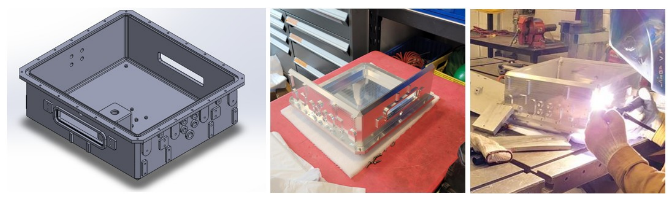

Fig. 2. Hull welding process

B. Electrical Design

1) Overall Architecture: The electrical architecture of AUVLite is purposefully designed to mirror the proven architecture of AUV8.1, with targeted adaptations to meet AUVLite's unique requirements. This strategy is driven by two main objectives: maximizing reliability and simplifying maintenance. By standardizing solutions across both vehicles, the team leverages established best practices, reduces integration risks, and streamlines troubleshooting and repairs.

However, AUVLite's reduced mission scope and tighter budget necessitated a careful selection of which subsystems to retain. As illustrated in Figure 3, several components present in AUV8.1 were omitted from AUVLite to optimize for weight, cost, and operational simplicity:

- **Actuation Control Module:** Removed, as only AUV8.1 requires advanced actuation for specific tasks.
- **Battery and BMS:** One battery and its associated Battery Management System (BMS) were eliminated. This reduces weight and complexity, at the expense of some operational autonomy—a trade-off deemed worthwhile for AUVLite's intended missions.

- **Doppler Velocity Log (DVL):** The DVL, the most expensive component in AUV8.1, was excluded due to budget constraints. While this makes navigation more challenging, the team compensates by relying on a new mapping system (see Section III-C2) and the IMU for localization.

This streamlined architecture preserves the core strengths of the original design while ensuring AUVLite remains lightweight, cost-effective, and maintainable. The result is a robust platform tailored for its specific operational context, without unnecessary complexity or expense.

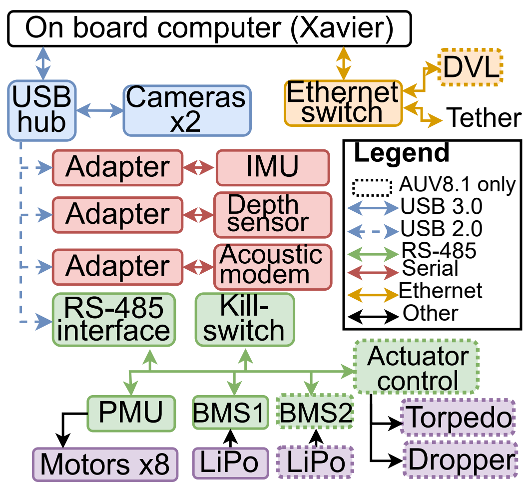

Fig. 3. Simplified architecture of AUV8 and AUVlite

2) Battery Management System (BMS): A new Battery Management System (BMS) was developed for both submarines this year, with two main objectives: enhancing operational safety and providing more accurate battery monitoring to extend test durations.

The BMS is built around the BQ40Z80 chip, which offers comprehensive hardware and software protections against overvoltage, undervoltage, overcurrent, and overtemperature [3]. It also provides real-time estimates of battery state of charge and remaining runtime.

Safety is ensured through a dual-layer approach: MOSFETs controlled by the BMS disconnect the battery in case of faults, while a secondary fuse acts as a fail-safe. Communication with the main computer is managed by a microcontroller interfacing with the BMS via I2C and connecting to the system over RS-485.

Thermal management is a key design focus. The BMS supports continuous currents up to 50A. MOSFETs with top-side thermal pads (see Figure 4) are mounted to contact the aluminum battery enclosure, efficiently transferring heat to the casing and surrounding water.

The BMS uses a two-board design: a high-current board with the BQ40Z80 and power components, and a separate low-power control board with the MCU and communication IC. This modular approach reduces costs and simplifies testing, as the control board can be evaluated independently using development kits.

These improvements significantly reduce operational and charging risks, while enhanced instrumentation allows operators to optimize battery usage and maximize submarine test time.

Fig. 4. PowerPAK 8 x 8LR package

3) Power Management Unit (PMU): The Power Management Unit (PMU) is a custom, highly integrated PCB that forms the electrical backbone of AUVLite. It manages safe and efficient power distribution to all subsystems, motor power control via a hardware killswitch, generation of motor control signals, and real-time monitoring of output currents and voltages.

The PMU uses a hybrid modular design: compact, function-specific modules (motor control, safety logic, monitoring) connect through a backplane and robust PCB-to-PCB connectors. This enables quick replacement of faulty modules, minimizes downtime, and isolates failures to affected subsystems.

Thermal management is central to the design. High-current paths are distributed across multiple modules to reduce localized heating, while motor driver modules are oriented at 90 degrees to the main board to optimize airflow and convection cooling. Thermal vias and thick copper pours further enhance heat dissipation.

The PMU provides real-time voltage and current telemetry to the main computer, enabling rapid diagnostics and increasing system reliability. This data-driven approach supports quick troubleshooting and enhances operational safety.

Overall, the new PMU design achieves a strong balance of compactness, maintainability, and safety—key for the demanding environment of AUVLite. Its modularity, improved thermal management, and advanced monitoring directly contribute to longer, safer, and more effective missions.

C. Software Design

1) Camera: This year the submarines incorporate new front facing cameras. The new cameras, (Zed mini and Zed2i) have been selected for the their inclusion of stereoscopic depth perception. This functionality lets us calculate the submarine distance to obstacles with much grater accuracy than the previous method (which were relying on rough estimation based on the size of the bounding box generated by the AI system). The cameras have been chosen for their high precision and small size. They also have been chosen for their use of passive stereoscopy in contrast with IR projector based solutions which tends to work very poorly underwater [4].

The addition of stereoscopic vision should greatly improve the reliability of the autonomous alignement system which inturn should result in faster and more successful missions.

2) Simultaneous Localization and Mapping System (SLAM): A new mapping system based on the SLAM (Simultaneous Localization And Mapping) algorithm has been added. This algorithm let us use the informations from the stereoscopic cameras to create a representation of the environment [5]. This implementation of SLAM is based on NVIDA's Isaac ROS library which let us use the GPU from our embedded computer to accelerate the algorithm. This implementation can reuse the map from previous run while also updating it for any changes, which should considerably reduce the map creation time during runs. Moreover, those information can be paired with image recognition system to identify important objects for the mission.

Overall, this new mapping system should significantly improve its speed during competition runs. Indeed, the previous navigation system which relied solely on 2d image from previous cameras and on the image recognition AI was by far the greatest contributor the length of our competition run.

3) Robotic Operating System 2 (ROS2): This year the migration to ROS2 has been completed. Initiated last year, this transition was driven by the deprecation of ROS1 as of May 2025 [6], and the need for a more robust, and future-proof framework. While full integration was not achieved in time for Robosub 2024, the ROS2-based stack is now operational and ready for Robosub 2025.

ROS2 introduces several key advantages over its predecessor. Most notably, it replaces the centralized node structure of ROS1 with a decentralized, peer-to-peer communication model. This architectural shift reduces single points of failure, enhances modularity, and simplifies the integration of new features and subsystems. The improved Quality of Service (QoS) settings in ROS2 allow fine-grained control over message delivery, reliability, and resource usage, which is critical for real-time operations and efficient bandwidth management in resource-constrained embedded systems.

The migration process was approached methodically, starting from the lowest layers of the stack. Custom hardware drivers were rewritten or adapted to ROS2, with a focus on maintaining or improving data rates and minimizing latency. Special attention was given to optimizing CPU and memory usage, leveraging ROS2's improved multi-threading and real-time capabilities. The processing layer (control and AI) was then refactored to ensure seamless data flow and compatibility with the new middleware.

One of the most significant challenges was the integration of legacy components, particularly the autonomous control system based on BehaviorTreeCPP.

This required a deep understanding of both the legacy codebase and the new ROS2 paradigms, as well as extensive documentation and knowledge transfer within the team. Despite these hurdles, the migration has resulted in a more maintainable and extensible codebase, with improved documentation and clearer interfaces between modules.

IV. Testing Strategy

The following section presents the team strategy regarding the testing and the validation of the AUV's various systems. The testing strategy for the mechanical systems, electrical systems and software systems will be presented.

A. Mechanical Testing

1) Water-tightness: The most important mechanical testing procedure is the water-tightness test. This test serves two purposes: it ensures that the hull is watertight after manufacturing and assembly, and it verifies that the AUV remains properly sealed before each deployment.

The first test is performed during the manufacturing and assembly process. It is a standard step to verify that all O-rings and gaskets are correctly installed. However, since this year's design includes welded components, the welds also need to be tested. To test for leak, the internal hull is put under negative pressure. In case of a leak, the AUV will quickly regain a normal pressure. A similar test is performed each time that the AUV is opened (see Appendix A and Appendix B).

B. Electrical Testing

1) Power Management Unit (PMU): The PMU testing procedure is designed to ensure the reliability, safety, and performance of the unit before integration into the AUV. The process is structured into three key phases: post-manufacturing testing, functionality and stress testing , and integration testing.

- **Post-manufacturing testing:** All major connections are verified to ensure critical signals are correctly routed and to confirm the absence of shorts. For more details, see Appendix C.
- **Functionality and stress testing:** Core and safety-critical features are validated, including power shutoff, motor control, and safety logic. Then, the motors are operated at full power while monitoring the temperature of the boards. During this test phase no major problems have been detected, although we did find that some MOSFET were receiving incorrect gate voltage due to the installation of some incorrect parts. For more details, see Appendix D.
- **Integration testing:** The PMU is installed in the submarine and tested in its operational configuration. Basic maneuvers are performed to verify correct performance in real-world conditions. Although this phase is pending completion due to ongoing mechanical assembly, previous tests provide confidence that the PMU will function as intended. For more details, see Appendix E.

2) Battery Management System (BMS): The first test phase focuses on the high-power board, which is initially connected to a development kit, allowing direct communication with the BMS chips via a graphical user interface. Through this interface, the team can program the BMS, test its core functionalities, and verify the accuracy of all measurement channels. This phase ensures that the basic functionalities of the BMS are functioning as intended before integration with the rest of the system.

The second phase involves connecting the control board to the high-power board, replacing the development kit. This step validates the firmware on the control board . To simulate real-world conditions and trigger safety features, a variable power supply is used in place of a battery, and a set of potentiometers simulates the individual battery cells. By intentionally inducing fault conditions (e.g., overcurrent, overvoltage), the team verifies that the BMS responds appropriately by activating its protection mechanisms. The detail procedure is presented in Appendix F.

C. Software Testing

1) Camera: The testing process for the cameras mainly included running them solely with the provided SDK and tools, followed by running provided ROS2 nodes and observing the quality of the cameras with the integrated ROS2 telemetry (RQT).

2) Simultaneous Localization and Mapping System (SLAM): The SLAM algorithm was tested in three main stages: land, water, and integration. Land tests focused on tuning parameters such as the camera model, sensor settings, and subsystem selection (landmarks, observations, odometry) to optimize accuracy and minimize sensor jitter. Water tests evaluated the precision of the generated maps compared to land results, allowing adjustments to expected accuracy. Integration tests combined SLAM outputs with AI-provided information to ensure correct landmark tagging. This staged approach systematically validates each component while minimizing unknown variables.

3) Robotic Operating System 2 (ROS2): The decentralized nature of ROS2 greatly facilitated the ability to test the various systems. Since there is no longer a need for a roscore node, the team was able to implement unit tests that could test each system in isolation. The approach for the drivers is running a data stream check with the hardware plugged in, while the other systems may run with either mock data or some kind of manual testing. For system integration testing the simulation is used as it is able to validate the functionality of the processing and management layers. The final level of testing used to validate the global functionality of ROS2 is a ”Pool Test” where the system is run on the prototype under strict supervision.

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Diamond: Innovox, AÉETS
Platinum: Altium, Drillmex, ÉTS Diplomés et Philantropie, Solidworks
Gold: Teledyne, Labelbox, Vectornav
Silver: Crac Transport, MacArtney, Pacometal, Hakko, Digi-Key, Parc Olympique, Hakko, Fondation ASÉQ
Bronze: Anodisation Québec, Bluerobotics, Blue Trail engineering, Fila3D

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APPENDIX

APPENDIX A: MECHANICAL ENCLOSURE TESTING

ENCLOSURE GENRAL TESTING PROCEDURE V1-0

Enclosure general air vacuum testing procedure

ID: TEST-MEC-GEN-001-V1-0
Rev: V1-0 Applicable submarines: N/A

Abstract

This document presents a generalized testing methodology to validate the watertightness of custom mechanical enclosure using air vacuum.

Revision history

Version	Date	Changes
V1-0	2024-06-30	• Initial document creation

Prerequisite

Hardware / Others	Tools
Hardware 1x Enclosure to test ?x Sealing hardware (Gasket/O-ring) of the enclosure to test **Others** 1x Molykote 111 silicone grease	**Tools** 1x Mityvac Hand Operated Vacuum Pump (from bluerobotics) 1x Pressure Relief Valve (from bluerobotics) 1x Pressure Relief Valve Backfill Adapter (from bluerobotics) 1x Vacuum Plug (from bluerobotics) 1x ¼" Vacuum hose (from bluerobotics) ?x Appropriately sized torque wrenches

Procedure

The following test procedure is based on the bluerobotics vacuum procedures [1], [2].

1. Inspect all Gaskets and O-rings. Verify the following criteria **(abort test in case of failure):**
   a. **CRIT-1: all Gasket and O-ring shall show have no visual damage such as cracks**
   b. **CRIT-2: all Gasket and O-ring shall be exempt from any contaminants such as dust or sand**
2. Spread Molykote silicone grease over the surface of the Gaskets and O-rings
3. Carefully place gaskets and O-ring on the mating faces

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Fig. 5. Mechanical Enclosure Testing - Page 1

ENCLOSURE GENRAL TESTING PROCEDURE V1-0

4. Close the enclosure using the appropriate torque spec for the screws, as defined in the specific enclosure documentation.
5. Install the pressure relief valve with greased O-ring on the enclosure. Use a torque of 3.5Nm.
6. Attach clear vacuum hose to the vacuum pump
7. Insert the barbed end of the Vacuum Plug into the vacuum hose.
8. Insert the rubber stopper into the hole on the Vacuum Plug to seal it up
9. Turn the knob on the side of the vacuum pump so it is in the “VACUUM” setting
10. Pump the hand pump to approximately 15 inHg (47.4 kPa), and monitor for about 30 seconds to a minute. Verify the following criteria **(interrupt procedure in case of failure) :**
    a. **CRIT-3: the pressure does not decrease by more than 0.5 inHg (1.7 kPa)**
11. De-pressured
12. The Pressure Relief Valve (PRV) plunger has threads at the top to accept the threads on the Backfill adapter. Screw on the adapter clockwise into the PRV. The O-ring on the Backfill adapter will seat into the PRV plug.
13. As you screw on the Backfill Adapter the plunger is pulled up, creating a sealed path into the enclosure. Continue turning the Backfill Adapter into the PRV plug all the way until it stops and cannot be turned further.
14. Insert the Vacuum Plug into the Backfill Adapter. At this point the Vacuum Plug and the Backfill Adapter can be used with a backfilling system to backfill the enclosure with an inert gas such as nitrogen or to pull a vacuum inside the enclosure.
15. Pump the hand pump, removing air and decreasing the pressure inside the enclosure to approximately 29 inHg (98 kPa) corresponding to a water depth of about 10m.
16. Let the enclosure sit in a depressurized state for 12 hours
17. After the 12 hours, verify the following criteria **(interrupt procedure in case of failure) :**
    a. **CRIT-4: the pressure does not decrease by more than 0.5 inHg (1.7 kPa)**
18. De-pressured and Unscrew the Backfill Adapter counter-clockwise to remove it. As the Backfill Adapter is unscrewed the plunger is released and reseals the PRV.

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Fig. 6. Mechanical Enclosure Testing - Page 2

APPENDIX B: PRE-WATER TEST

PMU TESTING PROCEDURE V2

Pre-water test – AUV8.1 - AUVLite ID: TEST-GEN-AUV8-001-V2-0 Rev: V2-0 Applicable submarines: AUV8.1 and AUVLite	SONIA

Abstract

This document presents the pre-water test procedure for AUV8.1 and AUVLite. The main goal of this procedure is to avoid water leak in the submarine. The other goal is to verify the core submarine functionalities prior to the insertion of AUV8.1 and AUVLite in the water.

This test procedure shall be followed before putting AUV8 in the water in all instances where AUV8 was previously opened.

Revision history

Version	Date	Changes
V1-0	2024-06-29	• Initial document creation
V1-0	2025-06-27	• Update for AUV lite

Prerequisite

Hardware	Others
1x AUV8 1x Portable network box (*duckbox*) 2x Batteries battery pack **Tools** 1x Mityvac Hand Operated Vacuum Pump (from bluerobotics) 1x Pressure Relief Valve Backfill Adapter (from bluerobotics) 1x Vacuum Plug (from bluerobotics) 1x ¼'' Vacuum hose (from bluerobotics) 1x latop	1x pool 3x team members 1x diver

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Fig. 7. Pre-Water Test - Page 1

PMU TESTING PROCEDURE V2

Electrical Procedure

1. Using a multi meter in continuity mode, verify continuity between pin 1 & 4 (refer to Figure 1) of both battery connectors on the submarine hull. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-1: No continuity between pin 1 & 4 on left connector**
   b. **CRIT-2: No continuity between pin 1 & 4 on right connector**

Figure 1

2. Using a multi meter in continuity mode, verify continuity between pin 1 (refer to Figure 1) of both battery connectors on the submarine hull. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-3: No continuity between pin 1 of left connector and pin 1 of right connector**
3. Using a multi meter in continuity mode, verify continuity between pin 4 (refer to Figure 1) of both battery connectors on the submarine hull. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-3: Continuity between pin 4 of left connector and pin 4 of right connector**
4. Connect both battery pack. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-4: Battery level indicators of the PMU fully lights up**

Software procedure

5. Connect the laptop to the *duckbox* wifi network
6. Connect AUV8 and the *duckbox* using the tether.
7. After a ~ 1 minute, start a ping test with the address 192.161.0.31 on the laptop. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-5: Responses to the ping request are present**

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Fig. 8. Pre-Water Test - Page 2

PMU TESTING PROCEDURE V2

8. Start a SSH session with the Xavier. Start the submarine system using the script `launch_auv8.sh`
9. Launch the telemetry module. Verify the following criteria **(interrupt procedure in case of failure)** :
   a. **CRIT-6: Both batteries indicator on the telemetry are > 80%**
10. Pull the kill-switch. Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-7: Telemetry kill indicator in telemetry shows the kill as pulled**
    b. **CRIT-8: LED labeled KILL on the PMU is off**
11. Push the kill-switch. Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-9: Telemetry kill indicator in telemetry shows the kill as pushed**
    b. **CRIT-10: LED labeled KILL on the PMU is on**
12. In the telemetry, click "activate all motors". Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-11: all motors start making a 3 notes sound (i.e. ESC startup sound)**
    b. **CRIT-12: the motor activation LED on the PMU lights up**
13. In the telemetry, set the submarine state to "dry mode". In the motor widget, click on "start dry test". Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-13: Each motor start rotating, one after the other, following the order defined in Figure 2**

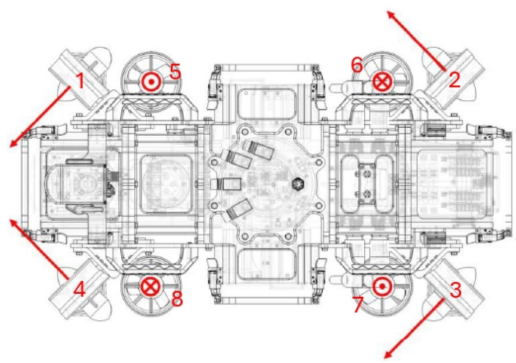

Figure 2: Motor numbering on AUV8 (front of AUV8 facing the left)

14. In the telemetry, set the submarine state back to "normal".
15. In the telemetry, open the camera viewer. Ask a team member to pass its hands on front of both cameras. Verify the following criteria **(interrupt procedure in case of failure)** :

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Fig. 9. Pre-Water Test - Page 3

PMU TESTING PROCEDURE V2

a. **CRIT-14: Both images are present, movement can been seen on both images**

Mechanical procedure (caps)

16. Verify all of the acrylic caps on both side the submarine. Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-15: The o-ring of the front AND the rear cap is visibly compress along the entire permitter of the cap**
    b. **CRIT-16: All 4 clips of both front AND rear cap are close**
    c. **CRIT-17: All 4 clips of both front AND rear cap are locked (try to physically open all clips)**
17. The verification of the previous step should be redone by another team member
    a. **CRIT-18: The inspection of the caps shall be done by at least by two team members.**

Mechanical procedure (vacuum test)

The following test procedure is based on the bluerobotics vacuum procedures [1], [2].

18. Attach clear vacuum hose to the vacuum pump
19. Insert the barbed end of the Vacuum Plug into the vacuum hose.
20. Insert the rubber stopper into the hole on the Vacuum Plug to seal it up
21. Turn the knob on the side of the vacuum pump so it is in the “VACUUM” setting
22. Pump the hand pump to approximately 15 inHg (47.4 kPa), and monitor for about 30 seconds to a minute. Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-19: the pressure does not decrease by more than 0.5 inHg (1.7 kPa)**
23. De-pressured
24. The Pressure Relief Valve (PRV) plunger has threads at the top to accept the threads on the Backfill adapter. Screw on the adapter clockwise into the PRV. The O-ring on the Backfill adapter will seat into the PRV plug.
25. As you screw on the Backfill Adapter the plunger is pulled up, creating a sealed path into the enclosure. Continue turning the Backfill Adapter into the PRV plug all the way until it stops and cannot be turned further.
26. Insert the Vacuum Plug into the Backfill Adapter. At this point the Vacuum Plug and the Backfill Adapter can be used with a backfilling system to backfill the enclosure with an inert gas such as nitrogen or to pull a vacuum inside the enclosure.
27. Pump the hand pump, removing air and decreasing the pressure inside the enclosure to approximately 15 inHg (47.4 kPa).

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Fig. 10. Pre-Water Test - Page 4

PMU TESTING PROCEDURE V2

28. Monitor the gauge for about 5 minutes. Verify the following criteria **(interrupt procedure in case of failure)** :
    a. **CRIT-19: the pressure does not decrease by more than 0.5 inHg (1.7 kPa)**
29. De-pressured
30. Unscrew the Backfill Adapter counter-clockwise to remove it. As the Backfill Adapter is unscrewed the plunger is released and reseals the PRV.

References

[1] "Pressure Relief Valve Installation and Usage," Blue Robotics. Accessed: Jun. 30, 2024. [Online]. Available: https://bluerobotics.com/learn/pressure-relief-valve-installation-and-usage/

[2] "Using the Vacuum Plug and Hand Pump," Blue Robotics. Accessed: Jun. 30, 2024. [Online]. Available: https://bluerobotics.com/learn/using-the-vacuum-test-plug/

Fig. 11. Pre-Water Test - Page 5

Appendix C: PMU testing procedure (post manufacturing testing)

PMU TESTING PROCEDURE V2

PMU testing procedure (post manufacturing testing)

ID: TEST-ELE-PMU-003-V1-0
Rev: V2-0 Applicable submarines: AUV8.1, AUVlite

Abstract

This document presents a test procedure to the test the PMU after manufacturing

Revision history

Version	Date	Changes
V1-0	2025-02-12	• Initial document creation

Prerequisite

Hardware

1x PMU main board
4x PMU motor module
1x PMU MCU module
1x Safety module

Tools

1x Multimeter with continuity testing capabilities

Others

1xESD protection bracelet

Procedure

1. Verify that correct resistors have been fitted on the motor board (refer to the motor number written on the board and compare with Tab. 1). Different combinations of resistor will result in different address.

Tab. 1

Motor number	Fitted Resistor	Fitted Resistor
M1	R21	R29
M2	R47	R57
M3	R23	R29
M4	R50	R57
M5	R25	R21
M6	R47	R53
M7	R25	R23
M8	R53	R50

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Fig. 12. PMU testing (post-manufacturing) - Page 1

PMU TESTING PROCEDURE V2

2. Figure 1 show the pad assignation of the major power net of the board. With the multimeter in continuity testing verify that the pads are connected with the appropriate nets. Also verify the absence of shorts between the nets.

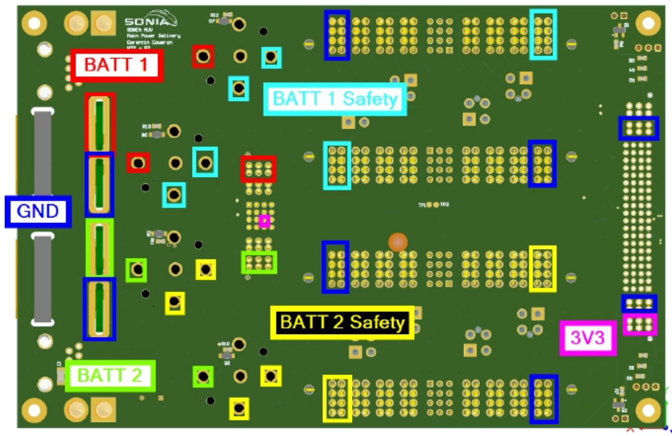

Figure 1

3. Connect the 4 motor boards main board
4. Figure 2 present the pad assignments of major power nets for the motor board. Verify that the net match with the main board (refer to Figure 1)

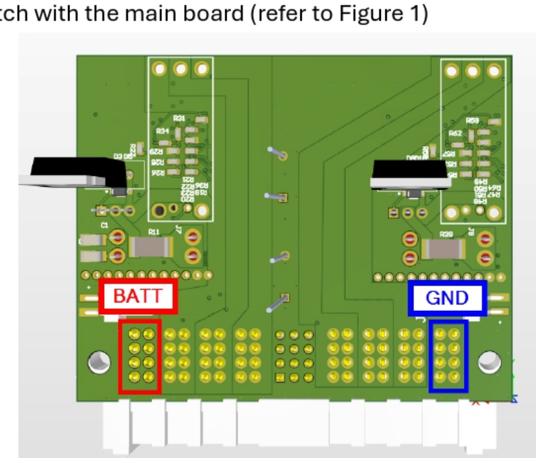

Figure 2

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Fig. 13. PMU testing (post-manufacturing) - Page 2

PMU TESTING PROCEDURE V2

5. Connect the safety board to the main board
6. Figure 3 present the pad assignments of major power nets for the motor board. Verify that the net match with the main board (refer to Figure 1)

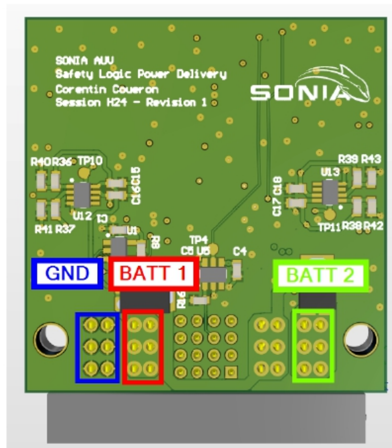

Figure 3

7. Connect the safety board to the main board
8. Figure 4 present the pad assignments of major power nets for the motor board. Verify that the net match with the main board (refer to Figure 1)

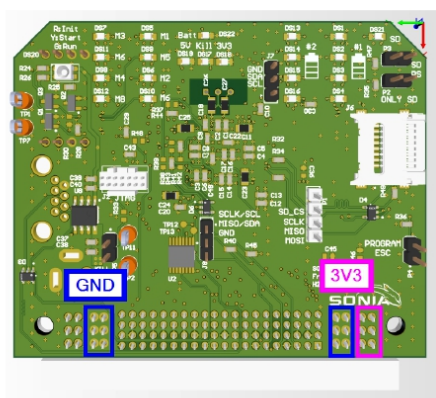

Figure 4

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Fig. 14. PMU testing (post-manufacturing) - Page 3

APPENDIX D: PMU TESTING PROCEDURE (FUNCTIONALITY TESTING AND STRESS TEST)

PMU TESTING PROCEDURE V2

PMU testing procedure (functionality testing & stress test)

ID: TEST-ELE-PMU-001-V2-0

Rev: V2-0 Applicable submarines: AUV8.1, AUVlite

SONIA

Abstract

This document presents a test procedure to the test the PMU individually

Revision history

Version	Date	Changes
V1-0	2024-06-29	• Initial document creation
V2-0	2025-04-03	• Update for AUVlite • Change testing method to use testing program

Prerequisite

Hardware

1x PMU main board
4x PMU motor module
1x PMU MCU module
1x Safety module
2x banana to XT-96 wires

Tools

1x Dual Variable PSU with 10 amps capability (or 2x Variable PSU with 10 amps capability)
1x Motor-pole assembly

Tools (continued)

1x Kill switch simulation board
1xLaptop
1x Multimeter
1x 12V PSU with barrel connector

Others

1x Water container (at least 1m deap)
1x Local with water access, water drain and power outlet (e.g. D-1034)
1x folding table
1x electrical tape
2x team members
1xESD protection bracelet

Procedure

1. Clean the water container (if necessary)
2. Fill up the water container and install close to the water drain
3. Install the folding table ~1.5m away from the water container

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Fig. 15. PMU testing (functionality testing and stress test) - Page 1

PMU TESTING PROCEDURE V2

4. Ground yourself with an ESD protection bracelet
5. Assemble the PMU modules with the PMU main board
6. **Make sure that PSU in NOT connected yet to PMU**. Set the voltage of **BOTH** channel to 16.6V, set the max current of **BOTH** channel
7. Power the ON the PSU, verify that **BOTH** channels are at 16.6±0.2V, adjust if necessary
8. **Power OFF the PSU**
9. Follow the connection from Figure 1

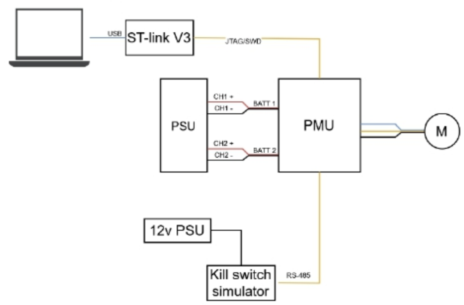

Figure 1: Connection diagram

10. Secure all wires using tape
11. Power ON the PSU. Verify the following criteria **(interrupt test in case of failure)**:
    a. **CRIT-1: PSU CH1 is in C.V. mode (constant voltage mode)**
    b. **CRIT-2: PSU CH2 is in C.V. mode (constant voltage mode)**
12. Activate the kill switch simulator. Verify the following criteria **(interrupt test in case of failure)**:
    a. **CRIT-3: PSU CH1 is in C.V. mode (constant voltage mode)**
    b. **CRIT-4: PSU CH2 is in C.V. mode (constant voltage mode)**
    c. **CRIT-5: The relays make an audible click sound**
    d. **CIRT-6: LED labeled "KILL" on MCU module lights up**
    e. **CIRT-7: Both battery level indicator on the MCU module fully light up**
    f. **CRIT-8: LED labeled "KILL" on all 4 Motor modules lights up**
13. Deactivate the kill switch simulator. Power OFF the PSU.
14. Connect the motor-pole assembly to the M1 Connector
    a. **Note**: One team member should operate the motor-pole assembly, the other team member should do the remaining to reduce the splashing the electronics. The table with the electronic setup should be ~1.5m away from the motor-pole assembly operator.
15. Power ON the PSU

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Fig. 16. PMU testing (functionality testing and stress test) - Page 2

PMU TESTING PROCEDURE V2

16. On the laptop, load the testing program in Mbed Studio
17. In the program, de-comment the code to activate all motors
18. Click on “Run program”
19. Activate the kill switch simulator. Verify the following criteria **(interrupt test in case of failure):**
    a. **CRIT-9-M1: PSU CH1 is in C.V. mode (constant voltage mode)**
    b. **CRIT-10-M1: PSU CH2 is in C.V. mode (constant voltage mode)**
    c. **CRIT-11-M1 : The motor make a 3 notes sound (i.e. ESC startup)**
20. Make sure that the motor-pole assembly is submerged in the water container and that he motor-pole assembly is securely hold by the operator
21. In the test program, set the pulsewidth of the pwm of motor 1 to 1680 μs.
22. Click on “Run program”
23. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-12-M1: Motor is rotating in a clockwise direction as view from the back of the motor**
24. In the test program, set the pulsewidth of the pwm of motor 1 to 1320 μs.
25. Click on “Run program”
26. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-13-M1: Motor is rotating in a counterclockwise direction as view from the back of the motor**
27. In the test program, set the pulsewidth of the pwm of motor 1 to 1800 μs.
28. Click on “Run program”
29. Hold the motor to this power level for 10 minutes. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-14-M1: Motor is rotating at steady rate for the entire duration of the test**
30. Deactivate the kill-switch. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-15-M1: Motor immediately stop rotating**
31. Reactivate the kill switch. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-16-M1: Motor stays stopped**
32. Set the pulsewidth of the pwm of motor 1 to 1800 μs (neutral), deactivate motor 1, reactivate motor 1, to motor 1 to 1600 μs. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-17-M1: Motor rotate**
33. Deactivate motor 1. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-17-M1: Motor immediately stop rotating**

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Fig. 17. PMU testing (functionality testing and stress test) - Page 3

PMU TESTING PROCEDURE V2

34. Deactivate the kill switch simulator. Power OFF the PSU.
35. Disconnect the motor
36. Re do steps 14 to 35 with the motors 2 to 8. For the motor connector, use connector MX, where X is the motor number. The criteria identification, use MX, where X is the motor number (e.g.: **CRIT-17-M3** for motor 3)

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Fig. 18. PMU testing (functionality testing and stress test) - Page 4

APPENDIX E: PMU TESTING PROCEDURE (INTEGRATION)

PMU TESTING PROCEDURE V1

PMU testing procedure (integration)

ID: TEST-ELE-PMU-002-V1-0
Rev: V1-0 Applicable submarines: AUV8

Abstract

This document presents a test procedure for the integration of the PMU with AUV8

Revision history

Version	Date	Changes
V1-0	2024-06-30	• Initial document creation

Prerequisite

Hardware	Others
1xAUV8 with PMU installed 1x Portable network box (*duckbox*) 2x Batteries	1x Pool 3x team members 1x Diver
Tools 1x Laptop 1x Tether	

Procedure

1. Follow the pre-water procedure for AUV8, as defined in TEST-GEN-AUV8-001-V1-0 (Pre-water test – AUV8)
2. Verify that the diver is ready to receive the submarine in the water
3. Ask two team members to take the submarine and introduced it the water with the help of the diver. Verify the following criteria **(continue test in case of failure):**
   a. **CRIT-1: Submarine is stable and flat relative to the pool water level**
4. Ask the diver to put the submarine in the middle of the pool
5. Start the submarine control
6. In the telemetry set a way point 2m in front, 1m below surface
7. Execute the waypoint mission in 3s. Verify the following criteria **(continue test in case of failure):**
   a. **CRIT-2: The submarine moves in a straight line to the programmed waypoint**

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Fig. 19. PMU testing (integration) - Page 1

PMU TESTING PROCEDURE V1

8. Execute the previous step with way points to the left, right and back of the submarine
9. Stops the submarine control.
10. Ask the diver to bring the submarine back to the center of the pool.
11. Execute the “trick shot” mission. Verify the following criteria **(continue test in case of failure):**
    a. **CRIT-3: The submarine shall rotate around the 3 axis**

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Fig. 20. PMU testing (integration) - Page 2

APPENDIX F: BMS TESTING

PMU TESTING PROCEDURE V1

BMS testing

ID: TEST-ELE-BMS-001-V1-0
Rev: V1-0 Applicable submarines: AUV8.1, AUVlite

Abstract

This document presents a test procedure to the test the PMU after manufacturing

Revision history

Version	Date	Changes
V1-0	2025-06-12	• Initial document creation

Prerequisite

Hardware

1x BMS board
1x BQ40Z80EVM-020
4x 500 Ω resistors
4x 500 Ω multiturn potentiometers
1x breadboard
1x set of connection wires
1x 5 Ω power resistor

Tools

1x Computer with BQSTUDIO installed
1x Variable power supply
1x Multimeter

Others

1xESD protection bracelet

Procedure

1. Create a ladder of resistors with 500 Ω resistors and potentiometers in series on the bread board. Connect the power supply to both end of the resistor ladder. Connect the BMS with the resistor ladder and the power supply. Connect the BMS with the BQ40Z80EVM-020. Connect the BQ40Z80EVM-020 with the computer. Refer to Figure 1 for the connection diagram.

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Fig. 21. BMS test - Page 1

PMU TESTING PROCEDURE V1

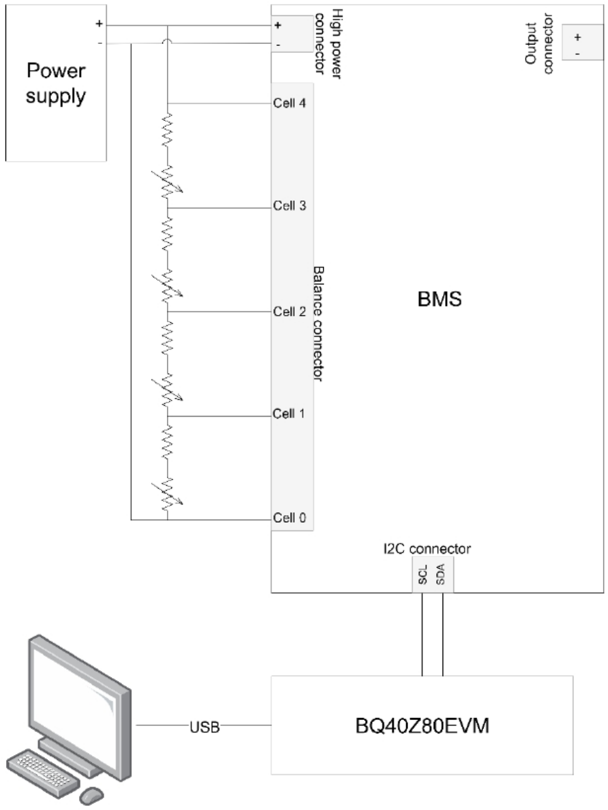

Figure 1

2. With a multimeter adjust each potentiometer such that each potentiometer-resistor couple have a 1kΩ resistance
3. Set the power supply to 15.4V
4. Power on the power supply
5. Briefly connect the power supply to the output of the BMS (while maintaining the connection input). This should wakeup the BMS
6. On the computer, open BQSTUDIO
7. The BMS should be automatically detected
8. In BQSTUDIO, program the BQ chip:
    a. click on the “Data memory” button

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Fig. 22. BMS test - Page 2

PMU TESTING PROCEDURE V1

   b. Click “import”
   c. Navigate to the BMS subfolder on the intranet, choose BMS_SONIA.gg.csv
9. The BMS should now be programmed
10. Go back to the Registers tab
11. In first list, check the value of “Voltage” against the voltage of the power supply (measure the power supply voltage using a multimeter)
12. Reduce the voltage to 12V and verify again
13. Increase the voltage to 16.8V and verify again
14. In the same list, check the cells voltage against the measure voltage at the cell input
15. Change slightly the potentiometer of each cells and verify again
16. Connect a multimeter in current mode (10A range) to the 5 Ω power resistor at the output of the BMS, as shown in Figure 2

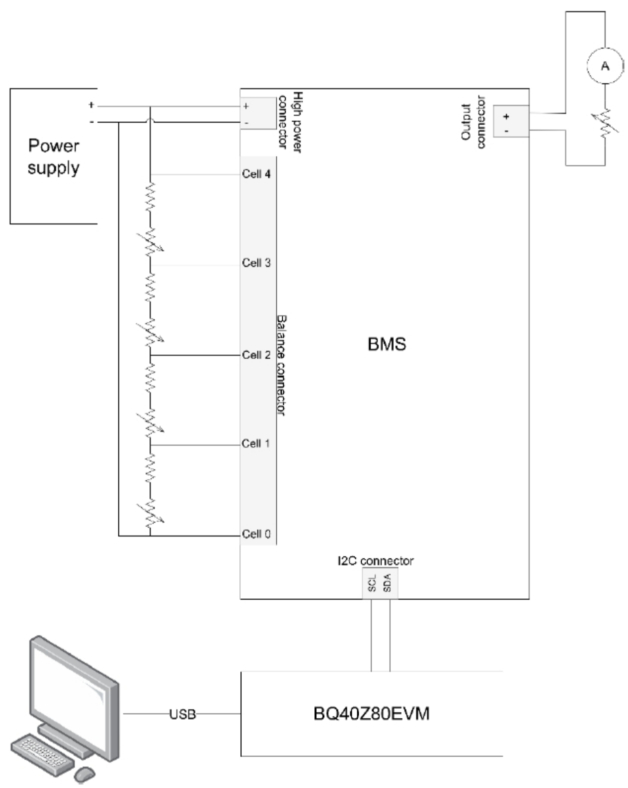

Figure 2

17. On the BQSTUDIO interface, click on CHG_FET_TOGLE and DSG_FET_TOGLE

Fig. 23. BMS test - Page 3

PMU TESTING PROCEDURE V1

18. Verify that the current measured by the multimeter is twice the value displayed by BQSTUDIO
19. Click again on CHG_FET_TOGLE and DSG_FET_TOGLE
20. Click on PDSG_FET_TOGLE and CHG_FET_TOGLE, check the current again
21. Power off the power supply
22. Connect a second power supply to the output, as shown in Figure 3

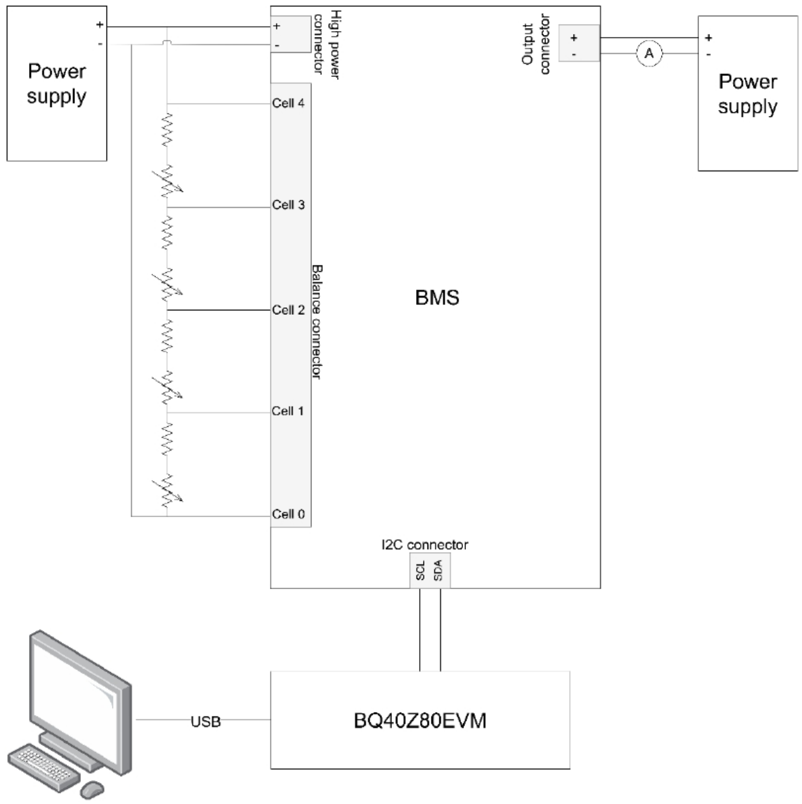

Figure 3

23. Set the input power supply at 15.8V, set the output power supply at 16.8V. Power on the input power supply then the output power.
24. In the BQSTUDIO software, click on CHG_FET_TOGLE and DSG_FET_TOGLE
25. Verify that charging voltage matches the voltage of output power supply
26. Verify that charging current matches the current of the output power supply
27. Power off the power supplies

Fig. 24. BMS test - Page 4

PMU TESTING PROCEDURE V1

28. Disconnect the BQ40Z80EVM-020 and the output power supply. Connect the MCU board, and the load to the BMS, as shown in Figure 4

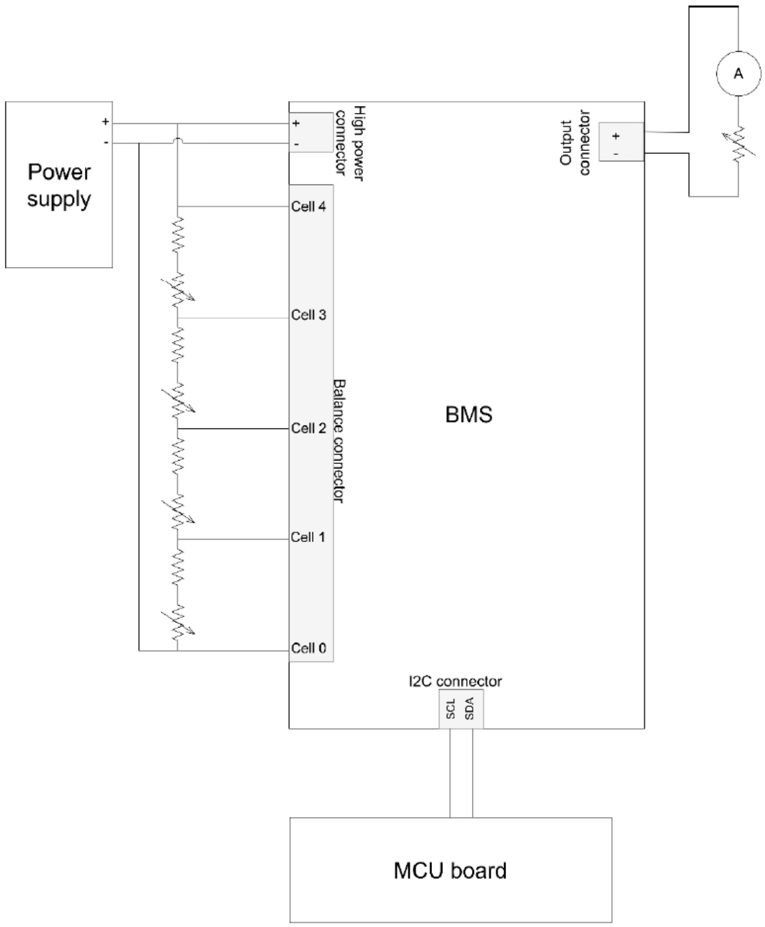

Figure 4

29. Set the power supply to 16.8V
30. Power on the power supply
31. Check that current flow across the load
32. Decrease the voltage of the power supply to 10V
33. Verify that the current stopped flowing to the load
34. Increase the voltage back to 16.8V
35. Verify that the current now flows through the load

Fig. 25. BMS test - Page 5

PMU TESTING PROCEDURE V1

36. Disconnect the multimeter and the load
37. Short the output of the BMS
38. Check that no voltage is present on the output of the BMS
39. Power off the power supply, disconnect the load and connect the second power supply to the input of the BMS
40. Set the input power supply to 16.0 V and the output power supply to 16.4 V
41. Power on the input power supply and then the output power supply
42. Check that current does flow from the output power supply to the BMS
43. Increase the voltage of the Input power supply to 17V and the output power supply to 18V
44. Verify that the current stopped flowing from the Output power supply

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Fig. 26. BMS test - Page 6

APPENDIX G: SONIA AUV PUBLIC DOCUMENTATION

The club SONIA AUV has been hosting a publicly accessible wiki (https://wiki.sonia.etsmtl.ca/) for the past four years. The wiki presents an overview of the various projects and design decisions made regarding the submarines. Its purpose is to share the knowledge accumulated over the years with both future team members and members of other teams.

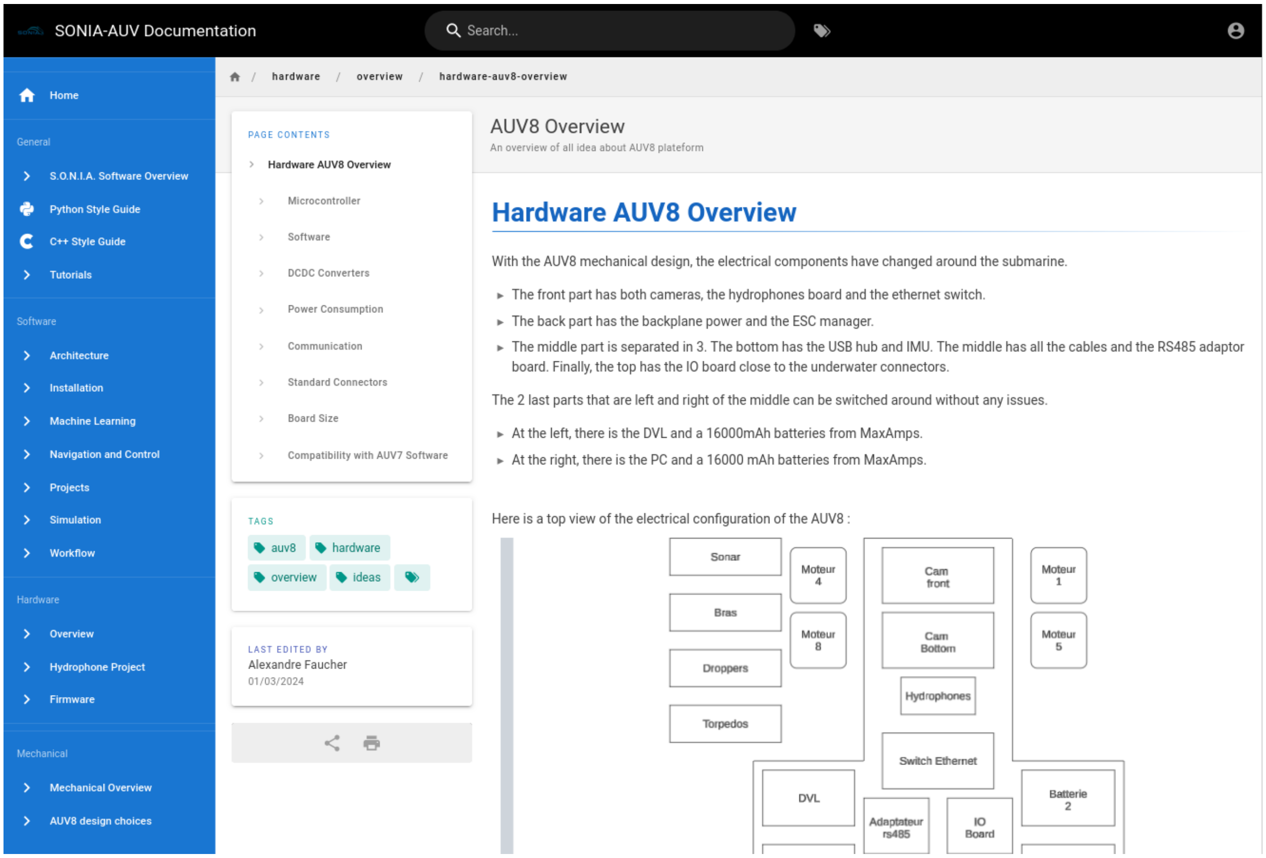

Fig. 27. SONIA's wiki

The club also host its full software stack on GitHub (https://github.com/sonia-auv) under various open licenses with over 100 projects publicly available.

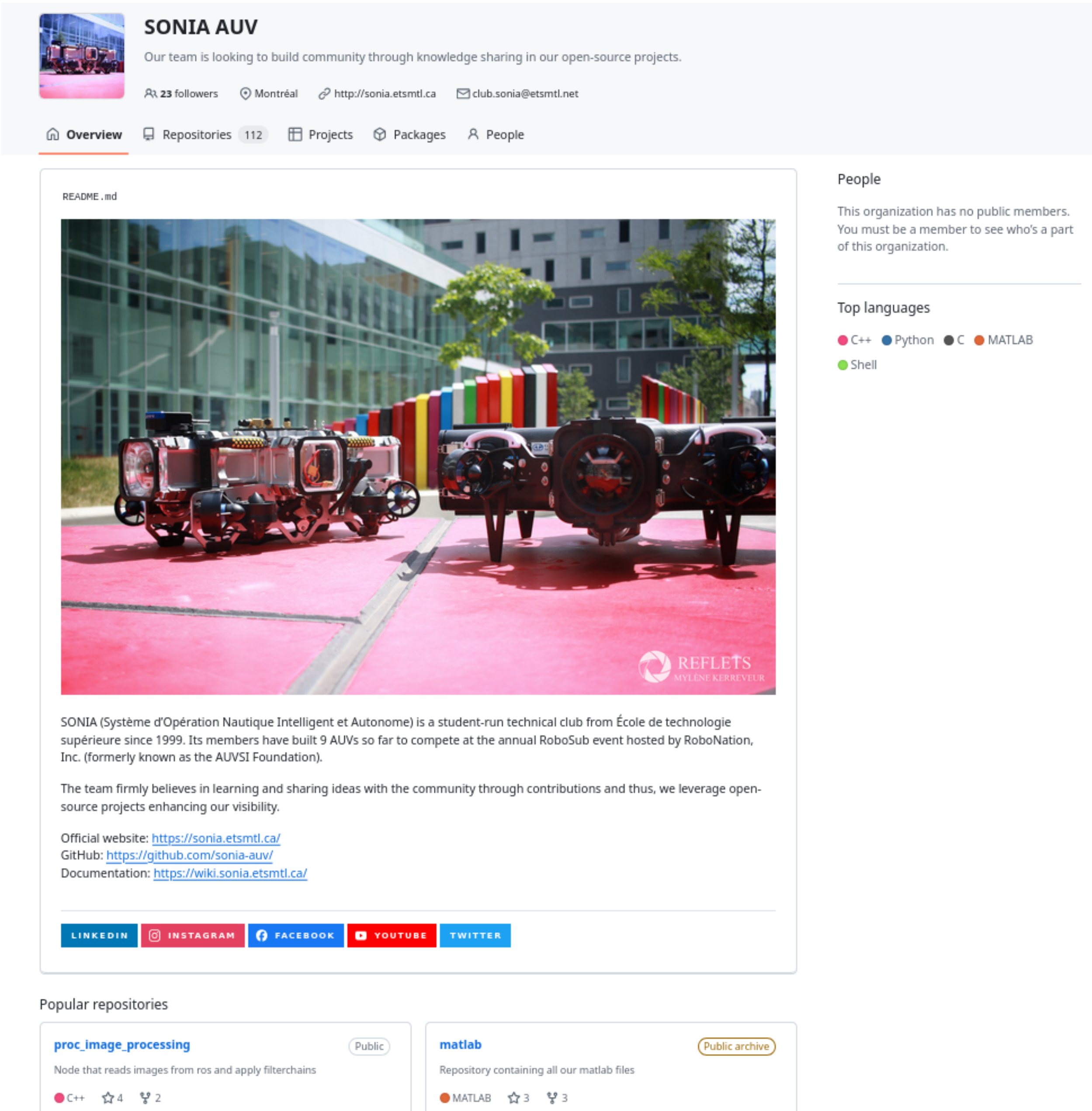

Fig. 28. SONIA's github