

S.O.N.I.A. AUV: System Architecture and Performance Enhancements for RoboSub 2026

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Abstract—S.O.N.I.A. (Système d’Opération Nautique Intelligent et Autonome) is a robotics club from the École de Technologie Supérieure in Montréal dedicated to constructing underwater vehicles since 1999. Comprised of 20 undergraduate members with expertise in mechanical, electrical, automated production, and software engineering, the club aims to customize the latest platforms, AUV8.1 and LITE1, for the upcoming competition while training the new generation of team members. This year’s objectives consisted of improving the reliability of both AUV and optimizing current systems with the collaboration of the three departments. These objectives were based on our competition, design, and testing strategies, which we will present in this paper.

Index Terms – Autonomous Underwater Vehicle, Technical Design Report, RoboSub, RoboNation

I. INTRODUCTION

S.O.N.I.A. is a student-run robotics club from the École de technologie supérieure (ÉTS) in Montreal, Quebec, Canada. The team was founded in 1999 and has participated in every RoboSub competition ever since 2000.

This year, the team has decided to take a more conservative approach towards the competition goals. Taking prototypes LITE and AUV8.1, the team has decided to refine the existing solution to maximize not only the scoring potential, but also system performance and safety. This report will cover the innovation design, the competition strategy, the design strategy, and the testing strategy. The innovation design is the implementation of innovative ideas that are not related to directly improving performance at the competition but deemed important in an overall capacity. The competition strategy focuses on

defining the team’s best point-scoring approach, while the design and testing strategies detail the work put in to successfully execute the competition strategy approach.

II. COMPETITION STRATEGY

The focus this year is to prepare the submarines to operate as efficiently as possible with newly developed technologies while improving their reliability. The objective is to build robust and optimized submarines capable of preventing issues like communication loss with the Doppler Velocity Log (DVL). Additionally, they improve the energy consumption of the LITE, the usage of the Jetson and provide more safety for the electrical components.

The chosen tradeoff is to prioritize the reliability of already integrated and mastered technology like the torpedo and droppers over new technology. This means the robotic arm and pingers are to be excluded from this year’s competition. The submarines are considered already complex and creating a solid base for the future is preferable. This will increase the ability to reach far more complex technology. However, the inter-submarine communication system will be considered in this year’s competition if all the team’s projects are within their respectful deadlines and submarines are able to complete the minimum required tasks set by the team.

The chosen competition strategy is designed to achieve two submarines working in collaboration to complete all possible tasks in their current state. The strategy has four levels, from least to most achievable strategy: minimum requirements, the

use of all working technologies, dual submarines and lastly, table strategy.

The strategy is designed to support different operating modes during the competition. It is a guideline that will allow the team to be able to adapt to any given situation that occurs during the competition, like one of the two submarines taken out of service.

1) Minimum strategy

This strategy ensures that LITE is fully operational. Firstly, the target will be to pass through the gate, which will demonstrate the reliability of the control system and if all electrical and mechanical components are in good condition. Secondly, the slalom to analyze how the mission system is working and the AI detection system's performance. Lastly, the return home of the submarine will showcase how much drift has been accumulated. These three missions are required to demonstrate that all minimum systems are tested and in good condition to perform at the competition. This strategy will serve as a backup if the AUV8.1 isn't operational for any given reason.

2) Use of all working technologies

This strategy is an evolution of the first strategy with the addition of new tasks that can only be performed by AUV8.1. This strategy is considered to have a good chance of getting to the third chance, the semi-final or the final.

The strategy adds tasks with the bin and torpedo, which were already integrated in the previous year. This strategy ensures both front and bottom cameras are operational. The order of operations is as follows: the submarine passes the gate, goes through the slalom, completes the task with the bins, completes the task with torpedoes and returns home to complete the mission.

3) Dual submarines

This strategy requires two operational submarines to achieve the fastest completion of all the previous tasks in addition to the octagon task.

The use of two submarines in the same run is a strategy the team has been aiming for during the year. With the success of this strategy, the team is guaranteed the final run in comparison to the previous year's performance.

The steps used in the strategy are to establish communication between the two submarines to determine how the submarines will operate. The LITE will pass through the gate, the slalom and complete its run with a return to home mission. During this operation, the AUV8.1 will directly move towards the bin task. After the completion of this task, it will move to the torpedoes and complete its run with a resurface in the octagon.

4) Table strategy

The strategy is used to the extent that all first three strategies are possible and if the team was able to complete the robotic arm project. It reuses the same strategy as the third strategy; however, the AUV8.1 will complete the table task before resurfacing in the octagon.

Missions	Minimal strategy	All systems	Two subs	Table
Lite	T	F	T	T
AUV8	F	T	T	T
Dropper	F	T	T	T
Torpedo	F	T	T	T
Communication	F	F	T	T
Octagon	F	F	T	T
Arms	F	F	F	T

Table 1: competition strategy table

III. DESIGN STRATEGY

A. Software Team Strategy

This year's objective for the software team is to solve all issues encountered during Robosub 2025 and optimize to further push the existing software. The main projects are the improvement of the mission system, a redesign of the AI and the integration of a new simulation.

1) AI

This year, the AI runner has been improved to optimize performance and reduce processing time. Previously, the detection system and all associated processing took between 250 ms to 2 seconds per image.

The processing time target was a constant 15 fps/ 66 ms. First, a rework of the current python code was realized, setting the time to 75 ms. To be

able to go under 66 ms, changing the format of the model used was necessary. The default format was onnx. While portable and executable on every computer, it doesn't fully optimize memory available on the GPU.

The new format used is TRT. Alone, it achieved a gain of 3 ms. To take it further, the compilation was configured to compile model from float 32 to float 16. This change achieved a general of 60 ms.

To further optimize capabilities, the code's language was changed from Python to C++ and CUDA. C++ has been chosen for communication on the ROS network and the usage of the CPU, while CUDA is used to push the preprocessing on the GPU. This offered substantial gains, with a time to process of 9 ms with the basic model and 50 detections.

Another improvement made for the AI part is detection training. To train the model, you need to have a data set labelled. This step was previously realized only by humans. To save time and effort, there is now a model trained to pre-label all images, so labellers only have to check and correct any anomalies. Furthermore, each obstacle will have a dedicated AI to specialize in detecting. Once the dataset and the precision of all the AIs are considered good, their data will be used to train another model that will be used to detect all the obstacles.

2) *Mission*

During Robosub 2025, the mission's files were split into two repositories. When some changes occurred on a part of the code, both had to be updated. To solve this problem, we combine the repository together to make only one. This change allows the mission system to become more reliable by guaranteeing proper updated files.

There was a complete remake of the way missions are made. Before starting coding, a decision schema needs to be made to accurately communicate the decision to the rest of the team. While coding, efficiency and flexibility are required to best promote autonomy in missions.

3) *New Simulation*

Repeatedly, certain versions of the simulation would work on some computers but not on others of the same specifications. To fix the problem, it

was decided to switch the new graphic simulation MATLAB provided for Robosub 2026, which directly integrates into Simulink.

B. Electrical Team Strategy

The electrical team plays a crucial role in providing the necessary infrastructure within the submarine. This includes the power distribution system, communication system, actuators, and motor control system. The electrical systems of AUV8.1 and LITE1 are presented in Fig. 1 and Fig. 2, respectively.

The heart of our submarine is the onboard computer (Xavier AGX). The Xavier is connected to the outside world and the DVL through an Ethernet connection. The other sensors (cameras, IMU, depth sensor, and acoustic modem) are connected through the USB bus. The remaining systems, namely the power management unit (PMU), the BMS, kill switch, and the actuator control board, are connected through an RS485 interface.

1) *BMS*

The Battery Management System (BMS) is the system that monitors the submarine batteries to ensure safe usage, prevent damage, and provides telemetry on the batteries. On a high level, the BMS monitors the input/output current of the battery, the voltage of all battery cells, and the temperature of the pack. Using this information, the system can determine the state of charge and state of health of the battery, allowing us to optimize battery usage. The same data can also be used to determine if the battery is operating within safe parameters (e.g., overcurrent, undervoltage, etc.). If a parameter falls outside the safe operating window, the high-current path of the battery can be interrupted using power MOSFETs.

This year, we modified our BMS design to increase the supported output current from 50 to 90 A. This allows us to use our BMS system with Lite1, as this system is powered by only one

battery instead of two, which increases the load on the remaining battery. We achieved an increased current output by improving the cooling management of various parts of the BMS, notably the power MOSFETs. We also added new functionality to the BMS with new permanent failure modes and a new black box feature.

The permanent failure mode provides an additional safety layer by permanently disabling the battery should other safety mechanisms fail. For example, if the power MOSFETs fail to interrupt the high-power path of the batteries, the battery pack can be disabled. This safety layer is implemented using a triggerable fuse controlled by an external MOSFET. The fuse includes a small heating element that can trigger the fuse, permanently interrupting the path between the battery and the rest of the system.

The black box system constantly records the state of the BMS as well as the values of the BMS sensors. This can assist the team in understanding why a specific safety condition was triggered. This would be particularly useful in the case of a permanent failure, as the BMS chip could be extracted from the system and analyzed.

In summary, we modified our BMS system to both increase the level of protection and support our second submarine. This should help us avoid dangerous situations, while also helping us optimize battery usage and increase our testing time.

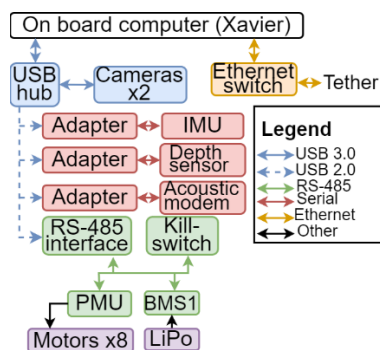


Fig. 1. LITE1's electrical architecture

2) Inter-vehicle Communication

To develop a system of communication between submarines, two options were available to us, developing acoustic communications or visual communications using LEDs. Acoustic communications needed a lot more development time than the LED, so the visual communication method was chosen. This offers a second advantage, as communications are easy to add and are readable by a human, at the cost of needing to align the submarines to communicate. Therefore, it is only usable at the start of a run, to always make sure to engage communications with the other sub.

A third advantage is the ability to display important information specifically for the operator or the diver without the need to have the submarine connected to the operator. This is a great improvement for the safety of the submarine. Information like battery status and state of the submarine can be displayed and read easily.

C. Mechanical Team Strategy

The Mechanical Team's strategy primarily focuses on system modifications promoting reliability and consistency over newer features.

1) Torpedo

Due to the error in the unit of measurement in the first versions of Robosub's Team time, we were asked to deploy the torpedoes from 1.5 meters to receive the maximum number of points. While the error was later corrected in the documentation, the mechanical team decided to take on the challenge for Robosub 2026.

To effectively add distance to the torpedo's range, they are made using the same fabrication method as the flotation additions from 2025 (S.O.N.I.A., 2025). This method consists of 3D printed ASA with a smooth surface finish. The smooth surface finish is achieved by letting the 3D printed part in a custom-made vapour chamber filled with acetone to close surface porosity and smoothen the surface.

Manufacturing using 3D printing gives the opportunity to control the torpedo density. The torpedoes are made to have a slightly lower density than water, making them float up to the surface after completing its trajectory. The smooth

hydrodynamic shape, optimized with the surface treatment, reduces the drag, helping us reach a firing distance up to 1.5 m. Closing the surface porosity also helps the part keep its light density by not capturing water.

2) *AUV8.1 internal racking*

During the Robosub 2025 competition, one of the major problems the team had was a frequent loss of connection to the DVL. This caused a loss of practice time and ultimately prevented us from utilizing both submarines to their fullest extent. The most realistic hypothesis is that the wire attached from the external DVL to its communicating port had a too small bent radius, which caused the disconnection.

To remove this problem, the placement of internal components has been modified by redesigning electrical component racking in AUV8.1. To fix the connection issues, the DVL is secured in a position that minimizes any movement of the connecting wire and keeps it at an acceptable bent radius. The other components were adapted to the unique interior shape as to optimize cable management and ease of access during assembly.

The new racking has prevented any new loss of connection to the DVL during the 80 hours of testing so far and is to be considered a success.

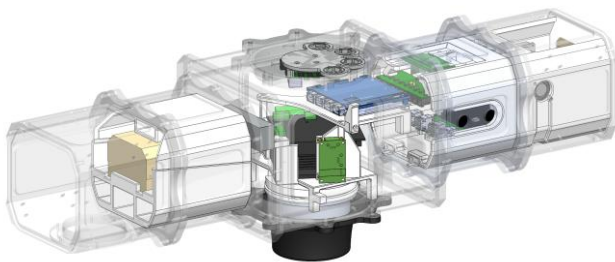


Fig. 2. AUV8.1's new internal racking

3) *LITE1 cover redesign*

A problem that occurred last year was the buoyancy of the LITE1 prototype, which was too high and was making the prototype float to the surface. Steel plates were added inside the hull as a temporary solution to add some weight. To remove that added weight while keeping the

buoyancy at a good balance, the top part of the hull was redesigned.

Preliminary analysis showed that by flattening the cover and removing the steel plates, a buoyancy of 14% was achievable. However, by keeping the plates and installing the new cover, it would reduce to 2%, adding a considerable amount of control capabilities to the submarine as well as surpassing the initial goals of the project. Calculated data will be confirmed with physical testing once the manufacturing is done, and the steel plates will be adjusted to achieve close to perfect buoyancy.

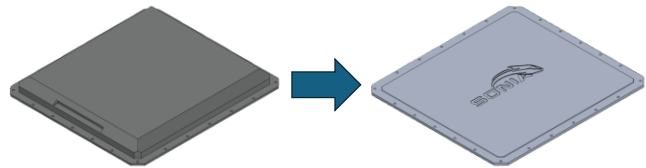


Fig. 3. New cover of LITE1

4) *Duckbox and tether*

The communication speed between the submarine and the software team had several chokepoints that have been improved upon. The previous tether was suspected of being a cause of slowed data transfer and upon inspection of the wires, corrosion was found in and around flexing points. A gel-filled ethernet cable was chosen to prevent any future corrosion issues. A major change was doubling the number of wire pairs soldered, effectively increasing the transfer speed.

Furthermore, the Duckbox has been updated with newer components. The Duckbox is composed of an onboard computer, a router and, up until this year, a switch. The on-board computer the NVIDIA TX2 has been replaced with a Lenovo Thinkstation P330 tiny. Its Wi-Fi chip improves the internet connection and now provides reliable performance, even in high-traffic network environments like at the competition. This computer's specifications allow the team to develop new quality of life projects, such as the implementation of Gitea. Gitea is a tool that allows hosting and managing repositories locally, reducing dependency on GitHub. This way, when an internet connection is not reliable or not

available, the team can continue working on the local Duckbox network without interruptions. The switch has been removed from the Duckbox design, as the number of connections is no longer a problem and it had the smallest data throughput of the system.

The improvements to the tether and the Duckbox have achieved an increase in speed from a theoretical 10mb/s (1mb/s in practice) to a tested 1Gb/s.

IV. TESTING STRATEGY

A. Software Testing Strategy

1) Simulation environment

Before conducting tests in a real environment, we utilized the Unreal environment to test our missions and filters. This simulation allowed us to replicate the real trajectory missions of the submarine, employing both AI and conventional vision within a virtual environment.

2) Communication inter-sub and mission

We have conducted tests for the communication inter-submarine alongside other tests to check the reliability of the communication and test if the task selected was correctly transmitted and executed.

B. Electrical Testing Strategy

Most of the electrical systems have been reused in previous years. As such, most of them had already been validated. Therefore, this year, most of our testing efforts regarding the electrical systems were focused on the BMS.

1) BMS

This year, we extensively tested the BMS system to validate its performance. To do so, we created a test bench with a high-power load and a high-current power supply. This test bench allowed us to validate the various safety protections of the BMS, as well as confirm its current output capability. The same setup was also used to calibrate the BMS sensors.

While most tests were relatively straightforward, our biggest challenge was managing the power output of the BMS. We

solved this problem by sourcing a high-power load for the BMS and adding active cooling to the system.

C. Mechanical Testing Strategy

The most important mechanical testing procedure is the watertightness 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. To test for leaks, the internal hull is put under negative pressure. In case of a leak, the AUV will quickly regain normal pressure.

By implementing thorough software, electrical, and mechanical testing strategies, we ensure the reliability, performance, and readiness of our submarines for the competition.

ACKNOWLEDGMENT

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Bronze: Anodisation Expert, Blue Robotics, Flex-Kote, Blue Trail engineering, Fila3D, Ordre des ingénieurs du Québec.

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APPENDIX A
COMPONENT SPECIFICATIONS (AUV8.1)

Component	Vendor	Model/Type	Specs	Custom/ Purchased	Cost	Year of purchase
Buoyancy Control	-	Added Volume	Foam and 3D print pieces	Custom	150\$	2025
Frame	Homemade	CNC aluminium system	6061-T6 CNC machined, anodized and painted	Custom	-	2020 2024
Waterproof Housing	Homemade	CNC aluminium system	6061-T6 CNC machined, anodized and painted	Custom	8 000\$	2020 2024
Waterproof Connectors	MacArtney	Subconn connector	Wet Mate	Purchased	5000\$	2020 2025 2026
Thrusters	Blue Robotics	T200 (x8)	0.02 kg f	Purchased	200\$/each	2019
Motor Control	Emax	Bullet Series ESC (x8)	30A	Purchased	15\$/each	2019
High Level Control	-	LTV MPC	-	Custom	-	2022
Actuators	-	Droppers only	Solenoid Activation	Custom	-	2022
Battery	MaxAmps	4S 16000mAh	14.8V	Purchased	2000\$	2020-2024
Regulator	3V3	SONIA AUV	16V to 3V3	Custom	8\$	2024
CPU	Nvidia	Jetson AGX Xavier	32GB RAM	Purchased	2000\$	2020
Internal Comm Network	-	RS485	4 twisted pairs Ethernet cables	Custom	-	2025
External Comm Network	ConnectTech	XDG021	1000 Mbps Switch	Purchased	-	2026
Compass	VectorNav	VN-100 Rugged AHRS	Standard calibration +25°C	Purchased	-	2022
Inertial Measurement Unit (IMU)	VectorNav	VN-100 Rugged AHRS	Standard calibration +25°C	Purchased	-	2022
Doppler Velocity Log (DVL)	Teledyne	Pathfinder	600kHz,140m	Purchased	20 000\$	2020
Manipulator	-	-	-	-	-	-
Vision (front)	Stereolab	ZED mini	30FPS, 4MP	Purchased	400\$	2025
Vision (bottom)	Flir	Chameleon 3 USB	55FPS, 3.2MP	Purchased	600\$	2020
Acoustics	Bruel & Kjaer	8103	0.1 to 180kHz	Purchased	-	2020
Inter-vehicule communication	SONIA AUV	PCB	LED communication	Custom	60\$	2026
Algorithms: Vision	Ultralytics Nvidia	YOLO TensorRT	- -	Custom Custom	- -	2026 2026
Algorithms: Acoustics	-	-	-	-	-	-
Algorithms: Localization and Mapping	Matlab	Extend Kalman Filter	50hz	-	-	2021
Algorithms: Autonomy	Behavior tree	Finite-state-machine	-	Custom	-	2024
Open-source software	OpenCv, Behavior tree, TensorRT, ROS2, Unreal Engine, WikiJS, Github					
Team Size	17					
Expertise ratio	11/17					
Testing time: simulation	75 hours					
Testing time: in- water	130 hours					
Programming Languages	C/C++, Bash, Python, Matlab, Simulink, CUDA					

APPENDIX B
COMPONENT SPECIFICATIONS (LITE)

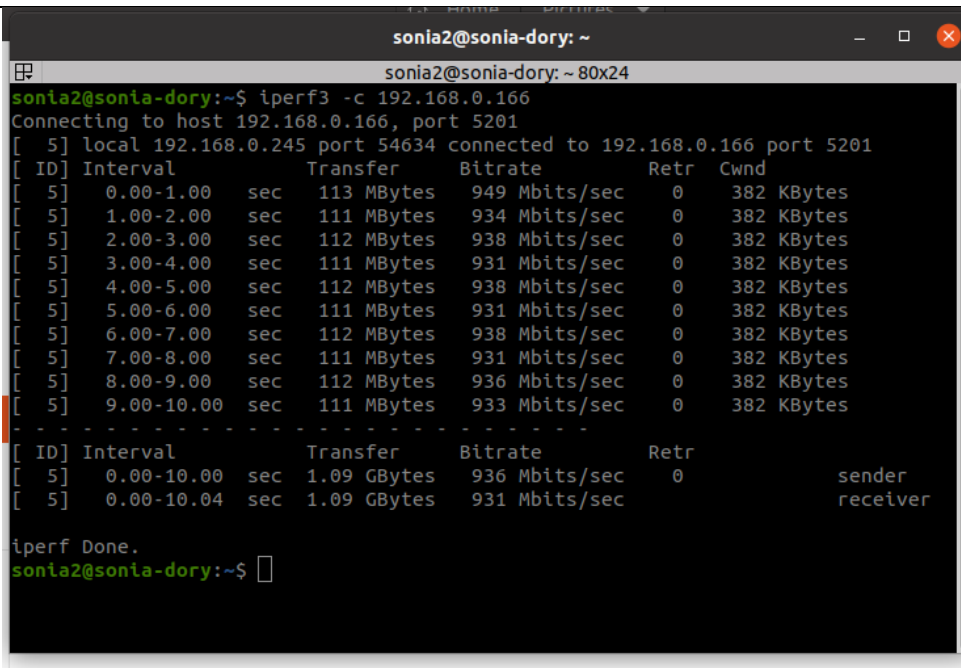
Component	Vendor	Model/Type	Specs	Custom/ Purchased	Cost	Year of purchase
Buoyancy Control	-	-	-	-	-	-
Frame	Homemade	CNC aluminium system	6061-T6 CNC machined, colored anodize	Custom	600\$	2025
Waterproof Housing	Homemade	CNC aluminium system	6061-T6 CNC machined, Powder coated	Custom	4 000\$	2025
Waterproof Connectors	MacArtney	Subconn connector	Wet Mate	Purchased	2500\$	2025
Thrusters	Blue Robotics	T200 (x8)	0.02 kg f	Purchased	200\$/each	2025
Motor Control	Emax	Bullet Series ESC (x8)	30A	Purchased	15\$/each	2025
High Level Control	-	LTV MPC	-	Custom	-	2025
Actuators	-	-	-	-	-	-
Battery	MaxAmps	4S 16000mAh	14.8V	Purchased	1000\$	2025
Regulator	3V3	SONIA AUV	16V to 3V3	Custom	8\$	2024
CPU	Nvidia	Jetson AGX Xavier	32GB RAM	Purchased	2000\$	2019
Internal Comm Network	-	RS485	4 twisted pairs Ethernet cables	Custom	-	2025
External Comm Network	ConnectTech	XDG021	1000 Mbps Switch	Purchased	-	2026
Compass	VectorNav	VN-100 Rugged AHRS	Standard calibration +25°C	Purchased	-	2022
Inertial Measurement Unit (IMU)	VectorNav	VN-100 Rugged AHRS	Standard calibration +25°C	Purchased	-	2022
Doppler Velocity Log (DVL)	-	-	-	-	-	-
Manipulator	-	-	-	-	-	-
Vision (front)	Stereolab	ZED 2i	30FPS, 4MP	Purchased	550\$	2025
Vision (bottom)	-	-	-	-	-	-
Acoustics	-	-	-	-	-	-
Inter-vehicule communication	SONIA AUV	PCB	LED communication	Custom	60\$	2026
Algorithms: Vision	Ultralyrics Nvidia	YOLO TensorRT	- -	Custom Custom	- -	2026 2026
Algorithms: Acoustics	-	-	-	-	-	-
Algorithms: Localization and Mapping	Matlab	Extend Kalman Filter	50hz	-	-	2021
Algorithms: Autonomy	Behavior tree	Finite-state-machine	-	Custom	-	2024
Open-source software	OpenCv, Behavior tree, TensorRT, ROS2, Unreal Engine, WikiJS, Github					
Team Size	17					
Expertise ratio	11/17					
Testing time: simulation	75 hours					
Testing time: in-water	80 hours					
Programming Languages	C/C++, Bash, Python, Matlab, Simulink, CUDA					

Appendix [B] : Test plan and results

Test: Router communication speed test
ID: TEST-LOG-ROUTER-001-V1 REV: V1-0
Scope: Verify the speed communication in the router

Version	Date	Changes
V1-0	11/09/2025	Initial document creation

Start: 11/09/2025, 16 h 15 End: 11/09/2025, 16 h 30 Deadline: 11/09/2025, 23 h 59	Short result: The communication speed is 931 Mb/s.
Resource and Tools: <u>Hardware:</u> 2x Laptop (one client and one server) 2x Ethernet cable 1x Router	
Environment: In a clean working environment.	
Risk Management: Keep water, moisture and dust away from the inside of the Duckbox.	
Procedure: <ol style="list-style-type: none"> 1. Connect the server laptop to the router with an ethernet cable. 2. Connect the client laptop to the router with the second ethernet cable. 3. Open a terminal on the server laptop and run the following command on it; “Iperf3 -s” 4. Open a terminal on the client laptop and run the following command on it; “iperf3 -c <The-client-laptop-ip-address>” 	
Pass / Fail criterion: The communication speed needs to be around 1 Gb/s +/- 100 Mb/s	
Results:	



```
sonia2@sonia-dory: ~
sonia2@sonia-dory: ~ 80x24
sonia2@sonia-dory:~$ iperf3 -c 192.168.0.166
Connecting to host 192.168.0.166, port 5201
[ 5] local 192.168.0.245 port 54634 connected to 192.168.0.166 port 5201
[ ID] Interval          Transfer          Bitrate          Retr  Cwnd
[ 5]  0.00-1.00      sec    113 MBytes    949 Mbits/sec    0   382 KBytes
[ 5]  1.00-2.00      sec    111 MBytes    934 Mbits/sec    0   382 KBytes
[ 5]  2.00-3.00      sec    112 MBytes    938 Mbits/sec    0   382 KBytes
[ 5]  3.00-4.00      sec    111 MBytes    931 Mbits/sec    0   382 KBytes
[ 5]  4.00-5.00      sec    112 MBytes    938 Mbits/sec    0   382 KBytes
[ 5]  5.00-6.00      sec    111 MBytes    931 Mbits/sec    0   382 KBytes
[ 5]  6.00-7.00      sec    112 MBytes    938 Mbits/sec    0   382 KBytes
[ 5]  7.00-8.00      sec    111 MBytes    931 Mbits/sec    0   382 KBytes
[ 5]  8.00-9.00      sec    112 MBytes    936 Mbits/sec    0   382 KBytes
[ 5]  9.00-10.00     sec    111 MBytes    933 Mbits/sec    0   382 KBytes
-----
[ ID] Interval          Transfer          Bitrate          Retr
[ 5]  0.00-10.00     sec    1.09 GBytes    936 Mbits/sec    0
[ 5]  0.00-10.04     sec    1.09 GBytes    931 Mbits/sec
sender
receiver
iperf Done.
sonia2@sonia-dory:~$
```

The router has a data communication speed of 931 Mb/s.

References:

Link : "IPERF3 User manuals" arch Linux Link : <https://man.archlinux.org/man/iperf3.1.en>

Appendix C: Test plan and results 1

Test: Tether communication speed test
ID: TEST-LOG-TETHER-001-V1
REV: V1-0
Scope: Verify the speed communication in the tether

Version	Date	Changes
V1-0	11/09/2025	Initial document creation

Start: 11/09/2025, 16 h 00 End: 11/09/2025, 16 h 15 Deadline: 11/09/2025, 23 h 59	Short result: The communication speed is 930 Mb/s.
--------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------

Resource and Tools:	
<u>Hardware:</u> 2x Laptop (one client and one server) 1x Tether 1x LITE	<u>Tools:</u> 2x 8 mm keys

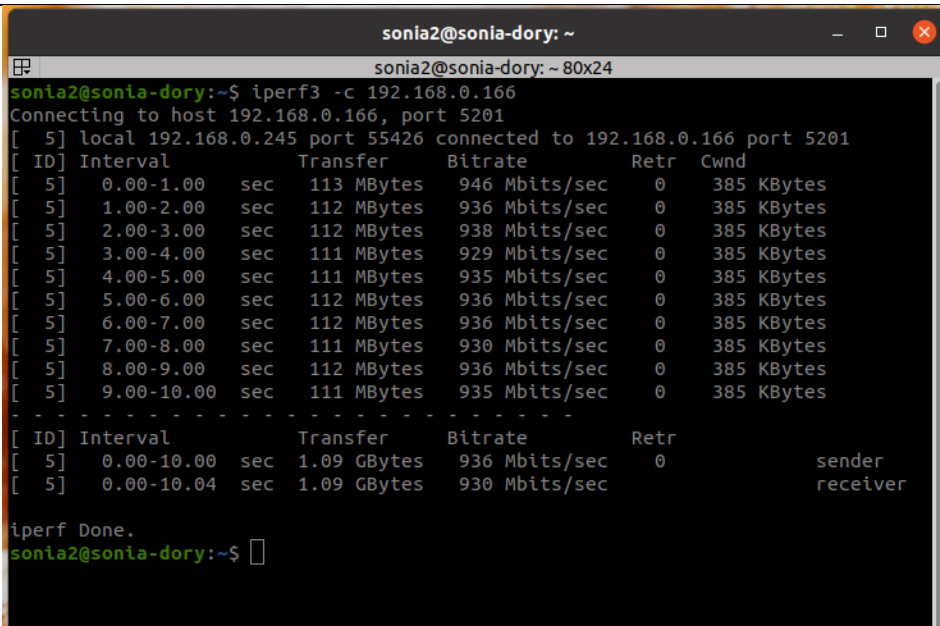
Environment: In a clean working environment.

Risk Management: Keep water, moisture, dust away from the inside of the submarine.

Procedure: <ol style="list-style-type: none"> 1. Connect the tether in the submarine communication port. 2. Connect the other side of the tether in the server laptop ethernet connection port. 3. Open the submarine cap to access the ethernet plug inside it. 4. Plug the ethernet port inside the submarine directly in the ethernet port of the client laptop 5. Open a terminal on the server laptop. 6. Run the following command on it: Iperf3 -s 7. Open a terminal on the client laptop: 8. Run the following command on it: iperf3 -c <The-server-laptop-ip-address>

Pass / Fail criterion: The communication speed needs to be around 1 Gb/s +/- 100 Mb/s

Results:

A screenshot of a terminal window titled 'sonia2@sonia-dory: ~'. The terminal shows the execution of the 'iperf3 -c 192.168.0.166' command. It displays connection details and a table of performance metrics over 10-second intervals. The average transfer rate is 930 Mb/s. The terminal output is as follows:

```
sonia2@sonia-dory:~$ iperf3 -c 192.168.0.166
Connecting to host 192.168.0.166, port 5201
[ 5] local 192.168.0.245 port 55426 connected to 192.168.0.166 port 5201
[ ID] Interval           Transfer             Bitrate             Retr  Cwnd
[ 5]  0.00-1.00   sec    113 MBytes        946 Mb/s             0    385 KBytes
[ 5]  1.00-2.00   sec    112 MBytes        936 Mb/s             0    385 KBytes
[ 5]  2.00-3.00   sec    112 MBytes        938 Mb/s             0    385 KBytes
[ 5]  3.00-4.00   sec    111 MBytes        929 Mb/s             0    385 KBytes
[ 5]  4.00-5.00   sec    111 MBytes        935 Mb/s             0    385 KBytes
[ 5]  5.00-6.00   sec    112 MBytes        936 Mb/s             0    385 KBytes
[ 5]  6.00-7.00   sec    112 MBytes        936 Mb/s             0    385 KBytes
[ 5]  7.00-8.00   sec    111 MBytes        930 Mb/s             0    385 KBytes
[ 5]  8.00-9.00   sec    112 MBytes        936 Mb/s             0    385 KBytes
[ 5]  9.00-10.00  sec    111 MBytes        935 Mb/s             0    385 KBytes
-----
[ ID] Interval           Transfer             Bitrate             Retr
[ 5]  0.00-10.00  sec    1.09 GBytes        936 Mb/s             0
[ 5]  0.00-10.04  sec    1.09 GBytes        930 Mb/s             0
iperf Done.
sonia2@sonia-dory:~$
```

The tether communication speed is 930 Mb/s.

References:

Link : "IPERF3 User manuals" arch Linux Link : <https://man.archlinux.org/man/iperf3.1.en>

Appendix D : Test plan and results

<p>Test: Blackbox: Battery Management System (BMS) simulation Overtemperature: Battery Management System (BMS) protection simulation</p>
<p>ID: ELE-BMSV1-PS1 REV: 1.1 Profile False PF simulation</p>
<p>Scope: Observe the BMS reaction while doing a charge, normal charge, discharge, overdischarge, extended discharge, short circuit, overheat. Monitor the data of the Blackbox when simulating a permanent failure</p>


Version	Date	Changes
V1-0	[02/02/2026]	
V1-1	[04/20/2026]	Added images

<p>Start: 02/23/2026 End: 02/23/2026 Deadline: [05/04/2026]</p>	<p>Short result: The protections worked as expected when simulating hot temperature and failure data saved</p>
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Resource and Tools


Hardware:

- EV2400




Computer: Windows 10 x64 Based

Thermal Camera




Software Application:

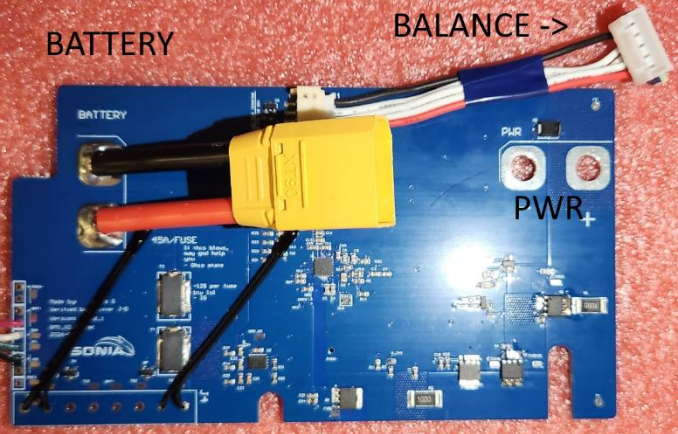
BQStudio



Microsoft's Excel 2024



Test subject
BMS E25 R2



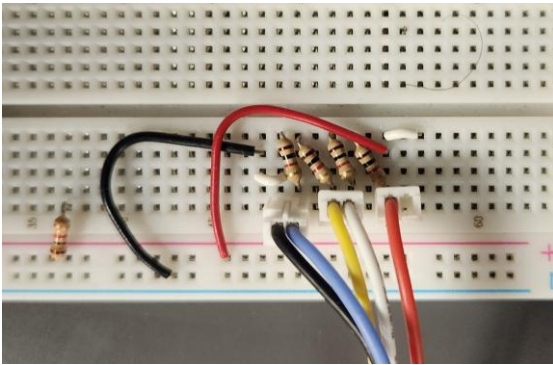
Power supply



Test subject
One Batterie



Breadboard balance simulation board



Heat gun



Others: USB A-A Cable
XT60 Custom cables
Wall plug power cable

Environment:

1. The overtemperature and black box validation tests were performed in a controlled laboratory environment without using a real battery pack. A resistor network mounted on a breadboard was used to simulate the individual battery cells connected to the BMS.
2. The setup included a programmable power supply to emulate pack voltage conditions, a heat gun to artificially increase the BMS temperature, and an external temperature probe to independently monitor thermal behavior during testing.

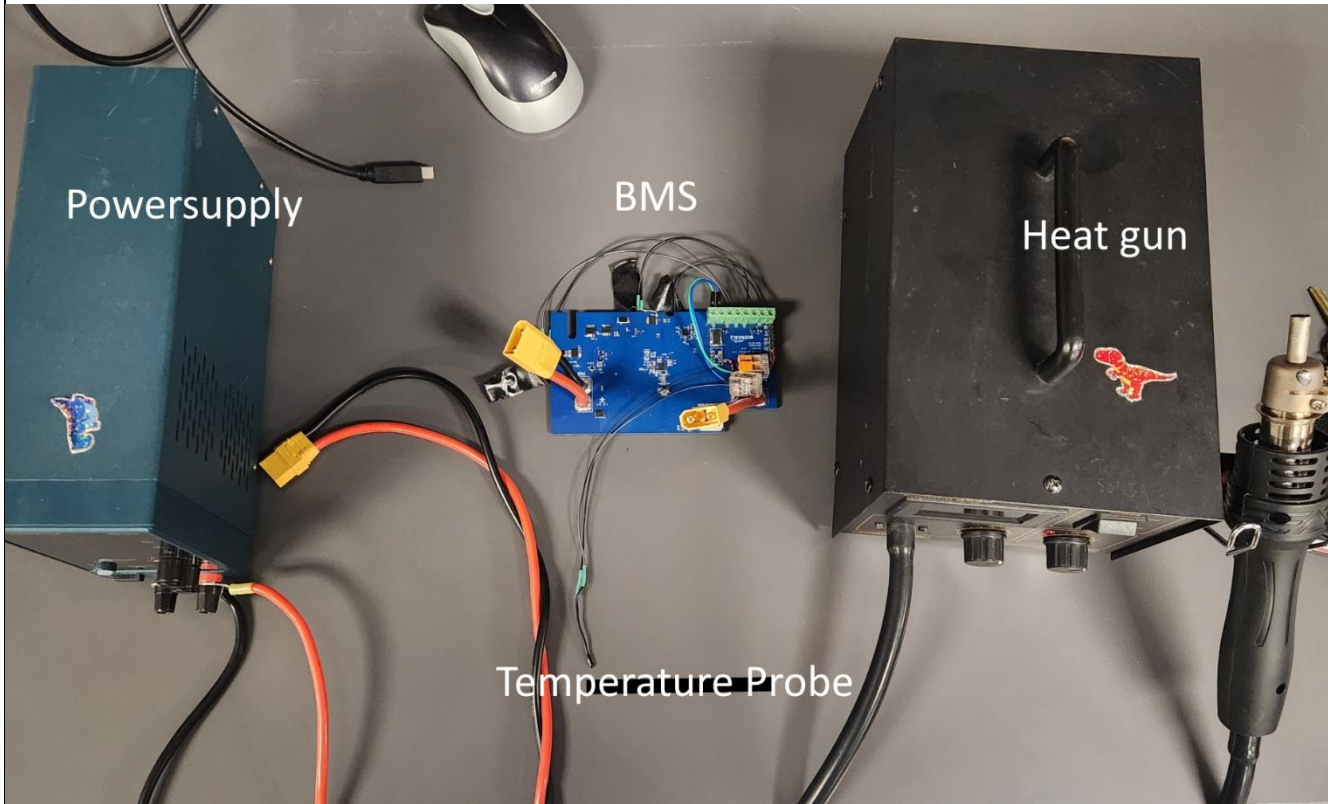


Figure 1 Test equipment

Risk Management:

⚠ Applying heat directly to the PCB using a heat gun could potentially overheat components or damage the board. Heat was applied progressively while continuously monitoring the temperature using both onboard sensors and an external temperature probe.

⚠ The temperature probes were connected through long wires to keep operators and monitoring equipment at a safer distance from the heated PCB and reduce the risk of accidental thermal damage.

⚠ The breadboard setup and floating wires introduced risks of accidental short circuits, unstable electrical connections, or unintended contact with energized conductors. All connections were inspected before energizing the setup, and the system remained continuously supervised during testing.

⚠ The heat gun itself presented a burn hazard due to its high operating temperature and exposed metal nozzle. Personnel avoided contact with heated surfaces and maintained safe handling distances throughout the test.

⚠ Since no real lithium battery was used during the experiment, the thermal and fire risks were significantly reduced compared to testing with a fully charged battery pack.

Procedure:

3. Connect the programmable power supply to the BMS power terminals.
4. Connect the breadboard balance connections simulating the battery cells to the BMS balance connector.
5. Power the breadboard through the PCB debugging test points used for voltage injection and signal validation.
6. Connect the BMS to the EVM.
7. Start the BMS by injecting a voltage at the input using the battery as the source (only required the first time the battery is connected) ⁽¹⁾.

¹ When initially disconnected, the BMS considers itself in undervoltage mode and will remain disabled until a charging condition is detected. This can be simulated by injecting voltage from the battery on the charging side

Test : Overtemperature (30 °C) and Blackbox**Procedure:**

1. Disable the fuse protection through BQStudio before beginning the test.
 - Normally, a Permanent Failure (PF) event would force the BMS to permanently stop operation and potentially blow the chemical fuse to isolate the battery pack for safety reasons. For this validation test, the fuse was intentionally disabled to allow controlled triggering of PF conditions without permanently damaging the hardware.
2. Enable the configured black box Permanent Failure logging feature in BQStudio.
 - The black box memory records diagnostic information whenever a PF event occurs, including voltage, current, temperature, battery gauging information, triggered protection flags, and watchdog states such as UV (Undervoltage), OV (Overvoltage), and more.
3. Enable the thermal protection failure monitoring and verify the temperature calibration values in BQStudio.
 - Compare the reported temperatures with the external temperature probe measurements and recalibrate the readings if necessary.
4. Progressively increase the Temperature probe (*Figure 1 Test equipment*) using the heat gun while continuously monitoring the BMS behavior in BQStudio.
5. Observe the thermal status transitions reported by the BMS:
 - LT = Low Temperature
 - MT = Moderate Temperature
 - HT = High Temperature
6. Continue heating until the system reaches the HT thermal region and monitor whether the BMS triggers a Permanent Failure event.
7. If a PF event is triggered, access the black box memory through BQStudio and review the recorded diagnostic information, including:
 - Cell voltages
 - Pack current before the failure
 - Temperature measurements
 - Triggered protection flags
 - Active watchdog states
 - Time elapsed since the previous PF event

Pass / Fail criterion:

- The fuse protection is correctly disabled, allowing controlled Permanent Failure (PF) triggering without permanently disabling the hardware.
- The black box logging system correctly records PF events and stores diagnostic information including voltage, current, temperature, triggered flags, and watchdog states.
- The thermal state transitions (LT, MT, HT) are correctly detected and reported in BQStudio as the PCB temperature increases.
- The BMS triggers the expected thermal protection or Permanent Failure event when the configured overtemperature threshold is exceeded.
- The black box memory remains readable after the PF event and contains valid diagnostic data associated with the protection trigger.
- No permanent hardware damage, uncontrolled overheating, smoke, or unsafe electrical behavior is observed during the test.

Overtemperature Results:

The configured thermal Permanent Failure threshold was intentionally set to 30 °C for validation purposes. During testing, the BMS correctly triggered the PF event when the measured temperature reached approximately 30 °C. when triggered, the thermal state reported by the BMS was LT

The reduced threshold simplified validation and improved safety by avoiding excessive heating of the PCB and nearby equipment. Under normal operating conditions, the system is configured for significantly higher safe operating temperatures, with thermal transitions configured around 30 °C for LT/MT behavior and approximately 45 °C for HT (High Temperature).

The overtemperature protection successfully demonstrated that the BMS could detect abnormal thermal conditions and react according to the configured protection settings.

Black Box Results:

The black box memory successfully recorded the Permanent Failure event triggered during the overtemperature test. The stored diagnostic information included the triggered PF condition, temperature readings, cell voltages, watchdog and protection flags, pack current, and timing information related to previous PF events.

Since no electrical load was connected during the experiment, the recorded current remained near zero and the cell voltages stayed within normal operating conditions throughout the test. The logged data confirmed that the failure was caused exclusively by the configured thermal protection trigger.

The black box functionality demonstrated that the BMS could retain detailed fault information after a protection event, allowing post-failure analysis directly through BQStudio. This diagnostic system can also be used to investigate other fault conditions such as short circuits, overcurrent, overvoltage, undervoltage, and additional Permanent Failure protections configured within the BMS.

References:

Datasheet (2): <https://www.ti.com/lit/ug/sluubz5/sluubz5.pdf?ts=1732297886825>

Appendix E: Test plan and results

Test: Charge: Battery Management System (BMS) protection simulation
ID: ELE-BMSV2-PS2
REV: 1.2 Profile test for higher current (40A- >80A)
Scope: Observe the BMS reaction while doing a charge, normal charge, discharge, overdischarge, extended discharge, short circuit, overheat

Version	Date	Changes
V1-0	[02/02/2026]	
V1-1	[04/20/2026]	Added images
V1-2	[04/26/2026]	Increased the BMS charge current limit

Start: 03/04/2026 End: 03/04/2026 Deadline: [05/04/2026]	Short result: The protections worked as expected when simulating an overcharge
-------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------

Resource and Tools
Hardware:

EV2400




Charger and power supply Reaktor
 Quadkore 300W




Computer:
 Windows 10 x64 Based

Software
Application:

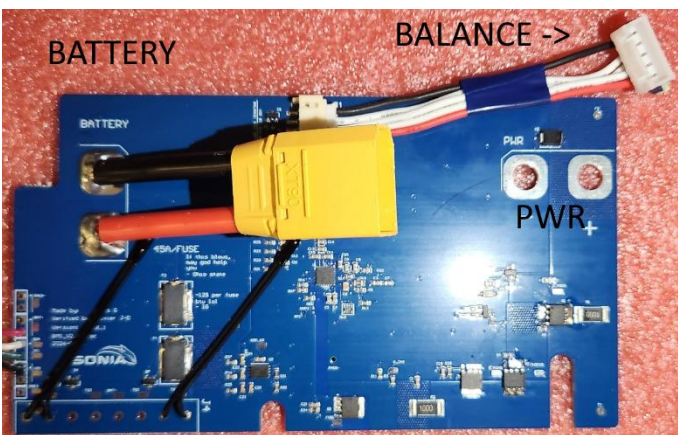
BQStudio



Microsoft's Excel 2024



Test subject
BMS_E25_R2



Thermal Camera

Others: USB A-A Cable
XT60 Custom cables
Wall plug power cable

Battery**Environment:**

8. The test was conducted in an authorized battery testing area designated for high-power electrical systems. The complete test protocol was reviewed and approved by Christian Belleau, the lead engineer overseeing all engineering clubs.
9. Testing was performed in an isolated and controlled room with restricted access. Safety measures included a sand bucket for lithium battery fire suppression, a fire-resistant cabinet for prolonged testing, continuous monitoring during operation, emergency shutdown procedures, and verification of all electrical connections before energizing the system.



Figure 2 Test equipment

Risk Management:

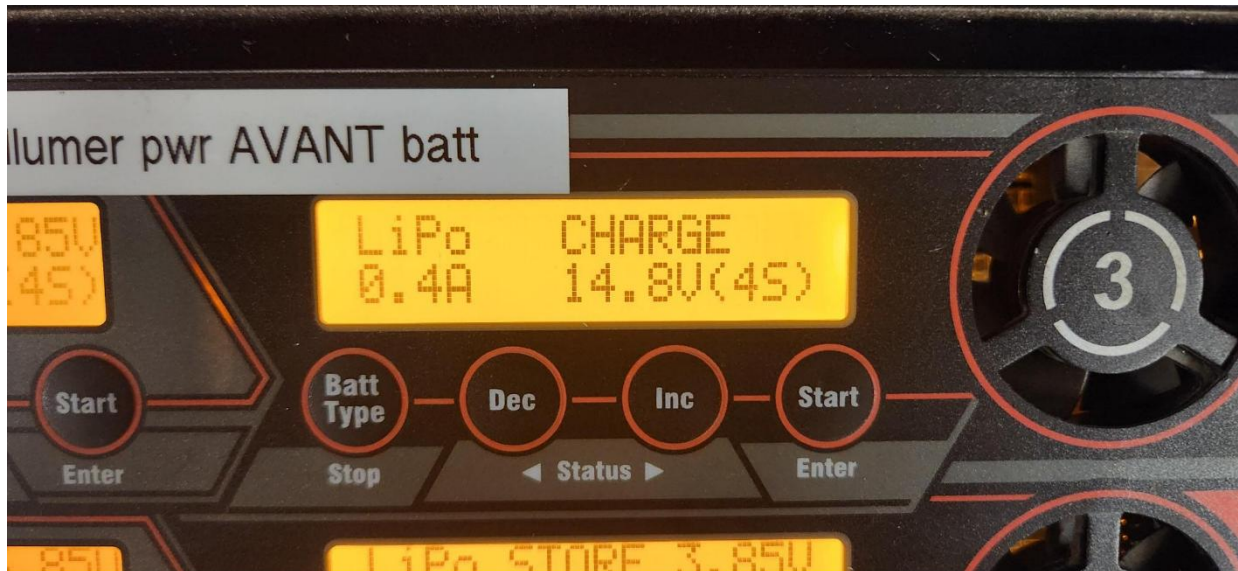
⚠ Incorrect handling could potentially damage the battery or create unsafe operating conditions. To reduce risk, all tests were performed with multiple team members supervising the procedure to verify manipulations and monitor system behavior. Testing was also conducted in a designated battery testing area equipped to safely manage potential battery ignition incidents, helping protect both personnel and the building infrastructure.

⚠ An overdischarge condition can potentially overheat not only the PCB, but also the connected equipment such as the charger, cables, and battery pack. To improve operational safety, a thermal camera was used throughout testing to continuously monitor the temperature of all critical components and quickly detect abnormal heat buildup.

Procedure:

1. Connect the battery to the BMS.
2. Connect the balance wires to the BMS.
3. Connect the BMS to the EV2400 (I2C and GROUND signal).
4. Start the BMS by injecting a voltage at the input using the battery as the source (only required the first time the battery is connected) ⁽¹⁾.
5. Connect the charger to the power side of the BMS.
6. Put the charger in normal Charging mode (not Balance Charge, since balancing is handled by the BMS).

(1) When initially disconnected, the BMS considers itself in undervoltage mode and will remain disabled until a charging condition is detected. This can be simulated by injecting voltage from the battery on the charging side

**Multiple test options****Fast Charge Test****Procedure:**

10. Set the charging current between 10 A and 16 A.
11. Verify that the battery state of charge is below 40% using BQStudio. If the battery exceeds this threshold, discharge the pack until the condition is met.
12. Start the charging process while continuously monitoring pack voltage, cell voltages, current, and temperature.
13. Continue charging for more than 40 minutes.

14. If the battery is not fully charged after 40 minutes, the BMS will automatically stop the fast charge process. Fast charging is intentionally time-limited to reduce thermal stress and improve power safety. Refer to the BQ40Z80 Technical Datasheet for additional details regarding the associated protection flags and safety functions (2).

Pass / Fail criterion:

- The BMS maintains stable charging operation between 10 A and 16 A.
- No unintended protection fault is triggered during normal fast charging operation.
- Temperatures of the PCB, battery, charger, and cables remain within safe operating limits.
- The BMS correctly terminates fast charging after the allowed operating duration if required.
- No abnormal behavior, smoke, odor, or excessive heating is observed.

Results:

The charging tests were successful. The BMS triggered the expected protection flags when the configured charge limits were reached, confirming that the protection behavior operated as intended. The battery, PCB, cable, and charger temperatures remained controlled during testing, with no abnormal heat buildup observed. The charge/discharge manipulation also helped improve the BMS understanding of the battery chemistry through its Impedance Track gauging behavior, which uses charge, voltage, current, temperature, and impedance data to improve state-of-charge estimation.

References:

Datasheet (2): <https://www.ti.com/lit/ug/sluubz5/sluubz5.pdf?ts=1732297886825>

Appendix F : Test plan and results

Test: Discharge: Battery Management System (BMS) protection simulation
ID: ELE-BMSV2-PS3
REV: 1.2 Profile test for higher current (40A- >80A)
Scope: Observe the BMS reaction while doing a charge, normal charge, discharge, overdischarge, extended discharge, short circuit, overheat. Monitor the data of the Blackbox when simulating a permanent failure


Version	Date	Changes
V1-0	[02/02/2026]	
V1-1	[04/20/2026]	Added images
V1-2	[04/26/2026]	Increased the BMS charge current limit

Start: 04/26/2026 End: 04/26/2026 Deadline: [05/04/2026]	Short result: The protections worked as expected when simulating high power discharge
-------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------


Resource and Tools

Hardware:

- EV2400



- Charger and power supply Reaktor Quadkore 300W




- Computer: Windows 10 x64 Based


Software

Application:

BQStudio

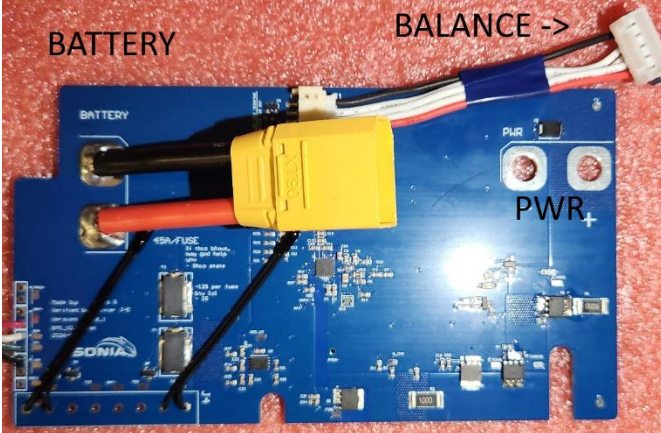




Microsoft's Excel 2024



Test subject

BMS E25 R2



<p>Thermal Camera</p>  <p>Others: USB A-A Cable XT60 Custom cables Wall plug power cable</p>	<p>Two Batteries</p> 
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Environment:

15. The test was conducted in an authorized battery testing area designated for high-power electrical systems. The complete test protocol was reviewed and approved by Christian Belleau, the lead engineer overseeing all engineering clubs.
16. Testing was performed in an isolated and controlled room with restricted access. Safety measures included a sand bucket for lithium battery fire suppression, a fire-resistant cabinet for prolonged testing, continuous monitoring during operation, emergency shutdown procedures, and verification of all electrical connections before energizing the system.



Figure 3 Test equipment

Risk Management:

⚠ Incorrect handling could potentially damage the battery or create unsafe operating conditions. To reduce risk, all tests were performed with multiple team members supervising the procedure to verify manipulations and monitor system behavior. Testing was also conducted in a designated battery testing area equipped to safely manage potential battery ignition incidents, helping protect both personnel and the building infrastructure.

⚠ An overdischarge condition can potentially overheat not only the PCB, but also the connected equipment such as the charger, cables, and battery pack. To improve operational safety, a thermal camera was used throughout testing to continuously monitor the temperature of all critical components and quickly detect abnormal heat buildup.

Procedure:

17. Connect the battery to the BMS.
18. Connect the balance wires to the BMS.
19. Connect the BMS to the EV2400 (I2C and GROUND signal).
20. Start the BMS by injecting a voltage at the input using the battery as the source (only required the first time the battery is connected) ⁽¹⁾.

¹ When initially disconnected, the BMS considers itself in undervoltage mode and will remain disabled until a charging condition is detected. This can be simulated by injecting voltage from the battery on the charging side

Multiple test options**Test A: Normal discharge (< 40A)****Procedure:**

21. Connect the BMS output to a programmable electronic load.
22. Configure the desired discharge current according to the equivalent resistance of the load using the relation: $(R = 16.8V / I_{desired})$
23. Start the discharge while continuously monitoring pack voltage, current, temperature, and individual cell voltages in BQStudio.
24. Continue the discharge until the BMS detects an undervoltage condition and safely terminates the discharge process.

Test B: Fast Discharge (> 40A)

25. Connect the BMS output as a power source to a high-current charger or load system rated for up to 80 A.
26. Connect a second battery pack to the charging side of the system to absorb the transferred energy. A higher-capacity battery is preferable for improved stability and safety.
27. Begin the discharge while continuously monitoring current, temperature, pack voltage, and individual cell voltages using BQStudio and external thermal monitoring equipment.
28. Verify that the BMS triggers the overcurrent protection if a current exceeding 85 A is maintained for more than approximately 10 seconds. The delay prevents unnecessary shutdowns caused by short current spikes.
29. Monitor thermal behavior carefully throughout the test. Continuous discharge near 85 A can overheat the BMS and associated equipment if maintained for extended periods. The system is designed to tolerate high-current peaks for short durations only.
30. Stop the discharge manually before the battery approaches 0% state of charge. Allowing the pack to fully reach undervoltage shutdown during high-current discharge can abruptly stop the charger/load system and may damage connected equipment.

Pass / Fail criterion: Test A

- The BMS maintains stable discharge operation at the configured current.
- Current and voltage measurements remain stable and coherent in BQStudio.
- The undervoltage protection triggers correctly when the minimum voltage threshold is reached.
- No abnormal overheating, smoke, odor, or unstable behavior is observed during discharge.

Pass / Fail criterion: Test B

- The BMS maintains stable high-current discharge operations within configured limits.
- Overcurrent and overtemperature protections trigger correctly under unsafe operating conditions.
- Temperatures of the PCB, battery, cables, and connectors remain within acceptable safety limits during normal operation.
- The undervoltage protection behaves as expected when low-voltage conditions are approached.
- No visible damage, smoke, fire, or uncontrolled thermal behavior is observed during testing.

Results:**Test A:**

During the low-current discharge tests, it was observed that the programmable electronic load provided more stable and precise current measurements than the digital multimeter. As a result, the BMS current calibration was adjusted using the electronic load measurements as the reference source.

The electronic load battery testing mode also included its own undervoltage protection, providing an additional safety layer during testing. Because the system already included multiple independent protection mechanisms — including undervoltage discharge stop, undervoltage fuse protection, undervoltage shutdown, dedicated cell monitoring circuitry, and onboard cell-level protections — deeper discharge validation tests were performed with increased confidence in the overall safety of the setup.

Test B:

During initial testing, the BMS stopped discharging at 65 A instead of the expected 80 A threshold. The issue was traced to the current threshold register size limitation, which limited the maximum configurable current value to 2^{16} mA. To correct this, the current scale factor was increased, allowing higher protection thresholds at the cost of reduced current protection precision.

After this adjustment, the discharge reached 60 A, but the test was limited by the charger overheating and being unable to provide additional current. Airflow was increased and the charger was allowed to cool before continuing. The test was then successfully repeated at 80 A for 2 minutes. Detailed measurements and observations are available in the test logs (3).

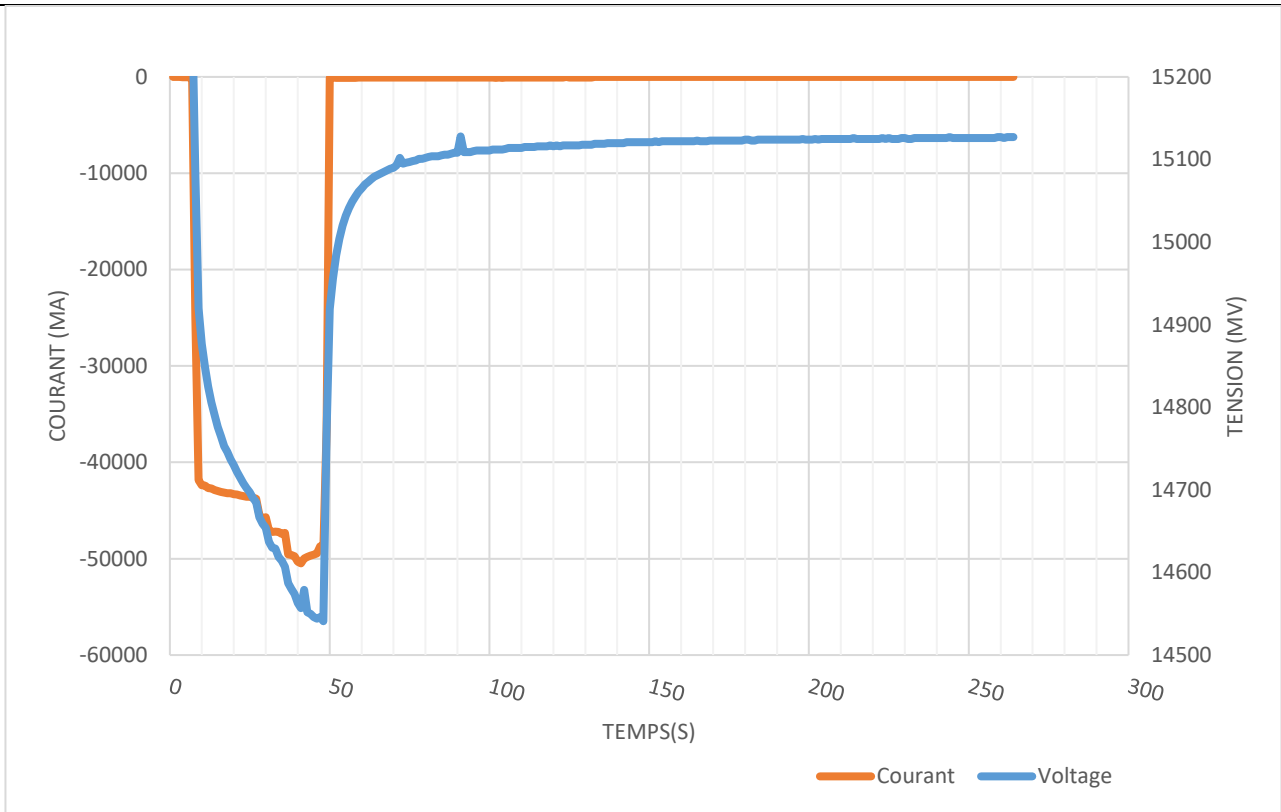


Figure 4 DISCHARGE (55A PEAK)

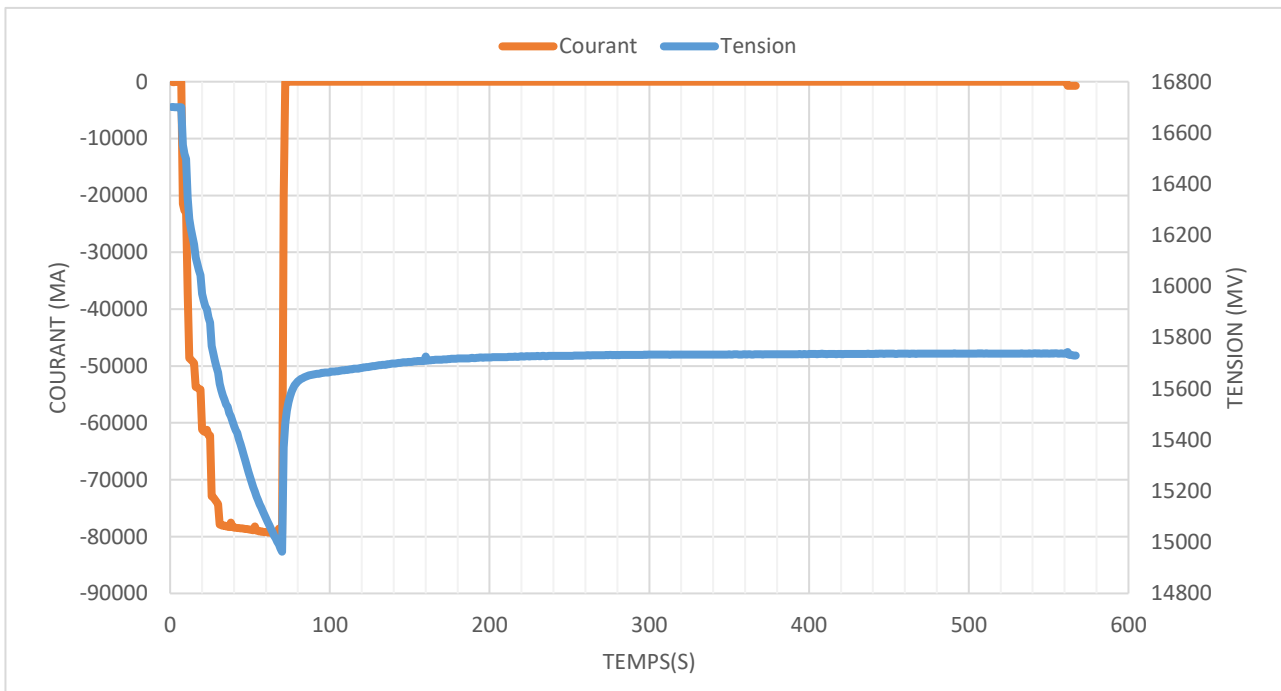


Figure 5 DISCHARGE (85A PEAK)

References:

Datasheet (2) : <https://www.ti.com/lit/ug/sluubz5/sluubz5.pdf?ts=1732297886825>

Logs (3): [26-04-2026 Pedro 60A 80A Test \(1\).xlsx](#)