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Situationally Aware Innovative Battery Management System for Next Generation Vehicles

InnoBMS - Deliverable report

D4.2 Rapid hardware prototype of the wireless battery module system

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Project summary

The core objective of InnoBMS is to develop and demonstrate (TRL6) a future-ready best-in-class BMS hard- and software solution that maximizes battery utilization and performance for the user without negatively affecting battery life, even in extreme conditions, whilst continuously maintaining safety. Concretely, the InnoBMS proposal will deliver a 12% higher effective battery pack volumetric density, a 33% longer battery lifetime and a demonstrated lifetime of 15 years. The results will be demonstrated using novel testing methods that give a 36% reduction in the testing time of a BMS. The results will be demonstrated in two use cases, one light commercial vehicle (Fiat Doblo Electric) and Battery Test Chamber (FMF). The key outcomes will enable a cost reduction of 12% and 9.7% for passenger cars and Battery Test Chamber, respectively. The core objective will be achieved through five technical objectives. 1) advanced hybrid physical and data-driven models and algorithms to enable a flexible and modular BMS suitable for a wide range of batteries. 2) Software for a fully connected and fully wireless BMS that acts as a communication server inside the vehicle E/E-architecture, the centre of connection, on-board diagnostics and decision-taking for all battery-related information. 3) A scalable, fully wireless and self-tested BMS hardware that enables using different battery sizes at different operating voltage levels, and smart sensor integration. 4) Better battery utilization and exploitation using cloud-informed strategies and procedure. 5) A heterogeneous simulation toolchain and automated test methods.

Publishable summary

The core objective of InnoBMS project is to develop and demonstrate (TRL6) a future-ready, best-in-class BMS hardware and software solution that maximizes battery utilization and performance for the user without negatively affecting battery life, even in extreme conditions, while continuously maintaining safety.

InnoBMS leverages on seven work packages, with WP4 focusing on the hardware element of the overall project based on the requirements and specifications from WP1 (T1.1 Use-case Definition, interfaces and computational requirements of the advanced functionalities covering both BMS (edge-cloud) and VCU for the use-cases).
WP4 designed BMS hardware to meet the highest safety and reliability requirements for automotive applications, and the assembly of advanced sensors to enable the BMS to provide more accurate and reliable information about the state of the battery.
WP4 focuses on four tasks. Firstly, the conceptualization of a modular BMS E/E layout including cell-to-pack focusing on ISO26262 and ISO21434, covering both 400V and 800V system which this report will focus on.
Following on from this definition of hardware, the design for automated assembly of CMB and implementation of wireless interface will be confirmed in the second deliverable of this WP4, D4.2 (Rapid hardware prototype of the wireless battery module system).
Subsequently Functional safety (i.e., ISO26262) and boundary condition-related testing of the battery pack with Battery test bench will take place during subsequent months to contribute to the report for D4.3 Advanced pack-level assembling for ultimate battery pack performance.
Finally, a fully wireless, connected and tested BMS hardware available for integration in the demo vehicle will be delivered aligning to the overall WP4 deliverable and reported on D4.4 Functional and safety-related testing of the battery pack.

This deliverable report, D4.2 in based on Task 4.2 Rapid hardware prototype of the wireless battery module system.

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Abbreviations & Definitions

Abbreviation	Explanation
CMB	Cell Monitoring and Balancing Circuit Board
WNM	Wireless Network Manager
BMS	Battery Management System
CMB	Cell Module Controller
sBMS	Sub Battery Management System
SoX	State of X
SoC	State of Charge
SoH	State of Health
SoS	State of Safety
EIS	Electro chemical Impedance Spectroscopy
AFE	Analogue Front End
LDOs	Low Drop Out
DCDC	Direct Current
SEooC	Safety Element out of Concept
AoU	Assumption of Use

Figure 1: Abbreviations

1 Introduction

The purpose of this document is to show the results of WP4 D4.2 which is the development and implementation of the Cell Module Controller (CMB).

Input from WP1, T1.2: Requirements specification for cloud-supported electric vehicle operation including V2x. This considers most relevant electric passenger car and light duty CV applications. This includes the identification of future operation scenarios and the related derivation of load cycles. Besides driving loads, also AC&DC charging and V2x related loads will be explored. Important general boundary conditions and guidelines come from foreseeable legislative and circular economy requirements. The Battery system perspective will be extended in direction of cost and aging relevant sub systems like chargers and connected stationary components. Cloud functionalities will be determined that give added value to important components and (sub) systems.
The improved BMS (HW and SW) is the core part of data generation and communication. Related additional functional requirements which will be investigated.

WP4.2 requires tasks to be undertaken to design and prepare the hardware deliverables for this project.
This deliverable provides detailed description of the following component: Cell Module Controller.
It shall be described the Interfaces of the CMB as well as the description of the CMB hardware and the implementation in the battery.

In accordance with the GA plan, the InnoBMS software and hardware will be ready for the whole range of voltages between 400V-800V.

2 Methods and core part of the report

2.1 Introduction to the task WP4.2

The Grant Agreement requires the design and creation of an E/E layout for wireless cell monitoring and balancing (CMB) using a Cell Management Integrated Circuit (AFE).

The CMB will send the data wireless to SBMS.

This document describes the architecture and design of the CMB including all interfaces to the BMS system.

The BMS system consist of the following components:

- Cell Module Controller: CMB
- Wireless Network Manager: WNM
- Battery control Unit: SBMS

2.2 Wireless CMB

The Wireless CMB is collecting all data (voltage, temperature) from the battery cells via AFE.

These data are transferred wirelessly via wireless chip (included in the CMB), to the wireless network manager (WNM) / SBMS.

One CMB is used per cell stack. If more stacks are used / needed more CMBs shall be used inside the battery. The number of CMBs required, depends on the battery layout on system level. One CMB can handle 18 cells. So, more CMBs are needed per cell stack.

2.3 Interaction / Implementation of WP4 in the INNO BMS System context

The WP4.2 requires the development and implementation of a Cell Module Controller (CMB). The CMB interact with the other system components in the following way:

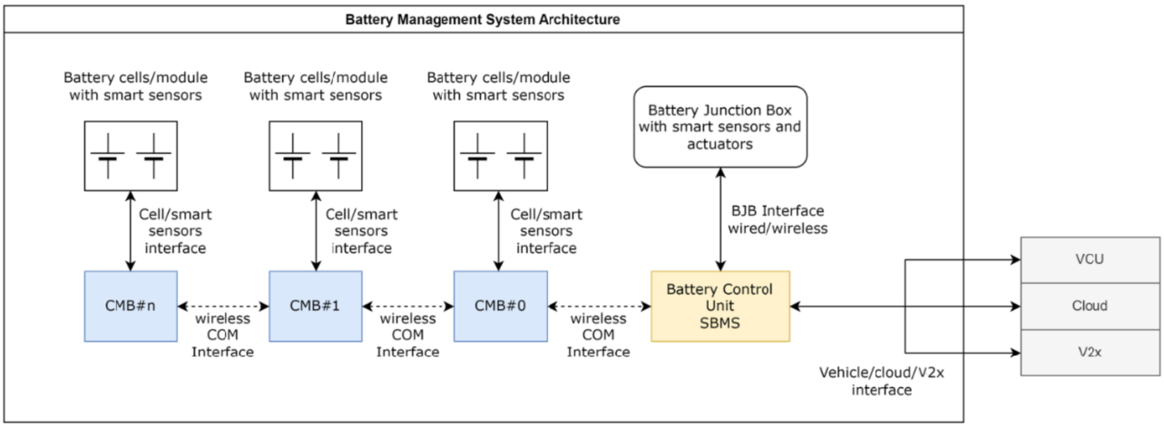


Figure 2: Implementation of CMB according to Grant Agreement

The communication between CMB and SBMS is realized via a gateway module to the SBMS. This gateway (network manager) is realized by a WNM/TI BCU which transfers the incoming wireless communication to a CAN protocol for the CMB.

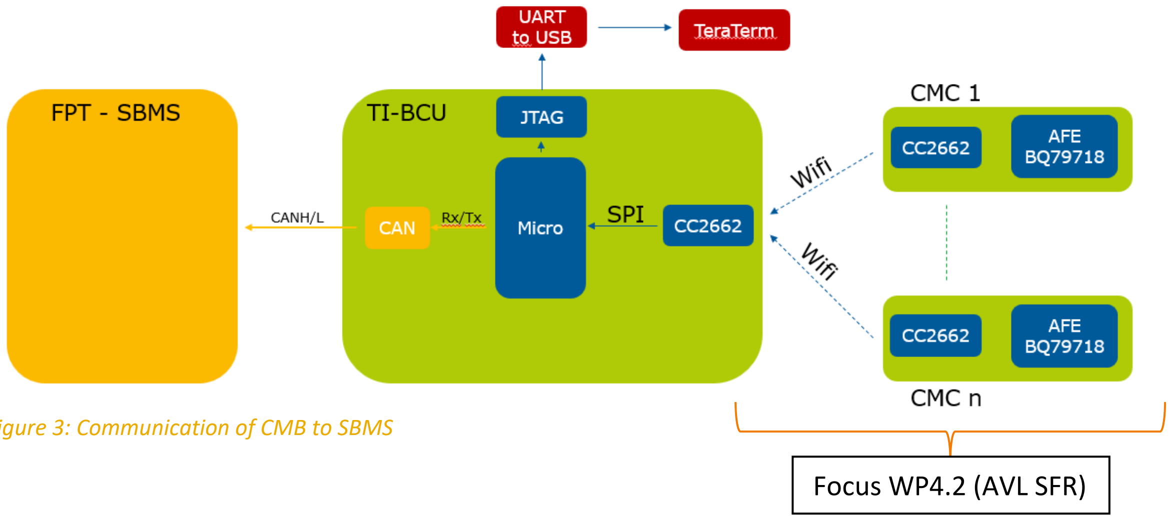


Figure 3: Communication of CMB to SBMS

3 Results

3.1 Technical Parameters for CMB

Parameter	Specification
Maximum number of cells	18
Minimum number of cells	LFP cells: 4 NMC cells: 3
Temperature Measurement Inputs	Internal NTCs: 3 External NTCs: 6
Balancing Current	222mA … 262mA (at a cell voltage of 4.2V)
Wireless	2.4 GHz ISM band.
Dimensions	Length: 90mm Width: 70mm Heigh: 12mm

Figure 4: Technical Parameters CMB

3.2 System Interfaces

3.2.1 Cell Connection Interface

The connectors have been defined by AVL-SFR and FMF together. There is one 36 pin Amphenol connector used.

Connector (Female) for wiring harness

Supplier	**Amphenol**
Number of Pins	**36 Pins**
Ordering Code	**10166410-W36000ALF**
Color	**Black**
Pitch	**2,54 mm**
CPA	**Yes**
Used Pins	**34**
Material	
Free Pins	**2**
Current Rating	**2A AC/DC**
Temperature Range	**-40°C - 105°C**

Table 1: Cell Connector

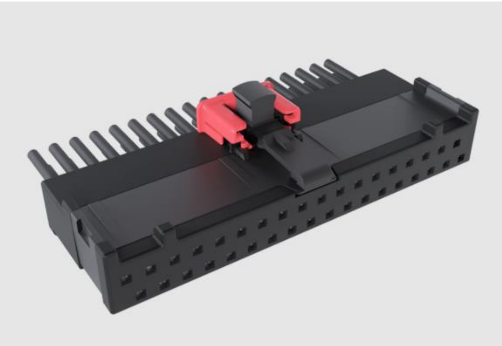


Figure 5: Cell Connnector

Pinning of the connector:

Pin Nr./ Designator	Schematic Signal Name	Type	Function
1	I_A_CELL_18	Power Supply Input	Cell voltage input for measurement
2	I_A_CELL_16	Power Supply Input	Cell voltage input for measurement
3	I_A_CELL_14	Power Supply Input	Cell voltage input for measurement
4	I_A_CELL_12	Power Supply Input	Cell voltage input for measurement
5	I_A_CELL_10	Power Supply Input	Cell voltage input for measurement
6	I_A_CELL_9	Power Supply Input	Cell voltage input for measurement
7	I_A_CELL_7	Power Supply Input	Cell voltage input for measurement
8	I_A_CELL_5	Power Supply Input	Cell voltage input for measurement
9	I_A_CELL_3	Power Supply Input	Cell voltage input for measurement
10	I_A_CELL_1	Power Supply Input	Cell voltage input for measurement
11	not connected		
12	not connected		
13	GND	Power Supply Input	GND Supply for Temperature Sensors
14	I_A_TEMP_2	Analog Input	Temperature Sensor Input
15	GND	Power Supply Input	GND Supply for Temperature Sensors
16	I_A_TEMP_4	Analog Input	Temperature Sensor Input
17	GND	Power Supply Input	GND Supply for Temperature Sensors
18	I_A_TEMP_6	Analog Input	Temperature Sensor Input
19	I_A_CELL_TOP	Power Supply Input	Power Supply Top Cell
20	I_A_CELL_17	Power Supply Input	Cell voltage input for measurement
21	I_A_CELL_15	Power Supply Input	Cell voltage input for measurement
22	I_A_CELL_13	Power Supply Input	Cell voltage input for measurement
23	I_A_CELL_11	Power Supply Input	Cell voltage input for measurement
24	I_A_CELL_BB	Power Supply Input	Cell voltage input for BusBar measurement
25	I_A_CELL_8	Power Supply Output	Cell voltage input for measurement
26	I_A_CELL_6	Power Supply Input	Cell voltage input for measurement
27	I_A_CELL_4	Power Supply Input	Cell voltage input for measurement
28	I_A_CELL_2	Power Supply Input	Cell voltage input for measurement
29	I_A_CELL_0	Power Supply Input	Cell voltage input for measurement
30	I_A_CELL_BOTTOM	Power Supply Input	Power Supply Bottom Cell
31	I_A_TEMP_1	Analog Input	Temperature Sensor Input
32	GND	Power Supply Input	GND Supply for Temperature Sensors
33	I_A_TEMP_3	Analog Input	Temperature Sensor Input
34	GND	Power Supply Input	GND Supply for Temperature Sensors
35	I_A_TEMP_5	Analog Input	Temperature Sensor Input
36	GND	Power Supply Input	GND Supply for Temperature Sensors

Figure 6 Pinning of the connector

3.3 CMB (Cell Module Controller)

The CMB is connected via Amphenol connector to the cells of the battery. The below table includes the content of the measurements that will be provided to SBMS via wireless interface.

The CMB includes 18 cell channel measurement for voltage and 6 temperature measurements:

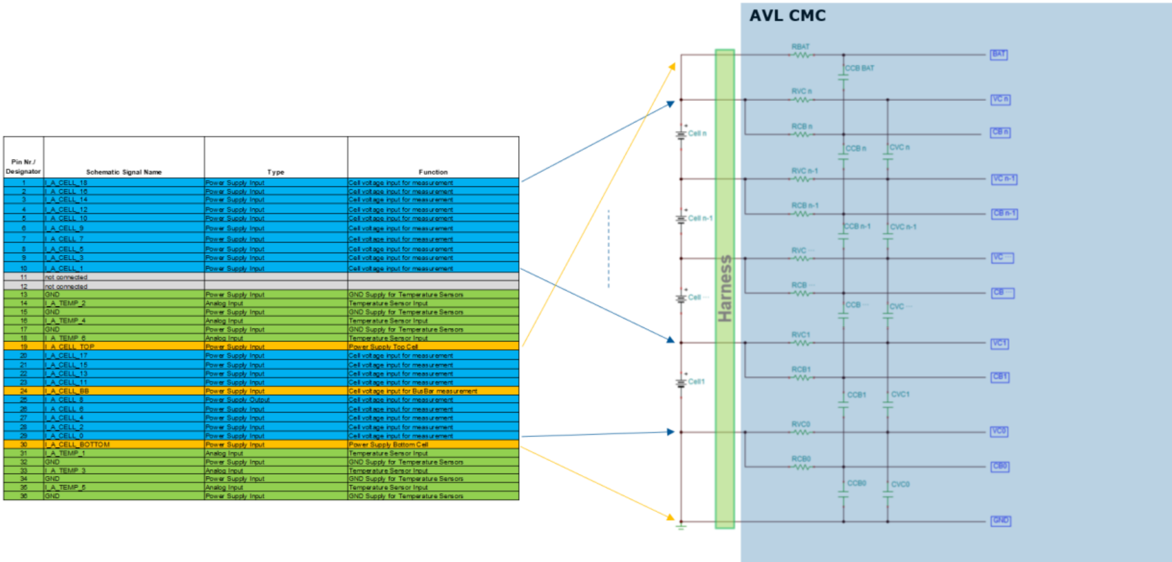
Number	Signal Name	Description
1	I_A_CELL_0	Bottom Cell voltage
2	I_A_CELL_1	Voltage measurement Cell 1
3	I_A_CELL_2	Voltage measurement Cell 2
4	I_A_CELL_3	Voltage measurement Cell 3
5	I_A_CELL_4	Voltage measurement Cell 4
6	I_A_CELL_5	Voltage measurement Cell 5
7	I_A_CELL_6	Voltage measurement Cell 6
8	I_A_CELL_7	Voltage measurement Cell 7
9	I_A_CELL_8	Voltage measurement Cell 8
10	I_A_CELL_9	Voltage measurement Cell 9
11	I_A_CELL_10	Voltage measurement Cell 10
12	I_A_CELL_11	Voltage measurement Cell 11
13	I_A_CELL_12	Voltage measurement Cell 12
14	I_A_CELL_13	Voltage measurement Cell 13
15	I_A_CELL_14	Voltage measurement Cell 14
16	I_A_CELL_15	Voltage measurement Cell 15
17	I_A_CELL_16	Voltage measurement Cell 16
18	I_A_CELL_17	Voltage measurement Cell 17
19	I_A_CELL_18	Voltage measurement Cell 18
20	I_A_TEMP_1	Cell Temperature Measurement 1
21	I_A_TEMP_2	Cell Temperature Measurement 2
22	I_A_TEMP_3	Cell Temperature Measurement 3
23	I_A_TEMP_4	Cell Temperature Measurement 4
24	I_A_TEMP_5	Cell Temperature Measurement 5
25	I_A_TEMP_6	Cell Temperature Measurement 6

Table 2: Input Interface

3.3.1 Depopulation of Cells

The CMB is capable to measure up to 18 cells. If less cells are needed the unused cells needs to be shorted on the CMB. When the pack only has **e.g. 14 cells**, the unused channels need to be handled properly to avoid measurement errors or fault conditions.

The following picture shows how the CMB need to be connected if all 18 cells are used:



Pin Nr./ Designator	Schematic Signal Name	Type	Function
1	I_A_CELL_18	Power Supply Input	Cell voltage input for measurement
2	I_A_CELL_16	Power Supply Input	Cell voltage input for measurement
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5	I_A_CELL_10	Power Supply Input	Cell voltage input for measurement
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21	I_A_CELL_15	Power Supply Input	Cell voltage input for measurement
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23	I_A_CELL_11	Power Supply Input	Cell voltage input for measurement
24	I_A_CELL_BB	Power Supply Input	Cell voltage input for BusBar measurement
25	I_A_CELL_8	Power Supply Output	Cell voltage input for measurement
26	I_A_CELL_6	Power Supply Input	Cell voltage input for measurement
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28	I_A_CELL_2	Power Supply Input	Cell voltage input for measurement
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35	I_A_TEMP_5	Analog Input	Temperature Sensor Input
36	GND	Power Supply Input	GND Supply for Temperature Sensors

Figure 7: Full population of 18 cells

If only 14 cells are used, then the CMB need to be connected in the following way:

- Connect Cell 1 to VC1, Cell 2 to VC2, … up to Cell 14 to VC14.
- The lowest potential (pack negative) goes to VC0 (sometimes called VSS or GND reference).
- The highest potential (pack positive) will be at VC14 in that case.

Depopulating the Unused Channels (VC15 – VC18)

- **Do NOT leave them floating** – this can cause noise or false readings.
- **Tie unused pins to the highest connected cell voltage** (VC14 in that case).
- So, connect **VC15, VC16, VC17, VC18** all to **VC14**.
- Ensure the **balancing resistors or FETs for those channels are not populated** (or disabled in firmware).
- In software configuration, set the device for **14 cells active** (WNM/TI BCU) so the IC ignores the extra channels.
- If you use **cell balancing**, make sure balancing is only enabled for the 14 active cells (in WNM/TI BCU SW)

Adaptions for the BCU firmware:

To ensure proper functionality of the CMB the BCU firmware need to be adapted / configured:

- **Cell Count Configuration**
  - In the **BQ79718 register map**, set the **number of cells = 14**.
  - This ensures unused channels are ignored in measurements and balancing.
- **Balancing Control**
  - Disable balancing for channels 15–18.
  - Configure balancing thresholds for active cells only.
- **Voltage Measurement**
  - Verify ADC channel mapping for VC0–VC14.
  - Perform calibration if required.
- **Fault Handling**
  - Disable open-wire detection for unused channels.
  - Enable fault detection for active cells.
- **Communication**
  - Confirm SPI or daisy-chain communication settings.
  - Update CRC and packet length for 14-cell configuration.
- **Diagnostics**
  - Run self-test and verify cell voltage readings.
  - Check that VC15–VC18 report as inactive or fixed voltage.

3.4 Wireless Interface of CMB

3.4.1.1 General

The communication from the Cells (CMB) to the BMS System is realized wireless via TI chipset CC2662

The CC2662R-Q1 from Texas Instruments is an automotive-qualified wireless MCU designed primarily for Wireless Battery Management Systems (WBMS). It uses a proprietary 2.4 GHz protocol optimized for reliable, low-latency communication in automotive environments.

Protocol Overview:

- **Type:** Proprietary SimpleLink™ WBMS protocol (not Bluetooth LE or Zigbee).
- **Frequency Band:** 2.4 GHz ISM band.
- **Data Rate:** Up to 2 Mbps.
- **Topology:** Typically star or mesh, tailored for battery module-to-central controller communication.
- **Range & Reliability:** High RX sensitivity (≈ –92 dBm) and output power up to +5 dBm with temperature compensation for robust automotive environments.
- **Compliance:** Meets ETSI EN 300 328, FCC Part 15, and ARIB STD-T66 for 2.4 GHz wireless devices

Key Features supporting the Protocol:

- **Programmable Radio:** Supports WBMS protocol stack stored in ROM.
- **Security:** AES-128/256, ECC, RSA, SHA-2, and TRNG for secure communication.
- **OTA Updates:** Over-the-air firmware upgrade capability.
- **Low Power:** TX current ≈ 7–9 mA, RX ≈ 6.9 mA; standby down to 0.94 µA.
- **Automotive Grade:** AEC-Q100 qualified, ISO21434 cybersecurity compliant.

3.4.1.2 Layer overview:

This picture shows the structure of the SimpleLink WBMS protocol:

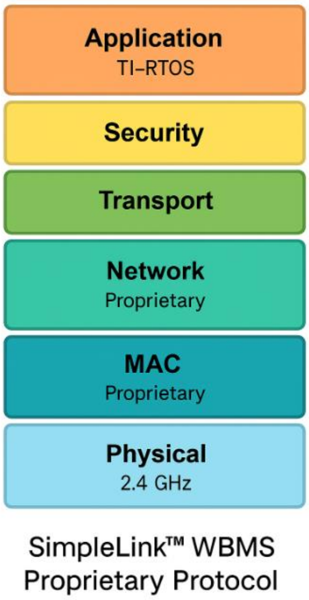


Figure 8: Layer Overview of wireless protocol

Physical Layer

- **Frequency:** 2.4 GHz ISM band.
- **Modulation: GFSK** (Gaussian Frequency Shift Keying).
- **Data Rate:** Up to **2 Mbps**.
- **Channel Management:** Frequency hopping for interference tolerance.
- **Range:** Optimized for automotive battery packs (up to several meters per module, scalable to large packs).
- **Power:** TX up to **+5 dBm**, RX sensitivity ≈ –92 dBm

MAC Layer

- **Topology: Star or Mesh** network for module-to-central controller communication.
- **Access Method: Time-slotting** for deterministic latency.
- **Keep-Alive Mechanism:** Ensures continuous connectivity even under harsh conditions.
- **Rejoin & Second-Life Support:** Nodes can rejoin after temporary disconnection.
- **Security at MAC:** AES-CCM encryption for frame integrity and confidentiality

Network Layer

- Proprietary addressing scheme optimized for **battery module identification**.
- **Frequency hopping sequences** managed at network level for robustness.
- **Key Refreshment Protocol:** Periodic cryptographic key updates for security.
- **Deterministic Scheduling:** Guarantees predictable communication for safety-critical systems

Transport Layer

- Reliable delivery with **acknowledgment and retransmission**.
- **Error detection and correction** integrated for high reliability in noisy environments.

Security Layer

- **AES-128/256 encryption**, **ECC**, **RSA**, **SHA-2**, and **TRNG** for secure key generation.
- **Device Attestation & Anti-Counterfeit** features for automotive cybersecurity compliance (ISO21434).
- **Secure OTA Updates** supported via encrypted firmware packages

Application Layer

- Implements **Wireless Battery Management System (WBMS)** functions:
    - Cell voltage and temperature monitoring
    - State-of-charge and health reporting.
    - Diagnostics and firmware updates.

- Runs on **TI-RTOS** in ROM for deterministic real-time behavior

3.4.2 Busbar Connection

The **BQ79718** from Texas Instruments is a battery monitor IC for high-voltage battery systems. It has a dedicated **BB pin (Busbar Measurement Pin)** to measure the voltage drop across the busbar.

How is the BB pin connected?

- The **BB pin** is connected directly to the **busbar potential**, typically at the end of the cell stack or at a defined point on the busbar.
- The reference for the measurement is the IC's internal ground (VSS) or a defined cell terminal.
- **Purpose:** To measure the voltage drop between the last cell connection and the busbar connection, to monitor contact resistance and power losses.
- According to TI documentation, there are several possible positions for the BB pin depending on the topology (e.g., in a 16S configuration at the positive terminal of the last cell or at the busbar end).

Key Points

- The BB pin is **not a current measurement pin**; it is for **voltage measurement**.
- It should be connected to the busbar through a **low-resistance connection** (direct or via a short conductor).
- For accurate measurement, the line to the BB pin should be as **short and low-inductance** as possible to minimize voltage drop caused by wiring.

The device supports three types of bus bar measurement:

- The busbar is kelvin connected through the BB pin when the busbar is located anywhere between the bottom of cell 7 and the bottom of cell 13. In this case the VC and CB ADCs can measure the busbar voltage through the subtraction method.

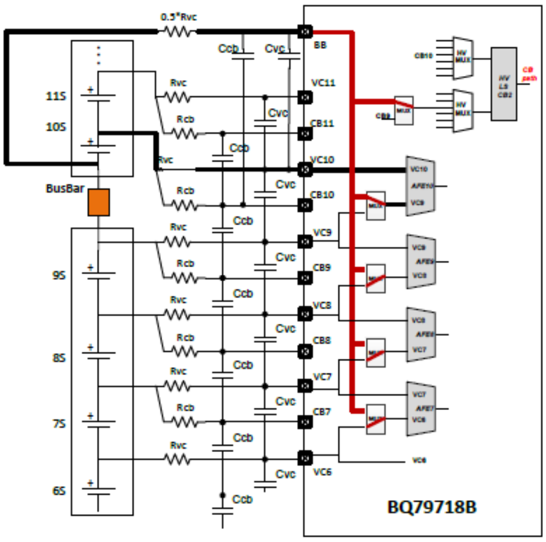


Figure 9: Busbar measurement

- The busbar is placed between two BQ79718 devices (CMBs). In this case the busbar voltage can be measured by using the GPIO of the upper device.

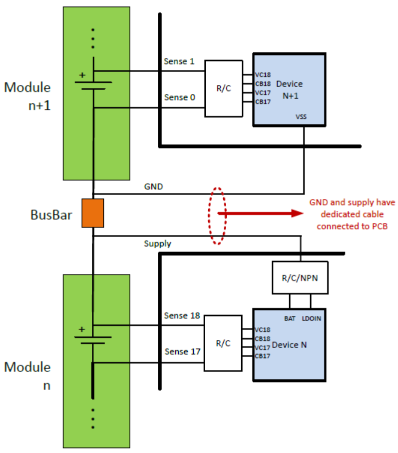


Figure 10: Busbar measurement between two CMBs

- The busbar occupies a regular VC/CB channel. In this case the busbar cannot be directly measured by the VC and CB ADCs.

3.4.3 Mechanical Interfaces

3.4.3.1 Mechanical Dimensions

The AVL CMB is designed with the following mechanical dimensions:

- Length: 90mm
- Width: 70mm
- Heigh: 12mm

Figure 11: Actual AVL CMB

The PCB shall be mounted without any housing by 4 screw connections.

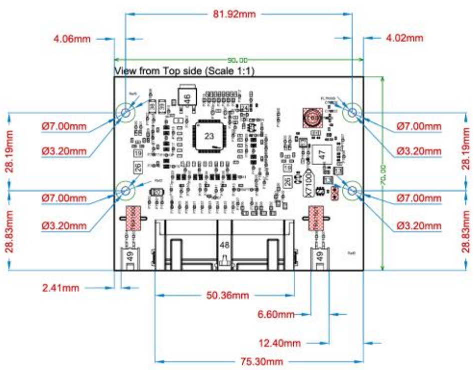


Figure 12: Hole positions

3.4.3.2 Location of the Antenna and the Wireless Chip

The antenna is located on the Top right corner of the PCB.

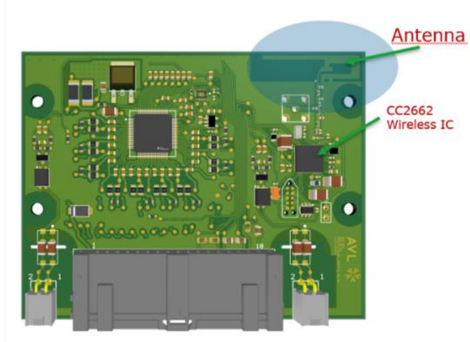


Figure 13: Location of the antenna

3.4.3.3 Connectors on CMB

The CMB consists of the following connectors:

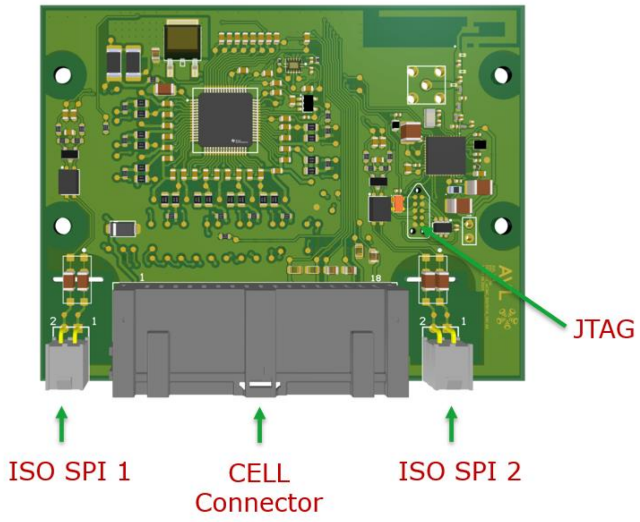


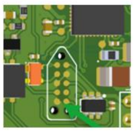
Figure 14: Connectors of CMB

a) Cell Connector:
Is described in chapter *3.2.1 Cell Connection Interface*.

b) JTAG connector:
This connector is used for flashing and debugging of the wireless IC CC2662 of CMB.

JTAG Connector for CC2662

Pin	Description
1	3,3V_CC
2	TMS
3	Cell Bottom (GND)
4	TCK
5	Cell Bottom (GND)
6	TDO
7	n.c.
8	TDI
9	Cell Bottom (GND)
10	RST_CC



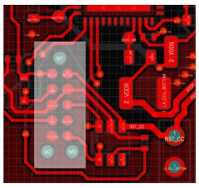


Figure 15: JTAG connector

c) ISO SPI connector:
These connectors are for future use and not used for INNO BMS project

3.5 Functional Safety

The BMS system is compatible to ISO26262.
The safety is covered by SBMS and CMB together on system level.

3.5.1 Functional Safety Compliance

All safety critical failures on Battery cell level will be detected by CMB. This will be handled by the AFE inside the CMB and communicated to the SBMS.

- **ISO 26262 ASIL-D Ready**: The AFE on CMB (BQ79718 from TI) as well as wireless communication IC (CC2662 from TI) are designed to meet the highest automotive functional safety standard (ASIL-D), which is essential for EV battery systems.
- Includes **diagnostic coverage** for internal circuits and communication paths.

3.5.2 Implemented Safety Measures of AFE

The BQ79718 provide the following safety measures. But the failure reaction shall be handled by SBMS which need to evaluate the relevant failure registers. This must be ensured by the system integrator.

3.5.2.1 Redundant Voltage and Temperature Monitoring

- Monitors up to 18 cells in series with high accuracy.
- Redundant measurement paths and self-check mechanisms ensure that faults in sensing are detected.
- External temperature sensors (NTCs) are implemented for thermal safety.

3.5.2.2 Built-in Fault Detection

- Detects **open-wire conditions, short circuits, and out-of-range** voltages.
- Continuous monitoring for cell balancing faults and communication integrity.

3.5.2.3 Communication Safety

- Uses SPI or daisy-chain communication with CRC checks for data integrity.
- Fault-tolerant communication ensures that corrupted data does not propagate.

3.5.2.4 Cell Balancing Safety

- Passive balancing with controlled current limits.
- Balancing is disabled automatically if abnormal conditions are detected (e.g., overvoltage, overtemperature).

3.5.2.5 Self-Test and Diagnostic

- Power-on self-test (POST) and periodic checks for ADC, memory, and logic circuits.
- Detects latent faults to maintain system reliability.

3.5.2.6 Integration with System-Level Safety

- Works with a battery management controller that supervises multiple BQ79718 devices.
- Provides **fault flags and status registers** for higher-level safety algorithms.

3.5.3 Role of CC2662 for Wireless BMS Safety

The **CC2662** is a wireless MCU from Texas Instruments designed for automotive applications. It is used in conjunction with battery monitoring ICs (AFE) BQ79718. Its contribution to safety includes:

3.5.3.1 Secure Wireless Communication

- Wi-Fi supports WPA2/WPA3 encryption and authentication, ensuring that only authorized devices can exchange battery data.
- Prevents man-in-the-middle attacks and unauthorized access to safety-critical information.

3.5.3.2 Data Integrity and Reliability

- Implements TCP/IP or UDP with error detection (checksums) for robust data transfer.
- Ensures accurate transmission of cell voltages, temperatures, and fault signals without corruption.

3.5.3.3 Redundancy and Fault Handling

- Provides diagnostic feedback on link quality and packet loss to the Battery Management Controller.

3.5.3.4 Low Latency for Safety Actions

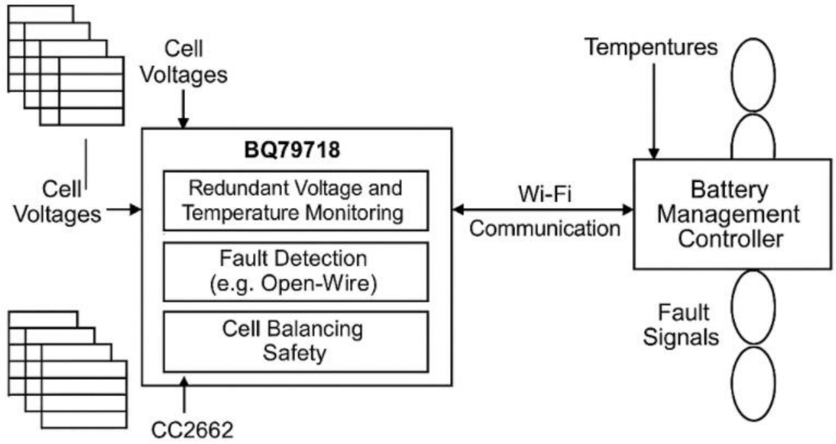
- Wi-Fi offers higher bandwidth and lower latency compared to BLE, enabling fast updates for real-time safety monitoring.

3.5.3.5 Compliance with Automotive Standard

- Wi-Fi modules for automotive applications are designed for ISO 26262 functional safety and AEC-Q100 qualification, ensuring reliability in harsh environments.

3.6 Functional Safety on CMB

The following picture shows the safety distribution between AFE and wireless IC and the communication to the SBMS.



Category	Description
Functional Safety	ISO 26262 ASIL-D-ready, diagnostic coverage for circults and communicastion
Monitoring	Redundant voltage and temperature sensing for up to 18 cells
Fault Detection	Open-wire, short-circuit, out-of-range voltage detection.
Communi-cation	Encryption, WPA2/WPA3, TCP/IP / UDP with error detection
Safety sal	Controlled passive balancing, auto-disable on abnormal conditions
Diagnostics	

Role of Wi-Fi (via CC266 or equivalent) in Wireless BMS Safety

- **Secure Wireeless Communication**
  Wi-FI supports WPA2/WPA3 encreptiond authentication. Prevents man-in-the-middle attacks and unauthorizimoed access to safety critical information
- **Data Integrity and Reliability**
  Implements TCP/IP or UDP vr detection (ohecksums) for robust data transfer, ensuring occurate transmission of ce-il voltages, temperatures, and fault signals without
- **Redundancy and Pault Handling**
  Maintainn redundant communica channels or fault in wired it wireless fails, enbiling rellabliity in harsh environments

Figure 16: Safety Implementation in CMB

3.7 Testing of CMB

Initial operating tests have been done for all CMC - before sending out.

3.7.1 Testsetup

The CMB is connected to the textbox where it is possible to adjust the voltage of all cells to ensure that the correct voltages are measured by the CMC and transferred wireless to BCU.
The cells can be activated or deactivated by switches on the testbox.

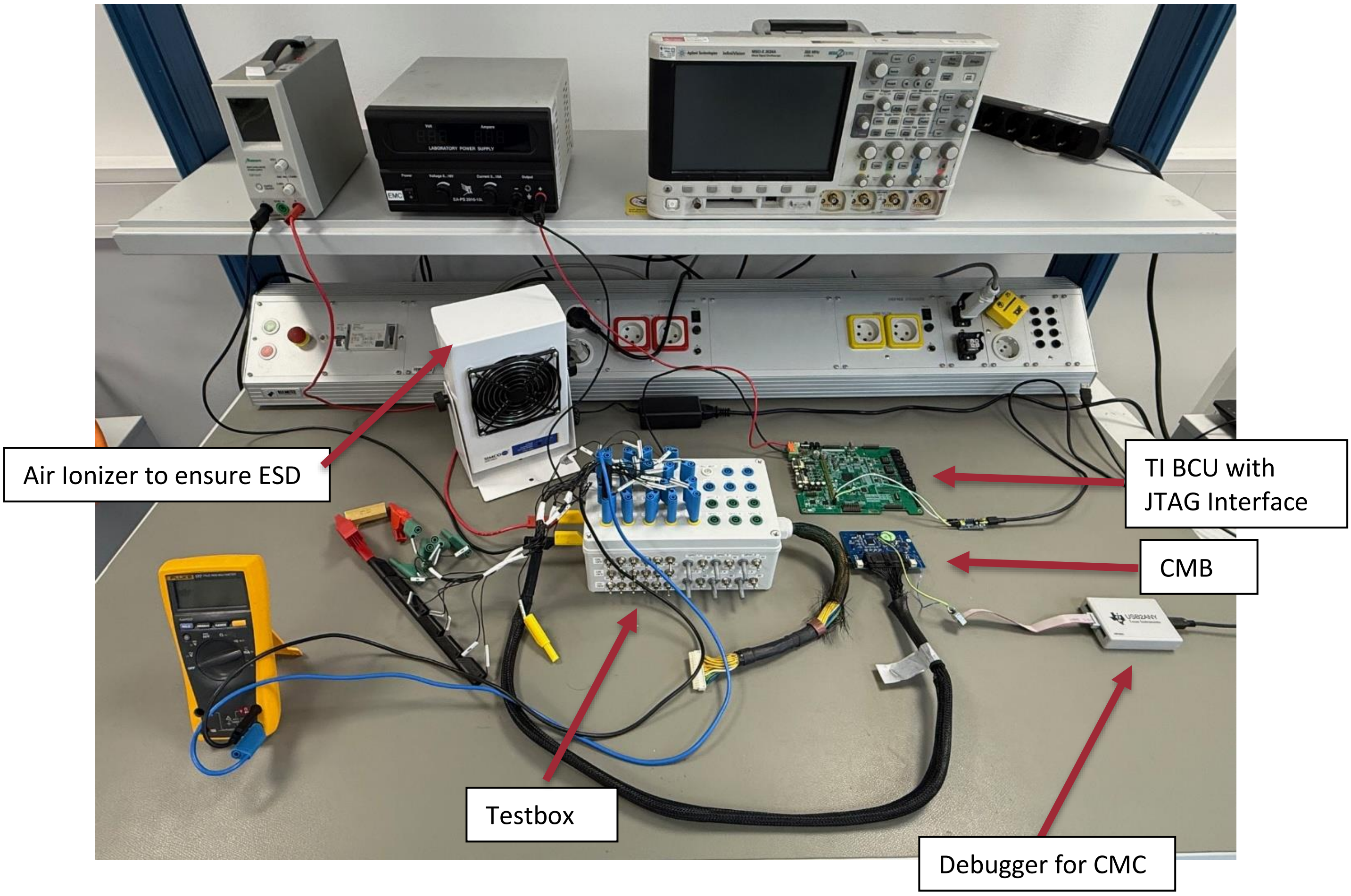


Figure 17: Testsetup

3.7.1.1 *Test of wireless communication*

The CMC is connected to the battery emulator / Testbox. The WNM / TI BCU is connected to an independent 14V power supply unit.
Software for wireless IC CC2662 was flashed on AVL CMC

After power up the wireless communication establishes automatically. And the CMC starts to transmit data to the WNM / TI BCU
For all CMCs the MAC – Adress was read out for each CMC.

CMC Tracking List					
Number	Datamatrix ID	Location	Flashed SW	Initial Operating Test	
1	SCL1583089	FMF	OK	OK	0x12 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
2	SCL1583096	FMF	OK	OK	0x27 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
3	SCL1583074	FMF	OK	OK	0x07 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
4	SCL1583082	FMF	OK	OK	0x08 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
5	SCL1583088	FMF	OK	OK	0x16 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
6	SCL1583091	FMF	OK	OK	0x0B 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
7	SCL1583094	FMF	OK	OK	0x0E 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
8	SCL1583086	FMF	OK	OK	0x26 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
9	SCL1583081	FMF	OK	OK	0x28 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
10	SCL1583092	FMF	OK	OK	0x19 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
11	SCL1583084	FMF	OK	OK	0x0C 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
12	SCL1583078	FMF	OK	OK	0x15 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
13	SCL1583077	FMF	OK	OK	0x17 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF
14	SCL1583075	FMF	OK	OK	0x06 0x5D 0x96 0xB5 0x68 0x34 0xFF 0xFF

Figure 18: CMC tracking list

3.7.1.2 *Test of cell voltage measurement*

A power supply of 60V (variable) is connected to the Test box. This voltage is divided through all cells. So depending on how many cells are active the voltage on the cell changes.
This power supply simulates the battery.

The supply voltage of the test box is variable to simulate different voltages on the cells. 3 different voltages are measured (min, typ and max values):

Voltage on Testbox	Physical voltage on one cell 14 cells active	Measured Voltage / Vaidation criteria of BCU (Terraterm)
52V	2,873V	2,8V < U < 3,0V
56V	3,096V	3,0V < U < 3,2V
60V	3,318V	3,2V < U < 3,4V

Figure 19: Cell voltage measurement

3.7.1.3 *Test of GPIO measurements (temperature)*

The CMB can handle up to 6 external temperature sensors and 3 internal sensors. The temperature sensor is simulated by an external 10kOhm resistor. The value which is measured by the CMC is read out via TeraTerm.

3.7.1.4 *Evaluation of results*

The measurements (temperature and cell voltage) are read out via the tool TerraTerm which is connected via JTAG to the WNM / TI BCU.

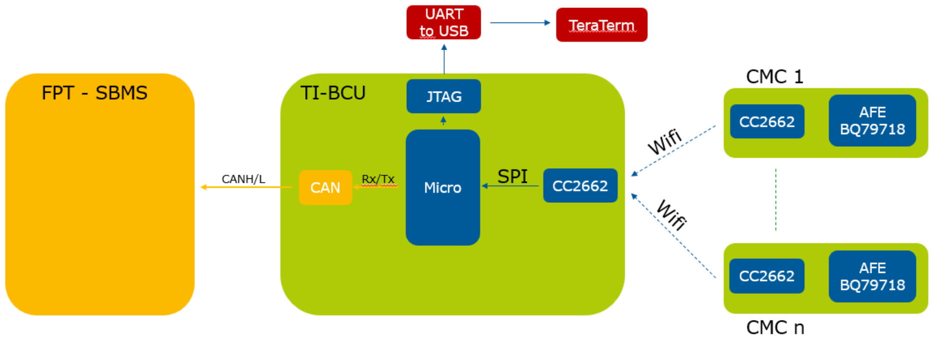


Figure 20: Connection via TerraTerm

After communication is established the TerraTerm tool shows the measured values by the WNM / TI BCU.

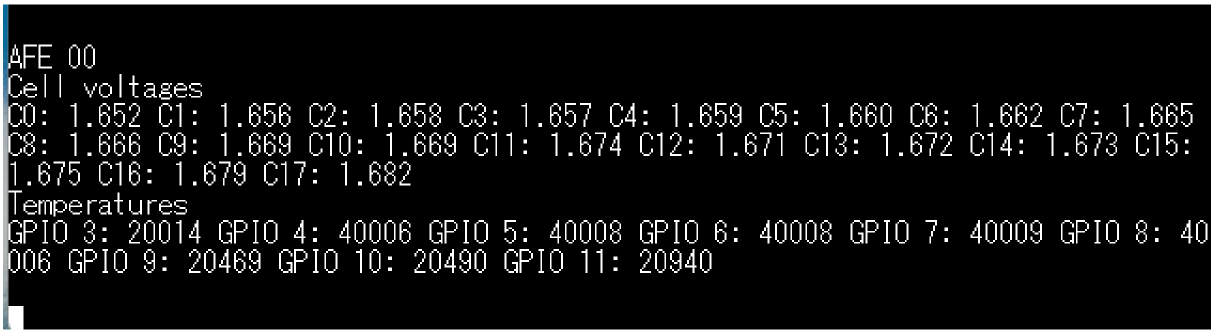


Figure 21: Example of TerraTerm

Here you see the number of the CMB (e.g. AFE 00), the measured cell voltages and the GPIO measurements. The cell voltages are direct voltage values. The GPIO measurements are shown in hex values.

This procedure is done for all CMBs and for different voltages as shown above.

Test Results:

Tested Sample	MAC Adress	Test of wireless Communication	Test of Cell voltage measurements	Test of GPIO Measurements external NTCs	Test of GPIO internal NTCs
#1	0x12 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#2	0x27 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#3	0x07 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#4	0x08 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#5	0x16 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#6	0x0B 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#7	0x0E 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#8	0x26 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#9	0x28 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#10	0x19 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#11	0x0C 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#12	0x15 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#13	0x17 0x56 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed
#14	0x06 0x5D 0x96 0xB5 0x68 0x34 0xFF 0xFF	passed	passed	passed	passed

Figure 22: Test Results

3.8 Contribution to project (linked) Objectives

This report is the second Deliverable for Work Package 4.2, Advanced BMS hardware and integration with advanced sensors following ISO26262 and ISO21434.
The task is to conceptualize a modular BMS E/E layout including cell-to-pack focusing on ISO26262 and ISO21434, covering both 400V and 800V systems.

3.9 Contribution to major project exploitable result

This deliverable contributes to the

- New design of the Cell monitoring and balancing wireless CMB

4 Risks and interconnections

4.1 Risks/problems encountered

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[1]	Solutions to overcome the risk
1	CAN communication on TI BCU	2	1	Support from TI requested
2	Lack of support from initial component supplier	1	1	Design changed from ADI to To chipset

[1)] Probability risk will occur: 1 = high, 2 = medium, 3 = Low

4.2 Interconnections with other deliverables

The output of WP D4.2 has direct influence on

- D4.3: Advanced pack-level assembling for ultimate battery pack performance
- D4.4 Functional and safety-related testing of the battery pack

The CMBs (14) needs to be implemented in the battery pack as well as the WNM/TI BCU which act as a gateway to CAN. Also, the CAN needs to be implemented in the TI SW for the WNM/TI BCU

5 References

Vasilyev, A., & Altun, E. (2024). *D1.1 - Requirements and interface definition.* InnoBMS GA No. 101137975. Retrieved from https://cordis.europa.eu/project/id/101137975/results

Bernhard Stanje (2024). *D2.1 - Data collection protocol.* InnoBMS GA No. 101137975. Retrieved from D2.1_Data collection protocol_AVL.pdf

InnoBMS_D4.1_Concept of Scalable monitoring, Control Unit and Sensorics Layout_FMF_V1.0-SENSITIVE_FINAL D4.1 Report

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Project partners:

#	Partner short name	Partner Full Name
1	VUB	Vrije Universiteit Brussel
2	TOFAS	TOFAS Turk Otomobil Fabrikasi Anonim Sirketi
3	BOSCH	Robert Bosch SRL
4	AVL	AVL List GmbH
5	AVL-SFR	AVL Software and Functions Gmbh
6	IDIADA	Idiada Automotive Technology SA
7	CID	Fundacion Cidetec
8	UL	Univerza v Ljubljani
9	THIL	Tajfun Hil Društvo sa Ograničenom Odgovornošću za Istraživanje, Proizvodnju, Rgovinu i Usluge Novi Sad
10	UNR	Uniresearch BV
11	FMF	FPT Motorenforschung AG
12	PTE	Potenza Technology Limited

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