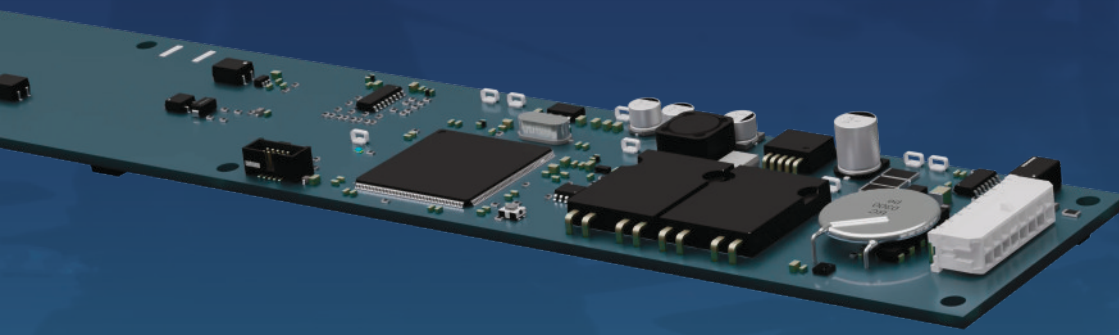
NOVELIC

CASE STUDY

Battery Management System for eMobility

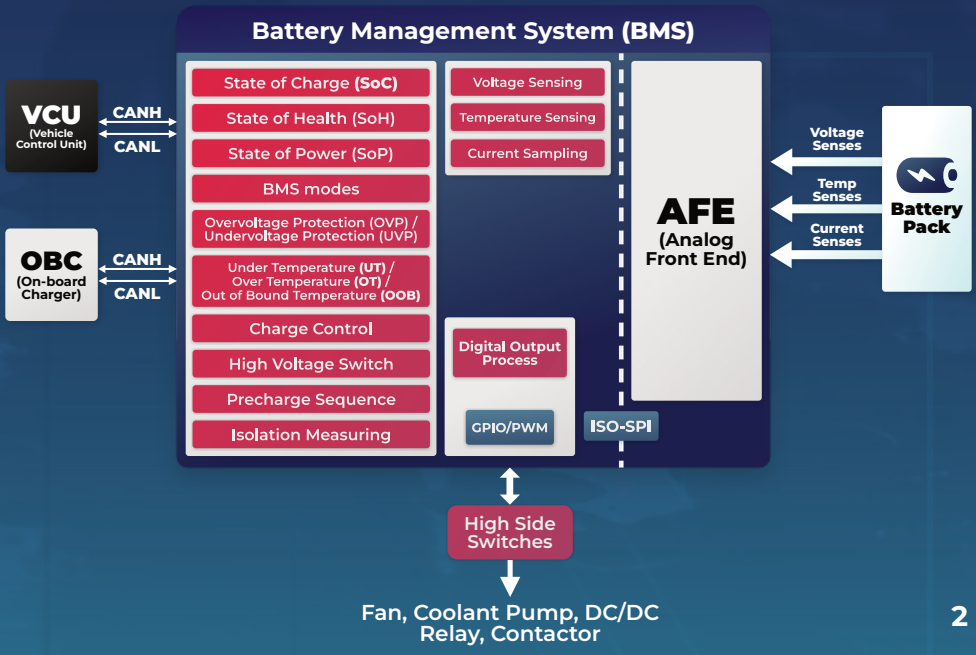


THE TASK

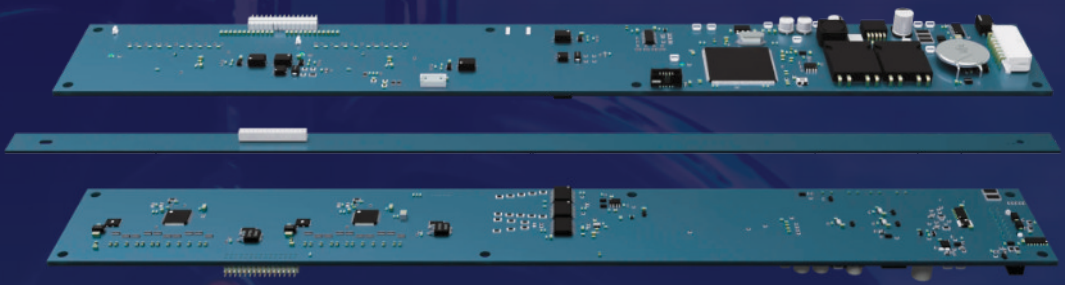
A United States-based manufacturer of electric scooters commisioned a design of a comprehensive Battery Management System (BMS) for 72V and 96V electric two-wheeler (e2W) battery packs, supporting capacities of 3.3 kWh, 4.5kWh and 6.6 kWh. The system was to provide full **battery pack protection**, **monitoring**, and **cell balancing** across parallel branches, while integrating **additional critical subsystems,** including cooling system controls and pre-charge circuitry as part of the same assembly.

CHALLENGES

Besides stringent technical requirements, an additional challenge was adapting to the available space, complying with the workflow of the integration with the battery pack, and thermal management of the resistors for balanced charging.



THE SOLUTION



Our battery management system (BMS) represents **a sophisticated technological solution for electric two-wheelers,** addressing critical challenges in battery performance, safety, and management. Designed to support voltage configurations of 72V and 96V, the system accommodates battery capacities ranging from 3.3 kWh to 6.6 kWh through an innovative dual-board modular architecture.

At the heart of the system lies a meticulously engineered main board featuring dual STMicroelectronics L9963-E Analog Front Ends (AFEs) that enable precise parallel branch voltage measurement. The system is based on an **NXP LPC5401x microcontroller,** providing a flexible bootloader capable of multi-branch battery configuration and secure firmware updates.

The system's communication infrastructure is built around **a CAN bus**, facilitating seamless interaction with the **Vehicle Control Unit (VCU)** and **On-Board Charger (OBC).**

Peripheral management is equally sophisticated, utilizing Solid State Relays (SSRs) to control critical vehicle systems, including the main contactor and pre-charging circuitry.

Furthermore, the BMS board supports the battery cooling system by utilizing strategically placed thermistors on both main and daughter boards, enabling precise temperature monitoring and control of the water pump and fan mechanisms through dedicated PWM-controlled outputs. This way, the system ensures optimal thermal performance across varying operating conditions.

Firmware capabilities extend far beyond basic monitoring, providing advanced tracking of **State of Charge** (SoC), **State of Health** (SoH), and **State of Power** (SoP). The protective mechanisms are robust, encompassing sophisticated voltage, current, and temperature protection strategies that prevent overvoltage, undervoltage, overcurrent, and out-of-bounds thermal conditions. The firmware update mechanism, sing the UDS protocol, ensures ongoing system adaptability and maintenance.

A key distinguishing feature of this BMS is its inherent **flexibility.** The hardware and firmware design allows for potential function delegation to the VCU. The firmware portability enables support for different microcontroller platforms. This approach minimizes engineering overhead and facilitates future system iterations and adaptations to the different customer and/or market demands.

The two-board architecture addresses critical spatial constraints through two primary interconnection approaches: rigid board-to-board connectors and flexible wire-to-board connectivity. This design philosophy ensures that the BMS can be integrated efficiently into various electric two-wheeler configurations while maintaining high standards of performance and reliability.

By combining advanced hardware design, comprehensive firmware capabilities, and a modular architectural approach, this Battery Management System sets a new benchmark in electric two-wheeler battery technology, delivering unparalleled performance, safety, and adaptability.

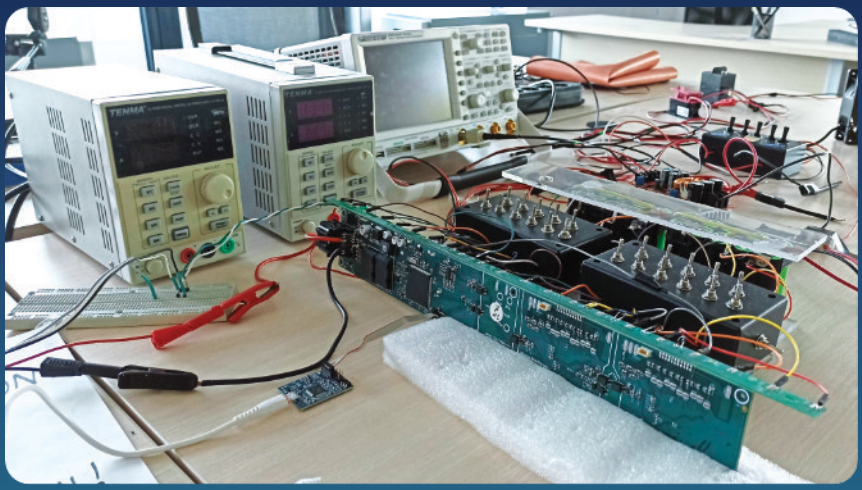


Fig 1. BMS for e2W on the test bench (with the battery pack)

TECHNICAL DATA AND FEATURES

Main Board Components:

- Two STMicroelectronics L9963-E Analog Front Ends (AFEs) for parallel branch voltage measurement
- Battery voltage powered electronics
- Cell balancing resistors and analog protection circuits
- Galvanically isolated SPI communication between the AFE and main MCU
- NXP LPC5401x MCU with external flash supporting XIP (Execute in Place)
- A **flexible bootloader** enabling multi-branch battery configuration and secure firmware updates with A/B firmware update strategy, which means if the new firmware is bad or have some issues, the device will roll back to the previous version. In this way, the robustness and integrity of the system during update process is increased.

Communication and control:

- CAN bus interface to Vehicle Control Unit (VCU) and On-Board Charger (OBC)
- UDS protocol firmware update capability
- Isolated voltage measurement (TI-AMC331)

Peripheral control via:

- Two Solid State Relays (SSRs) for main vehicle contactor and pre-charging
- PWM-controlled high-side switches for cooling system (water pump and fan)
- Low-power digital outputs for additional vehicle peripherals

Peripheral Control Architecture:

- Two Solid State Relays (SSRs) manage critical vehicle systems:
  - Main vehicle contactor
  - Pre-charging circuitry

Cooling System Control:

- Pulse Width Modulation (PWM) outputs drive:
  - Water pump
  - Cooling fan

Auxiliary Vehicle Controls

- Low-power digital outputs for supplementary peripherals (e.g., horn, headlight) as an option.

Comprehensive Temperature Monitoring:

- Thermistors deployed on main and daughter boards

Advanced Control Features:

- Charge management
- Peripheral system coordination

Design Flexibility Notes

- Adaptable Hardware/Firmware Architecture
- Option to minimize BMS board to AFE and immediate components
- Potential transfer of upper-layer monitoring functions to Vehicle Control Unit (VCU)
- Communication via isolated SPI interface

Firmware Portability:

- Code structure optimized for efficient migration across microcontroller platforms (e.g., STM32 MCU) with minimal engineering effort.

CONCLUSION

Our BMS represents a sophisticated technological solution for electric two wheelers and three-wheelers, addressing critical challenges in battery performance, safety, and management. Designed to support various voltage configuration and accommodates different battery capacities through the innovative dual-board modular architecture. It features advanced methods for battery use, care and protection.

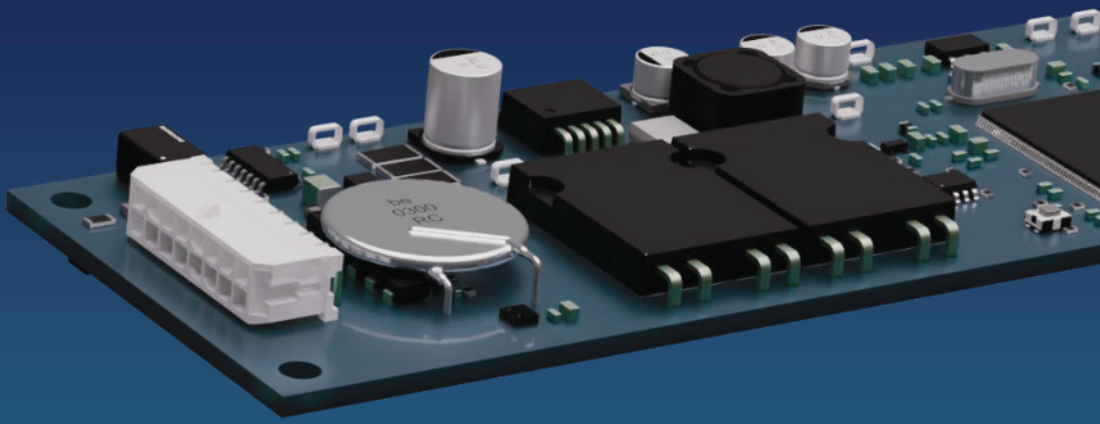
A key distinguishing feature of this BMS, besides advanced battery management functionality, is its inherent flexibility in HW & FW adaptability. It could be adjusted to be integrated in almost all battery packs' geometries and has additional dedicated IOs. With firmware update by using UDS protocol over CAN, it could be pre-configured for different battery packs voltages and configurations. Additionally, because of its firmware portability, it supports different microcontroller platforms. Our design minimizes engineering overheads and facilitates future system iterations and adaptations to the different customer and/or market demands.

HIGHLIGHTS

A FEATURE-RICH BATTERY MANAGEMENT SYSTEM

FLEXIBLE, PORTABLE AND SCALABLE

SAFE FIRMWARE UPDATES



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