MBSE-Enabled Development of Lithium-Ion Battery Module-to-Pack Architectures

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Background

- Lithium-ion batteries are increasingly used because of their high energy density and decreased degradation compared to battery cells of other chemistries.
- Module-to-pack assembly is challenging because of cell-to-cell variance and distribution of heat across the pack.
- Model-Based Systems Engineering uses digital models to organize the requirements, design, analysis, verification, and validation of complex systems.
- This centralized approach enables engineers to identify design errors and redundancies early in the development process, before implementation.

System Architecture Development

- Establishing system requirements and design parameters provides the foundation for developing a relevant, structured, and fully traceable MBSE architecture.
- Functional decomposition is a technique used in MBSE to identify and organize the primary functions of a system to organize it into top-level and sub-level components.
- Defining interfaces is essential for the flow of an MBSE diagram. Interfaces represent the type of data that is carried between each port connecting diagram components.
- MATLAB System Composer supports each stage of the MBSE process to efficiently develop a structured system architecture.

Objectives

- Develop an MBSE architecture for a lithium-ion battery pack system.

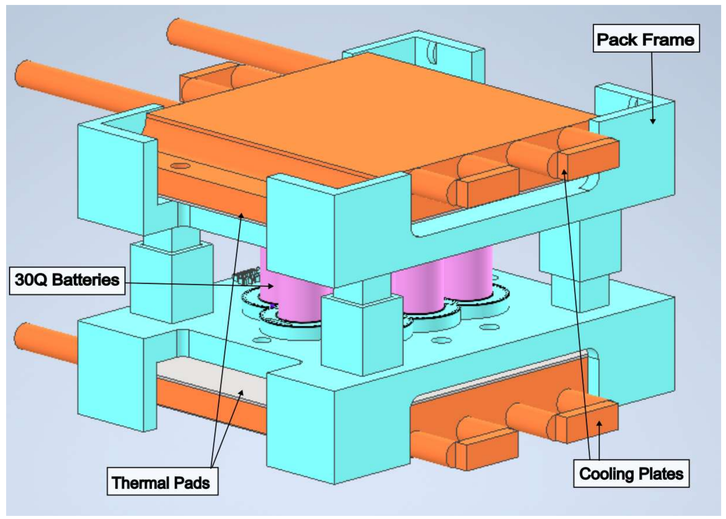

Figure shows a CAD model of the assembled battery pack with cooling plates attached.

Results

- A functional and traceable MBSE architecture made in MATLAB System Composer.

Category	Design Parameters
Mechanical	Vibration and shock limits
Thermal	Cell and water temperature limits, heat generation rate
Electrical	Pack nominal and maximum voltage, C-rate limits
Health	Cycle count, capacity fade rate
Safety	Overvoltage and undervoltage thresholds, overcurrent and short-circuit thresholds

Battery Module-to-Pack Architecture

- The top-level components of the MBSE diagram consist of Battery Module, Mechanical Structure, Thermal Management, Instrumentation, and cDAQ.
- The Mechanical Structure component consists of the pack frame and springs, and it is connected to the Battery Module component..
- The Thermal Management component consists of cooling plates and thermal pads, and it is also connected to the Battery Module.
- The Battery Module component consists of ten Samsung 30Q batteries in series, nickel strips, and a battery management system. The ten batteries are connected to the strain and temperature ports, and the nickel strips are connected to the current port of the Instrumentation component.
- The Instrumentation component consists of a strain gauge, a thermocouple, and current sense wires that are all connected to the cDAQ component.

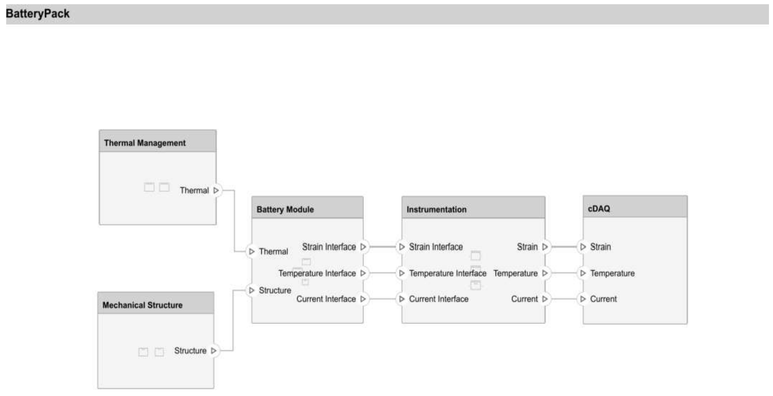

Figure shows the top-level architecture of the battery pack MBSE diagram

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