Test challenges when designing and validating a BMS

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E&A ELECTRONICS APPLICATIONS '23
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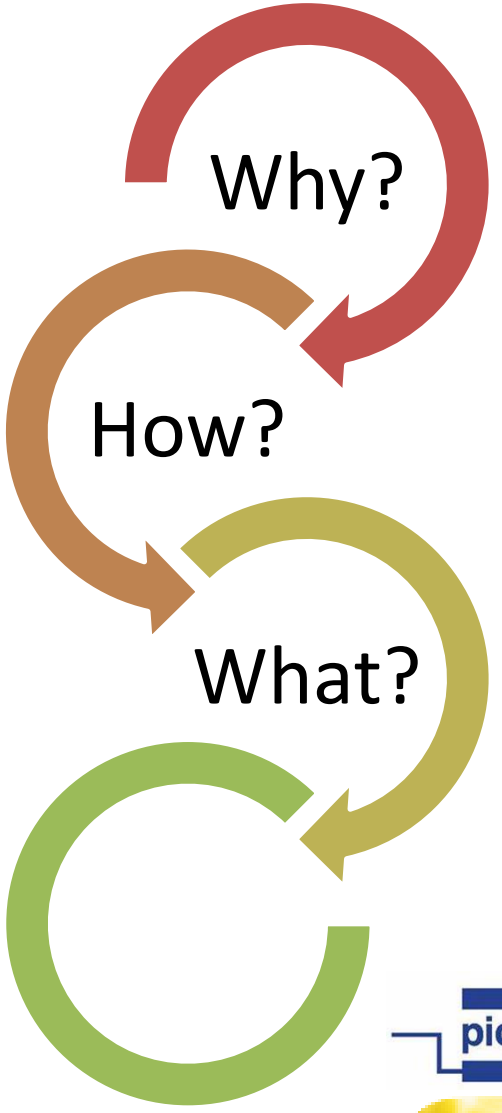
Agenda

- Importance of Testing during BMS Design
- Tackling BMS Test Challenges
- Real-world conditions vs Real-world Stimulus
- Components for a Test system
- Advantages of using a PXI based modular test system.

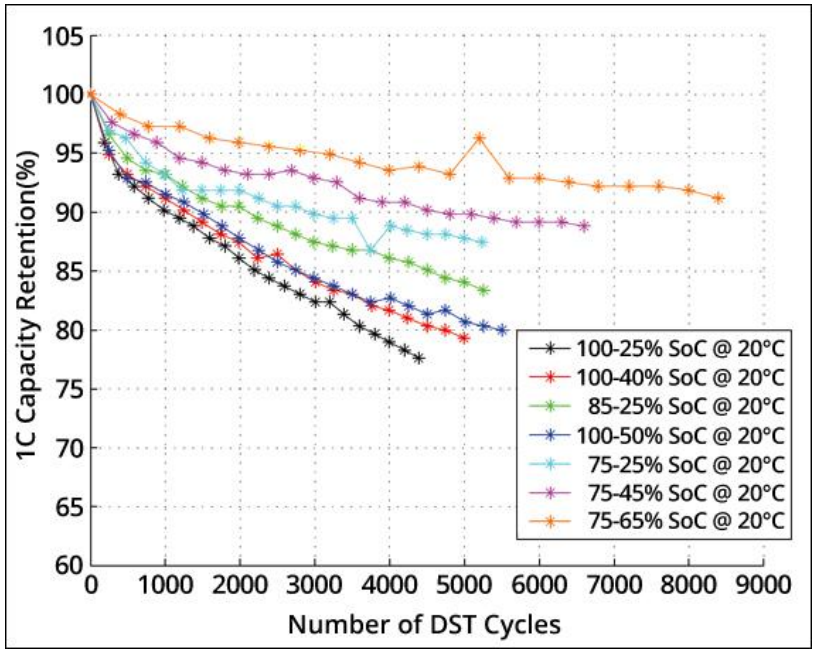


Importance of Testing BMS during Design - **Safety**

- Design a BMS to ensure battery packs are safe:
  - Lithium-Ion batteries are intrinsically unstable and, when used beyond their safe operation, can result in thermal runaways.
  - BMS constantly monitors voltages and temperatures across individual cells and current across the battery pack.
  - In case of a fault, the BMS must take appropriate actions to ensure the safety of the end users.

Importance of Testing BMS during Design - **Performance**

- Designing a BMS to ensure battery packs are healthy throughout their lifetime:
  - State-of-Charge (SOC), in simple terms is the % of battery showing on your phone or in your EV.
  - Accurate and effective estimation of SOC helps protect the battery, prevent overcharge or discharge, and improve the battery life.
  - The capacity retention of a battery can be prolonged over partially charging and discharging.



https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries

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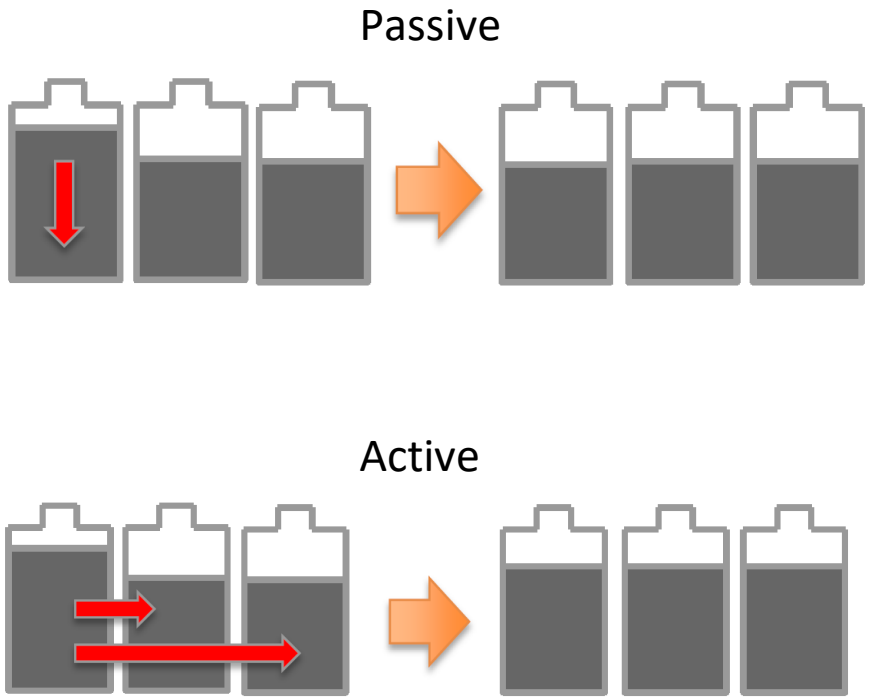
Importance of Testing BMS during Design - **Performance**

- A battery pack comprises several battery cells stacked together in series - each cell has its own characteristics.

- To ensure the overall state of charge is achieved, it is the BMS's responsibility to ensure all the cells in the pack charge or discharge at the same rate

- By providing effective **cell balancing** techniques, the BMS improves the available capacity of the battery pack and increases the longevity of battery cells.



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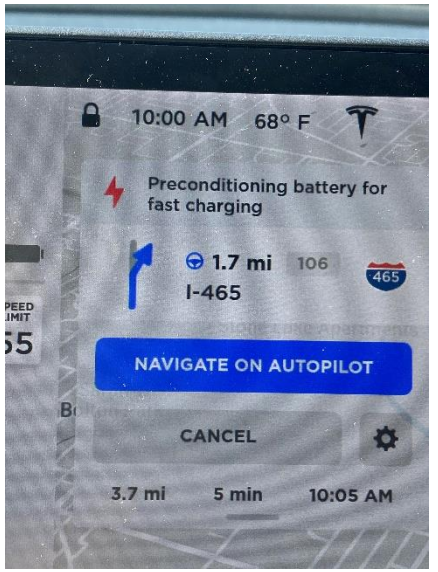
Importance of Testing BMS during Design - **Convenience**

- One of the biggest challenges EV users face is the amount of time it takes to charge.

- Intelligent algorithms for preconditioning batteries for fast charging.
  - Tesla preconditions the battery pack when navigated to a supercharger.

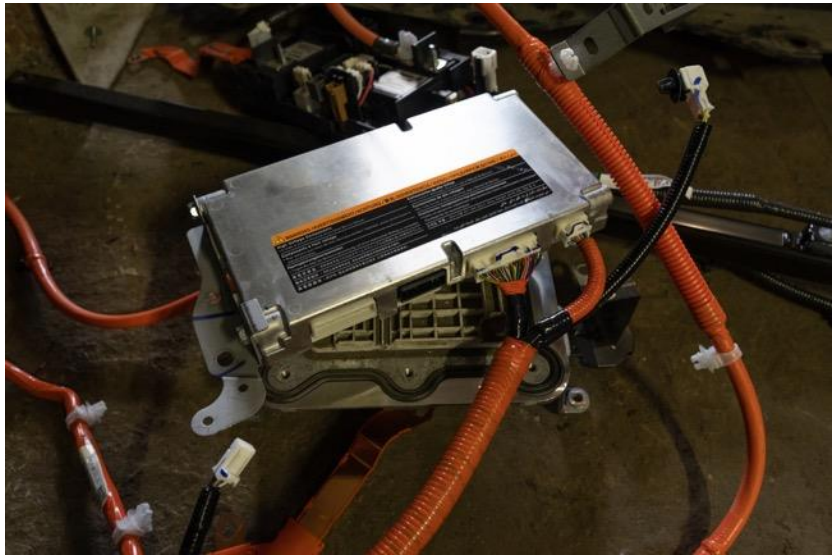
- InMotion's novel technique for cooling on cell level during fast charging to avoid battery degradation.



https://www.tue.nl/en/news-and-events/news-overview/13-07-2023-inmotion-develops-fastest-charging-electric-race-car-in-the-world

Tackling BMS Test Challenges

- The Battery Management System (BMS) controls almost all electronic functions of the EV battery pack.
- Developing a test strategy for an assembly as large, complex and powerful as an EV battery pack can be a daunting task.



Electric vehicle Battery Management System

Electric vehicle battery pack

Reliably Test the BMS Under Real-World Conditions

- During BMS development, engineers need a way to reliably test the BMS under real-world conditions to complete their verification and validation plans.
- Test strategies such as Hardware-in-the-Loop (HIL) testing are often performed at this stage.
- HIL testing involves simulating physical inputs and external connections to the pack while monitoring its outputs and behavior relative to design requirements.

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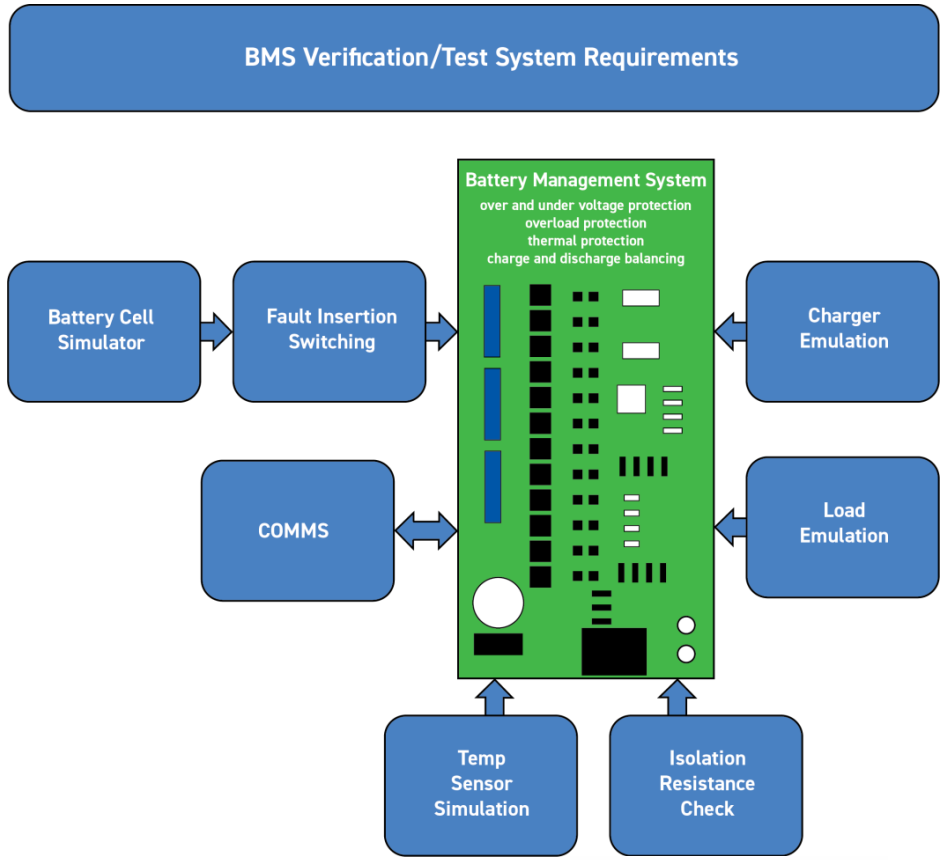
Reliably Test the BMS Under Real-World Conditions

- Accurately simulating all conditions the BMS could be subjected to is not easy.
- Consider the long-term cost of skipping testing for all conditions.
- Simulating nearly every combination is the only way to verify that the BMS reacts as intended.



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Why Not use Real World Stimulus

- Time to Test
  - You would need to cycle battery packs.
  - You would need to manipulate real-world conditions.
- Repeatability
  - Age and conditions affect results.
- Cost
  - You would need a setup for every BMS use case, leading to expense in purchase and storage.
  - Setups would need regular maintenance and upgrade.
- Safety
  - Taking batteries to extremes could cause catastrophic failure.
  - Battery Stacks are heavy and cumbersome.

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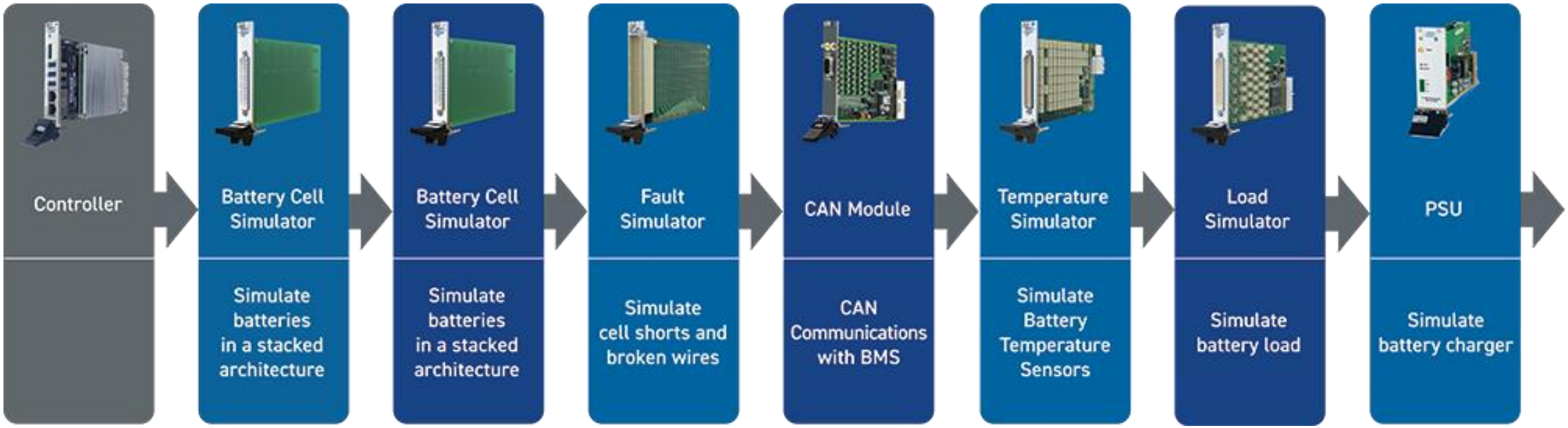
Components of a Test System



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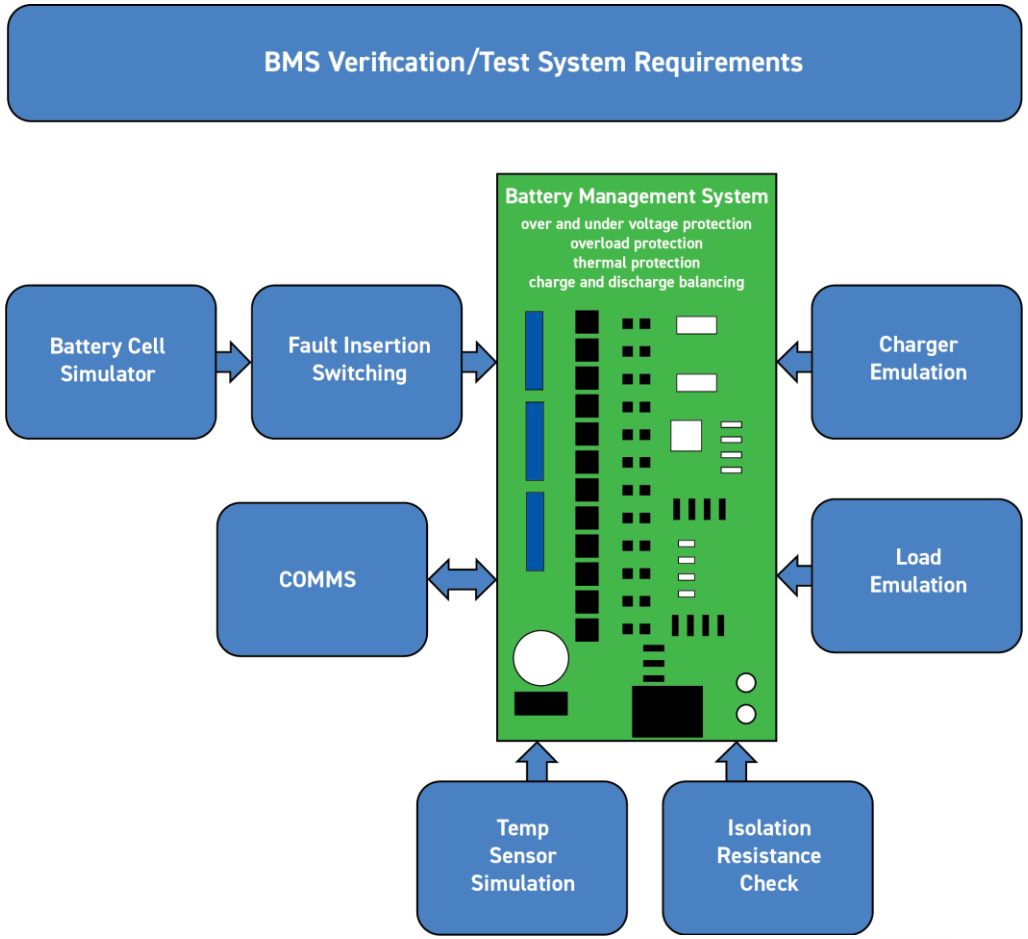
What May Need Testing/Simulating?

- Cells
  - State of charge
  - Charging / Discharging
- Sensors
  - Temperature of Battery Stack
- Isolation
  - Floating system
- Communication
  - Protocol
- Connectivity
  - Incorrect wiring



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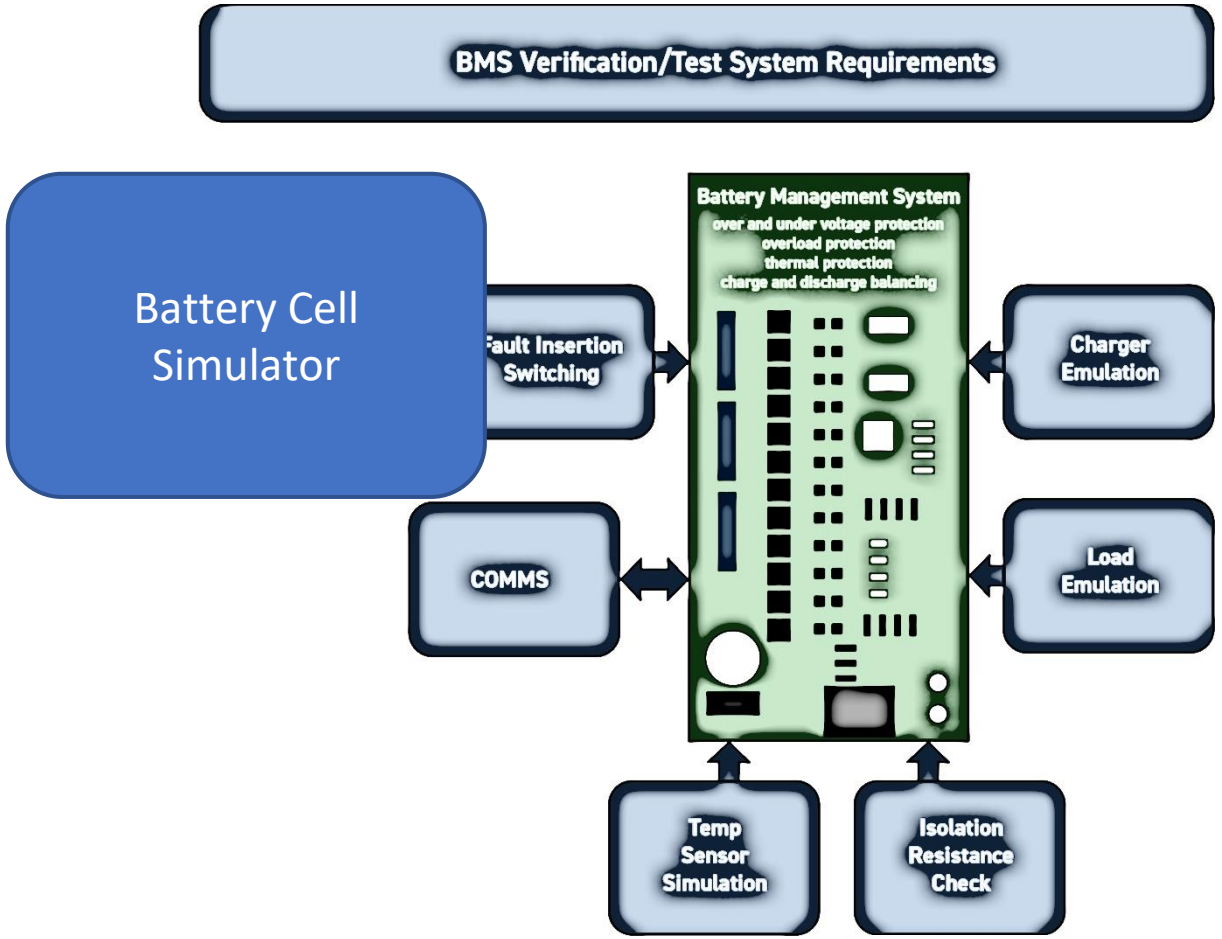
Battery Cell Simulator

- Simulates each cell's voltage and current output, with current sink to emulate cell charging.
- Programmable over full cell range with required precision.
- Cells must be stackable, with voltage isolation of full stack V.
- Ideally report V & I of each cell.
- Ideally each cell has independent remote sense connections.



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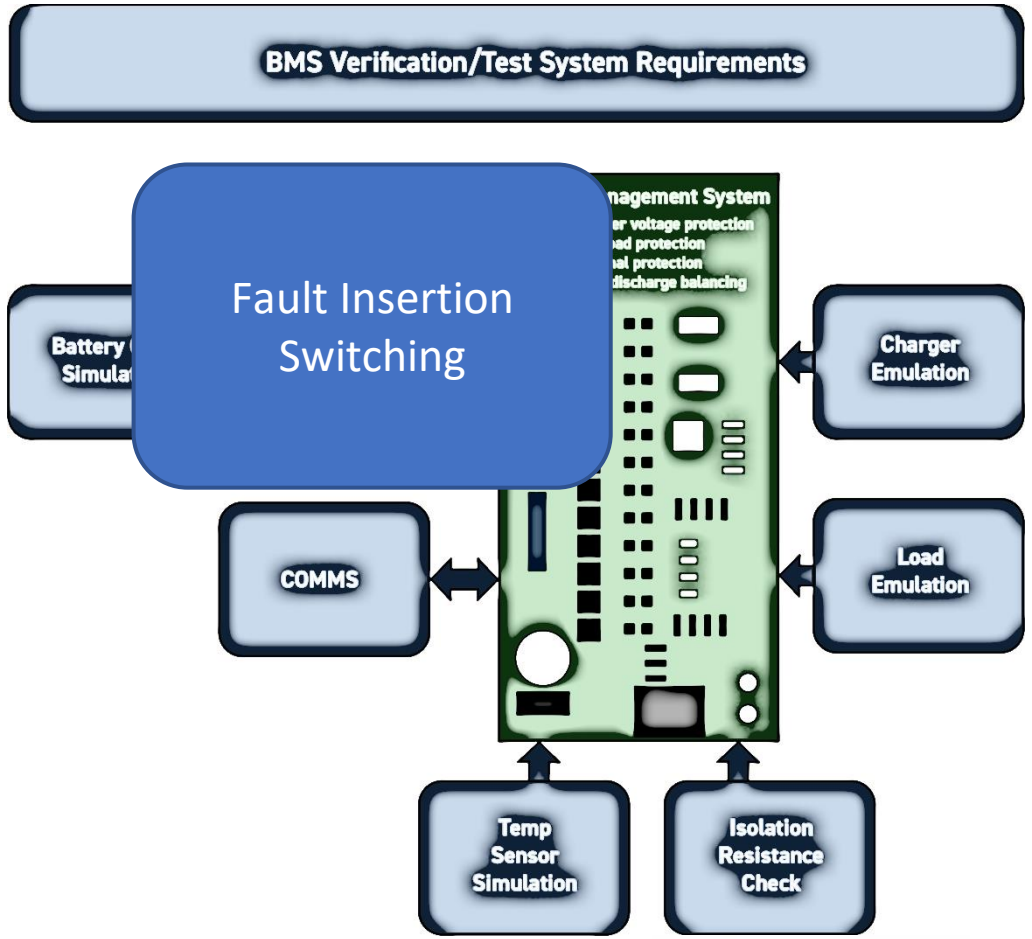
Fault Insertion Switching

- Simulates shorts and opens on each battery cell output and wiring faults between cells and BMS to verify BMS responses.
- Ideally simulate polarity reversal on each cell to simulate manufacturing errors.



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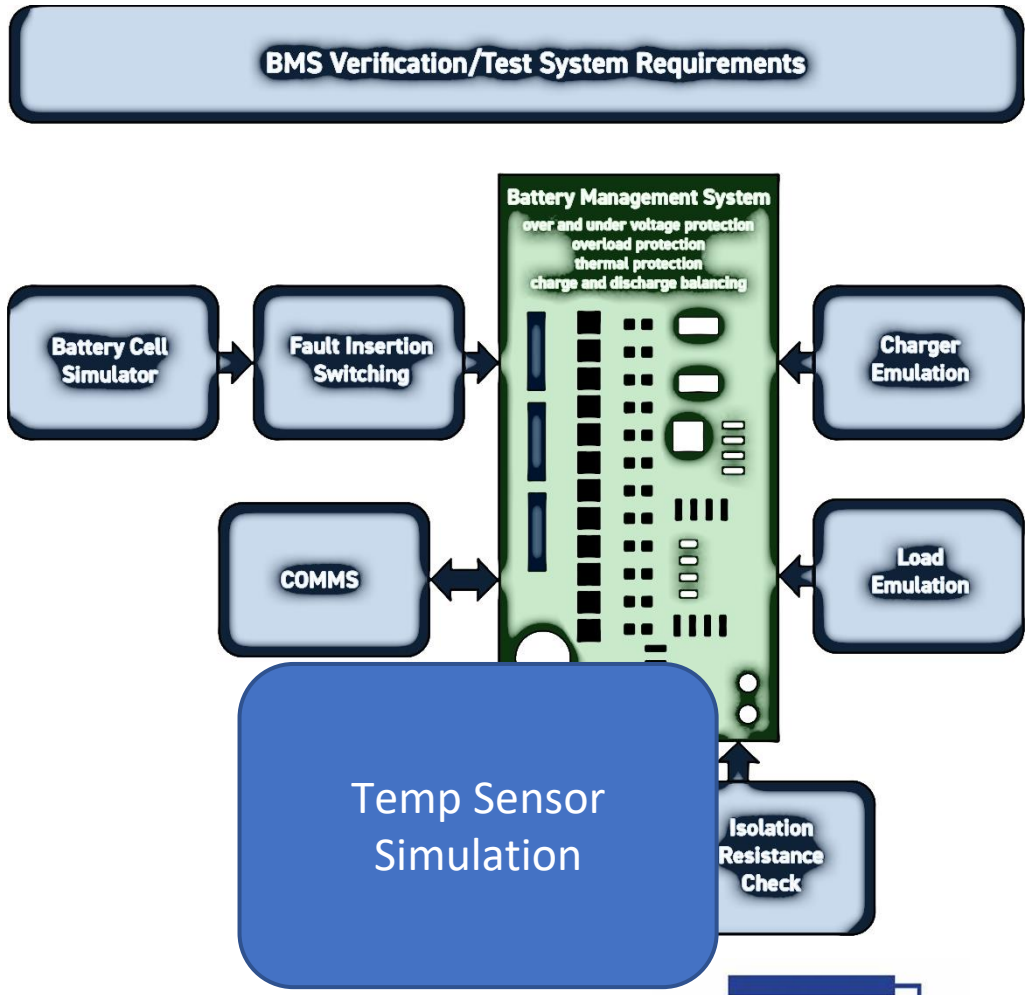
Temperature Sensor Simulator

- Simulates inputs to BMS from remote temperature sensors, e.g., RTDs and thermocouples.
- Programmable to verify BMS response to temp changes.
- Ideally simulate shorts & opens on each sensor.



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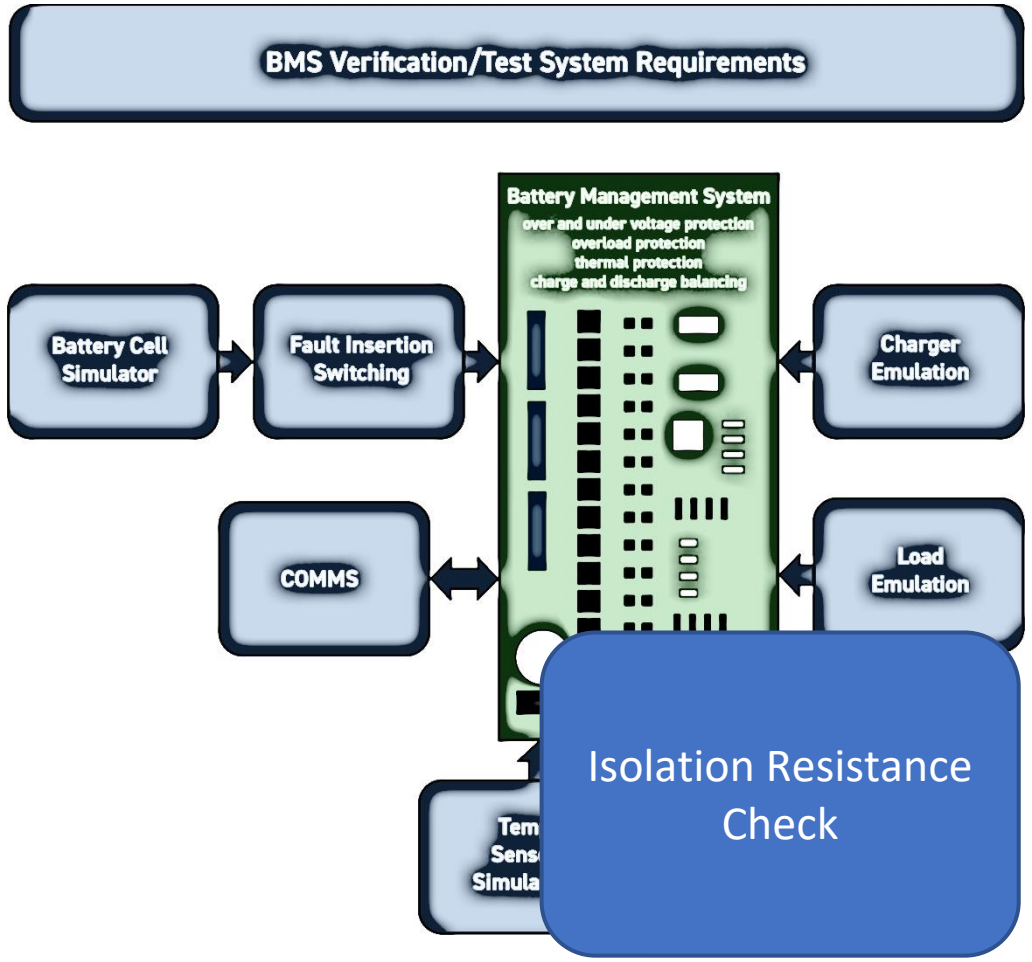
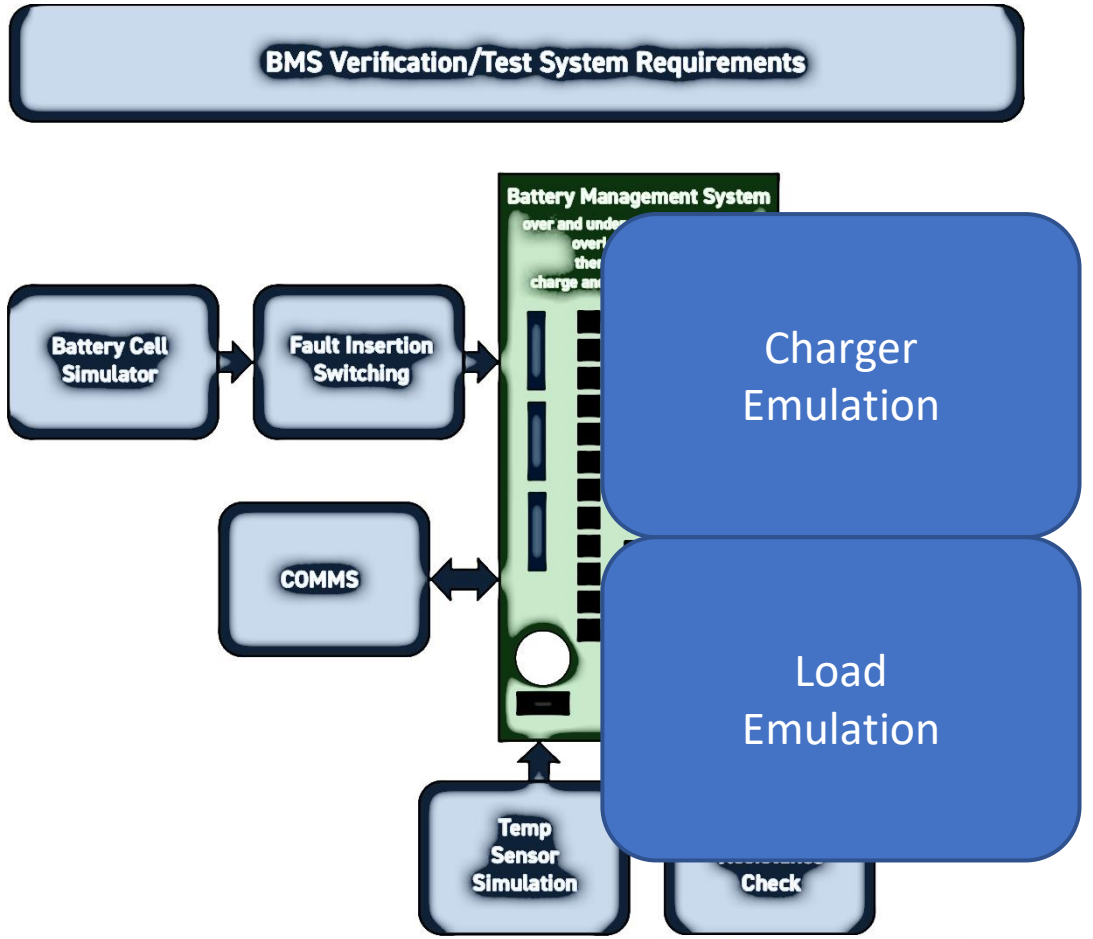
Isolation Resistance Simulator

- For BMS with Isolation monitor.
- Programmable high resistance with stack voltage standoff.



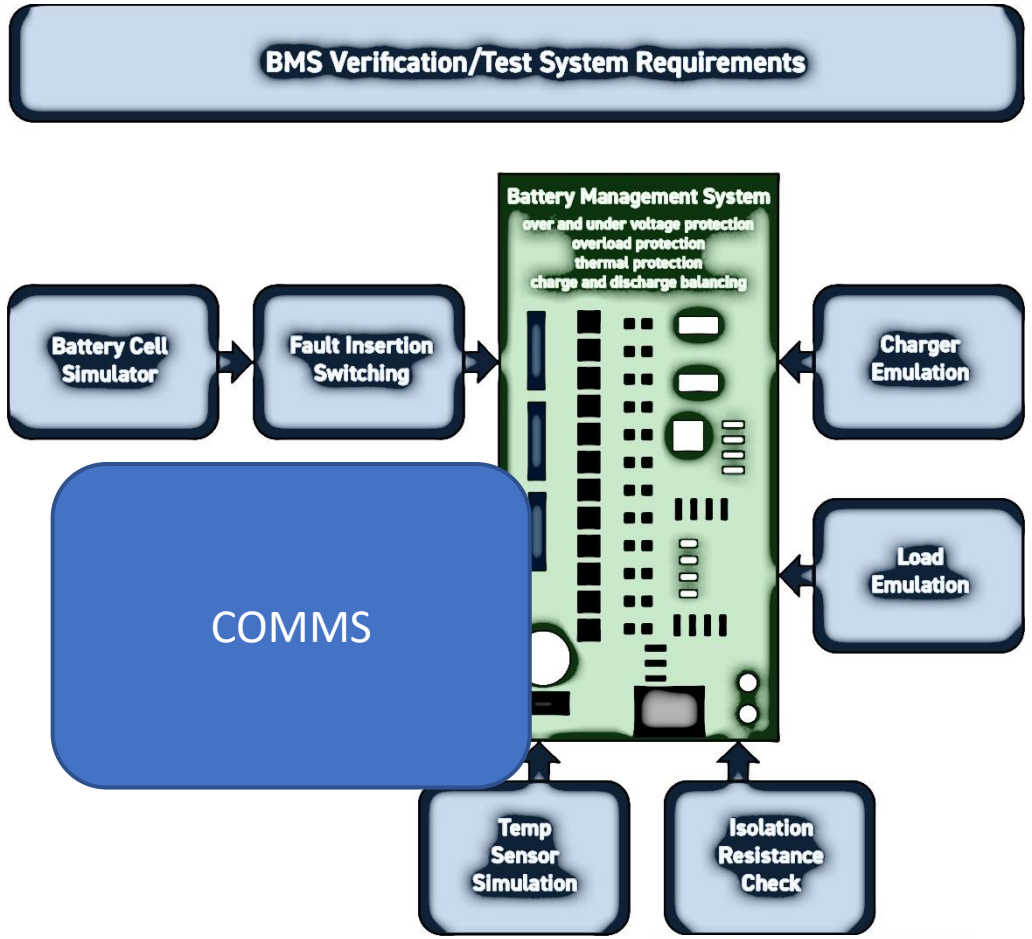
Charger & Load Emulation

- Programmable source to emulate charging current coming into BMS.
- Programmable resistive load to emulate Battery Stack loading.



COMMS

- Send commands to BMS and monitor status outputs.
- Typically CAN format to emulate communications with vehicle ECU.



Modularity to Overcome Test Challenges

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Advantages: Lower Cost & Increased Test Throughput

- Lower the cost of the test system and save time by using commercial technologies and standards.
- Increase your test throughput with fast measurement hardware and software capable of managing multiple test routings in parallel.

Advantages: Choice & Decreased Redesign Time

- PXI is an industry-standard open architecture supported by >60 leading T&M vendors.
- The time required to redesign test systems for new products will decrease by using flexible, modular software and hardware.

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Advantages – Small System Example

- Simple BMS System includes:
  - Battery Simulation Module
  - Programmable Resistor Module
  - RTD Simulation Module
  - Fault Insertion Module
  - Source Measurement Unit (SMU)
  - Contained in a PXIe Hybrid Chassis

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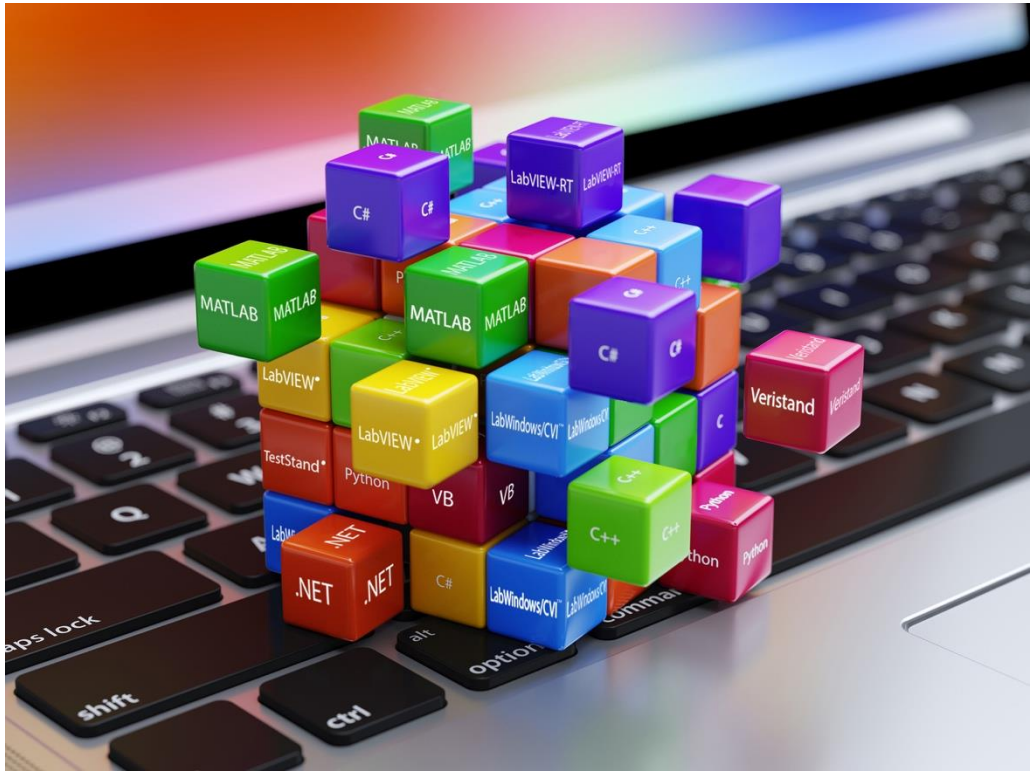
Advantages: Flexibility—Software

- An open platform also means an open software environment.
- Use your own software language.
- Quick program generation with a wide choice of APIs.
- Easy manual operation via soft front panels.



Advantages: Support

- Not tied to one vendor.
- Supported by a global network of system integrators.
  - Familiarity with PXI platform
- 1000’s of systems installed, guaranteeing long-term support.
- Ease of maintenance of a modular system with global support.

In Summary

- There are many challenges in BMS test.
- It is imperative to test the BMS under real-world conditions.
- Accurately simulating all conditions is not easy but could be costly if skipped.
- Simulating the system has many advantages:
  - Time to Test, Repeatability, Cost, Safety
- Different elements need Simulating / Testing:
  - State of charge, Charging, Discharging, Sensors, Isolation, Comms, Connectivity
- Using an industry-standard modular platform like PXI has many advantages:
  - Increase test throughput, Lower cost, Lower system redesign time, Flexibility in both hardware & software, Support

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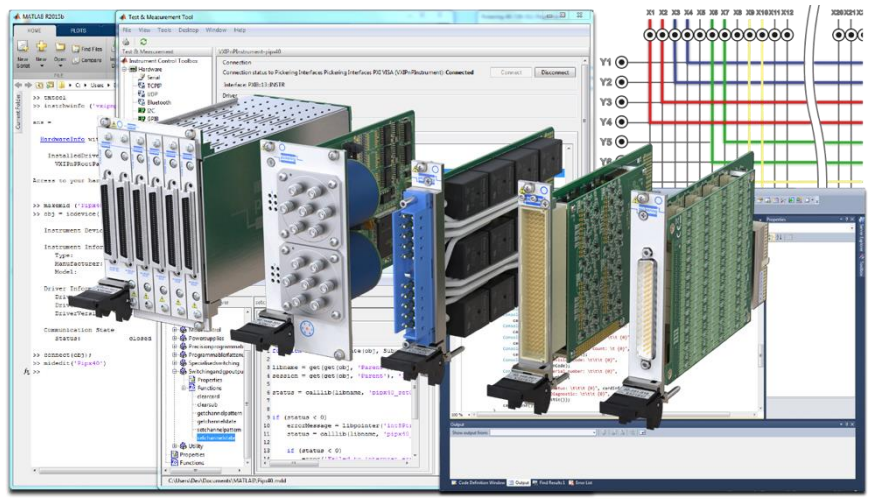
About Pickering Interfaces

- Platform independent switching and simulation solutions since 1988.
- Sales/support centers in UK, US, France, Germany, Sweden, Czech Republic and China.
- Sponsor Members of PXISA and LXI Consortium.
- Deep Product Portfolio:
  - E.g. – 1,600+ PXI modules, 290+ LXI products
- Strong Customer Focus.
- COTS and custom designs:
  - Cable/interconnect design tool and services
  - Field diagnostic self-test tools
- Long-Term Support:
  - Still support products designed in 1980’s



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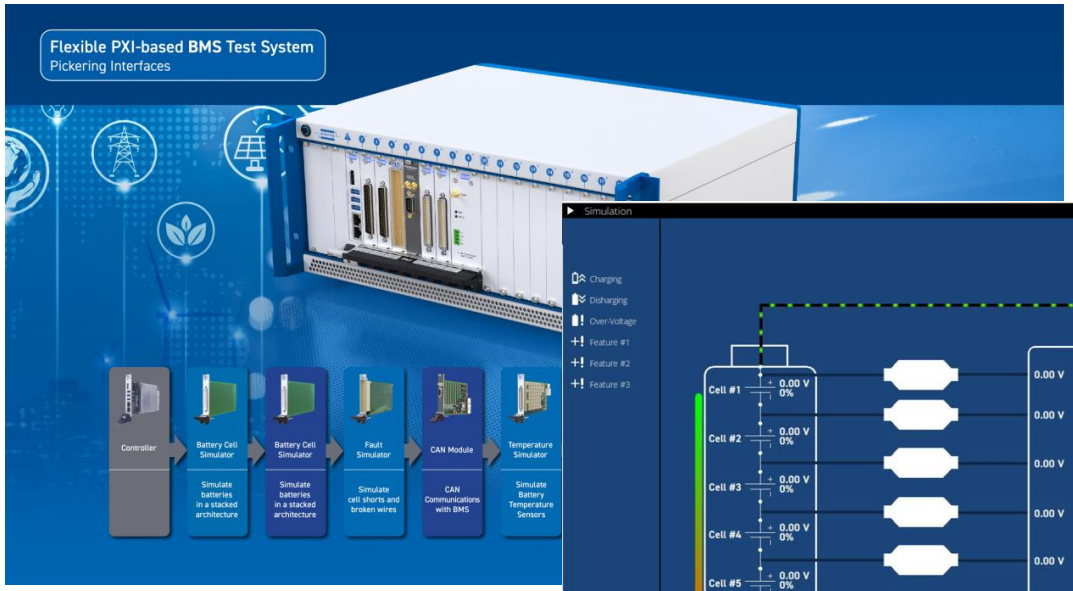

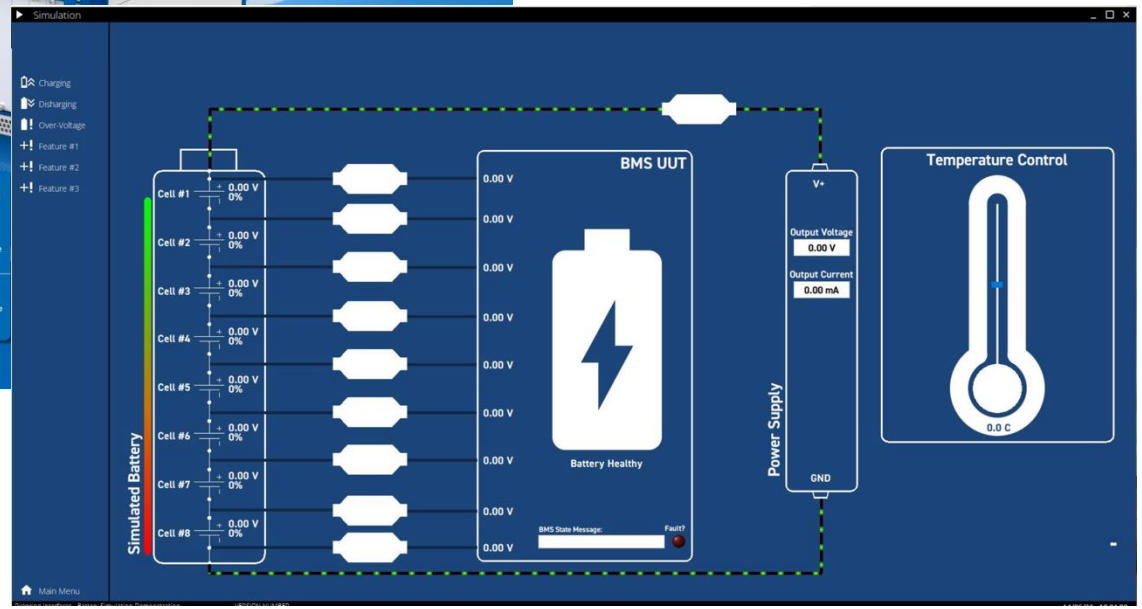

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