The Role of Testing in Ensuring the Functionality, Quality & Reliability of Battery Management Systems

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VIRTUAL CONFERENCE
EV ENGINEERING
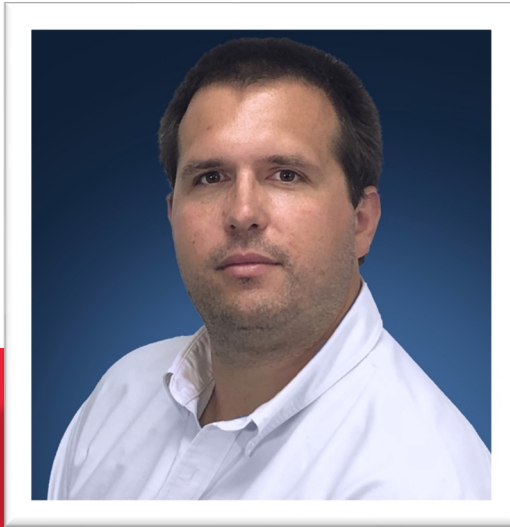
Paul Bovingdon
Simulation Product Manager
Pickering Interfaces
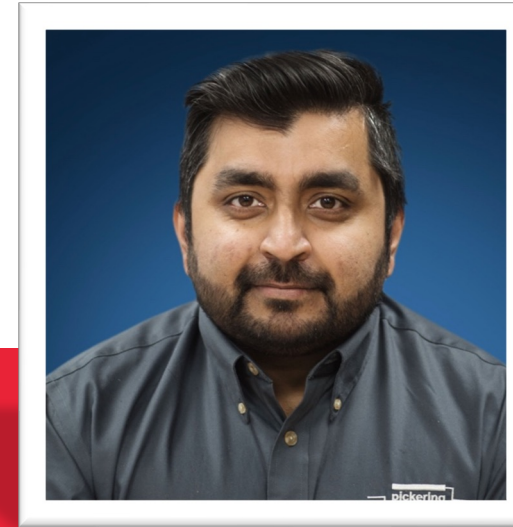
Noman Hussain
VP – Software & Strategic
Business Development
Pickering Interfaces

Why is Testing Important

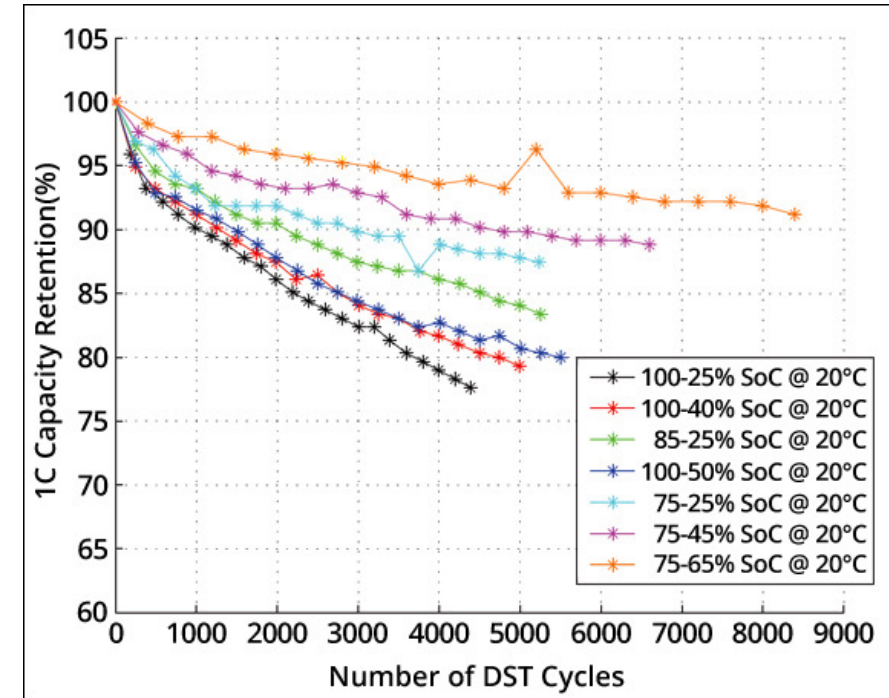# Importance of Testing BMS during Design - **Safety**

- 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.
    - BMS operates a contactor switch to isolate the battery pack from the load and the charger.
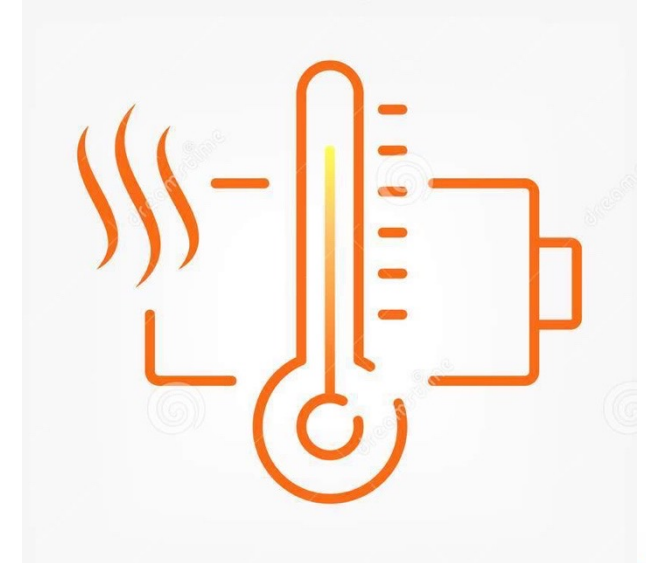
# Importance of Testing BMS during Design - **Performance**

- 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.

  - It is the BMS's core responsibility to estimate SOC accurately.

  - Accurate and effective estimation of SOC helps protect the battery, prevent overcharge or discharge, and improve the battery life.

  - An example here shows how the capacity retention of a battery can be prolonged over partially charging and discharging.

    - Around 75%-25% and/or 80%-20% is what is recommended by most EV manufacturers

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 to avoid overcharging and discharging.

- This is achieved by **Cell Balancing.**

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

- There are two different types of cell balancing techniques.

  - Active Cell Balancing: where excess energy from a cell is redistributed to other cells ($$$).

  - Passive Cell Balancing: where the system dissipates the energy of the highest voltage cell in the pack ($).

Passive

Active

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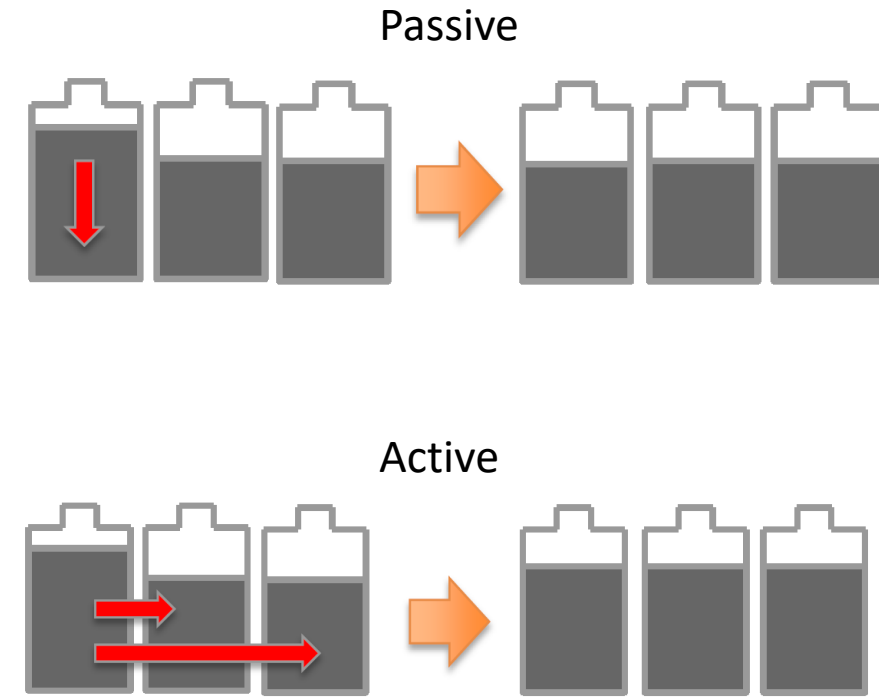
Why Simulate?

# 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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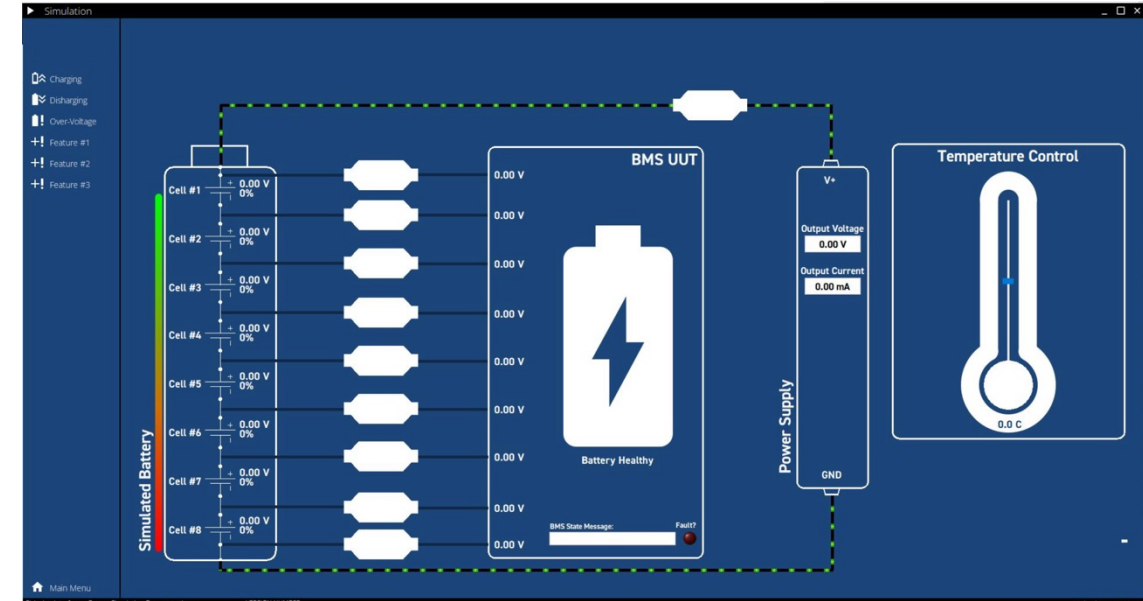# Reliably Test the BMS Under Real-World Conditions

- 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.
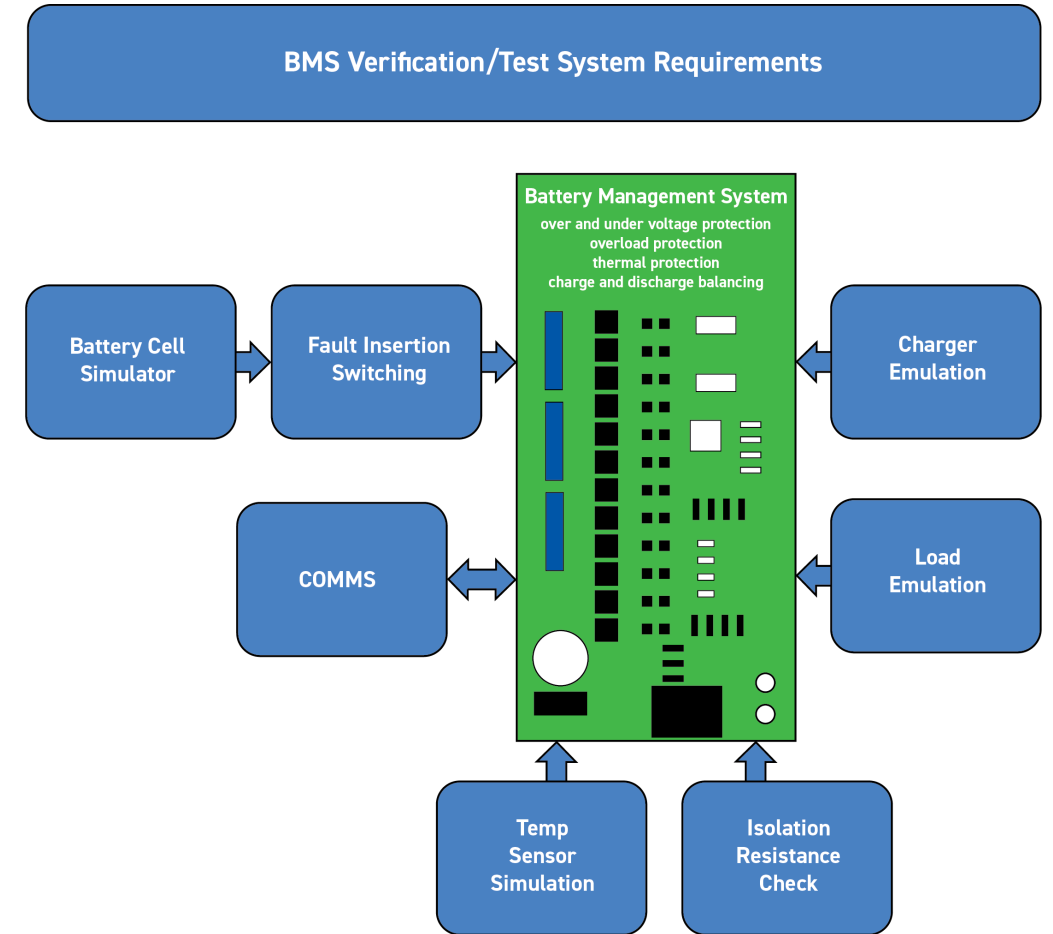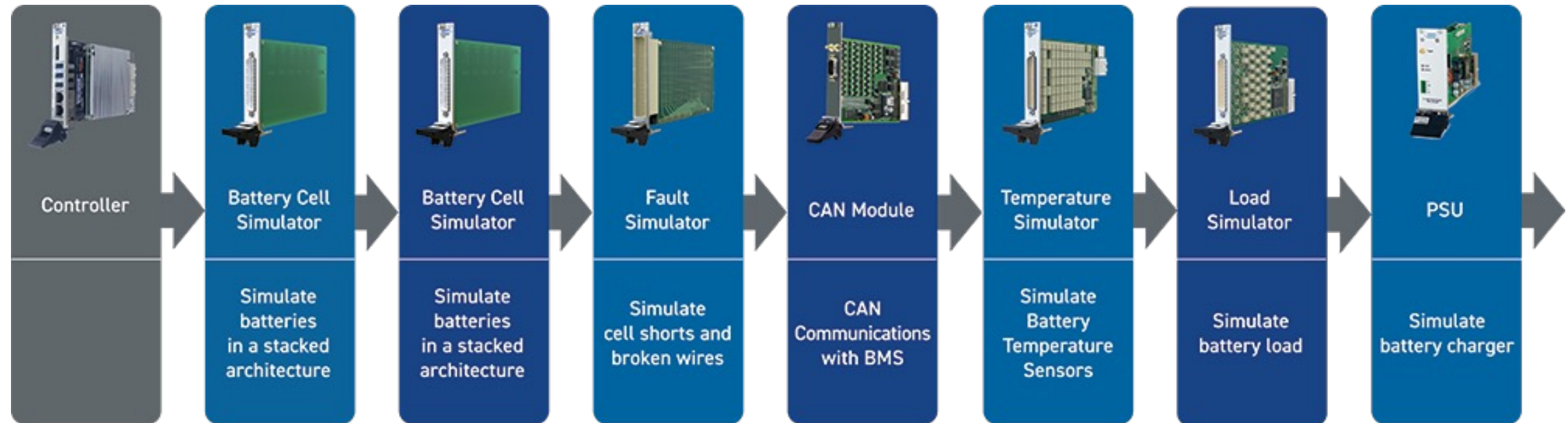
Why Not use Real World Stimulus

- 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.

Components of a Test System

Controller	Battery Cell Simulator	Battery Cell Simulator	Fault Simulator	CAN Module	Temperature Simulator	Load Simulator	PSU
	Simulate batteries in a stacked architecture	Simulate batteries in a stacked architecture	Simulate cell shorts and broken wires	CAN Communications with BMS	Simulate Battery Temperature Sensors	Simulate battery load	Simulate battery charger

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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
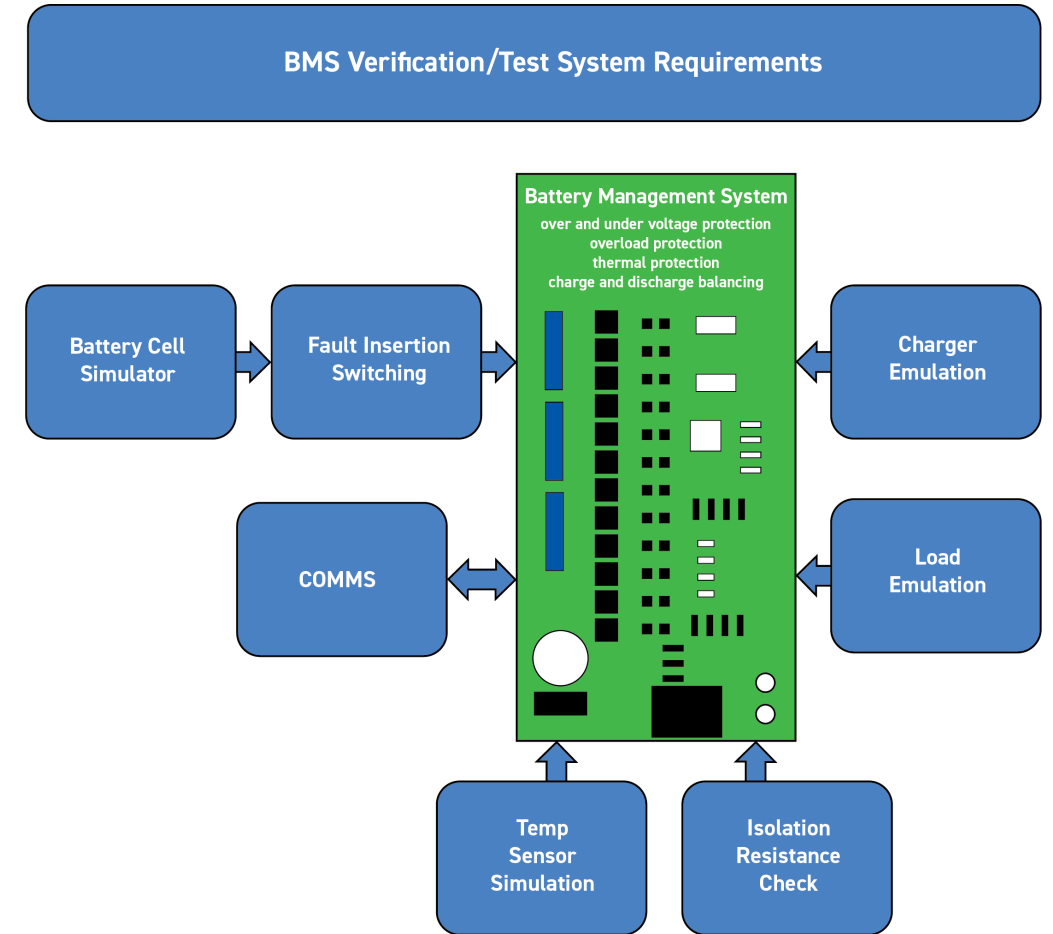
Battery Cell Simulator

- 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.
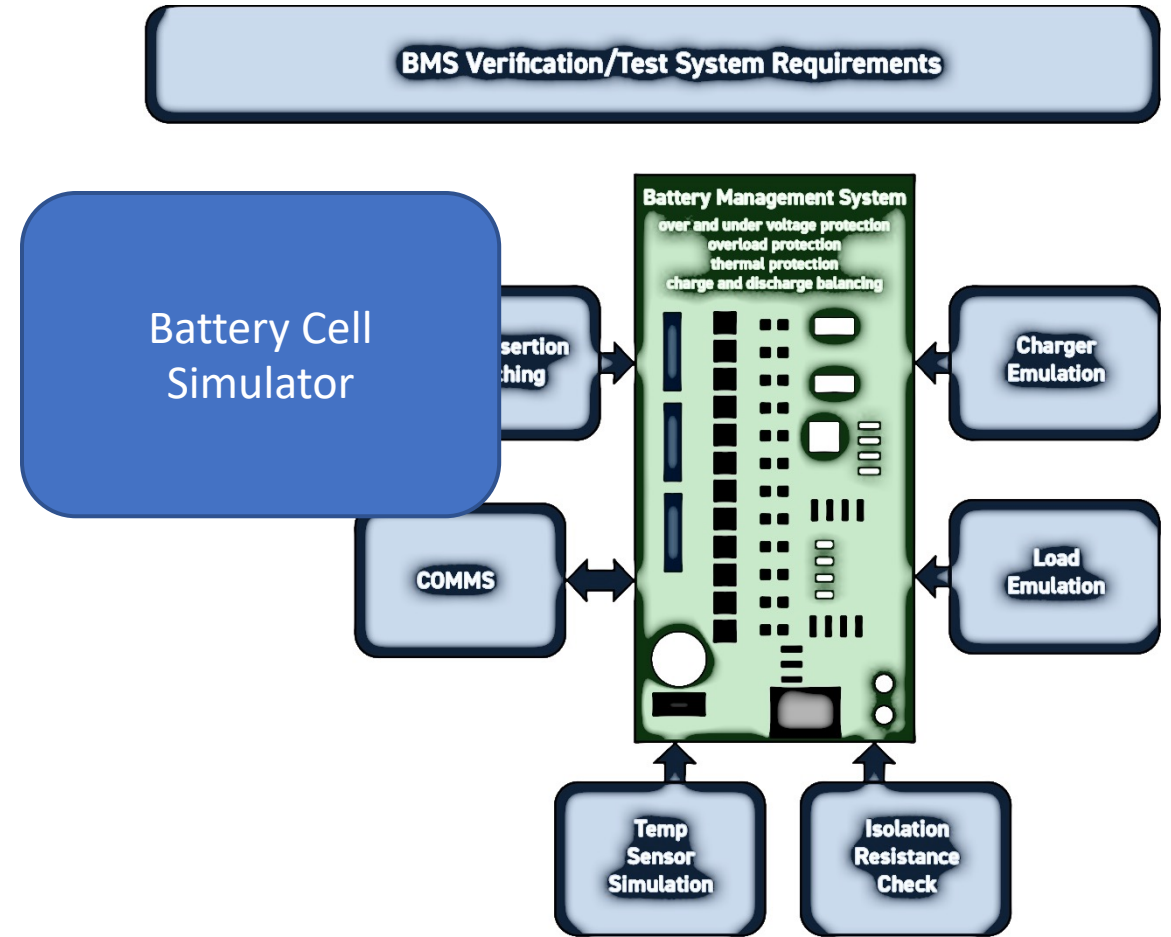
Fault Insertion Switching

- 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.
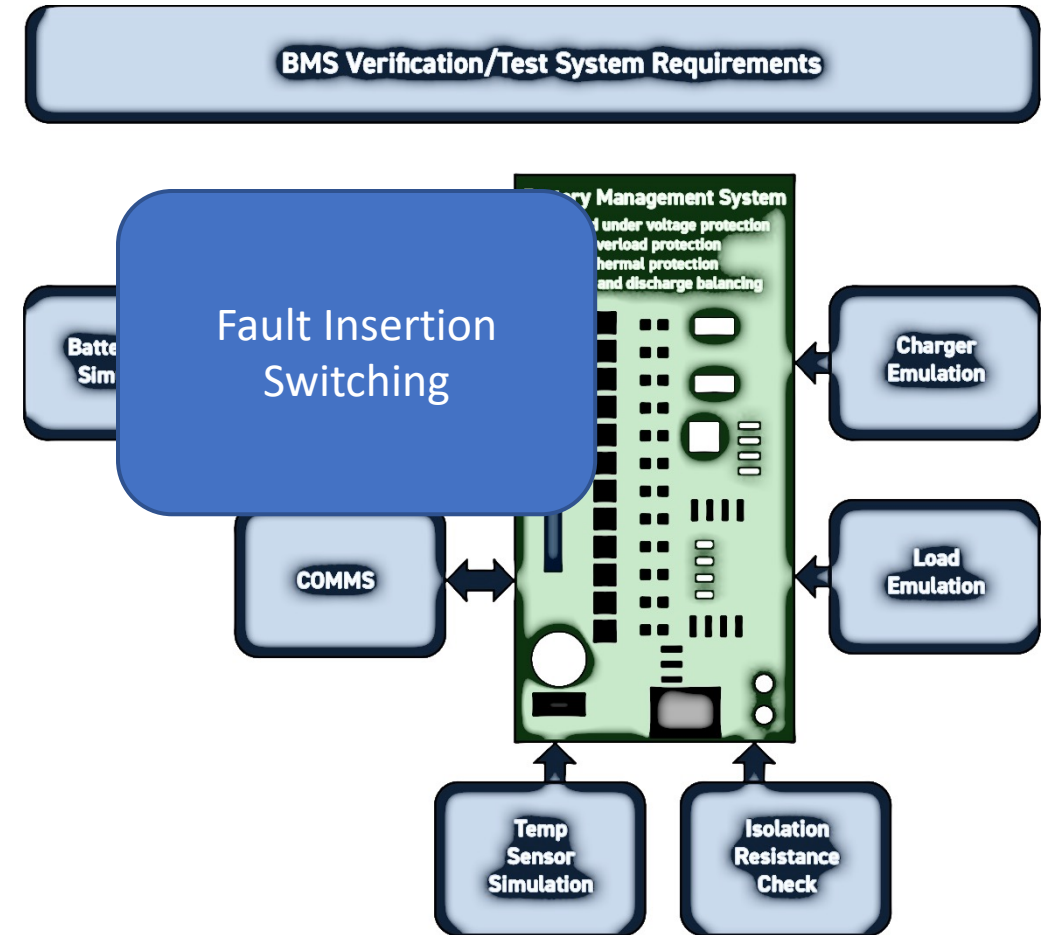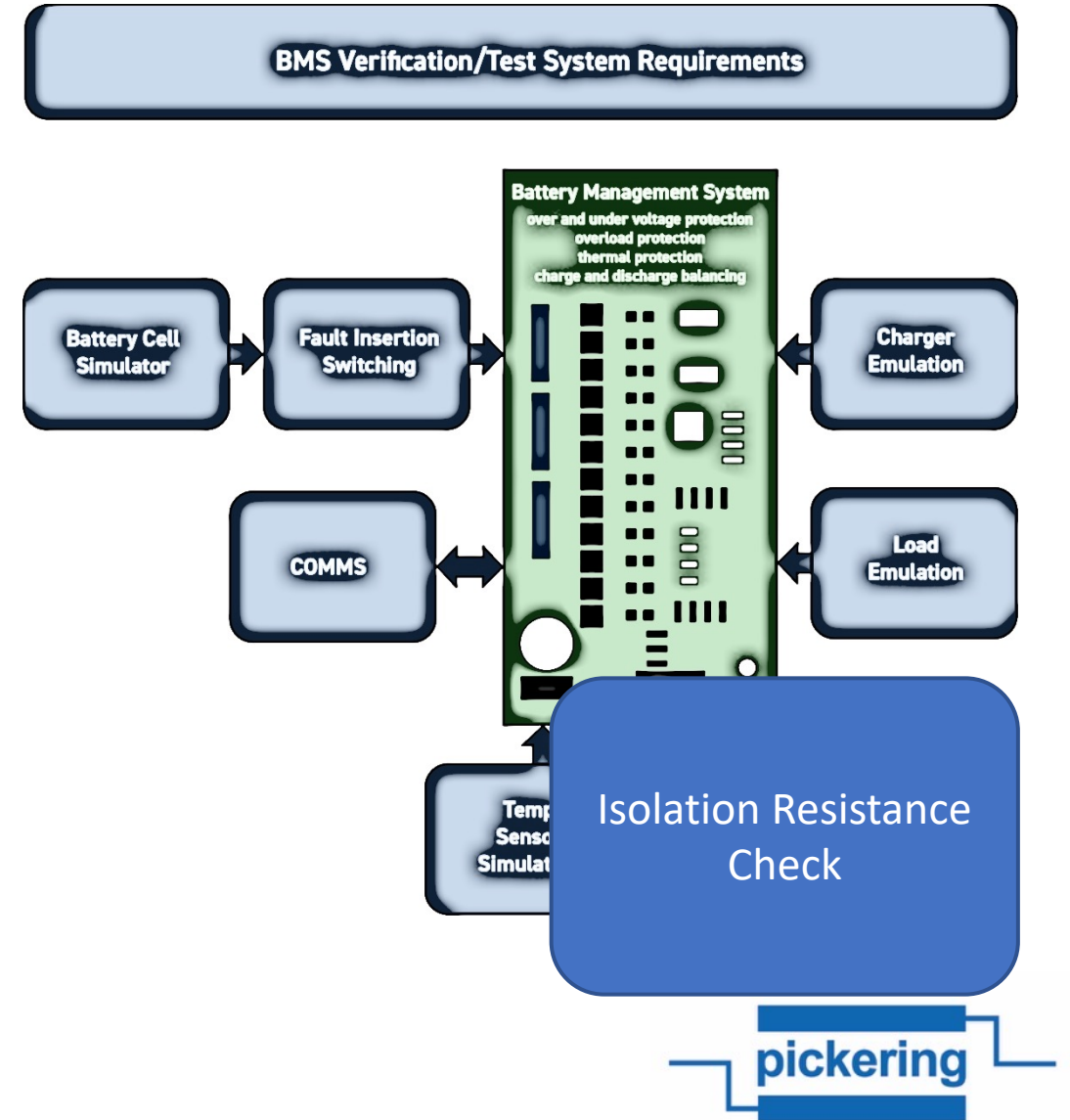
Temperature Sensor Simulator

- Simulates inputs to BMS from remote temperature sensors, e.g., RTDs and thermocouples.

- Programmable to verify BMS response to temp changes.

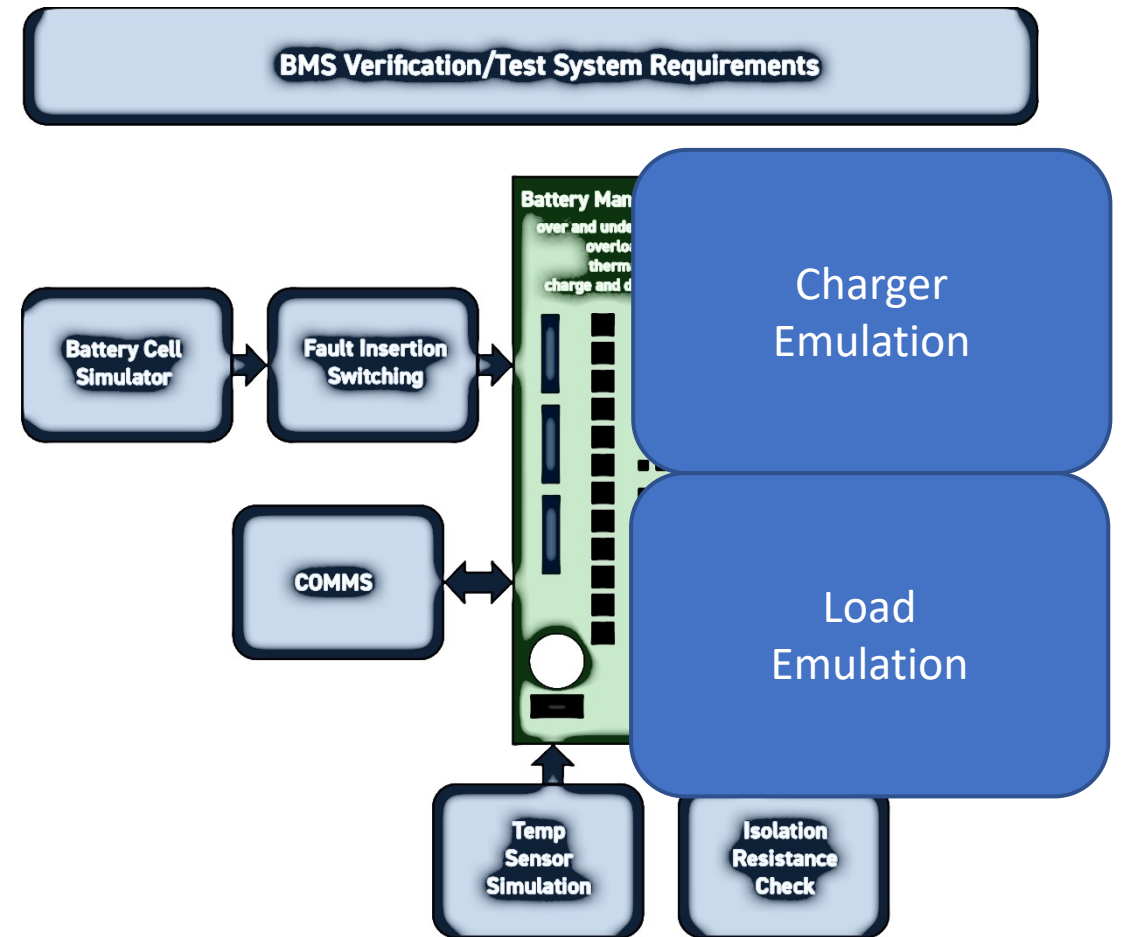- Ideally simulate shorts & opens on each sensor.
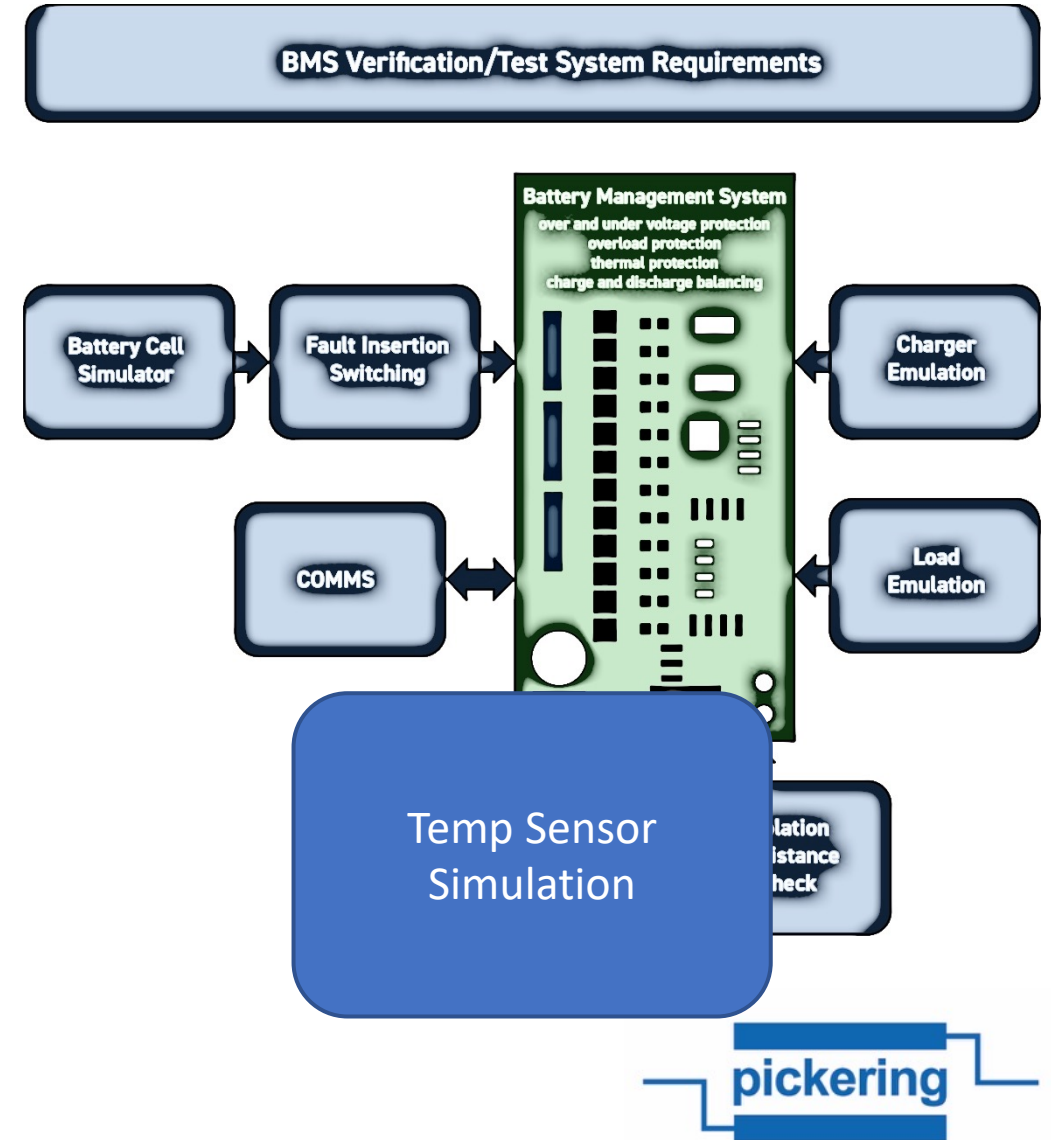
Isolation Resistance Simulator

- For BMS with Isolation monitor.

- Programmable high resistance with stack voltage standoff.
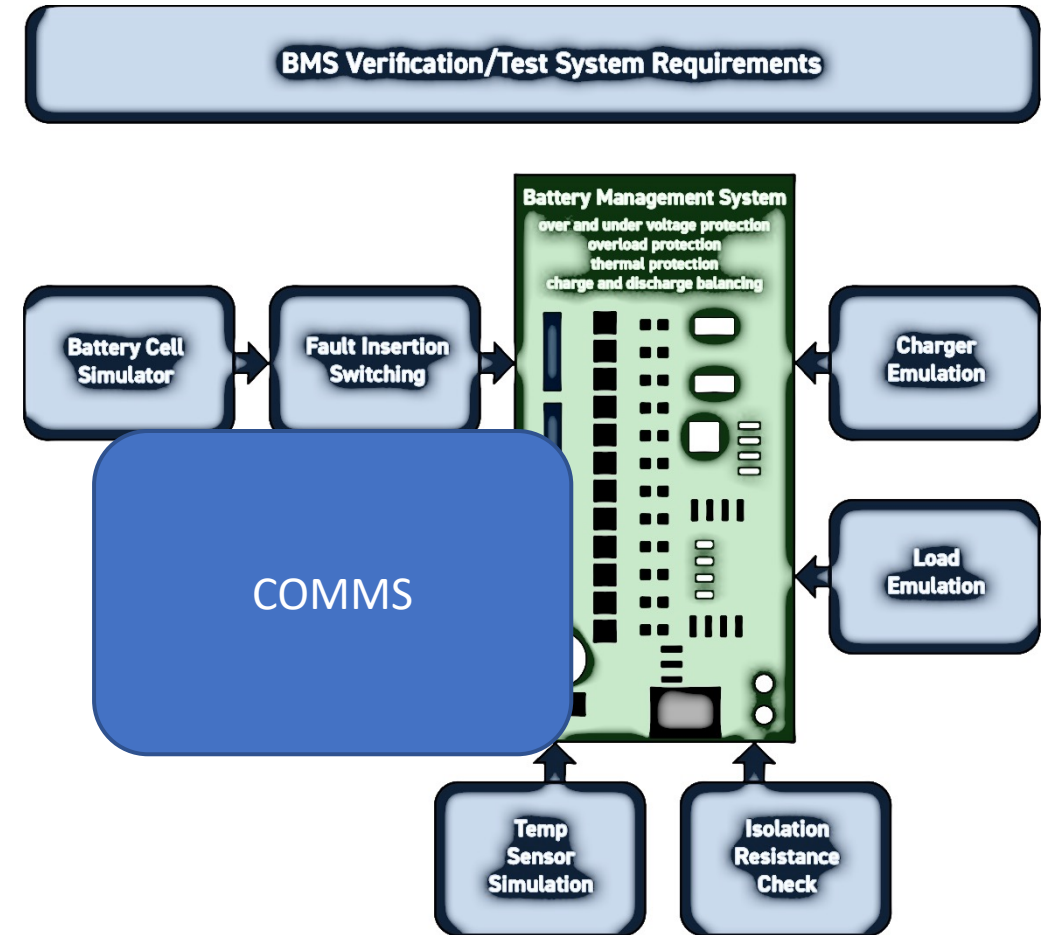

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Charger & Load Emulation

- 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.

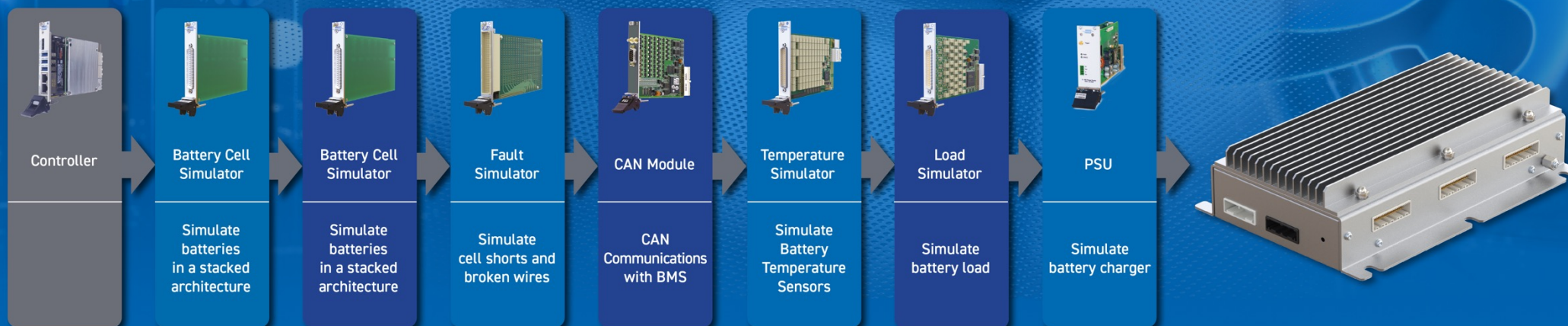- Typically CAN format to emulate communications with vehicle ECU.

Advantages of Modularity

Flexible PXI-based BMS Test System
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Controller

Battery Cell Simulator — Simulate batteries in a stacked architecture

Battery Cell Simulator — Simulate batteries in a stacked architecture

Fault Simulator — Simulate cell shorts and broken wires

CAN Module — CAN Communications with BMS

Temperature Simulator — Simulate Battery Temperature Sensors

Load Simulator — Simulate battery load

PSU — Simulate battery charger

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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.

Advantages: Flexibility—Hardware

- As your BMS and system complexity grow, there is no need for a new test system; build upon the existing one.

- Get precisely what you need the way you want it.

- Your test station will be flexible without being cumbersome to use.

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

Advantages – Growing the System

- Scale up your system by reusing existing modules and chassis and add additional modules for the addition of cells and other functionality.

- Expanded BMS System adds:
    - 18-slot PXIe Hybrid Chassis
    - Battery Simulation Module (x15)
    - High Voltage Switching
    - CAN Communication Module

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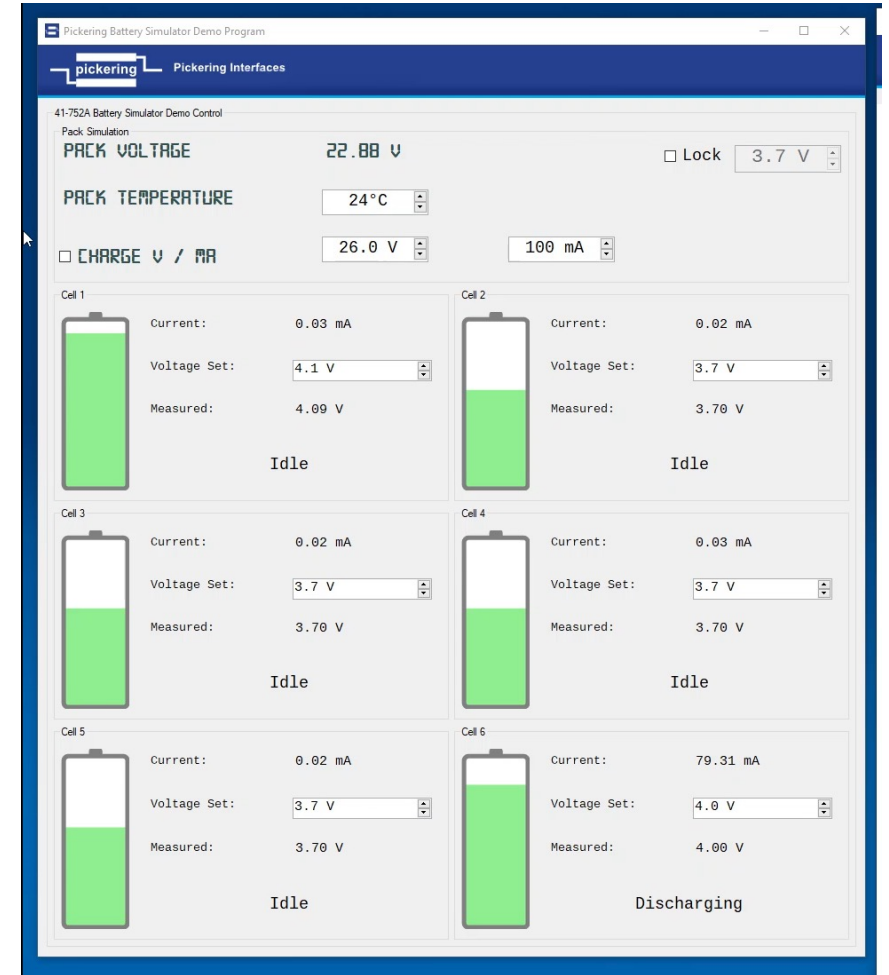# Advantages: Flexibility—Software

- 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.

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Advantages – Software Application Development

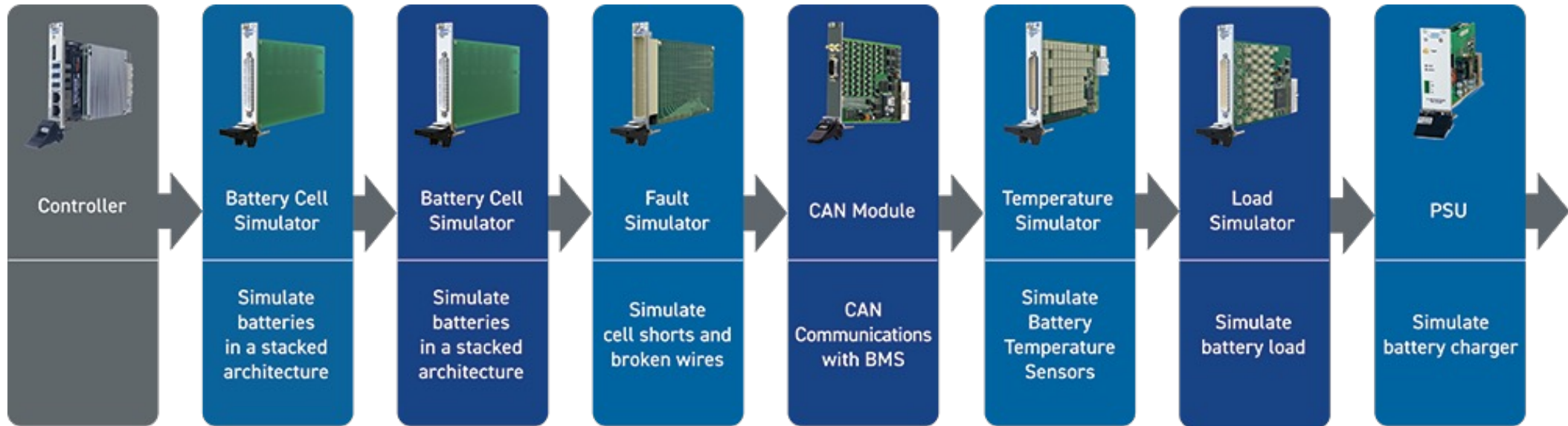Example of soft front panels for simple operation of individual modules

Example of an integrated graphical panel for the test system

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.

Pickering's PXI-based BMS Test

Controller	Battery Cell Simulator	Battery Cell Simulator	Fault Simulator	CAN Module	Temperature Simulator	Load Simulator	PSU
	Simulate batteries in a stacked architecture	Simulate batteries in a stacked architecture	Simulate cell shorts and broken wires	CAN Communications with BMS	Simulate Battery Temperature Sensors	Simulate battery load	Simulate battery charger

Create a fully flexible BMS test system with Pickering's PXI battery cell simulation module that can be combined with our other PXI switch and simulation modules, and other vendors' PXI modules, such as a CANbus interface.

Learn more at **pickeringtest.com/bms**

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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
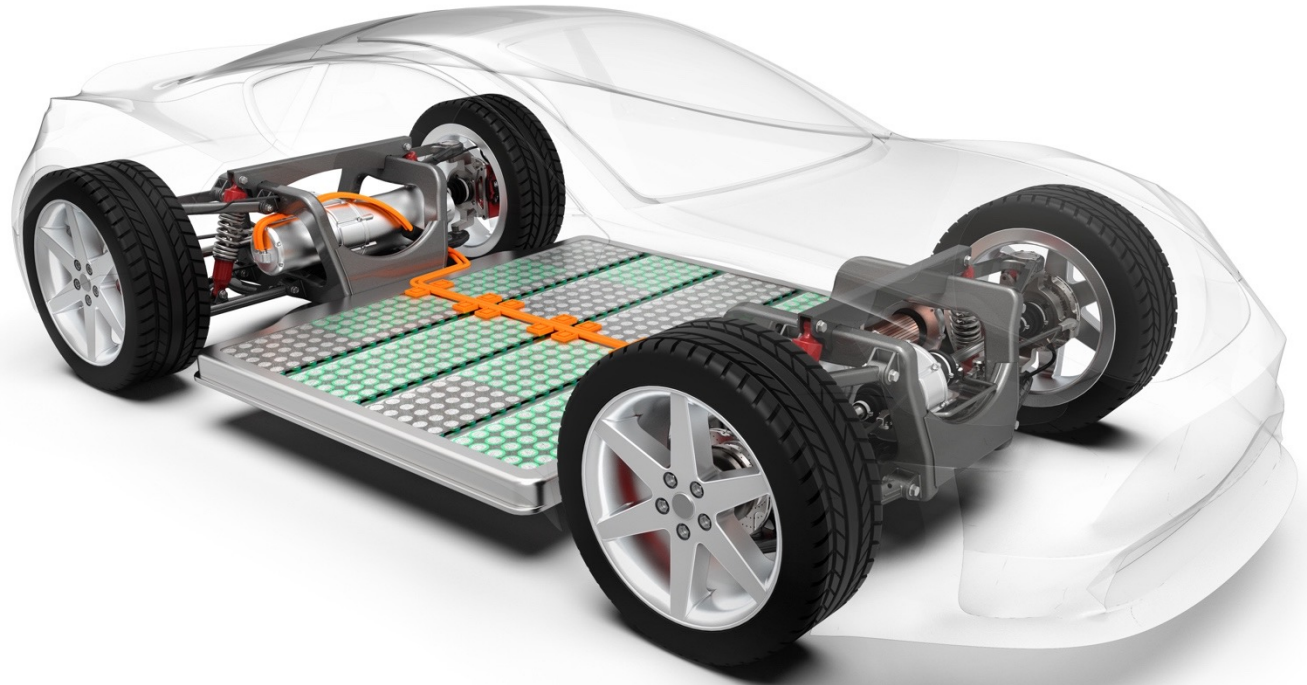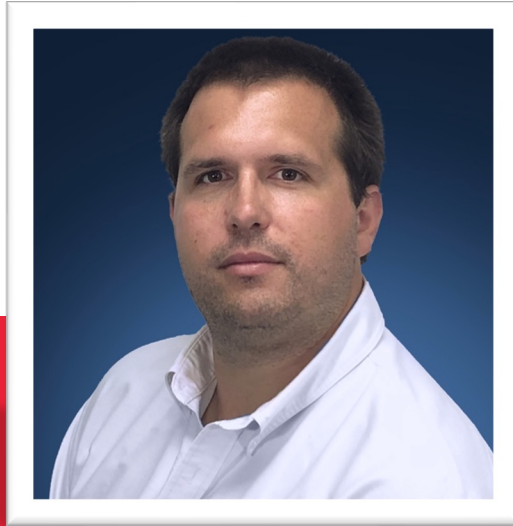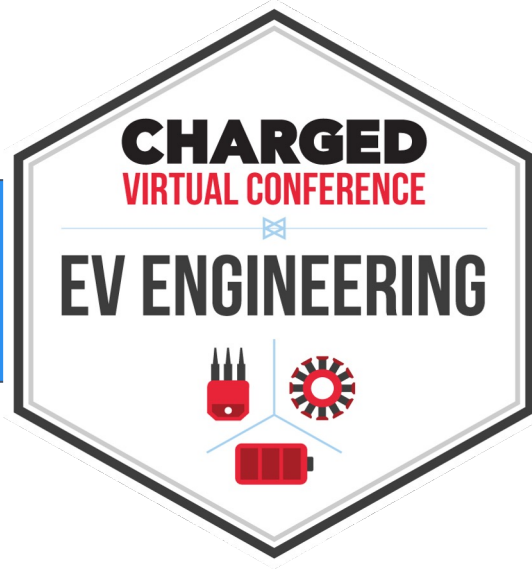
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About Pickering Interfaces

- 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
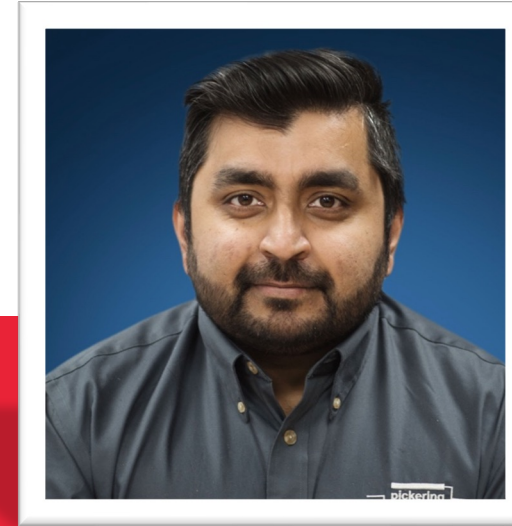 - Rarely obsolete
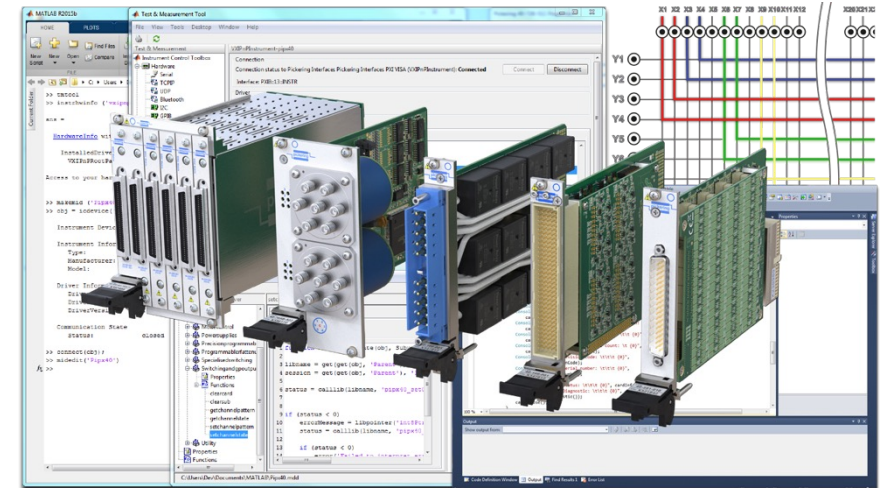
Questions??

Paul Bovingdon
paul.bovingdon@pickeringtest.com
pickeringtest.com/bms

Noman Hussain
noman.hussain@pickeringtest.com
pickeringtest.com/bms