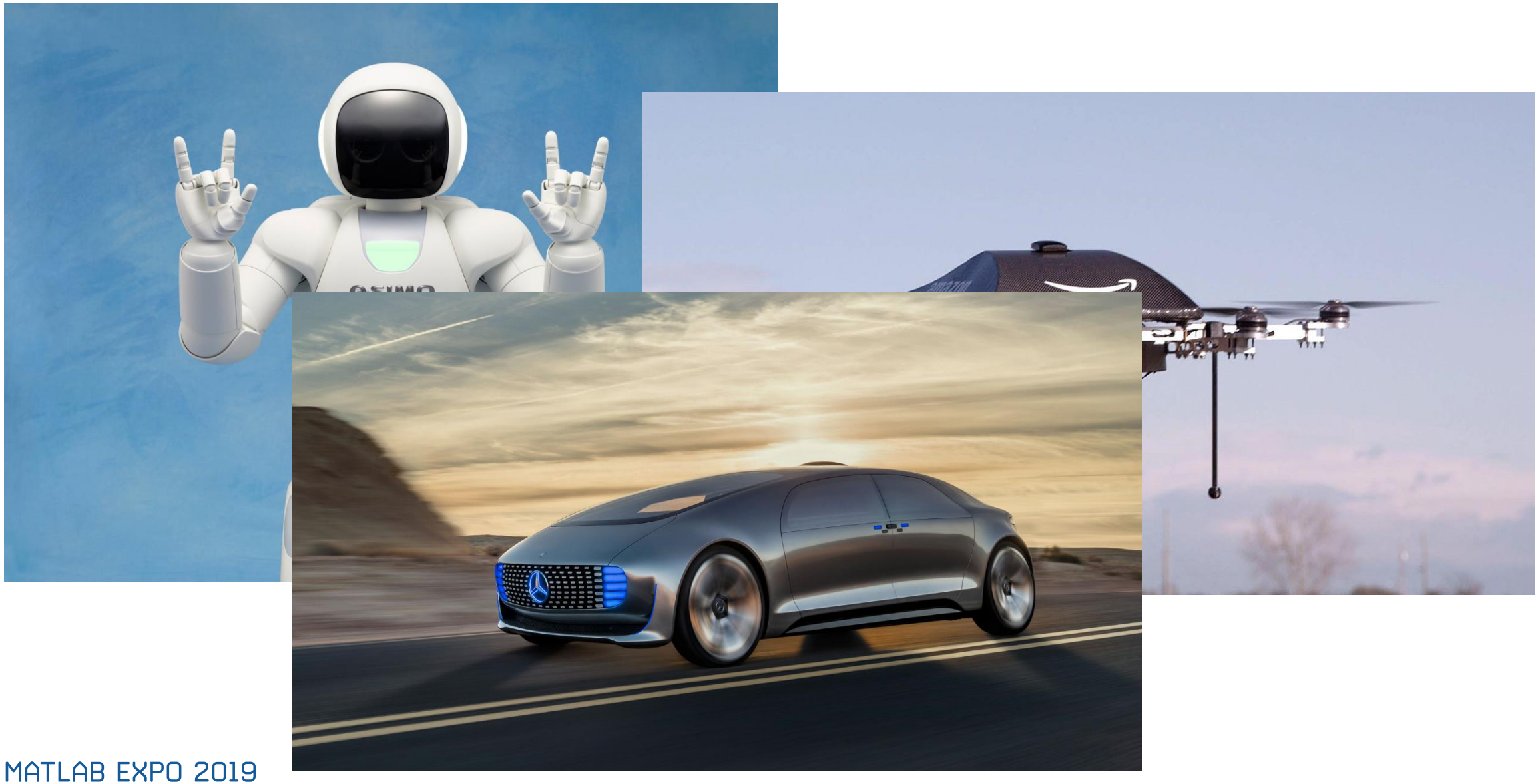
MATLAB EXPO 2019

Developing Battery Management System using Simulink

Prasanna Deshpande

Smarter systems require efficient battery



Challenges in Battery Modeling and Management

Battery Pack

- Modeling electro-chemical cell and its thermal dependency
- Scaling up the cell model to a battery pack model

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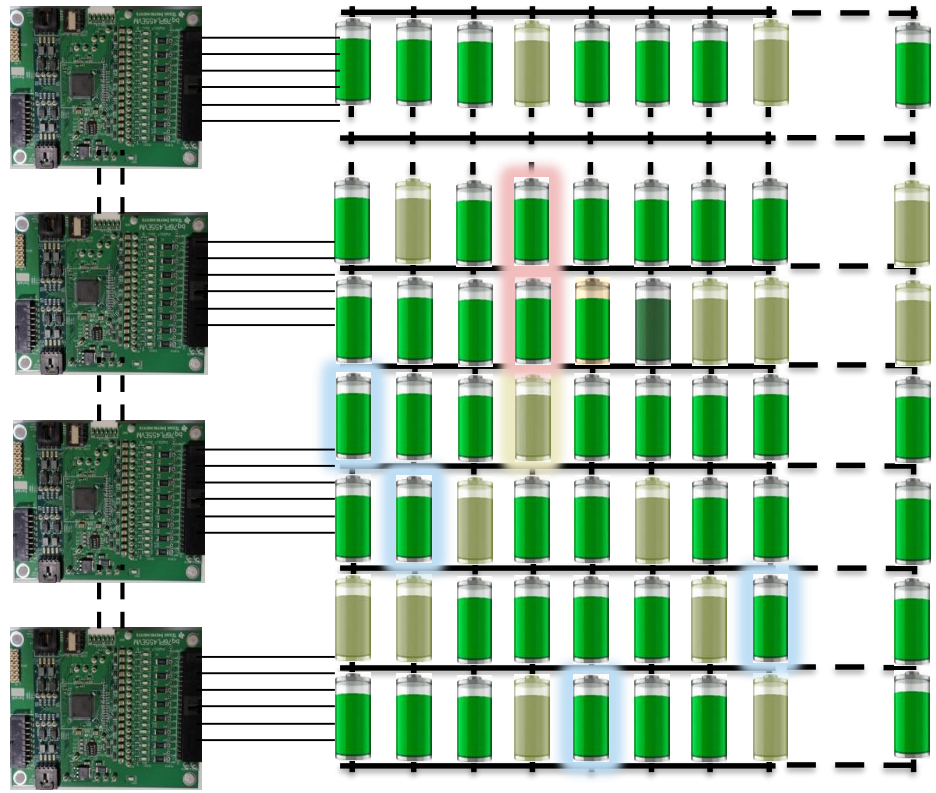
Challenges in Battery Modeling and Management

- Block / module voltage & temperature measurement
- Cell balancing, Contactor & pre-charge circuits

Electronics

Battery Pack



- Block voltage & temperature measurement
- Cell balancing, Contactor & pre-charge circuits

- Modeling electro-chemical cell and its thermal dependency
- Scaling up the cell model to a battery pack model

Challenges in Battery Modeling and Management

Current & Power Limits

Fault Handling

- How to design and verify different Battery Management functions?

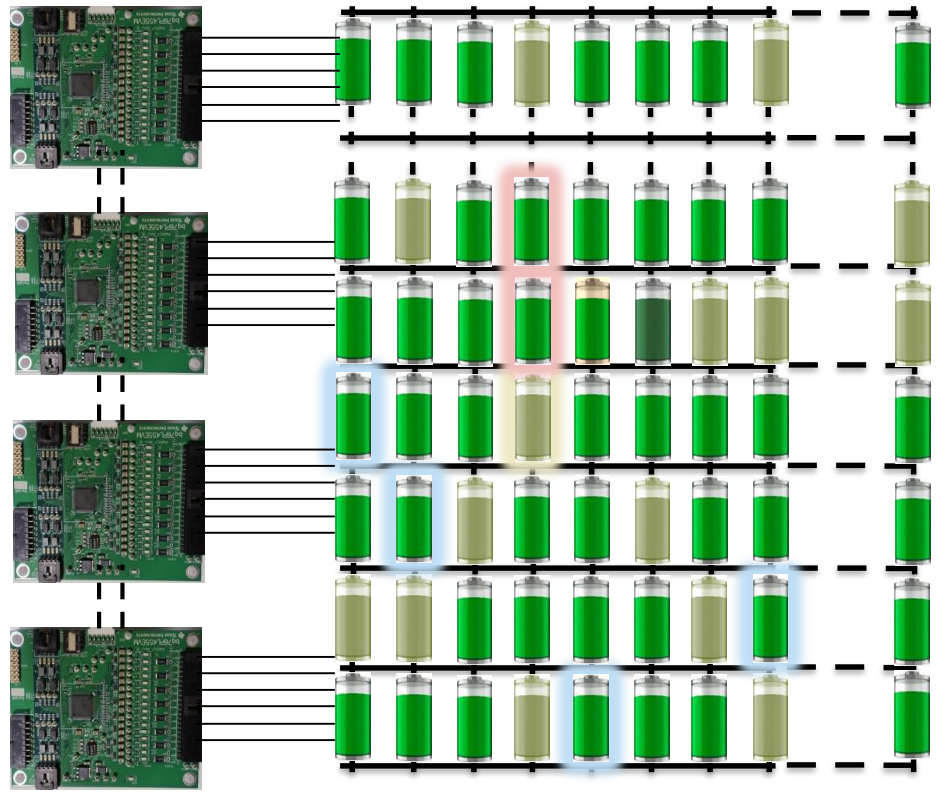
SoC Estimation

Thermal Management

Contactor Management

Electronics

Battery Pack



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Challenges in Battery Modeling and Management

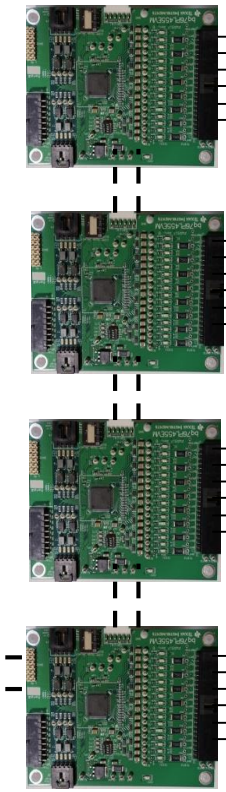
Software

```
if (((uint32_T)State_Machine_DW.temporalCounter_i3) < 15U) {
  State_Machine_DW.temporalCounter_i3 = (uint8_T)((int32_T)(((int32_T)
    State_Machine_DW.temporalCounter_i3) + 1));
}

if (((uint32_T)State_Machine_DW.is_active_c2_State_Machine) == 0U) {
  State_Machine_DW.is_active_c2_State_Machine = 1U;
  State_Machine_DW.is_MainStateMachine = State_Machine_IN_Standby;
  *rty_BMS_State = 0;
  State_Machine_DW.MonitorCurrLimMode = MonitorCurrLimModeType_NoCurrLimFaul
  State_Machine_DW.MonitorCellVoltageMode =
    MonitorCellVoltageModeType_NoCellVoltFault;
  State_Machine_DW.Delta = (real32_T)fabs((real_T)((real32_T)
    ((*rtu_Pack_Voltage) - sum_gyOCKAG3(rtu_Cell_Voltages))));
  State_Machine_DW.FaultPresent = false;
```

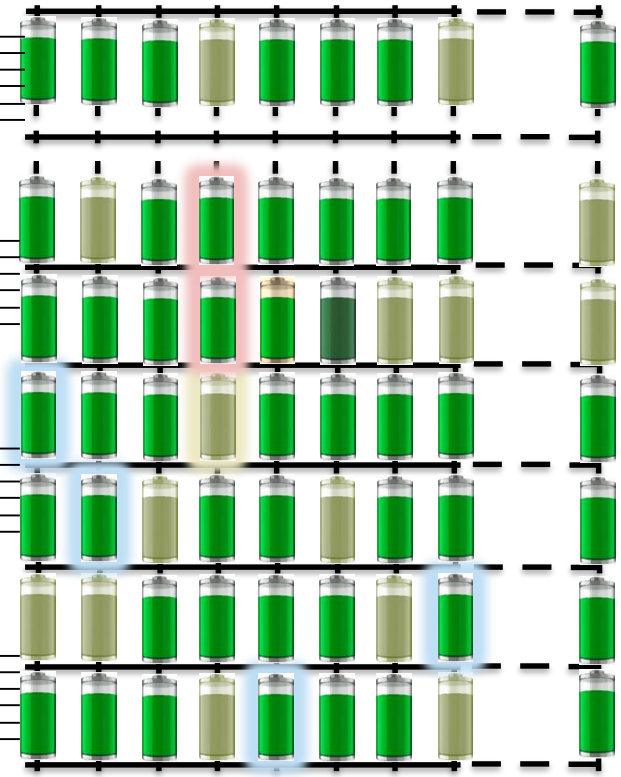
How to design and verify different Battery Management functions?

Electronics



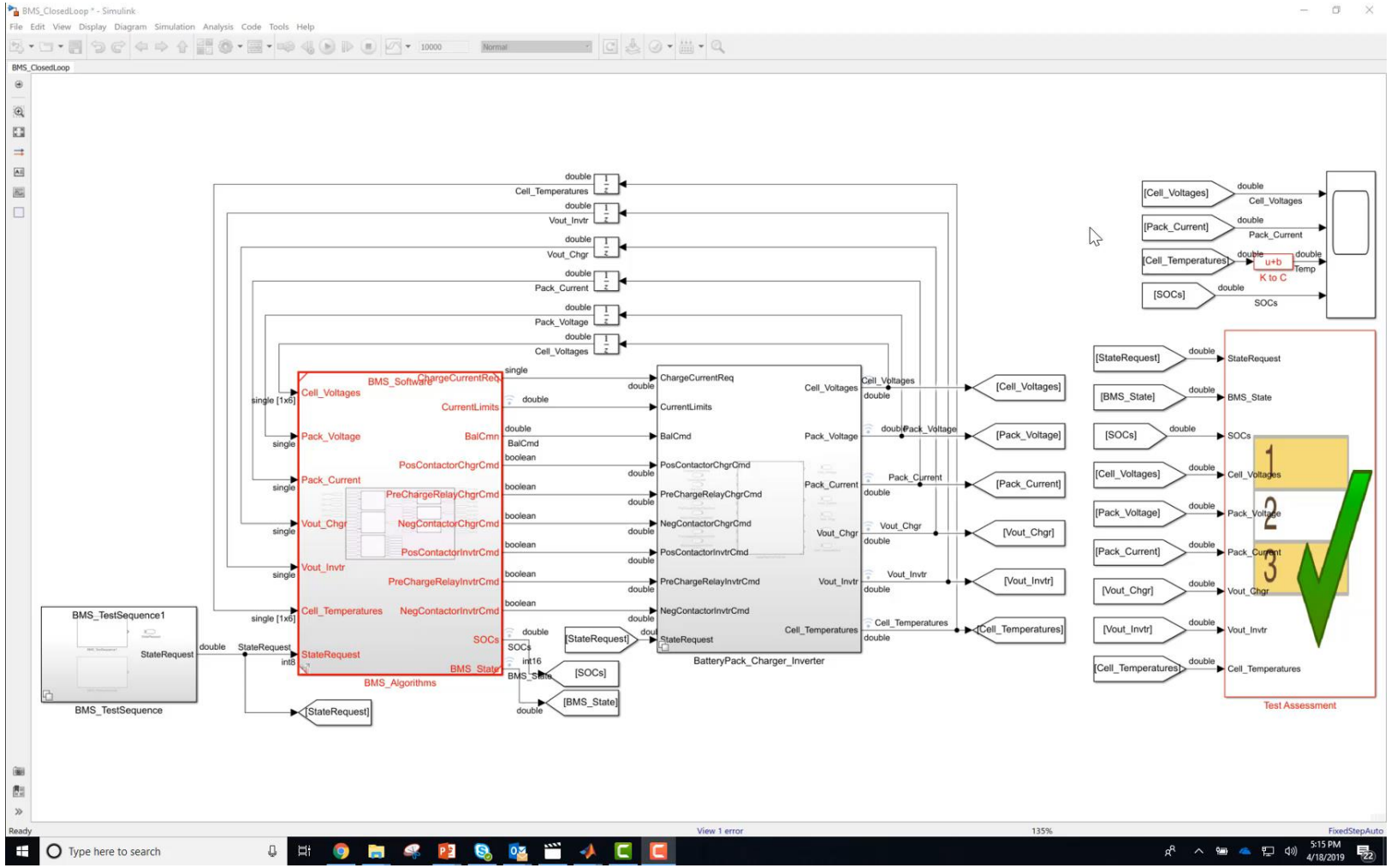
- Block voltage & temperature measurement
- Cell balancing, Contactor & pre-charge circuits

Battery Pack



- Modeling electro-chemical cell and its thermal dependency
- Scaling up the cell model to a battery pack model

Solution: System level simulation model for Battery



Agenda

- Capturing Dynamics of Battery Cell → Large Battery Pack
- Modeling the electronics: Contactors, Inverters, Loads
- Developing Battery Management Algorithms
- Generating C/C++ Code from BMS Algorithms
- Perform HIL Testing for BMS ECUs

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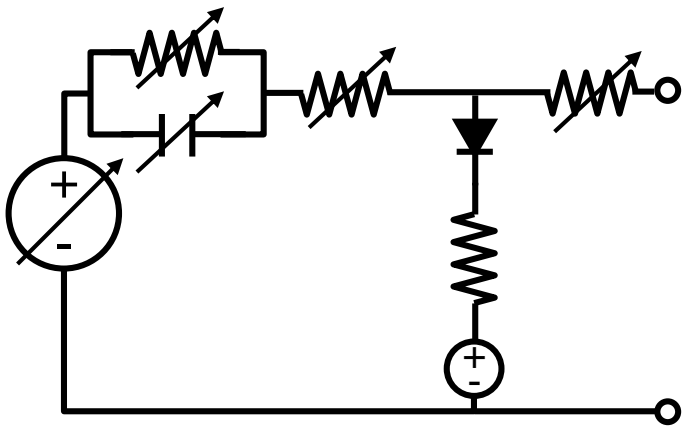
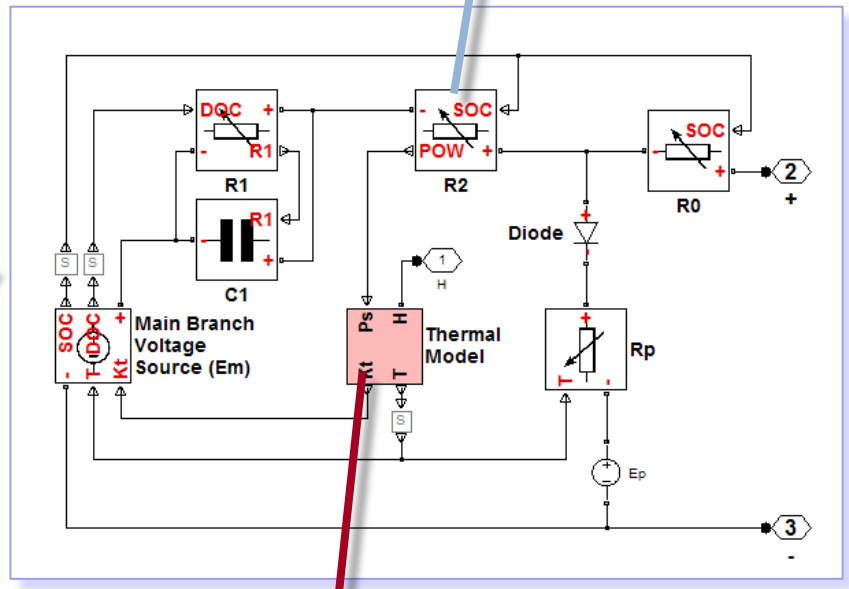
Battery cell modeling as RC equivalent circuit

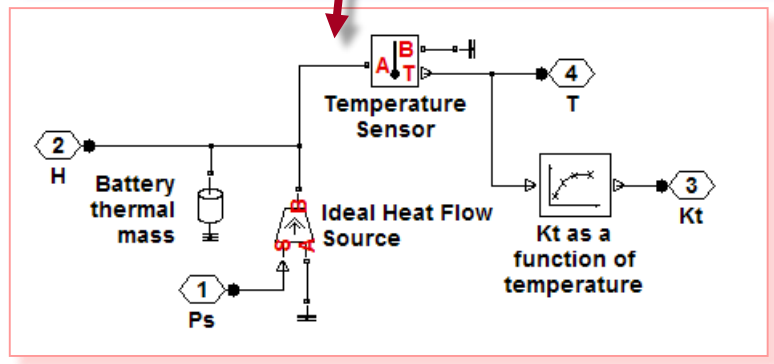
- 1RC Equivalent circuit representation of Battery cell
- Resistors, capacitor, and voltage source are dependent upon SOC and temperature



Battery cell equivalent discharge circuit

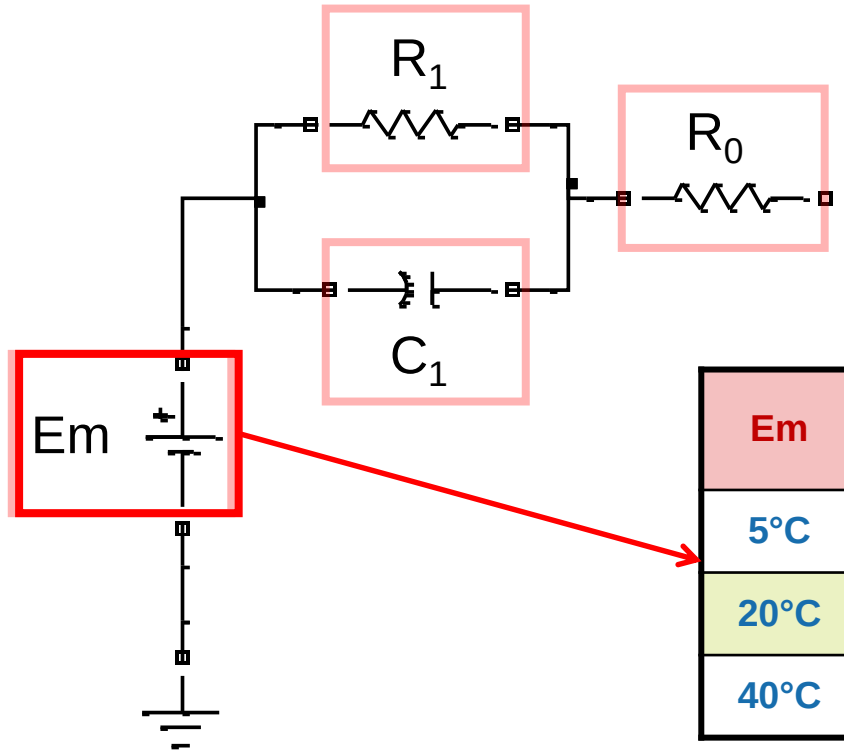
```
equations
  v == i*R20*exp(A21*(1-
  pow == v*i;
end
```





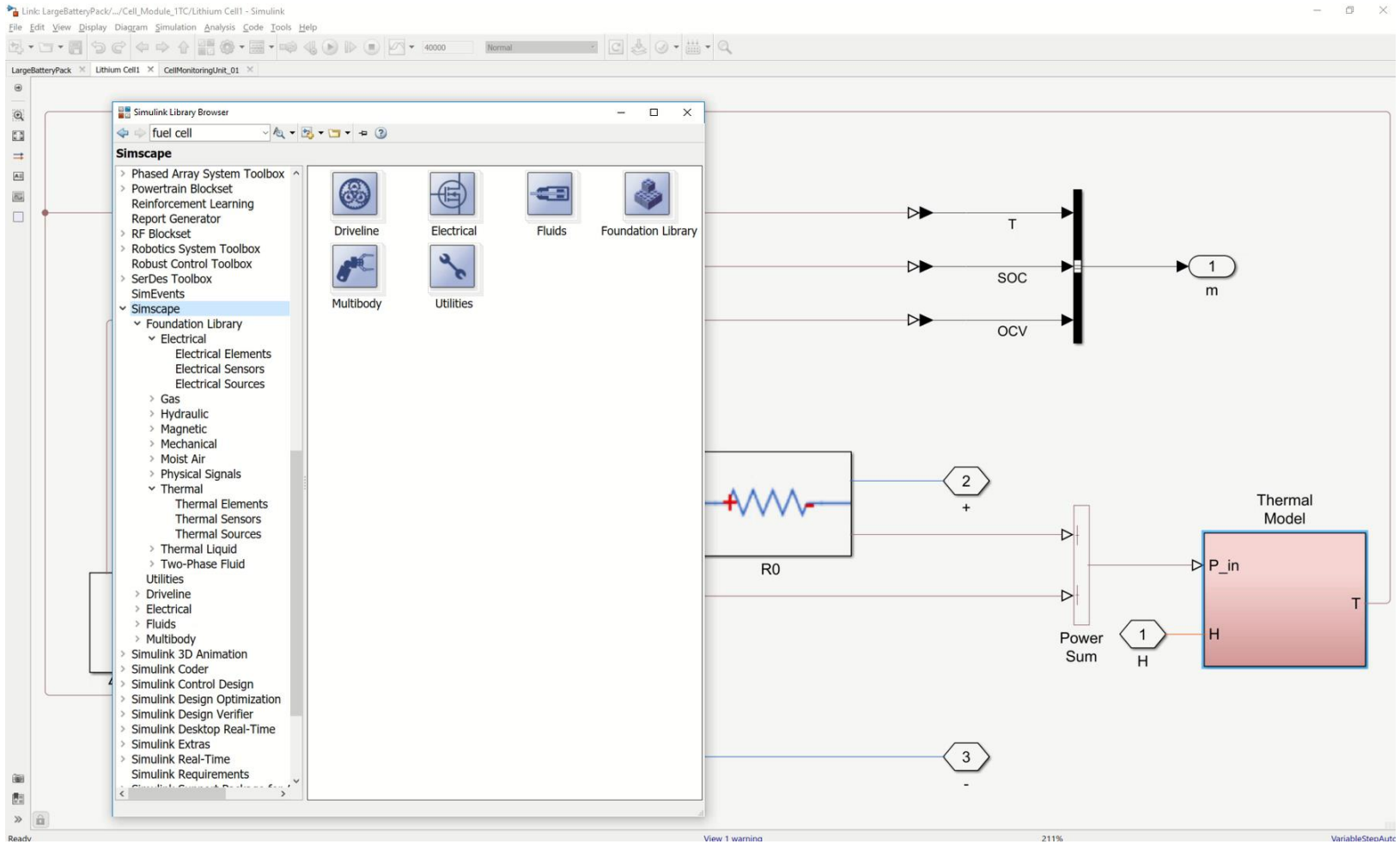
Circuit Elements – Lookup Tables

- Lookup tables can be used for each circuit element
  - Values will characterize the battery performance



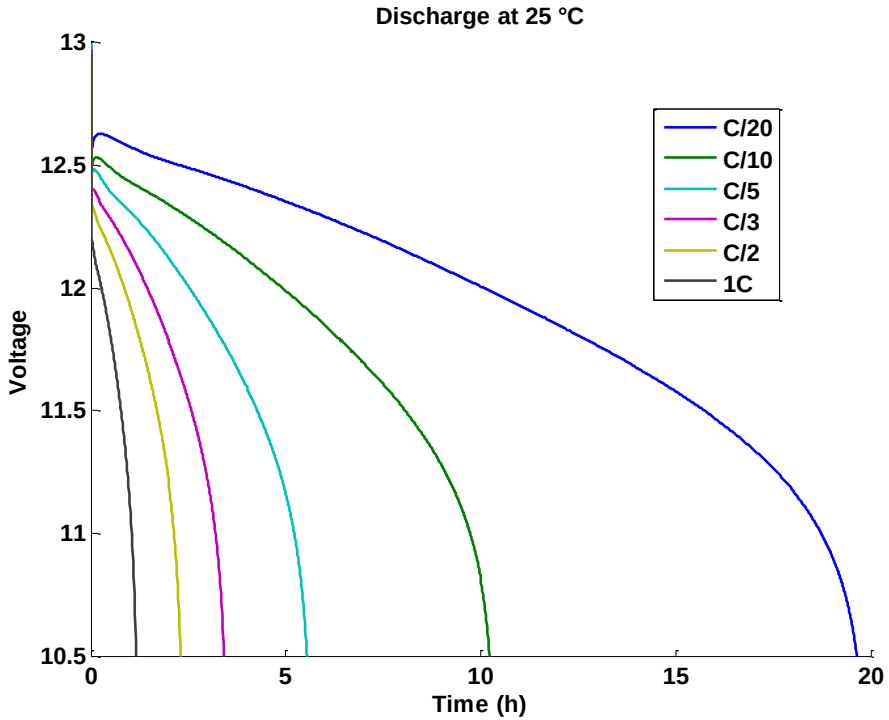
Em	SOC 1	SOC 0.9	SOC 0.8	…	SOC 0
5°C	4.20 V	4.10 V	4.05 V	…	3.50 V
20°C	4.18 V	4.07 V	4.02 V	…	3.49 V
40°C	4.15 V	4.02 V	3.97 V	…	3.43 V

Multi-domain modeling of battery pack using Simscape

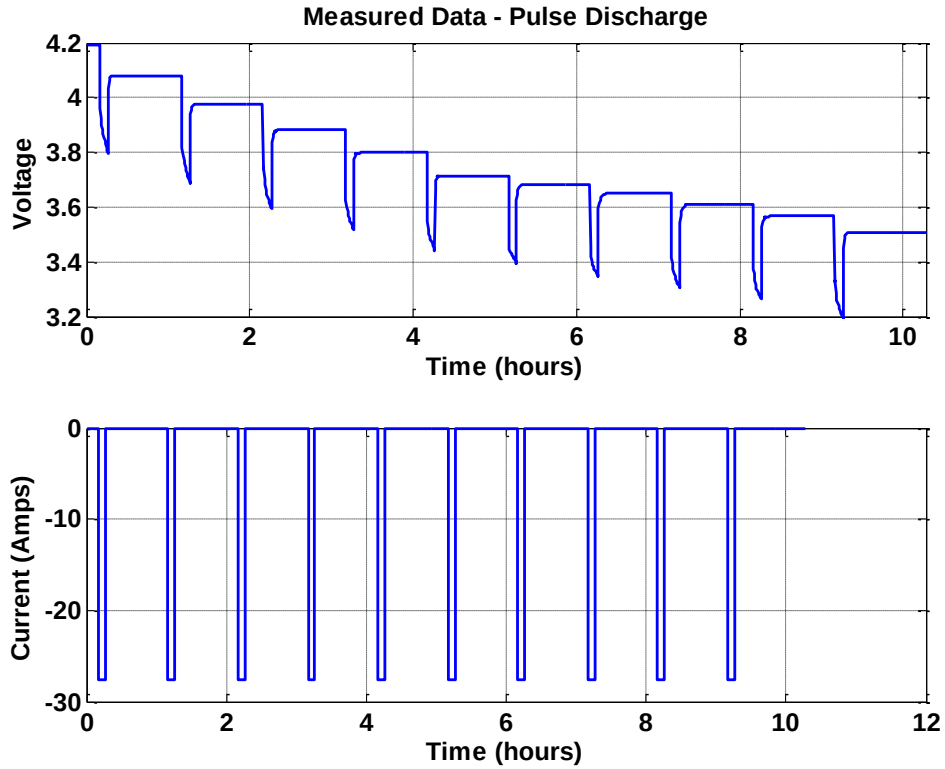


Battery data is collected by conducting a series of tests with the battery

- Used to determine battery capacity
  - Multiple Temperatures
  - Multiple Currents



- Used to determine battery dynamics
  - Range of SOC
  - Multiple Temperatures
  - Multiple Currents
  - Discharge and Charge Curves



Discovery Page on MathWorks website: Battery modeling

High Fidelity Electrical Model with Thermal Dependence for Characterization and Simulation of High Power Lithium Battery Cells

Tarun Huria, Massimo Ceraolo
Department of Energy and Systems Engineering

Javier Gazzarri, Robyn Jackey
MathWorks

SAE International

Battery Model Parameter Estimation Using a Layered Technique: An Example Using a Lithium Iron Phosphate Cell

2013-01-1547
Published
04/08/2013

Robyn Jackey, Michael Saginaw, Pravesh Sanghvi and Javier Gazzarri
MathWorks

Tarun Huria and Massimo Ceraolo
Università di Pisa

SAE INTERNATIONAL

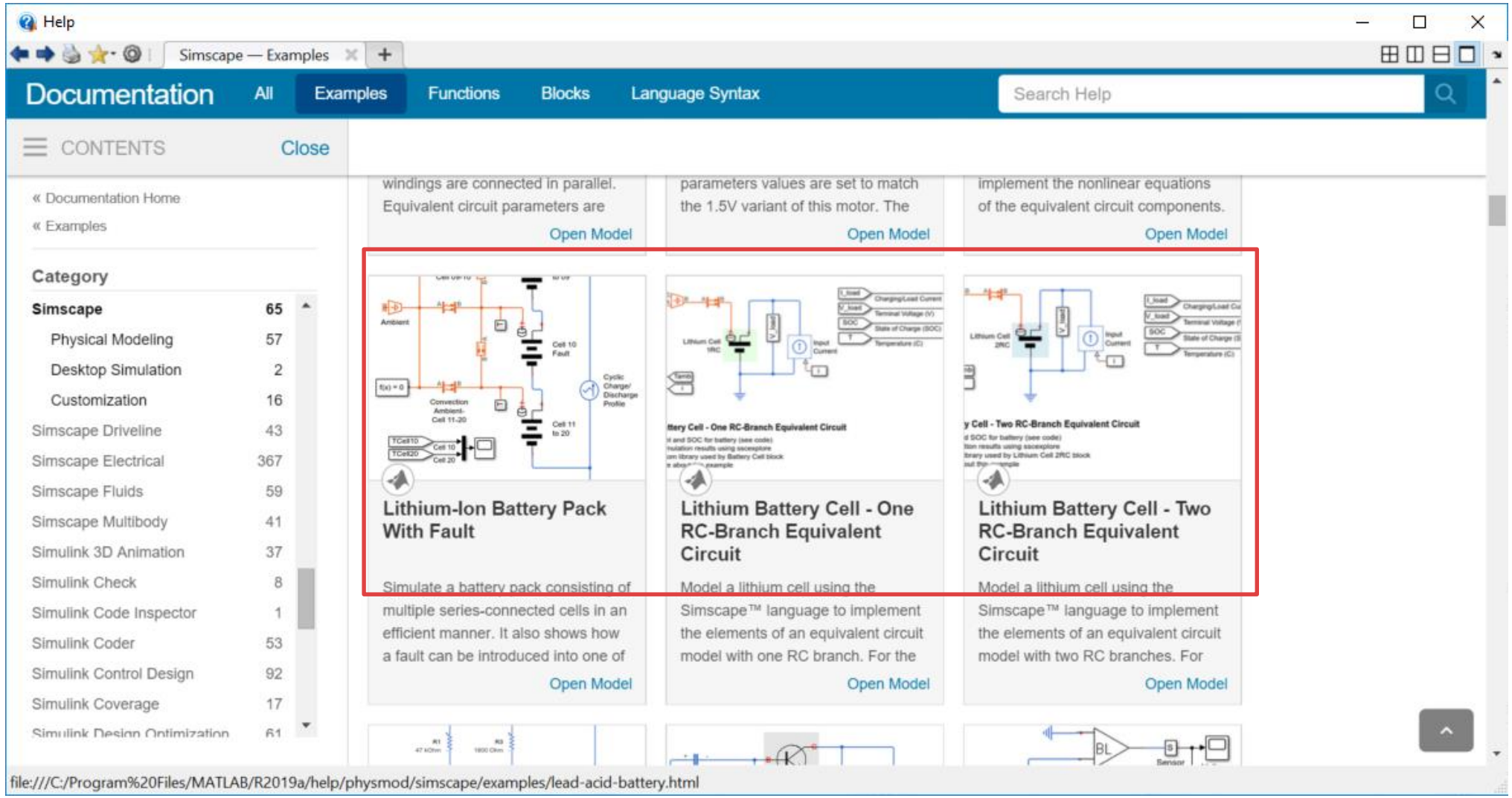
2015-01-0252
Published 04/14/2015

doi:10.4271/2015-01-0252
saealtpow.saejournals.org

Model-Based Parameter Identification of Healthy and Aged Li-ion Batteries for Electric Vehicle Applications

https://in.mathworks.com/discovery/battery-models.html?s_tid=srchtitle

Shipping examples in Simscape



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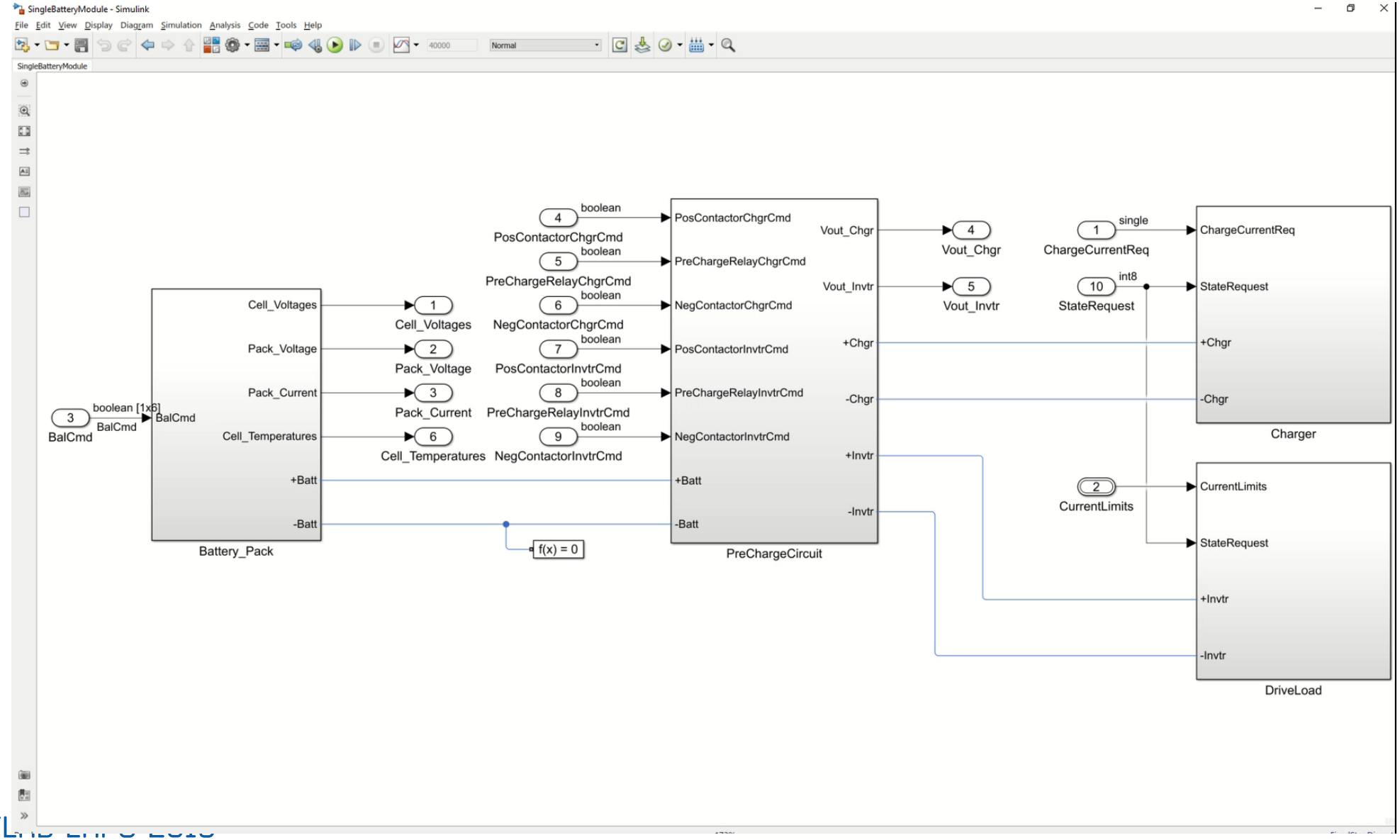
Role of electronics: Cell voltage measurement and pre-charge



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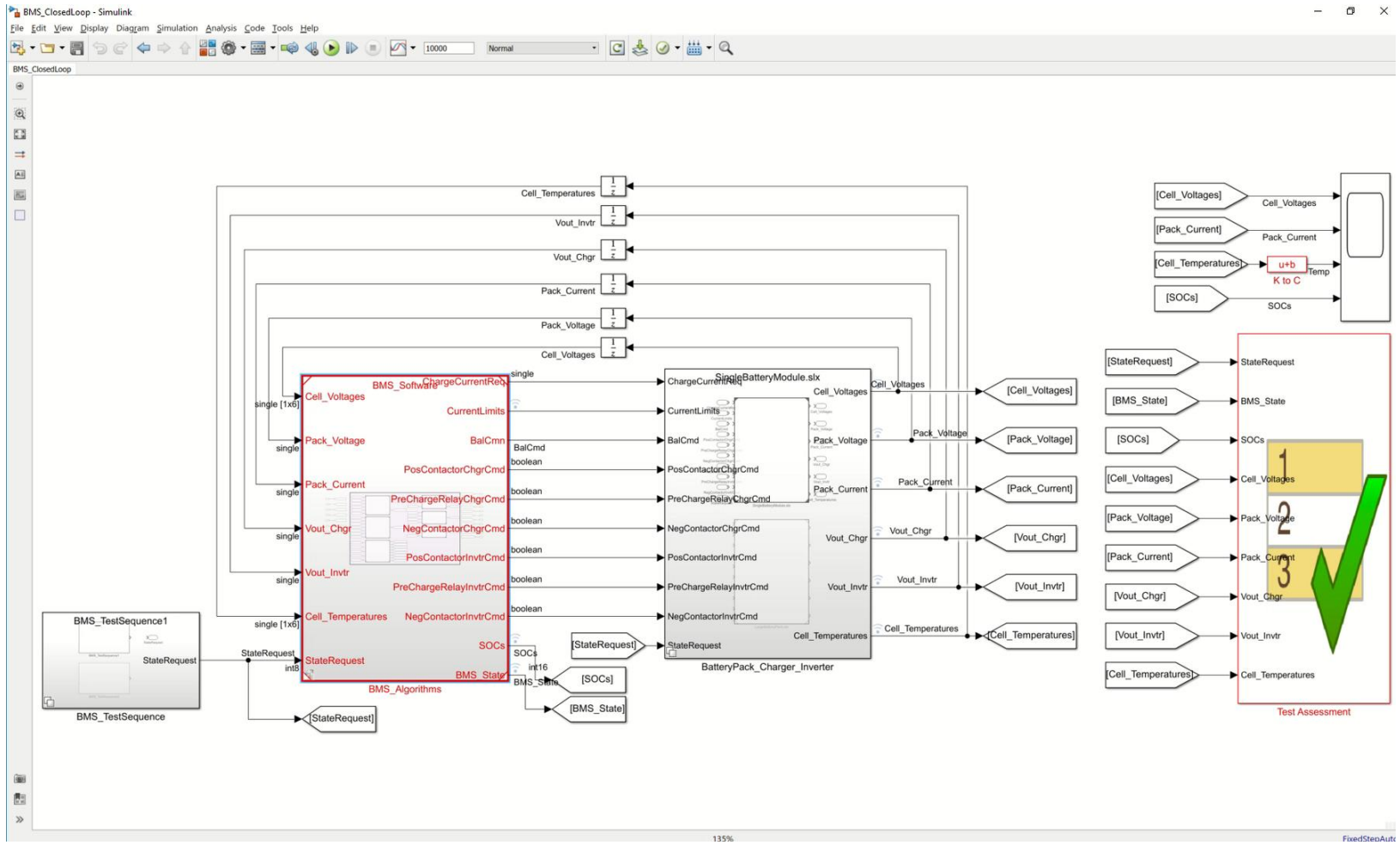
Battery Management Functions



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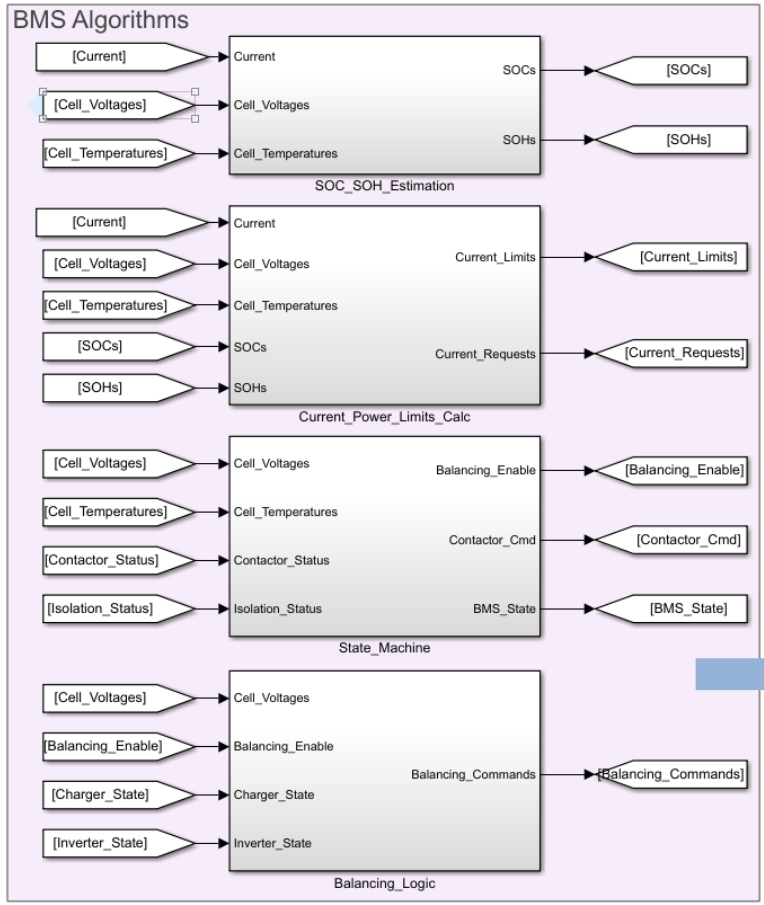
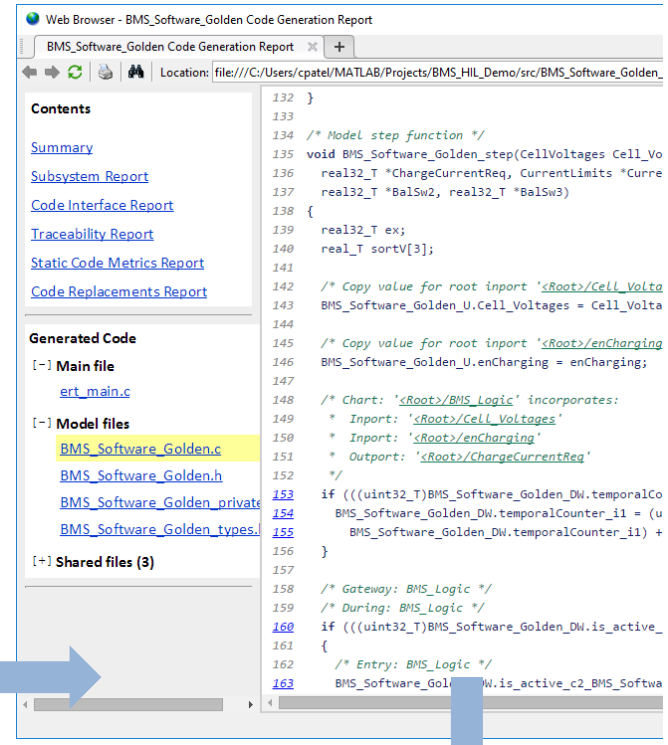
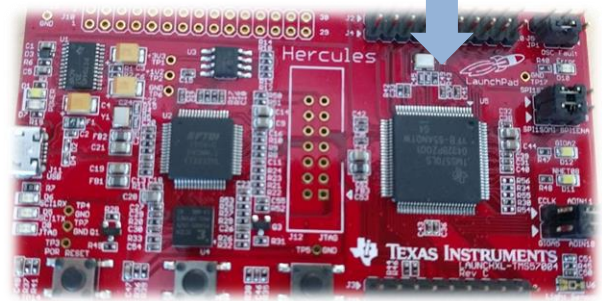
Generate C/C++ Code From BMS Algorithm Models

- Generate target optimized C/C++ code using Embedded Coder
- Fine-tune code optimizations, package and build generated code







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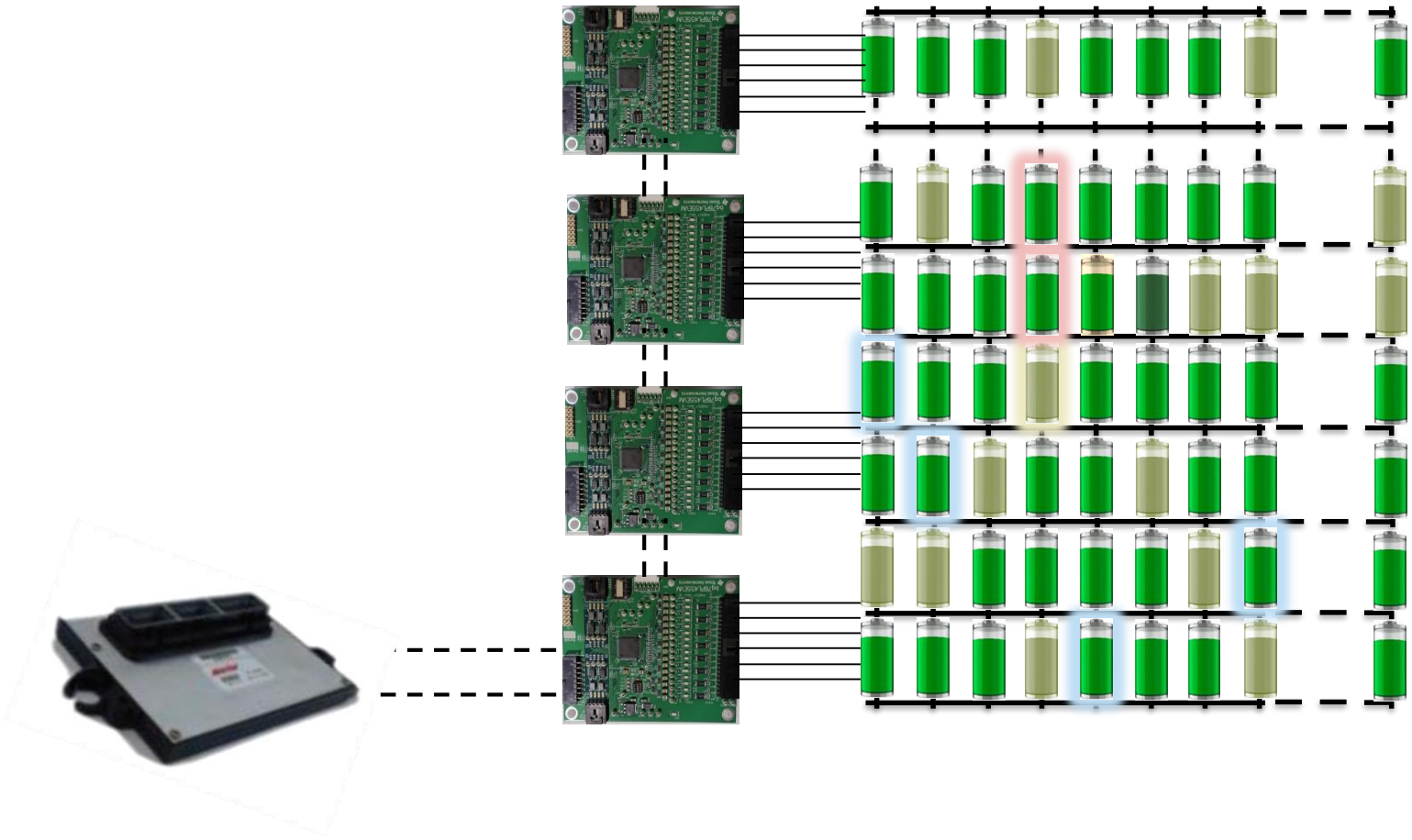
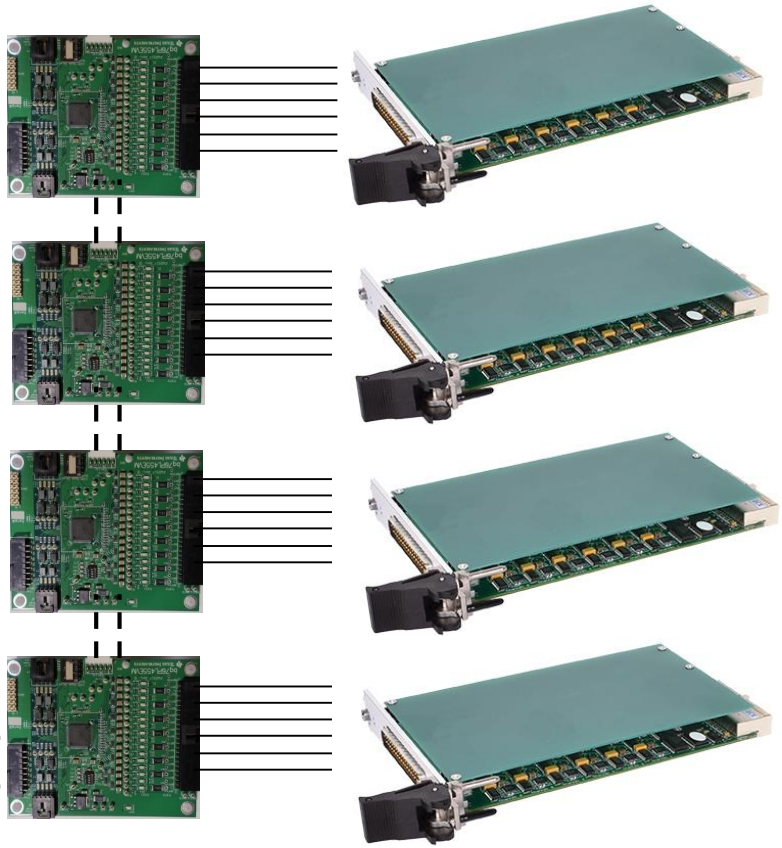
Perform HIL Testing for BMS ECUs (1/3)

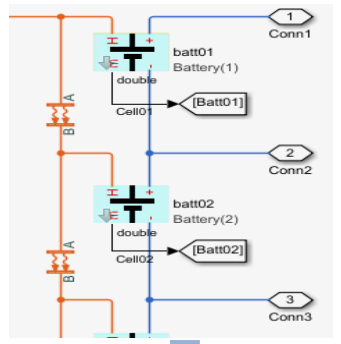


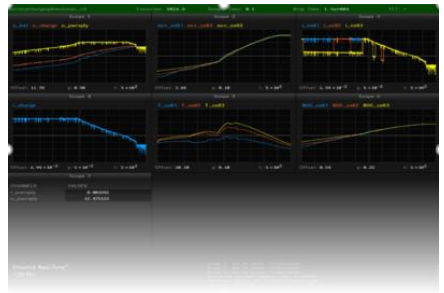
Testing ECUs with Battery Cells

- Longer test cycles
- Difficult to reproduce results
- Limited test automation
- Difficult to test fault conditions

Perform HIL Testing for BMS ECUs (2/3)







Automatic Code Generation

1 0 0 1 0 1 1 1 0 0 1 0 1

Wiring and Signal Conditioning

Perform HIL Testing for BMS ECUs (3/3)
IO991: Battery Emulation I/O Module

Key Features:

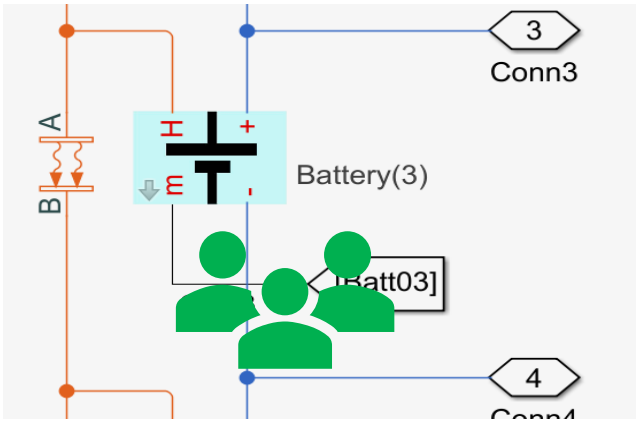
- 6 independent isolated channels
- Architecture allows series & parallel combinations
- Independent power and sense lines
- Voltage range of 0-7 V with 14-bit resolution
- 300 mA source to load
- 100 mA sink adjustable in 16 steps

Enables:

- Test automation and repeatable testing
- Fault testing safely
- Reuse testcases from earlier desktop testing

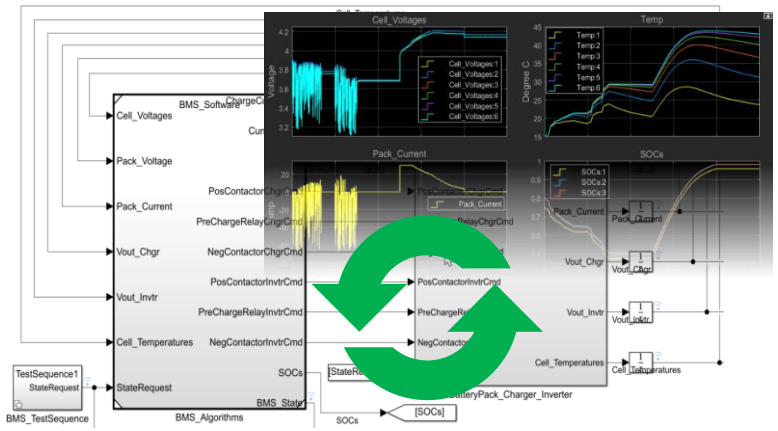
Summary

Multi-Domain



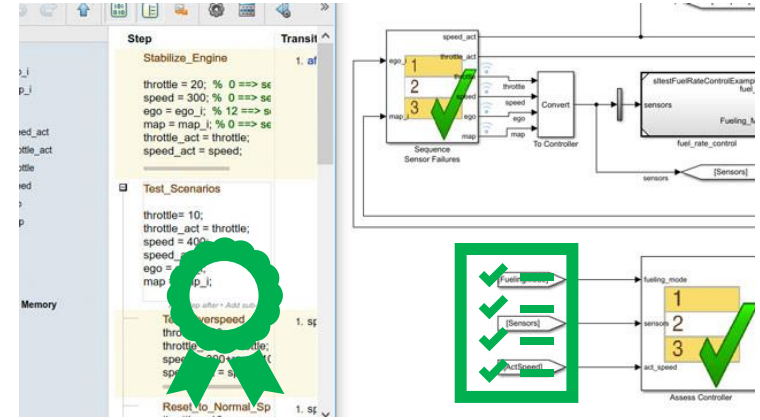
Collaborate Across Domains

Long Iteration Cycles



Reduce Iteration Time

Safety Critical System



Functional Safety Certification

Learn More about Battery Management System

WHITE PAPER

Developing Battery Management Systems with Simulink and Model-Based Design