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# Parameter Identification for a Battery Equivalent Circuit Model

TEST CELL AUTOMATION | LABORATORY MANAGEMENT | COMBUSTION ANALYSIS | SIMULATION | EMISSIONS
ENGINE | TRANSMISSION | ELECTRIC MOTOR | BATTERY/EV SYSTEMS | VEHICLE DYNAMICS

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# Agenda

- Introduction
- Battery Equivalent Circuit Model (ECM) and Parameter Identification
- A&D Technology — Battery Testing Solution
- ANSYS — ECM Tool
- Conclusion

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# Introduction

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# Background

- Energy Management System of HEV and EV
- Battery Management Functions
- Battery Modeling and Parameter Identification
    - Electrochemical Model
    - Equivalent Circuit Model

# Battery ECM and Parameter Identification

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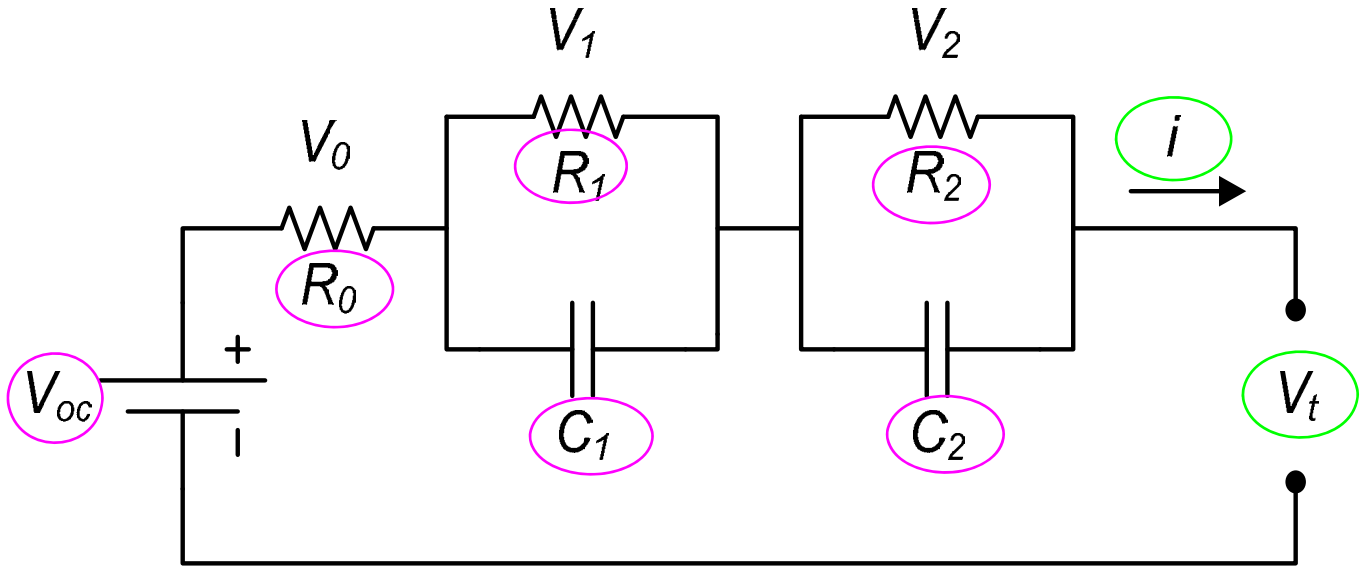
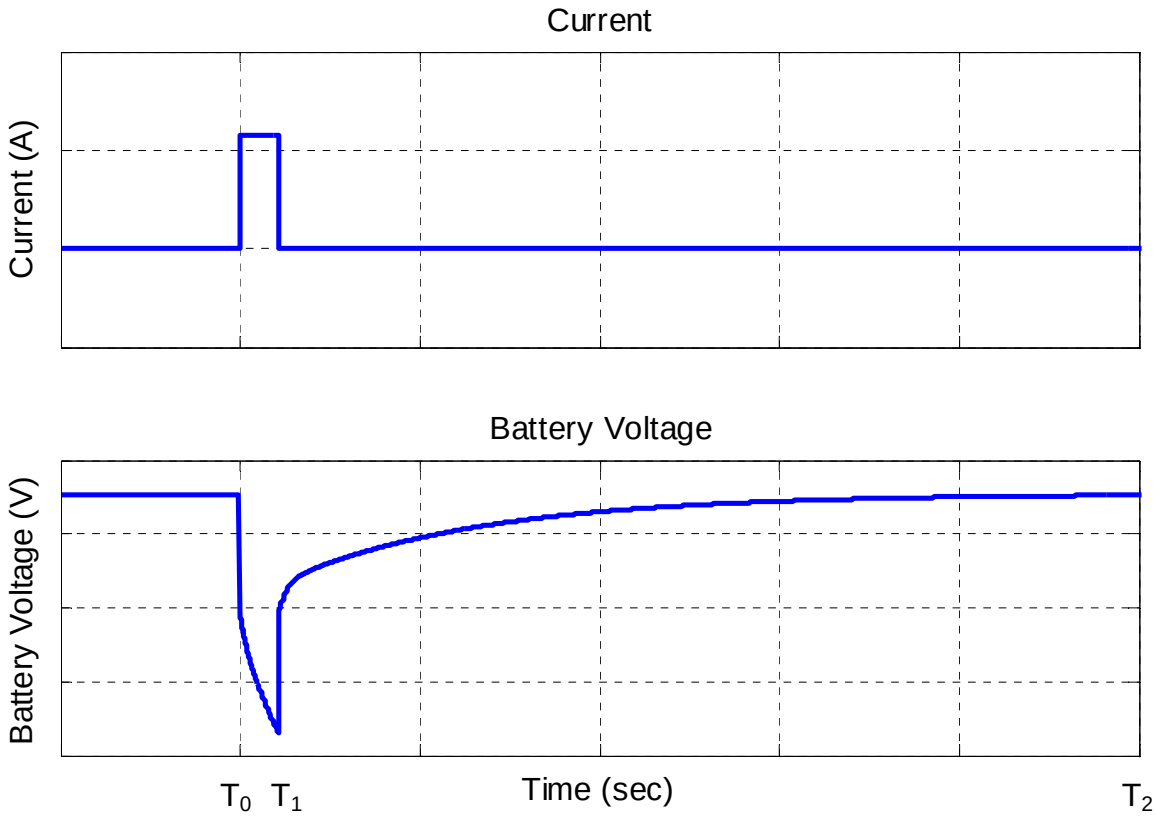
# Equivalent Circuit Model




- Battery OCV
- Ohmic resistance
- Two sets of parallel resistor-capacitor combination
  - mass transport effects
  - double layer effects

# Parameter Identification Tests

Constant current pulse discharge and charge tests at various SOC and current rates

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# Model Equations

$$V_t = V_{oc} - V_0 - V_1 - V_2$$

$$V_0 = iR_0$$

$$C_1 \frac{dV_1}{dt} + \frac{V_1}{R_1} = i$$

$$C_2 \frac{dV_2}{dt} + \frac{V_2}{R_2} = i$$

# Jiang and Hu's Method

$$U(t) = V_{10}e^{-\frac{t}{\tau_1}} + V_{20}e^{-\frac{t}{\tau_2}}$$

$$X = \int_0^t U(\tau) \cdot d\tau$$

$$Y = \int_0^t X(\tau) \cdot d\tau$$

$$Y = (\tau_1 + \tau_2)(-X) + \tau_1\tau_2(U_0 - U) + (V_{10}\tau_1 + V_{20}\tau_2)t$$

# Jiang and Hu's Method

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_m \end{bmatrix} = \begin{bmatrix} -X_1 & U_0 - U_1 & t_1 \\ -X_2 & U_0 - U_2 & t_2 \\ \vdots & \vdots & \vdots \\ -X_m & U_0 - U_m & t_m \end{bmatrix} \cdot \begin{bmatrix} \tau_1 + \tau_2 \\ \tau_1 \tau_2 \\ V_{10}\tau_1 + V_{20}\tau_2 \end{bmatrix}$$

Shugang Jiang, "A Parameter Identification Method for a Battery Equivalent Circuit Model", **SAE 2011-01-1367**
Xiao Hu, Lewis Collins, Scott Stanton, Shugang Jiang, "A Model Parameter Identification Method for Battery Applications", **SAE 2013-01-1529**

# A&D Battery Testing Solution

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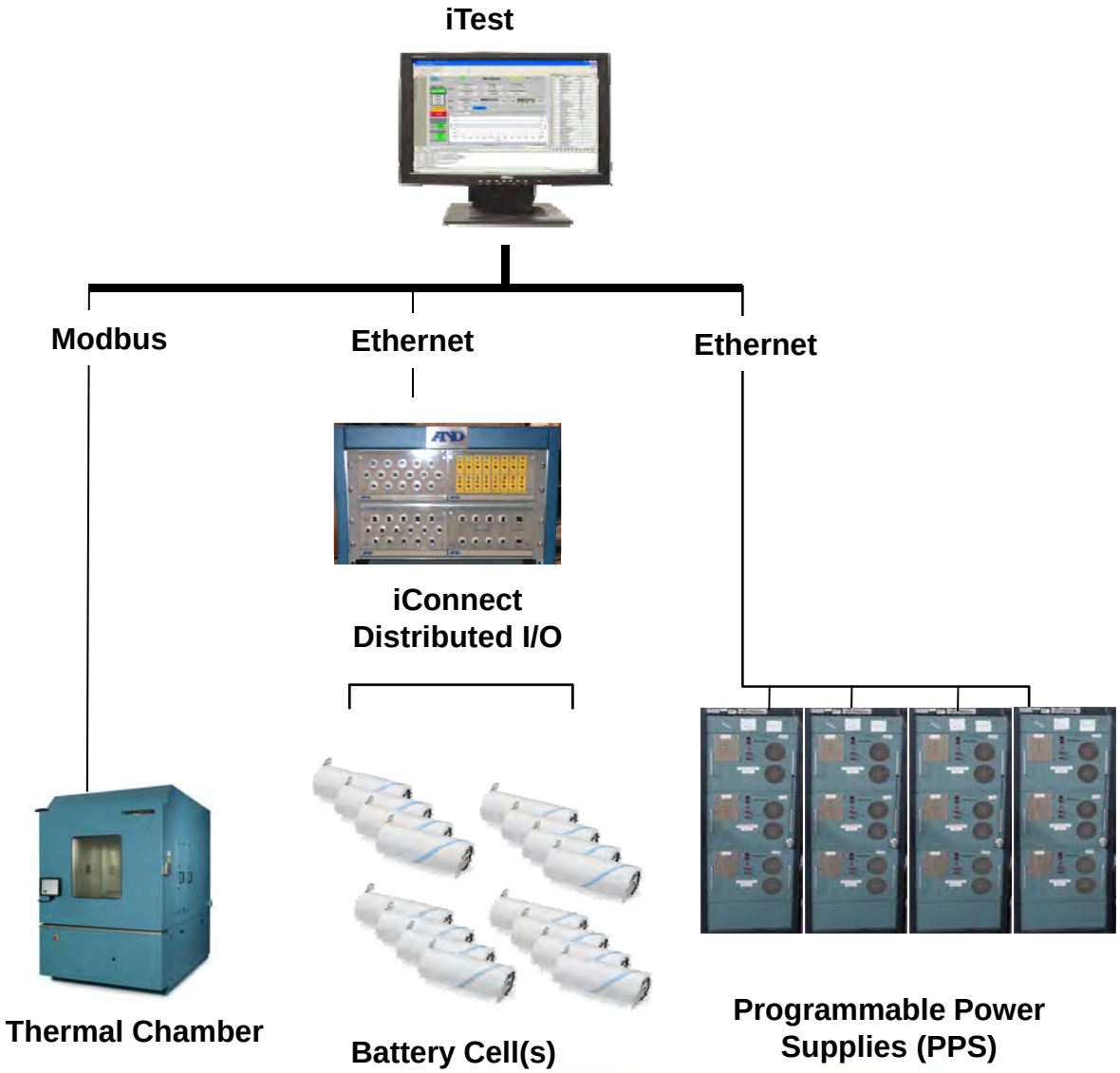


**Key Features**

Control up 16 cell test circuits
- 1 PPS with 16 circuits
- 4 PPS each with 4 circuits

iTest can be remote or local to cluster

**Standard System**

iTest PC
iTest software & application
iConnect I/O, Set of cables

**iTest interface (flexible)**

16 Analog In
16 Temperature
8 Digital In
8 Digital Out
2 Ethernet
1 Serial

**iTest Application Content**

GUI & Interface
- I/O
- Programmable Power Supply
- Thermal Chamber

Tests with Reports
- Hybrid Pulse Power Characterization
- General Static Capacity
- US06 Drive Cycle
- Cycle Life Test
- Calendar Life Test

Simulation mode

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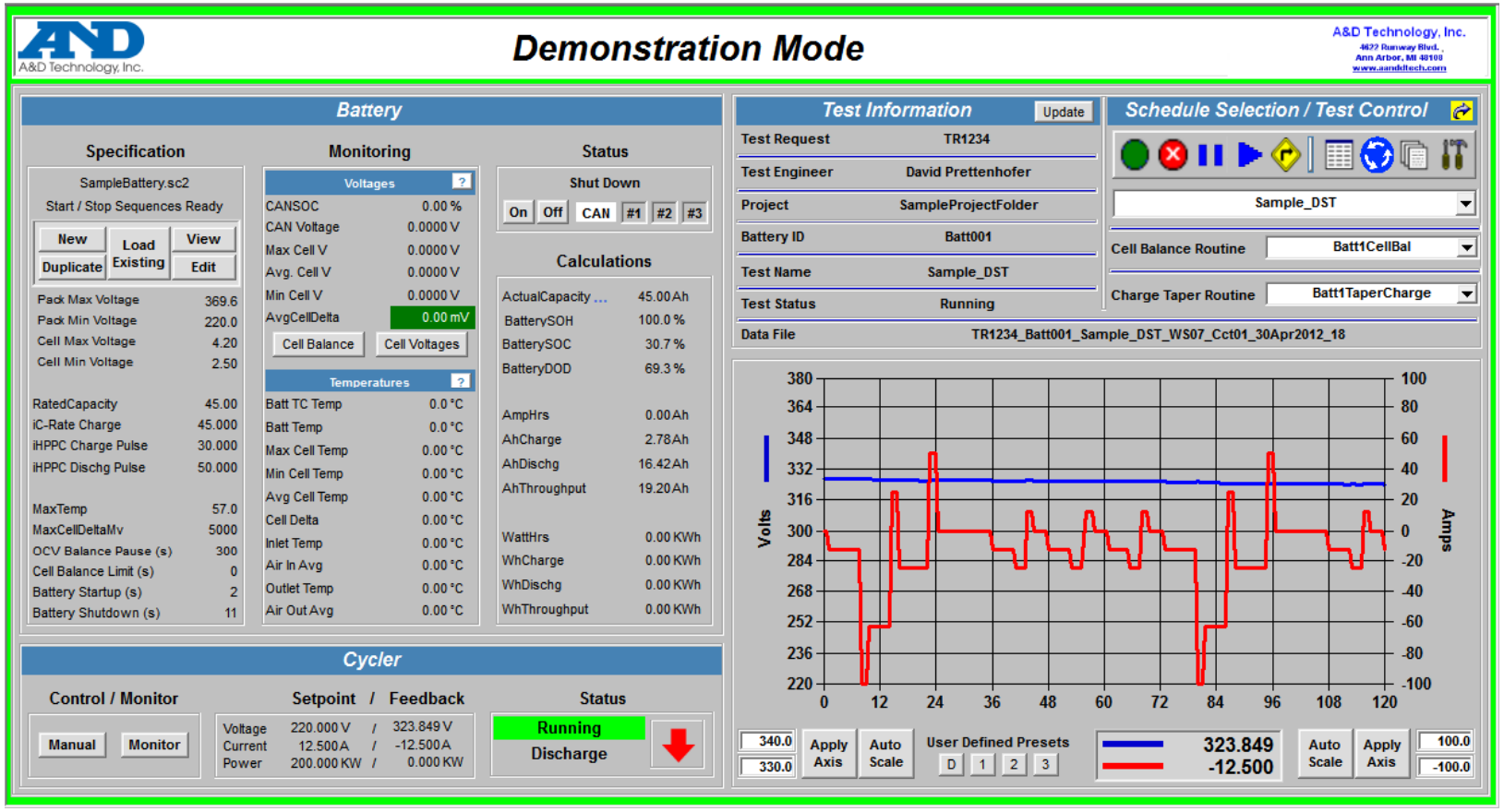
# Data Acquisition and Control

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# ANSYS ECM Tool

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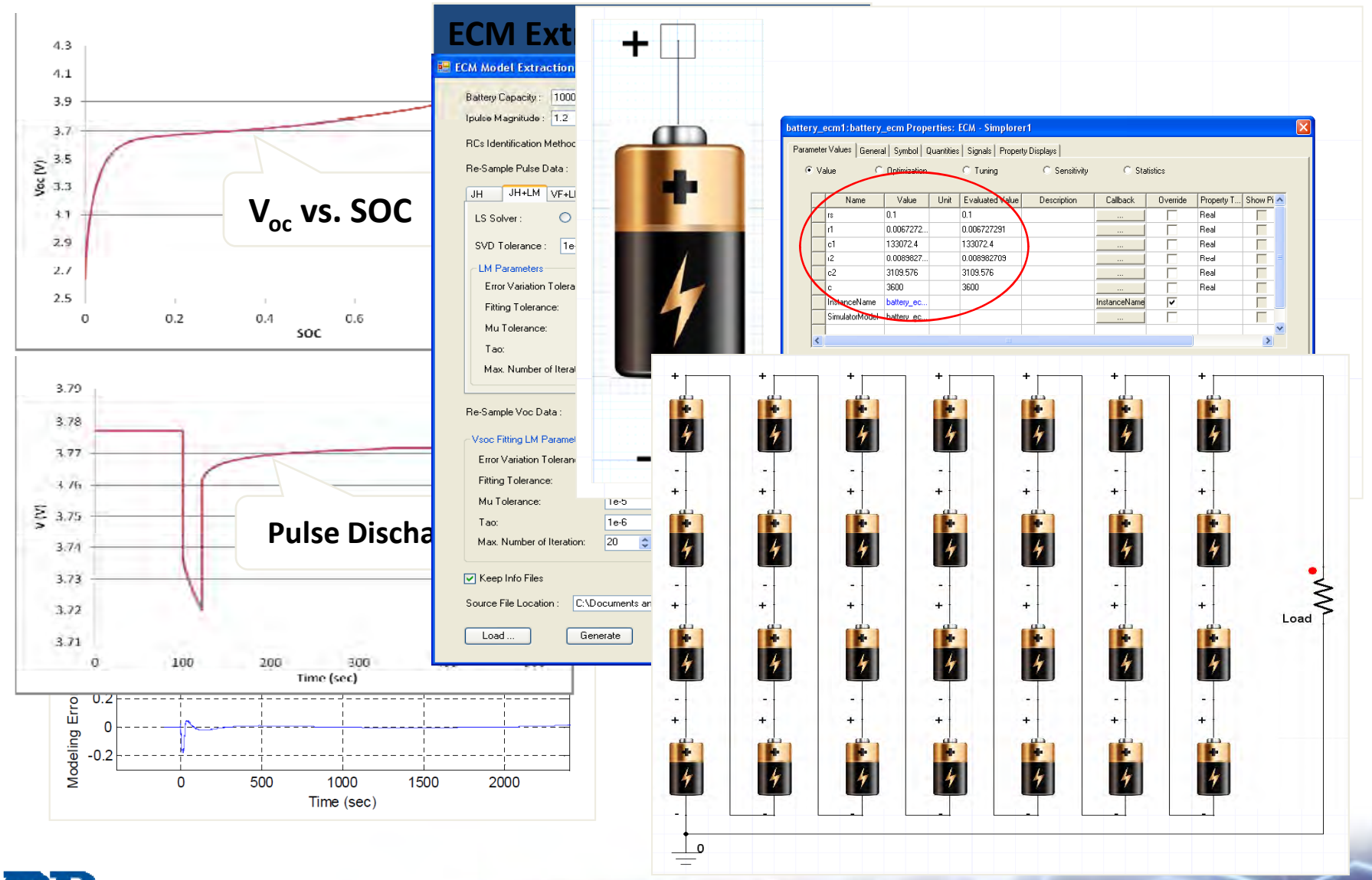
# ECM Parameter Extraction Tool

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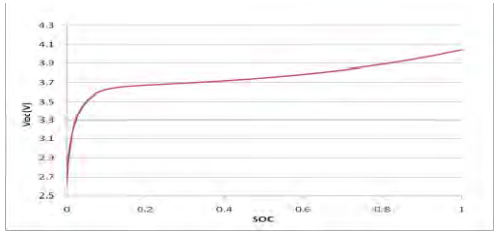
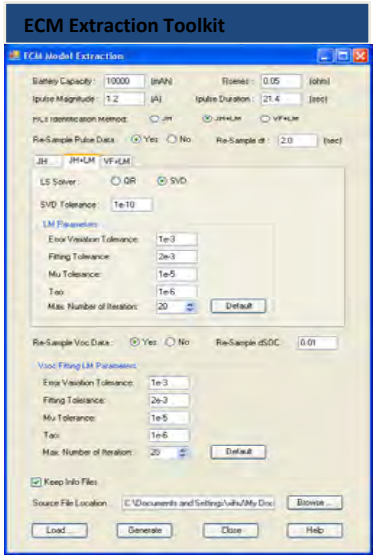
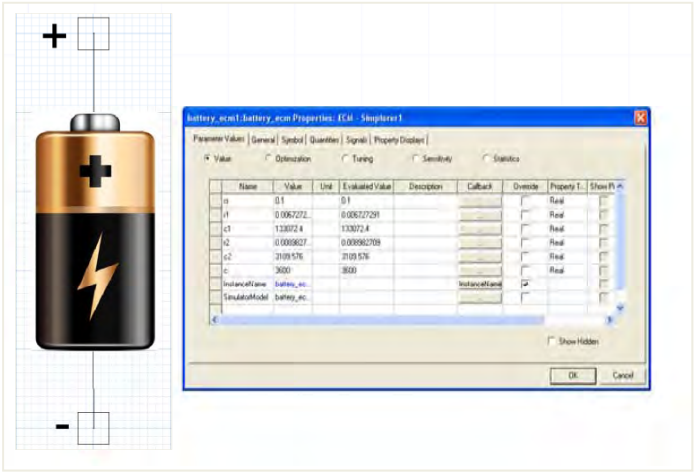
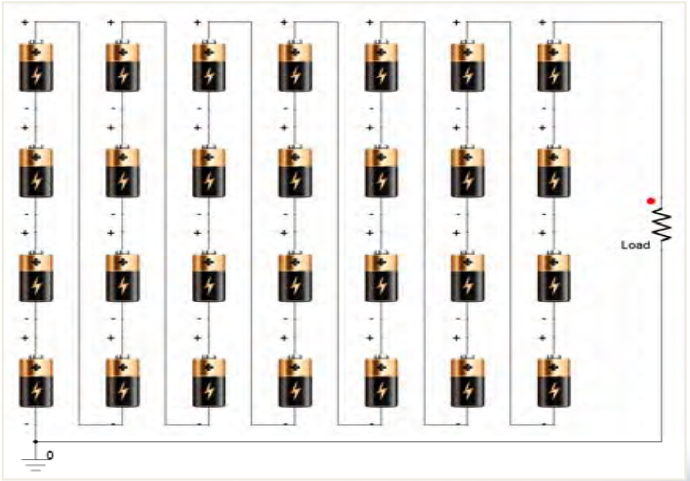
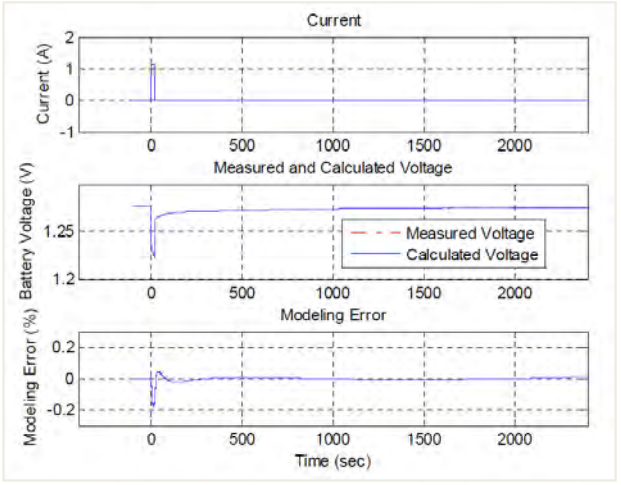
# ECM Parameter Extraction Tool






## ECM Model Workflow

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# Conclusion

# Conclusion

- Innovative method for the parameter identification of a battery equivalent circuit model
- Battery testing solution for parameter identification data collection
- Easy to use battery ECM tool

# Thank You!


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