



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



Shugang Jiang, A&D Technology Inc
Xiao Hu, ANSYS Inc.

June 4th, 2013



ANSYS Convergence Conference 2013

Agenda

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

Introduction



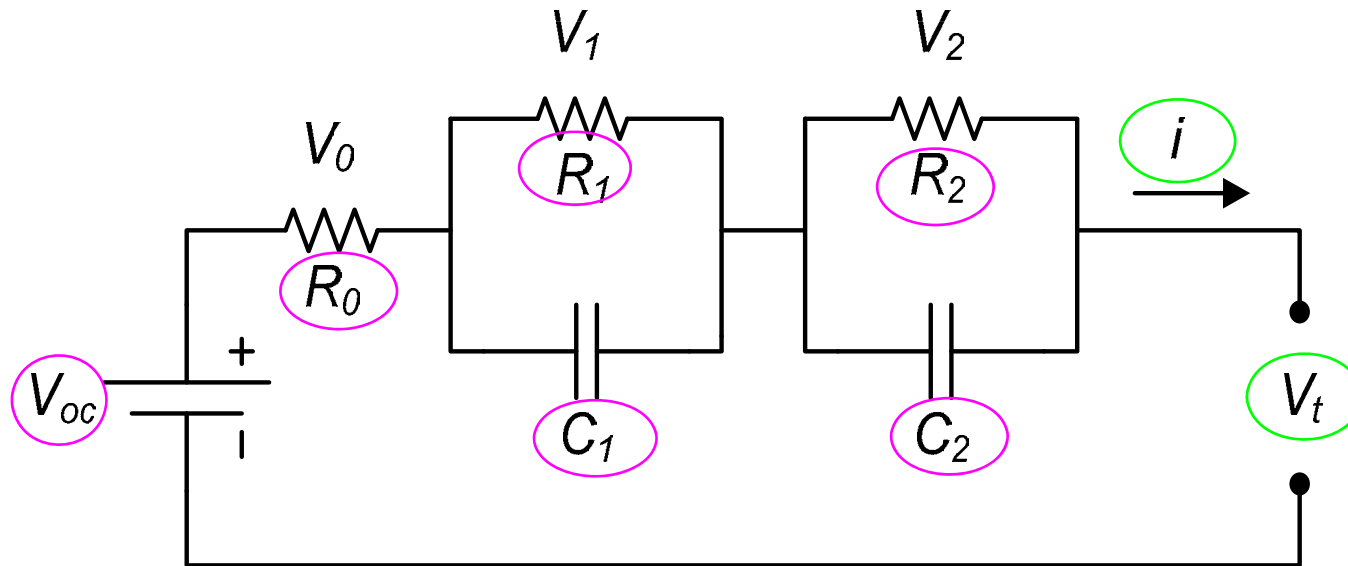
Background

- 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



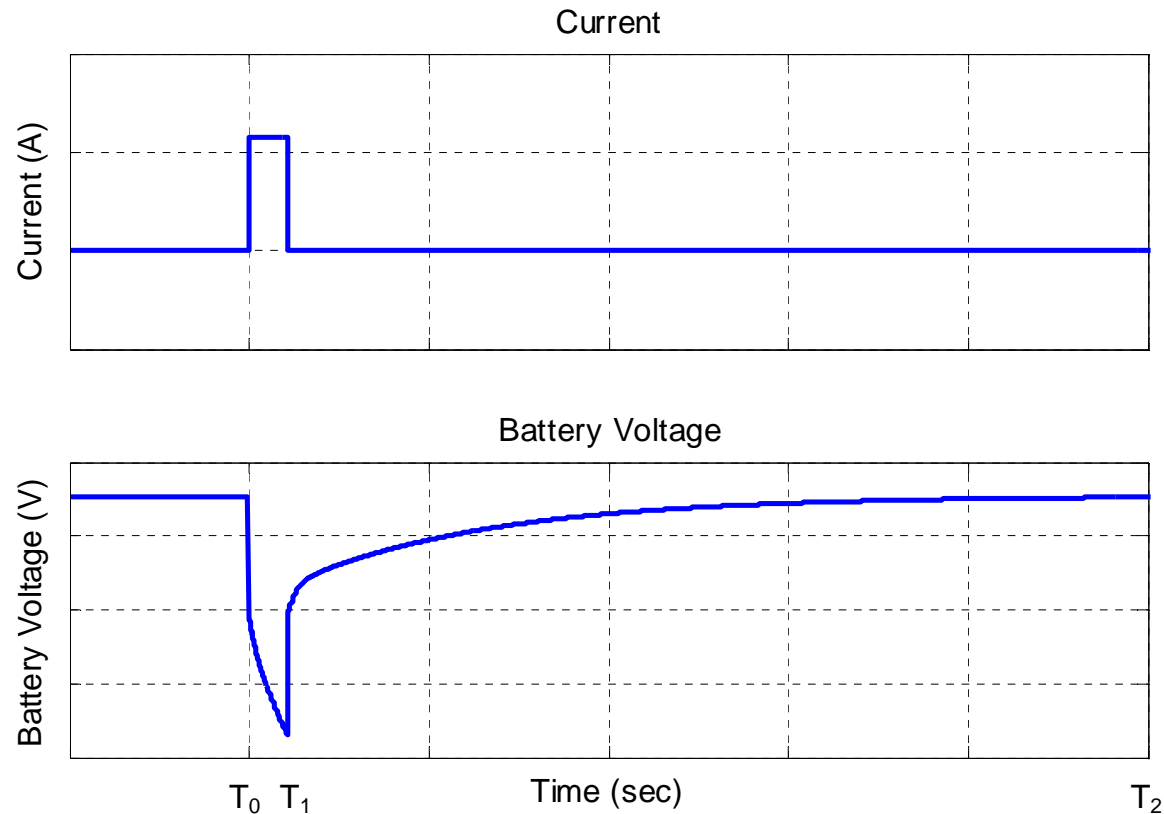
Equivalent Circuit Model



- 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



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



iTest



Modbus

Ethernet

Ethernet



**iConnect
Distributed I/O**



Thermal Chamber



Battery Cell(s)



**Programmable Power
Supplies (PPS)**

Key Features

Control up to 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

2 Ethernet

16 Temperature

1 Serial

8 Digital In

8 Digital Out

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

Data Acquisition and Control



A&D Technology, Inc.

Demonstration Mode

A&D Technology, Inc.
4622 Rawley Blvd.
Ann Arbor, MI 48108
www.aandtech.com

Battery

Specification

SampleBattery.sc2

Start / Stop Sequences Ready

New	Load	View
Duplicate	Existing	Edit

Pack Max Voltage	369.6
Pack Min Voltage	220.0
Cell Max Voltage	4.20
Cell Min Voltage	2.50
RatedCapacity	45.00
iC-Rate Charge	45.0000
iHPPC Charge Pulse	30.0000
iHPPC Dischg Pulse	50.0000
MaxTemp	57.0
MaxCellDeltaMv	5000
OCV Balance Pause (s)	300
Cell Balance Limit (s)	0
Battery Startup (s)	2
Battery Shutdown (s)	11

Monitoring

Voltages

CANSOC	0.00 %
CAN Voltage	0.0000 V
Max Cell V	0.0000 V
Avg. Cell V	0.0000 V
Min Cell V	0.0000 V
AvgCellDelta	0.00 mV

Cell Balance Cell Voltages

Temperatures

Batt TC Temp	0.0 °C
Batt Temp	0.0 °C
Max Cell Temp	0.00 °C
Min Cell Temp	0.00 °C
Avg Cell Temp	0.00 °C
Cell Delta	0.00 °C
Inlet Temp	0.00 °C
Air In Avg	0.00 °C
Outlet Temp	0.00 °C
Air Out Avg	0.00 °C

Status

Shut Down

On Off CAN #1 #2 #3

Calculations

ActualCapacity ...	45.00 Ah
BatterySOH	100.0 %
BatterySOC	30.7 %
BatteryDOD	69.3 %
AmpHrs	0.00 Ah
AhCharge	2.78 Ah
AhDischg	16.42 Ah
AhThroughput	19.20 Ah
WattHrs	0.00 KWh
WhCharge	0.00 KWh
WhDischg	0.00 KWh
WhThroughput	0.00 KWh

Cycler

Control / Monitor

Manual Monitor

	Setpoint	Feedback
Voltage	220.000 V	323.849 V
Current	12.500 A	-12.500 A
Power	200.000 KW	0.000 KW

Running

Discharge

Test Information

Test Request: TR1234

Test Engineer: David Prettenhofer

Project: SampleProjectFolder

Battery ID: Batt001

Test Name: Sample_DST

Test Status: Running

Data File: TR1234_Batt001_Sample_DST_WS07_Cct01_30Apr2012_18

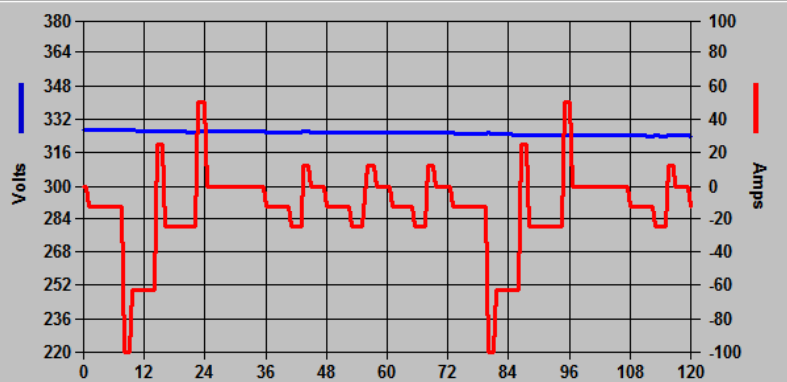
Schedule Selection / Test Control

Sample_DST

Cell Balance Routine: Batt1CellBal

Charge Taper Routine: Batt1TaperCharge

Graph



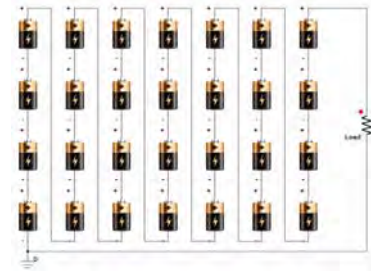
Volts (left axis), Amperage (right axis)

User Defined Presets: D 1 2 3

Voltage: 340.0 / 330.0 Amperage: 100.0 / -100.0

Current: 323.849 Power: -12.500

ANSYS ECM Tool



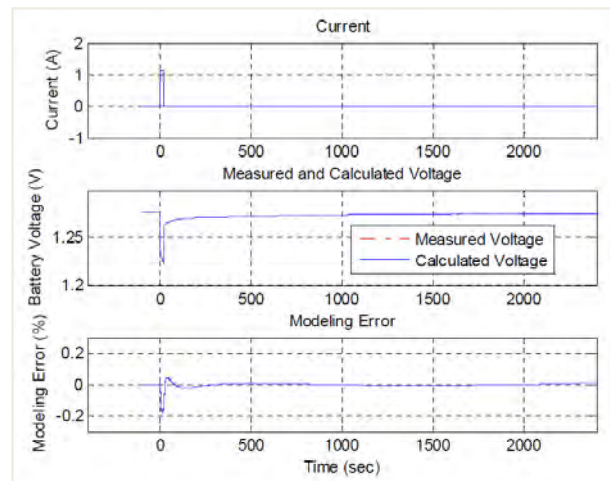
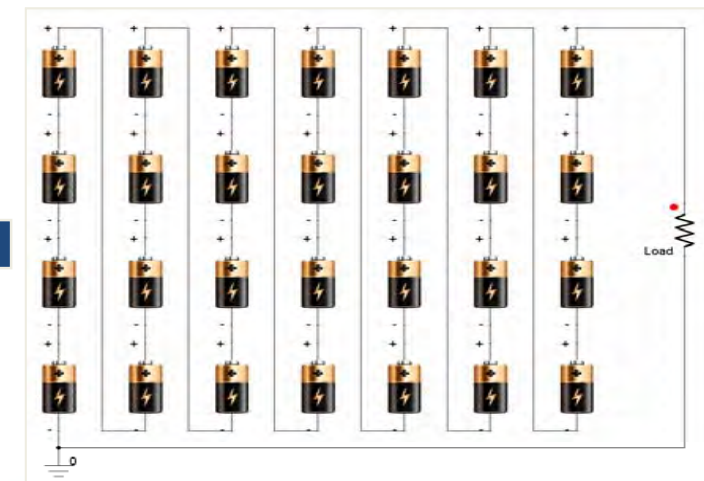
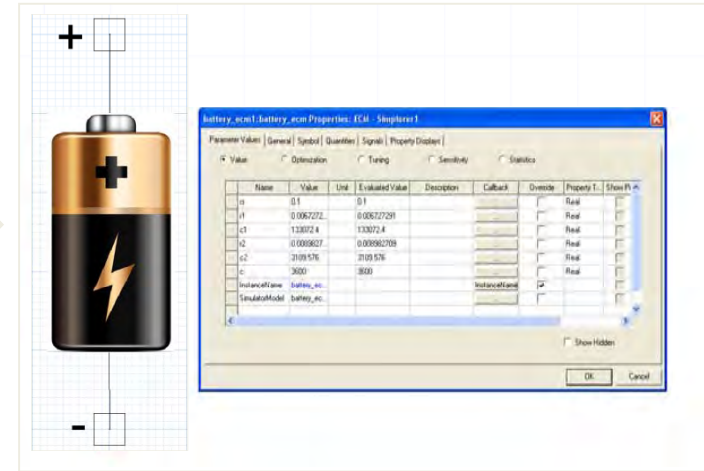
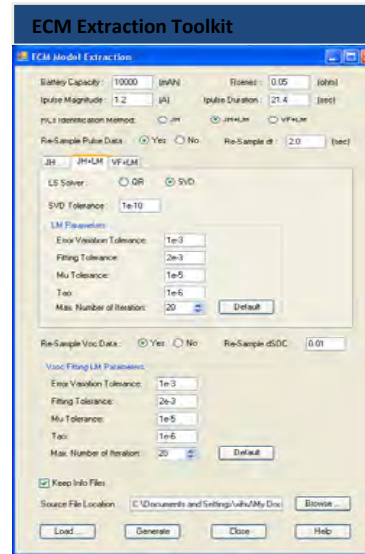
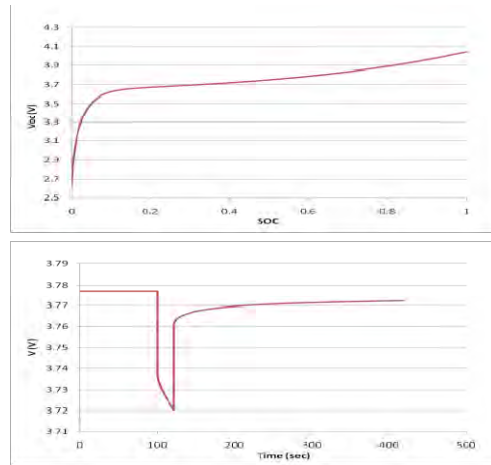
ECM Parameter Extraction Tool

The image displays the ECM Parameter Extraction Tool interface, which includes several key components:

- Graphs:**
 - V_{oc} vs. SOC:** A plot showing the open-circuit voltage (V_{oc}) in Volts versus SOC (State of Charge). The y-axis ranges from 2.5 to 4.3 V, and the x-axis ranges from 0 to 0.6 SOC. The curve shows a sharp initial rise followed by a gradual increase.
 - Pulse Discharge:** A plot showing the voltage (V [V]) versus Time (sec). The y-axis ranges from 3.71 to 3.79 V, and the x-axis ranges from 0 to 300 sec. It shows a step change in voltage during a pulse discharge.
 - Modeling Error:** A plot showing the modeling error versus Time (sec). The y-axis ranges from -0.2 to 0.2, and the x-axis ranges from 0 to 2000 sec. The error is mostly zero, indicating a good fit.
- ECM Model Extraction Dialog:**
 - Battery Capacity:** 1000
 - Pulse Magnitude:** 1.2
 - RCs Identification Method:** JH+LM
 - Re-Sample Pulse Data:** JH+LM
 - LS Solver:** JH+LM
 - SVD Tolerance:** 1e-5
 - LM Parameters:**
 - Error Variation Tolerance: 1e-5
 - Fitting Tolerance: 1e-6
 - Mu Tolerance: 20
 - Tau: 1e-6
 - Max. Number of Iteration: 20
 - Keep Info Files:**
 - Source File Location:** C:\Documents and Settings\user\My Documents\...
 - Buttons:** Load..., Generate
- Battery Model:** A 3D model of a battery with a plus sign (+) and a lightning bolt symbol.
- Parameter Values Table:** A table showing the extracted parameters for the battery model. The table is circled in red in the image.

Name	Value	Unit	Evaluated Value	Description	Callback	Override	Property T...	Show Pi
rs	0.1		0.1				Real	
r1	0.0067272...		0.006727291				Real	
c1	133072.4		133072.4				Real	
i2	0.0089827...		0.008982709				Real	
c2	3109.576		3109.576				Real	
c	3600		3600				Real	
InstanceName	battery_ec...						InstanceName	<input checked="" type="checkbox"/>
SimulatorModel	battery_ec...							
- Battery Pack Diagram:** A schematic diagram of a battery pack consisting of 24 individual battery cells connected in a 4x6 grid. A load resistor is connected across the terminals of the pack.

ECM Parameter Extraction Tool



ECM Model Workflow


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!

 734-822-9517

 734-973-1103

 sjiang@aanddtech.com

 www.aanddtech.com