

An Accurate Electrical Battery Model Capable of Predicting Lifetime and I-V Performance

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Motivation

Design Goal of Portable Electronics

- Low power dissipation
- Maximum battery lifetime

Model Applications

- Design energy-aware circuits and systems
- Optimize circuit and system performance
- Predict battery lifetime
- Emulate batteries with electronic circuits
- Improve battery energy efficiency

Modeling Methods

Electrochemical models

- Using deductive method (fundamental mechanism)
- Providing macroscopic and microscopic information
- Involving a system of coupled, time-variant, spatial, partial differential equations (numerical technique)

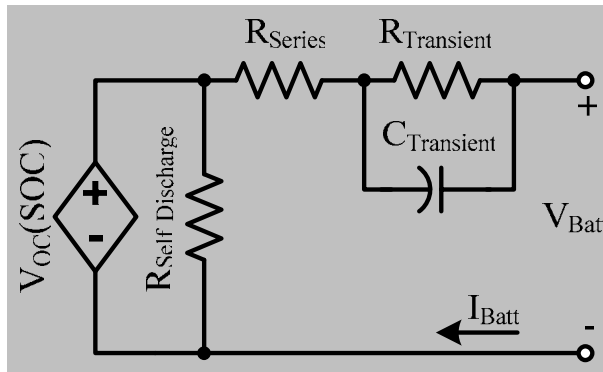
Mathematical models

- Using inductive method (empirical equations or mathematical methods)
- Providing system-level behavior (lifetime, efficiency, or capacity)
- Involving relatively complex mathematical equations

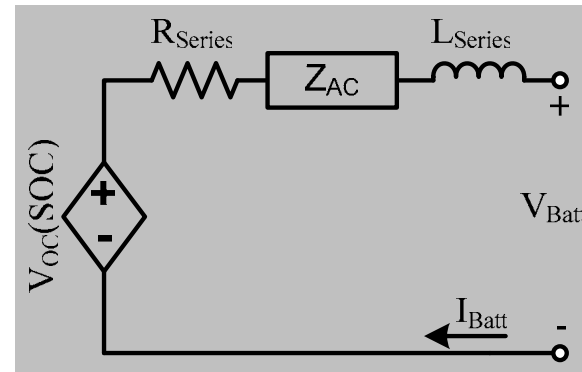
Electrical models

- Using inductive method (empirical equation)
- Providing lifetime and I-V performance
- Involving curve fitting of a bundle of measurement

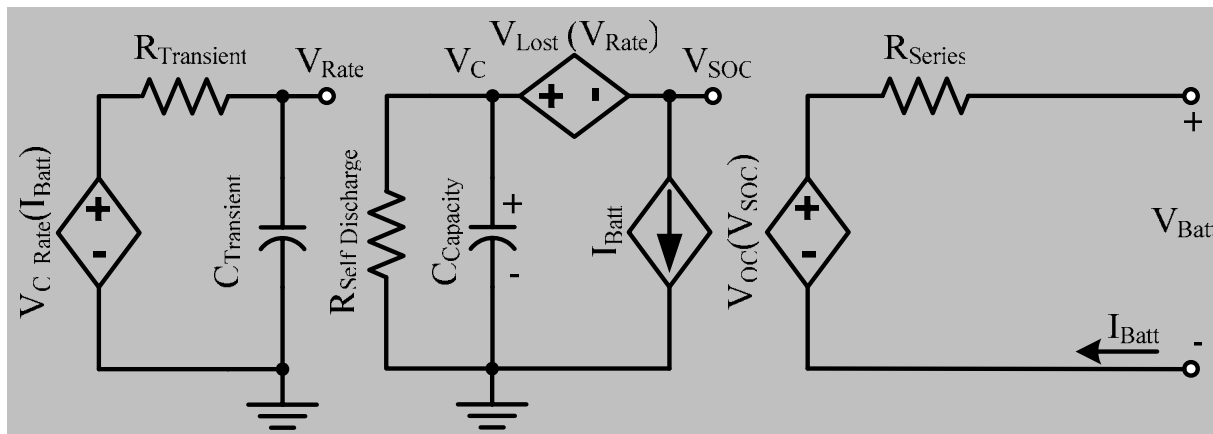
Electrical Models



(a)



(b)



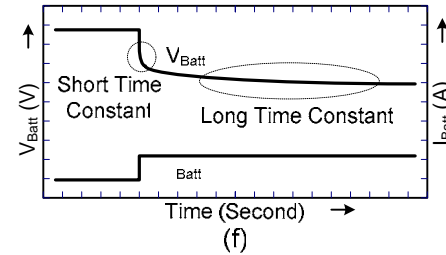
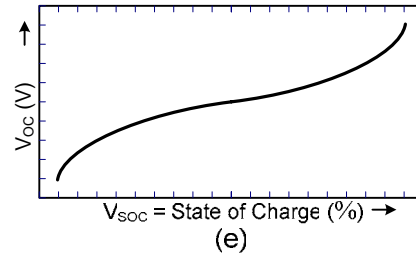
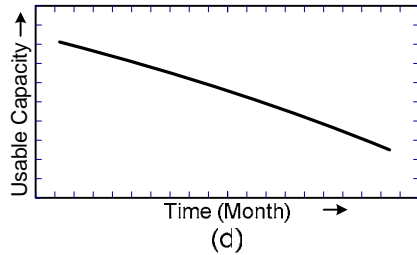
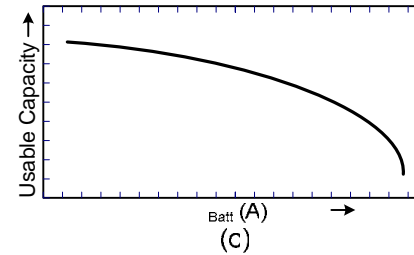
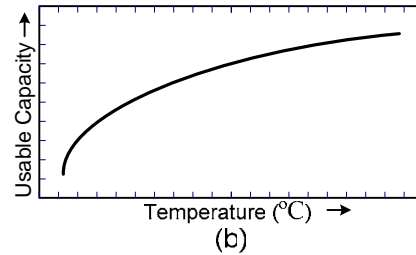
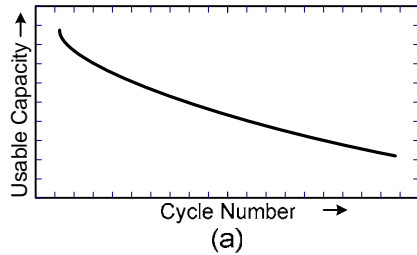
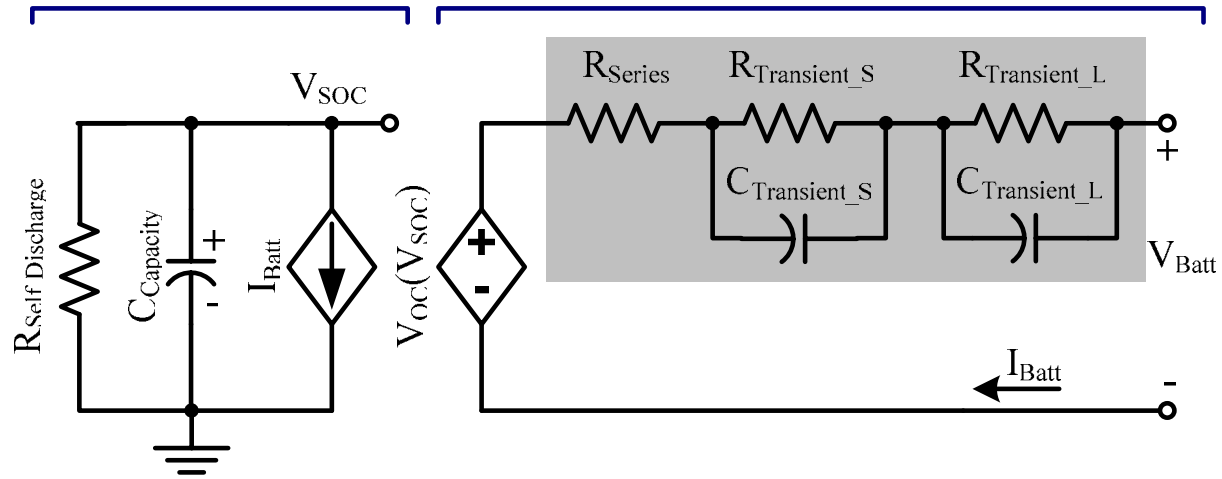
(c)

(a) Thevenin-based battery models, (b) Impedance-based battery models, and (c) Lifetime-based battery models

Proposed Model

Battery Lifetime

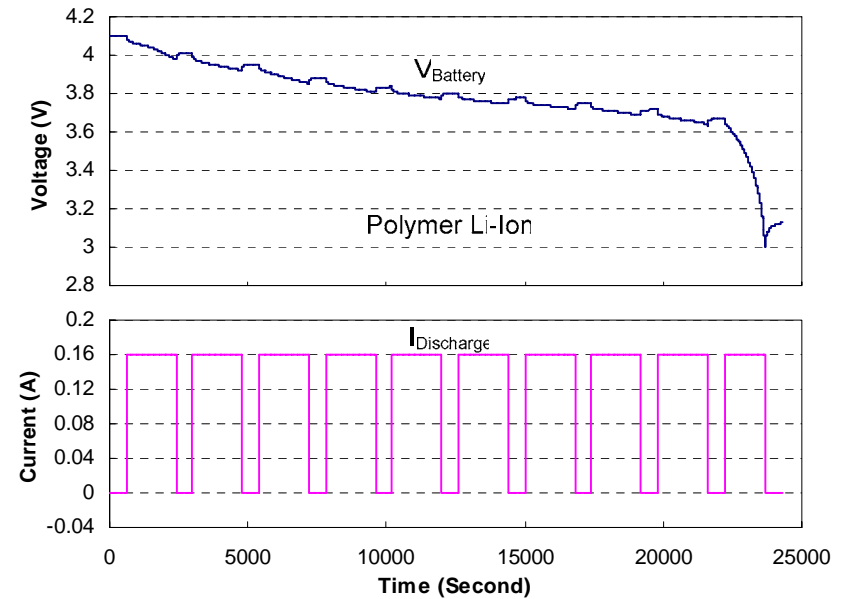
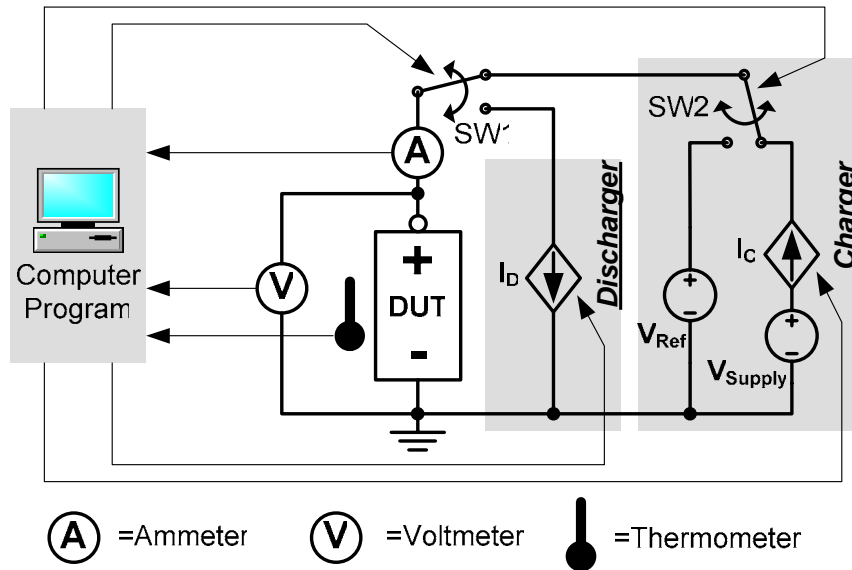
Voltage-Current Characteristics



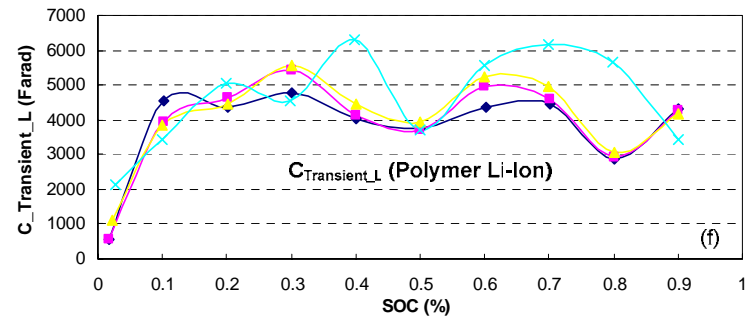
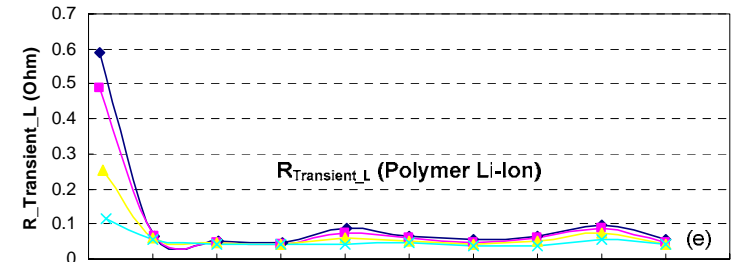
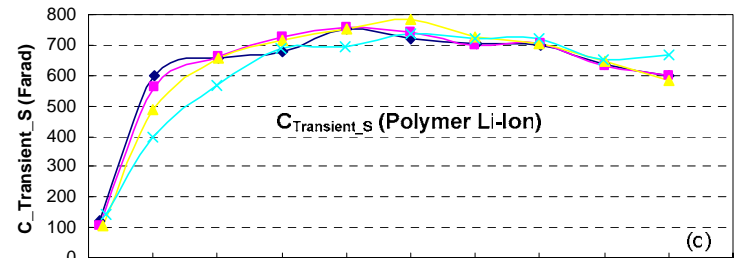
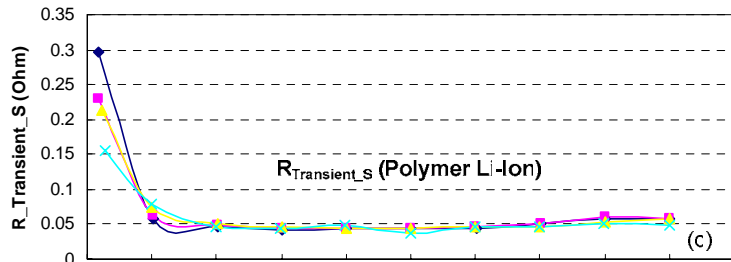
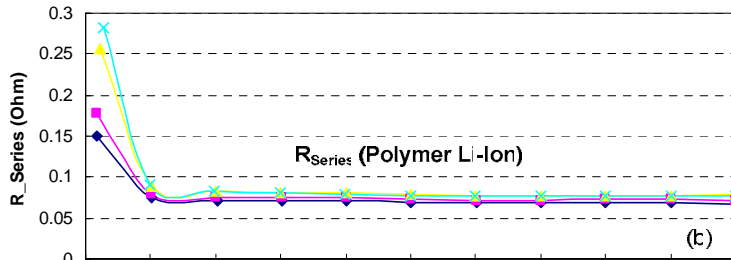
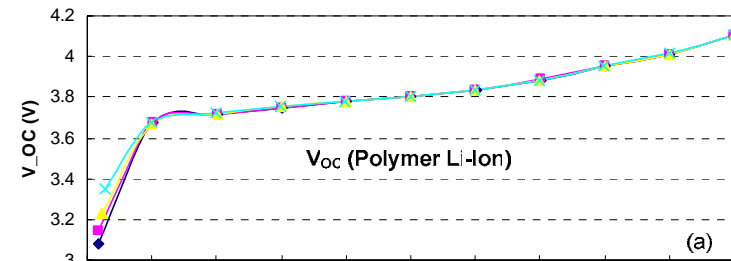
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Test System and Procedure



Model Extraction



◆ 80mA
 ■ 160mA
 ▲ 320mA
 × 640mA



Model Validation I

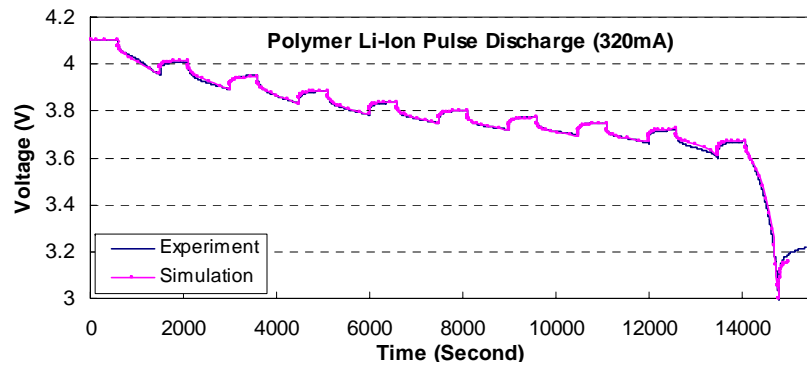
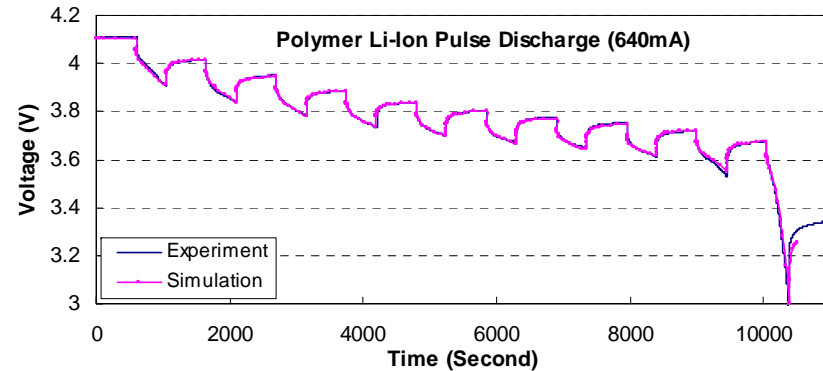
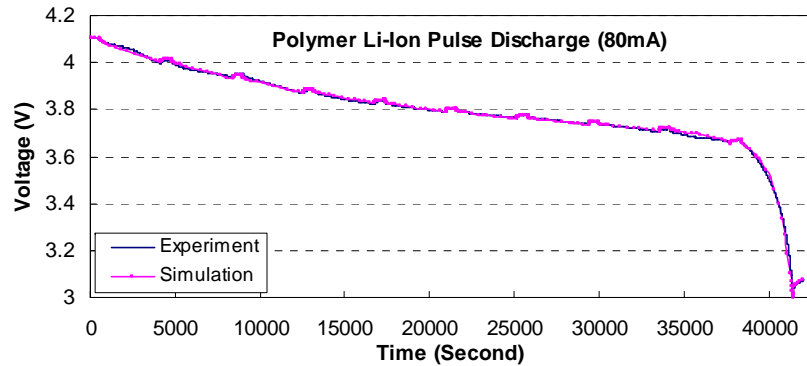


TABLE II
MODEL EXTRACTION ACCURACY (POLYMER LI-ION BATTERY)

Pulse Discharge Current (mA)	Max Error Voltage (mV)	Lifetime Error (%)
80	15	0.039%
160	17	0.118%
320	18	0.020%
640	21	0.029%



Model Validation II

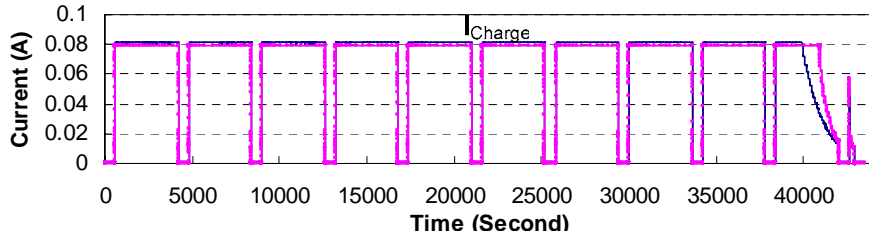
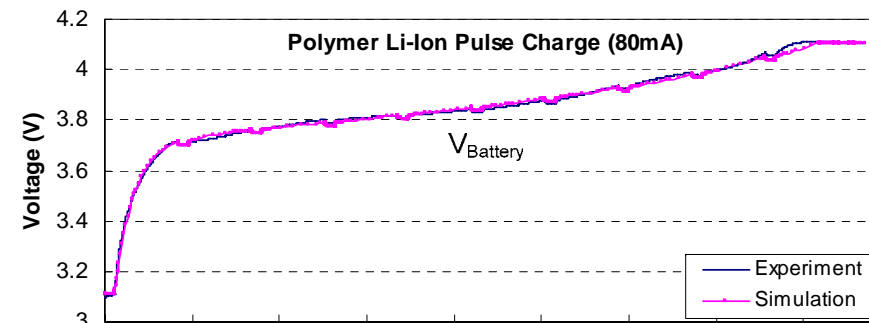
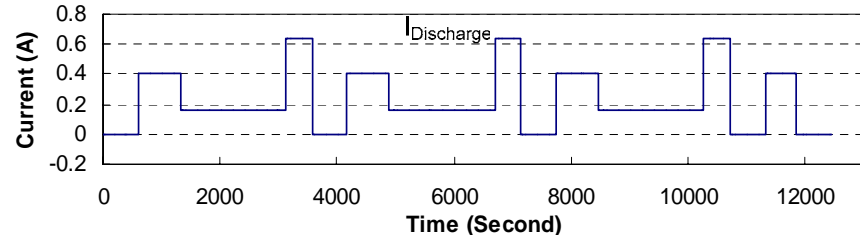
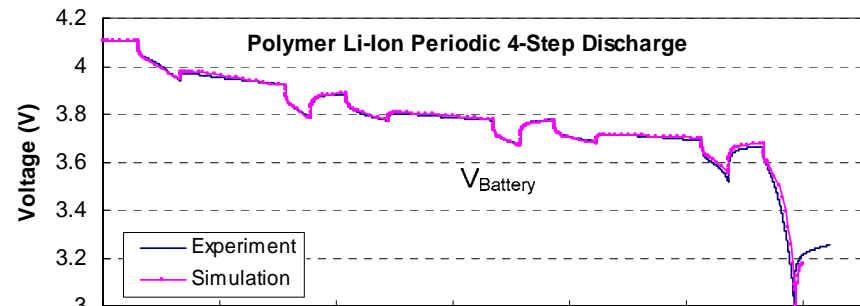
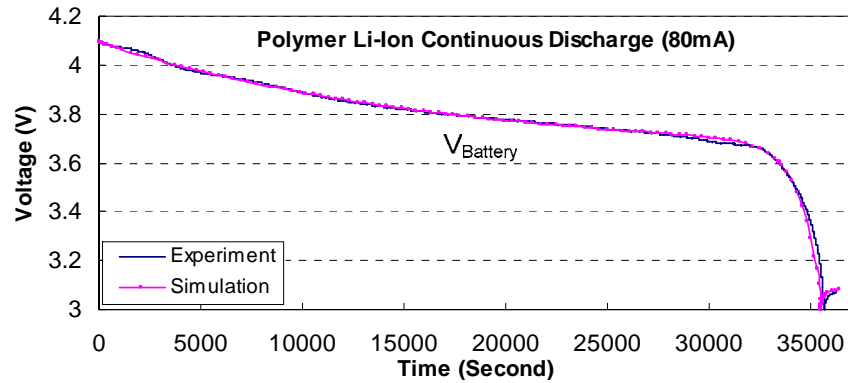


TABLE III

MODEL VALIDATION RESULTS (POLYMER LI-ION BATTERY)

Load Profiles	Max Error Voltage (mV)	Lifetime Error (%)
Continuous Discharge	15	0.395%
Pulse Charge	30	0.133%
4-Step Discharge	20	0.338%



Summary

- An accurate, intuitive, and comprehensive electrical model has been proposed to capture the entire dynamic characteristics of the battery.
- This model has been validated by comparing simulation results from Cadence with experimental data on polymer Li-Ion batteries.
- Less than 0.4% lifetime error and 30mV voltage error offers circuit designers the possibility to improve system efficiency and prolong battery lifetime for portable electronics.

