Lithium Ion Battery

Simplified SPICE Behavioral Model

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Contents

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1. Benefit of the Model

- The model enables circuit designer to predict and optimize battery runtime and circuit performance.
- The model can be easily adjusted to your own battery specifications by editing a few parameters that are provided in the datasheet.
- The model is optimized to reduce the convergence error and the simulation time

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2. Model Feature

- This *Li-Ion Battery Simplified SPICE Behavioral Model* is for users who require the model of a Li-Ion Battery as a part of their system.
- *Battery Voltage(V_{bat}) vs. Battery Capacity Level (SOC) Characteristic*, that can perform battery charge and discharge time at various current rate conditions, are accounted by the model.
- As a simplified model, the effects of cycle number and temperature are neglected.

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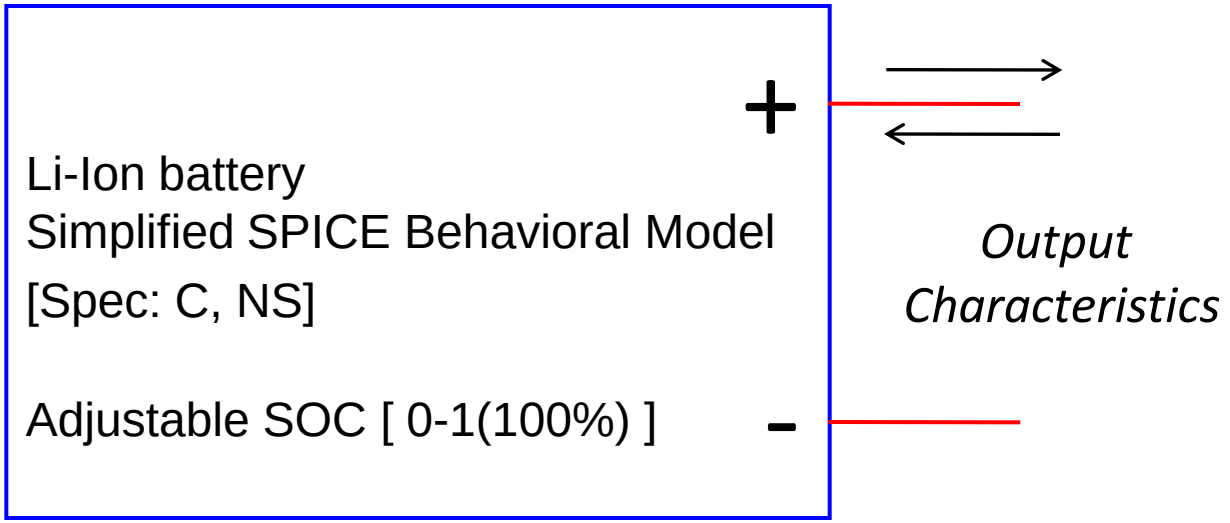
3. Concept of the Model



- The model is characterized by parameters: *C*, which represent the battery capacity and *SOC*, which represent the battery initial capacity level.
- *Open-circuit voltage (V_{OC}) vs. SOC* is included in the model as an analog behavioral model (ABM).
- NS (*Number of Cells in series*) is used when the Li-ion cells are in series to increase battery voltage level.

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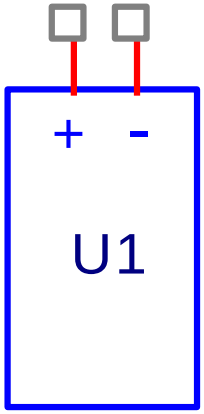
4. Parameter Settings



LI-ION_BATTERY
TSCALE = 1
C = 1.4
SOC = 1
NS = 1

(Default values)

Model Parameters:

C is the amp-hour battery capacity [Ah]

– e.g. C = 0.3, 1.4, or 2.8 [Ah]

NS is the number of cells in series

– e.g. NS=1 for 1 cell battery, NS=2 for 2 cells battery (battery voltage is double from 1 cell)

SOC is the initial state of charge in percent

– e.g. SOC=0 for a empty battery (0%), SOC=1 for a full charged battery (100%)

TSCALE turns TSCALE seconds into a second

– e.g. TSCALE=60 turns 60s or 1min into a second, TSCALE=3600 turns 3600s or 1h into a second,

- From the Li-Ion Battery specification, the model is characterized by setting parameters C, NS, SOC and TSCALE.

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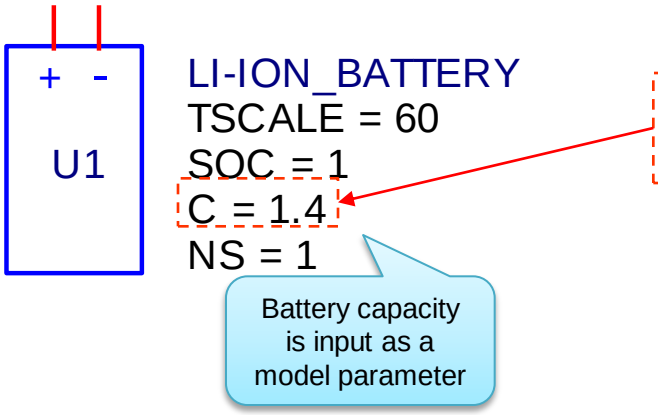
5. Li-Ion Battery Specification (Example)



Nominal Voltage		3.7V
Nominal Capacity	Typical	1400mAh (0.2C discharge)
Charging Voltage		4.20V±0.05V
Charging Std. Current		700mA
Max Current	Charge	1400mA
	Discharge	2800mA
Discharge cut-off voltage		2.75V

- The battery information refer to a battery part number LIR18500 of EEMB BATTERY.

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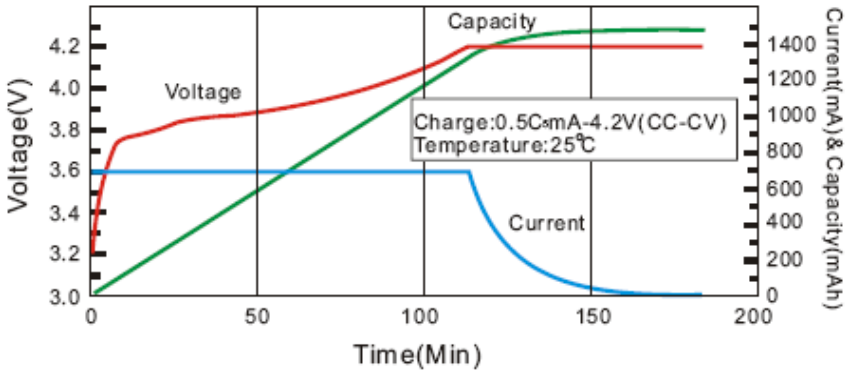
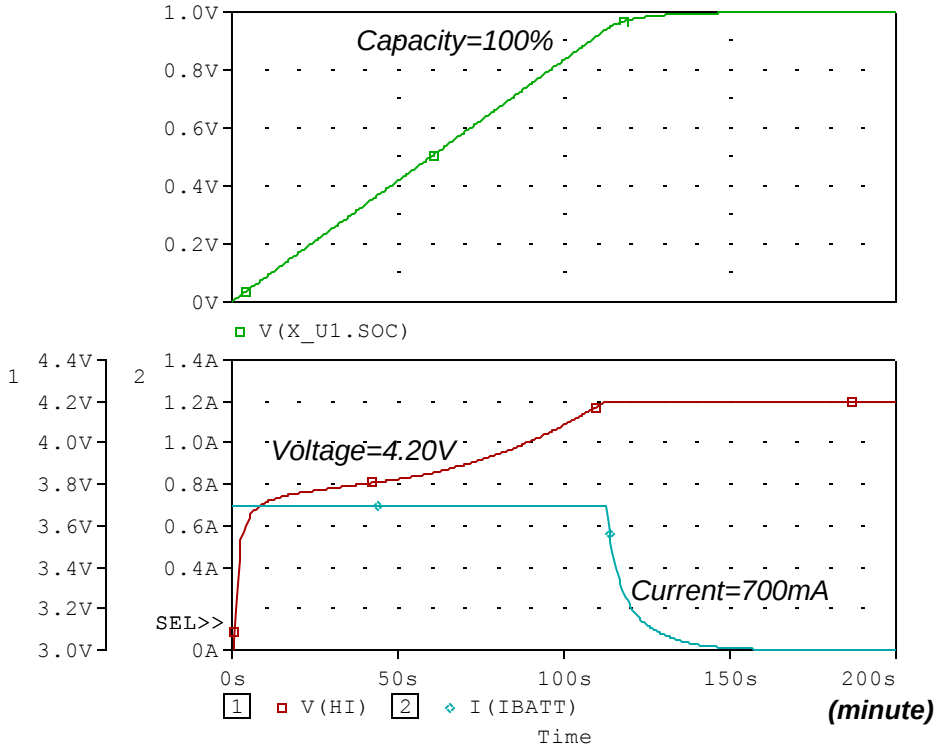
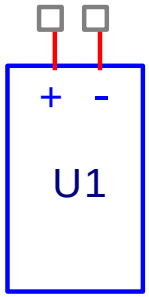
5.1 Charge Time Characteristic

Measurement



Simulation





LI-ION_BATTERY
TSCALE = 60
C = 1.4
SOC = 0
NS = 1

SOC=0 means battery start from 0% of capacity (empty)

- Charging Voltage: 4.20V±0.05V
- Charging Current: 700mA (0.5 Charge)

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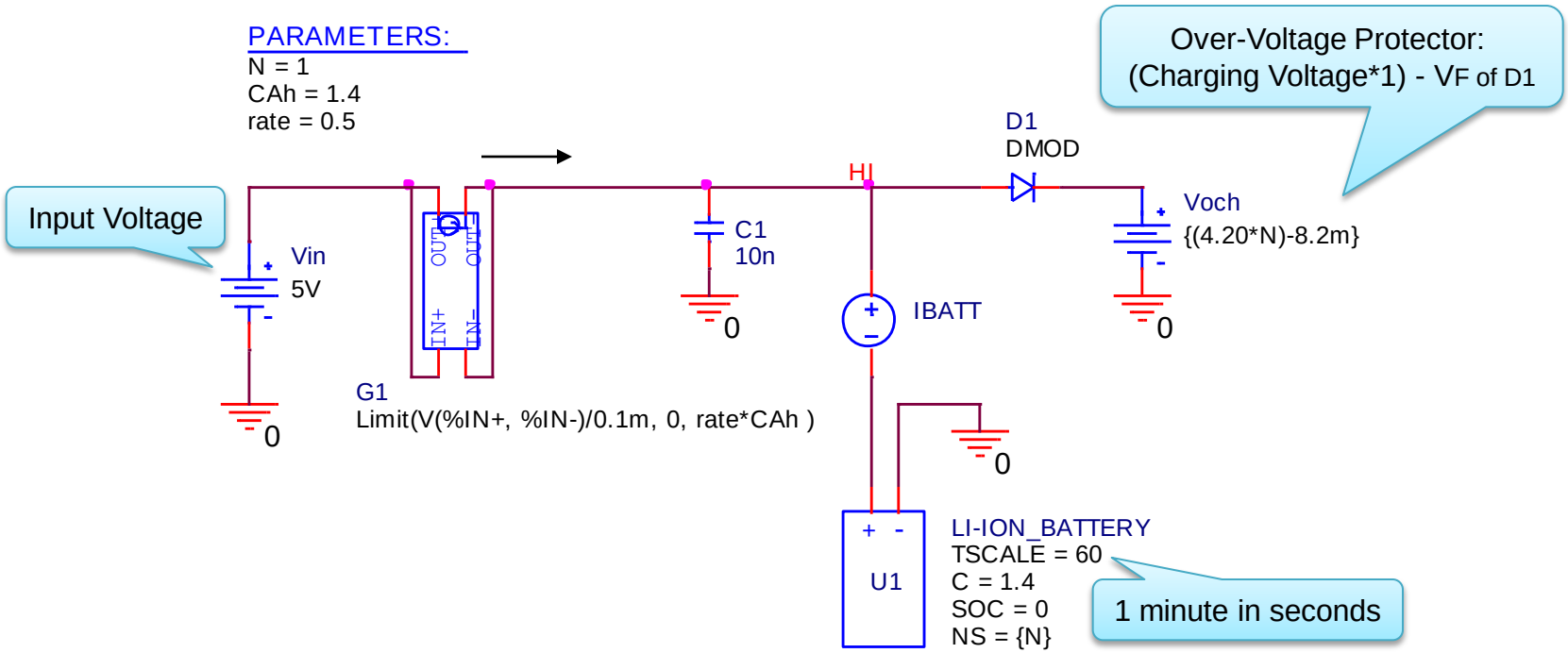
5.1 Charge Time Characteristic – Simulation Circuit and Setting



*Analysis directives:
.TRAN 0 200 0 0.5
.PROBE V(*) I(*) W(*) D(*) NOISE(*)

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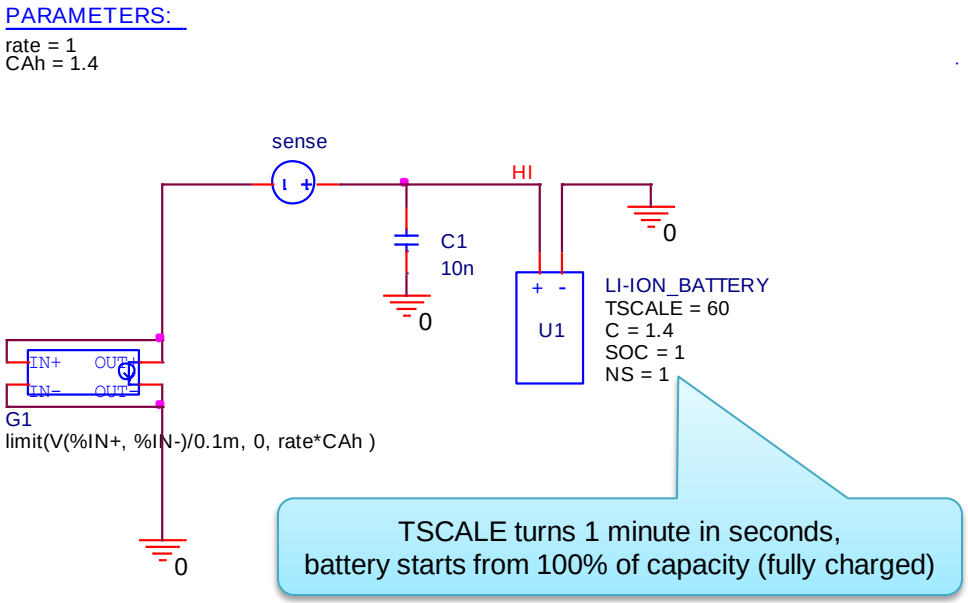
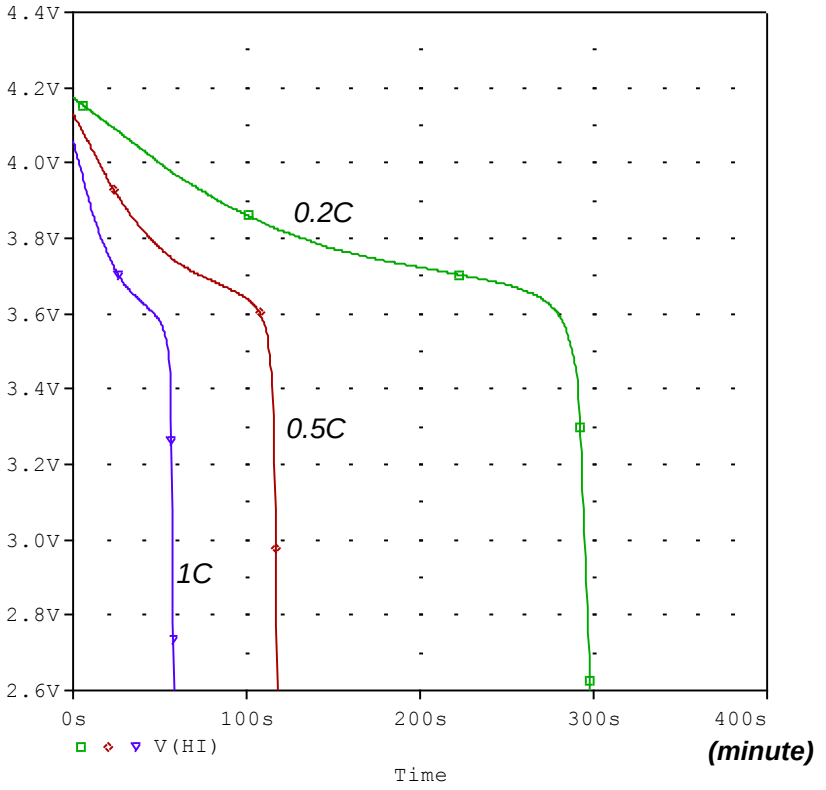
5.2 Discharge Time Characteristic

- Battery voltage vs. time are simulated at 0.2C, 0.5C, and 1C discharge rates.





*Analysis directives:
.TRAN 0 300 0 0.5
.STEP PARAM rate LIST 0.2,0.5,1
.PROBE V(*) I(*) W(*) D(*) NOISE(*)

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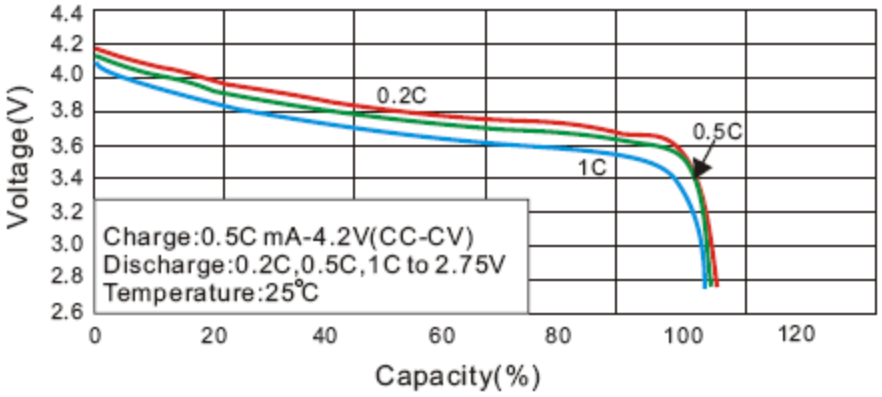
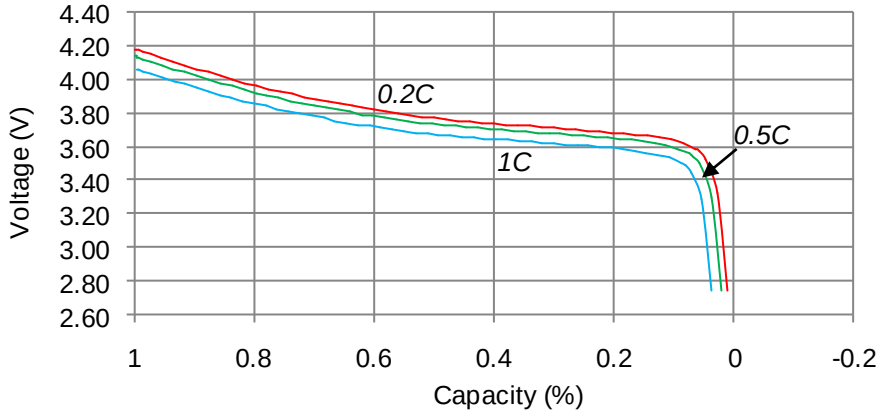
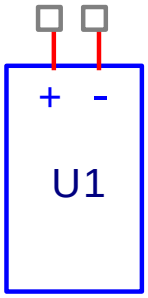
5.3 V_{bat} vs. SOC Characteristic

Measurement



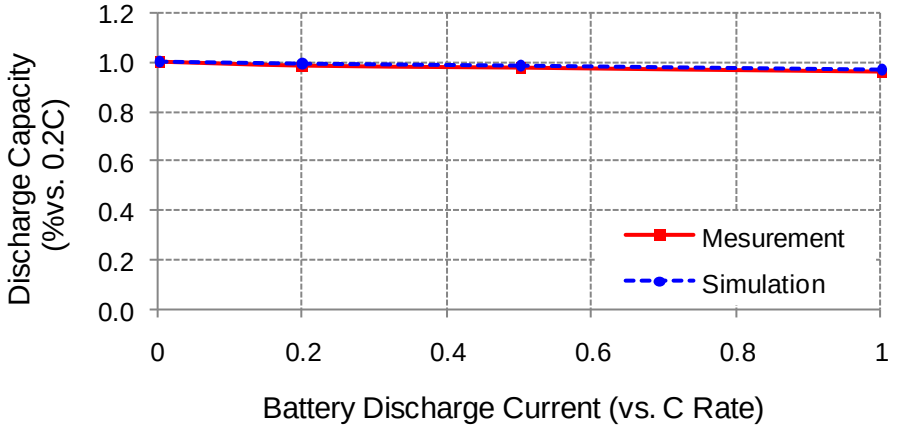
Simulation





LI-ION_BATTERY
TSCALE = 60
C = 1.4
SOC = 1
NS = 1

Simulation



- Nominal Voltage: 3.7V
- Capacity: 1400mAh (0.2C discharge)
- Discharge cut-off voltage: 2.75V

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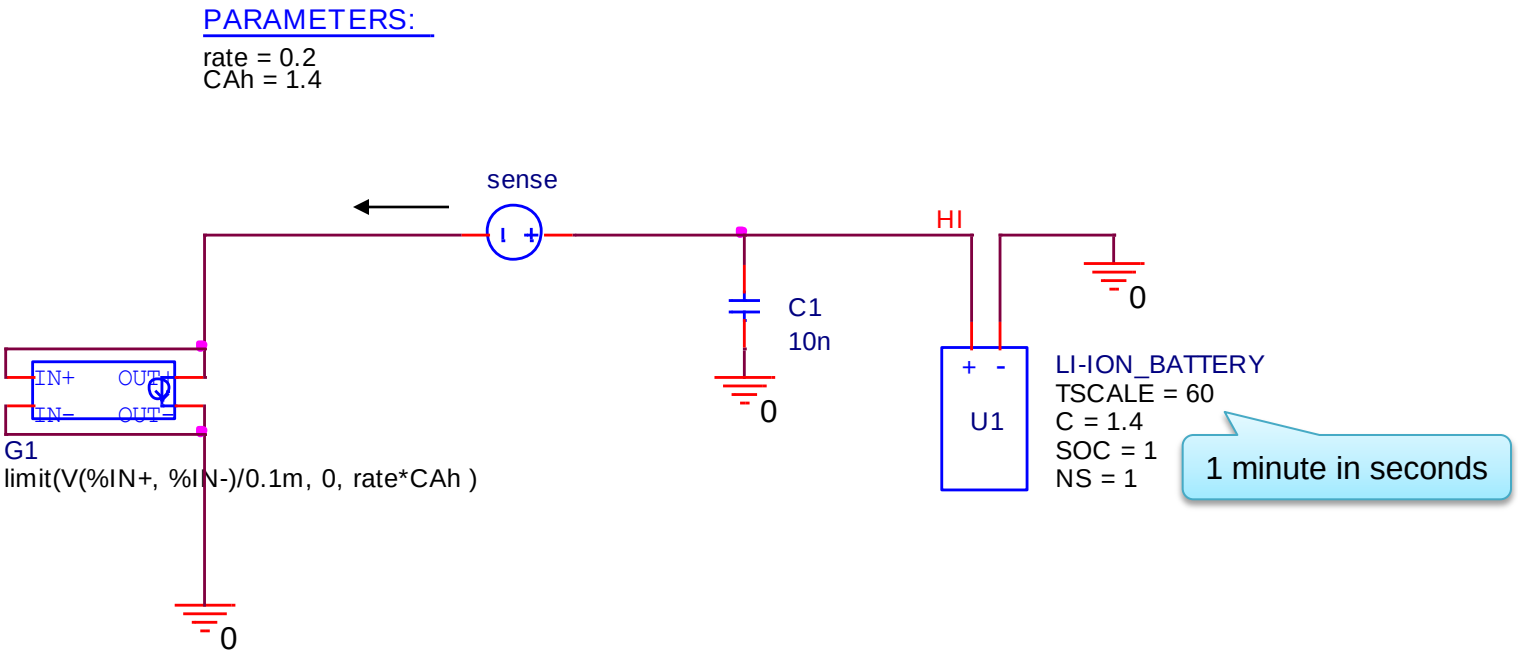
5.3 V_{bat} vs. SOC Characteristic – Simulation Circuit and Setting



*Analysis directives:
.TRAN 0 296.82 0 0.5
.PROBE V(*) I(*) W(*) D(*) NOISE(*)

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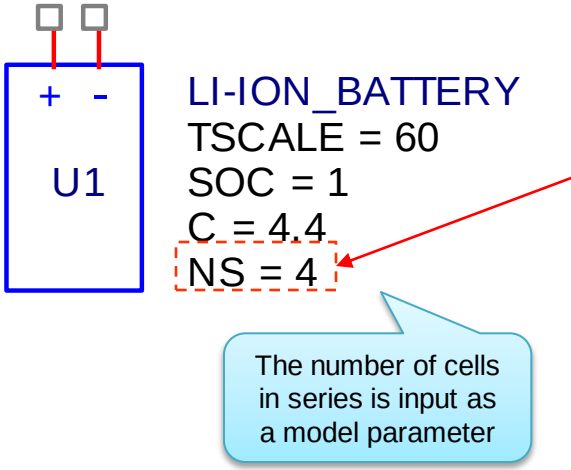
6. Extend the number of Cell (Example)



Basic Specification

Li-ion needs 4 cells to reach this voltage level

Output Voltage	DC 12.8~16.4V
Capacity of Approximately	4400mAh
Input Voltage	DC 20.5V
Charging Time	About 5 hours

- The battery information refer to a battery part number PBT-BAT-0001 of BAYSUN Co., Ltd.

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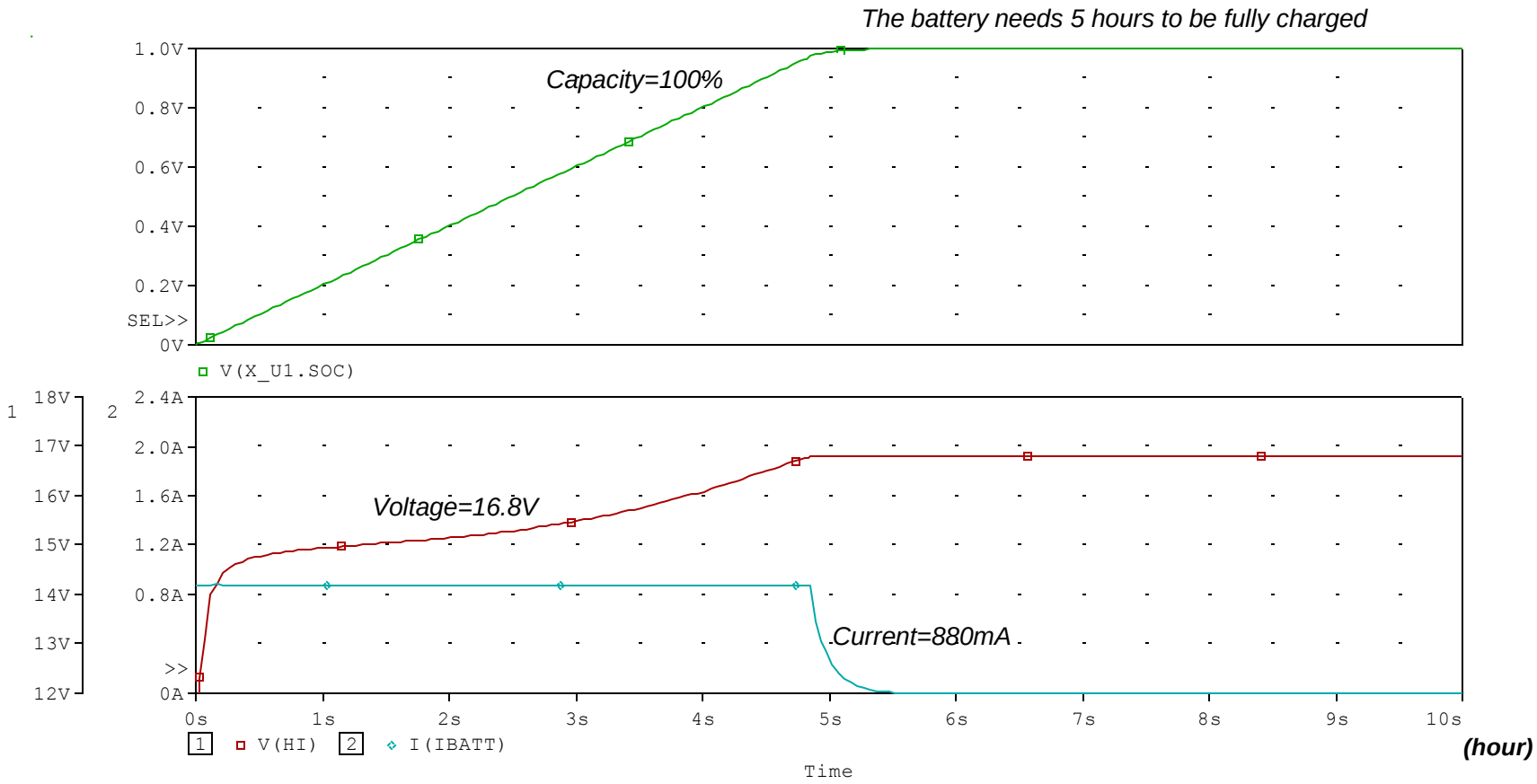
6.1 Charge Time Characteristic, NS=4



- Input Voltage: 20.5V
- Charging Voltage: 16.8V
- Charging Current: 880mA (0.2 Charge)

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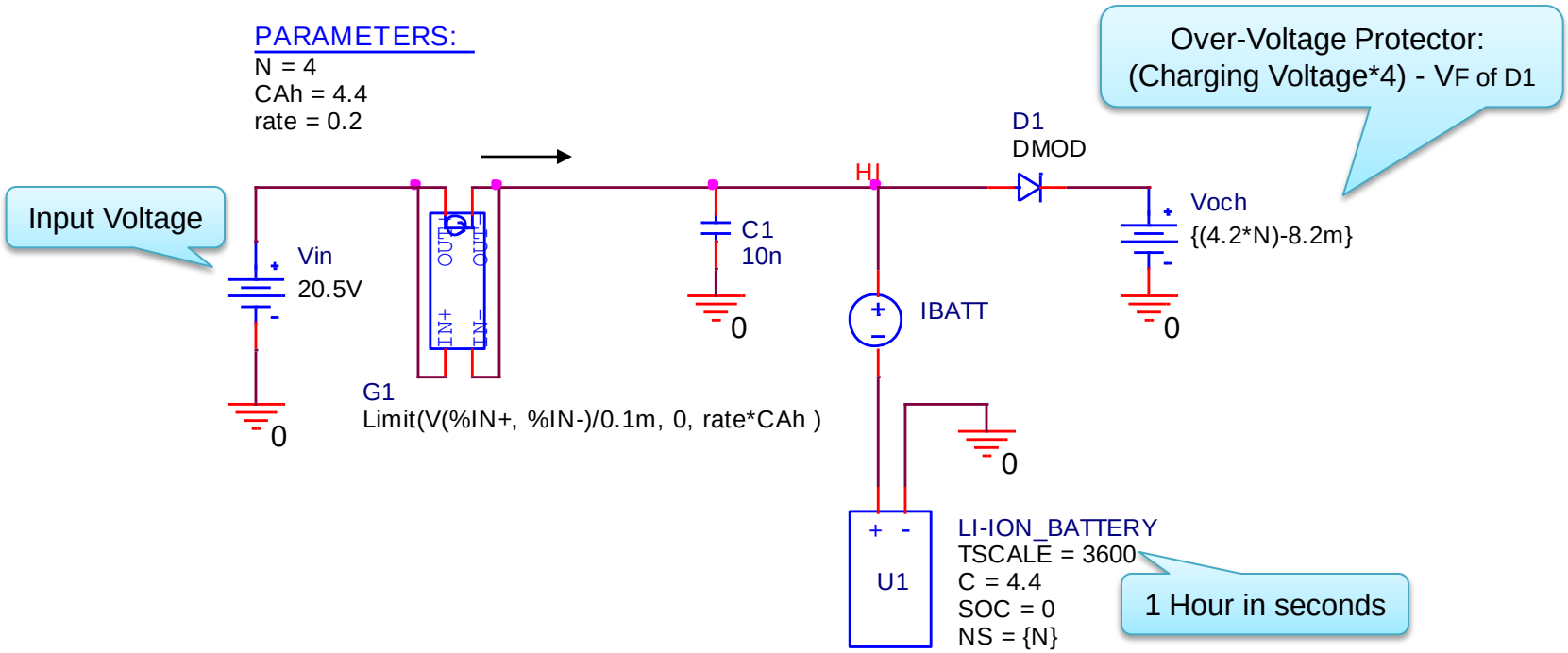
6.1 Charge Time Characteristic, NS=4 – Simulation Circuit and Setting



*Analysis directives:
.TRAN 0 10 0 0.05
.PROBE V(*) I(*) W(*) D(*) NOISE(*)

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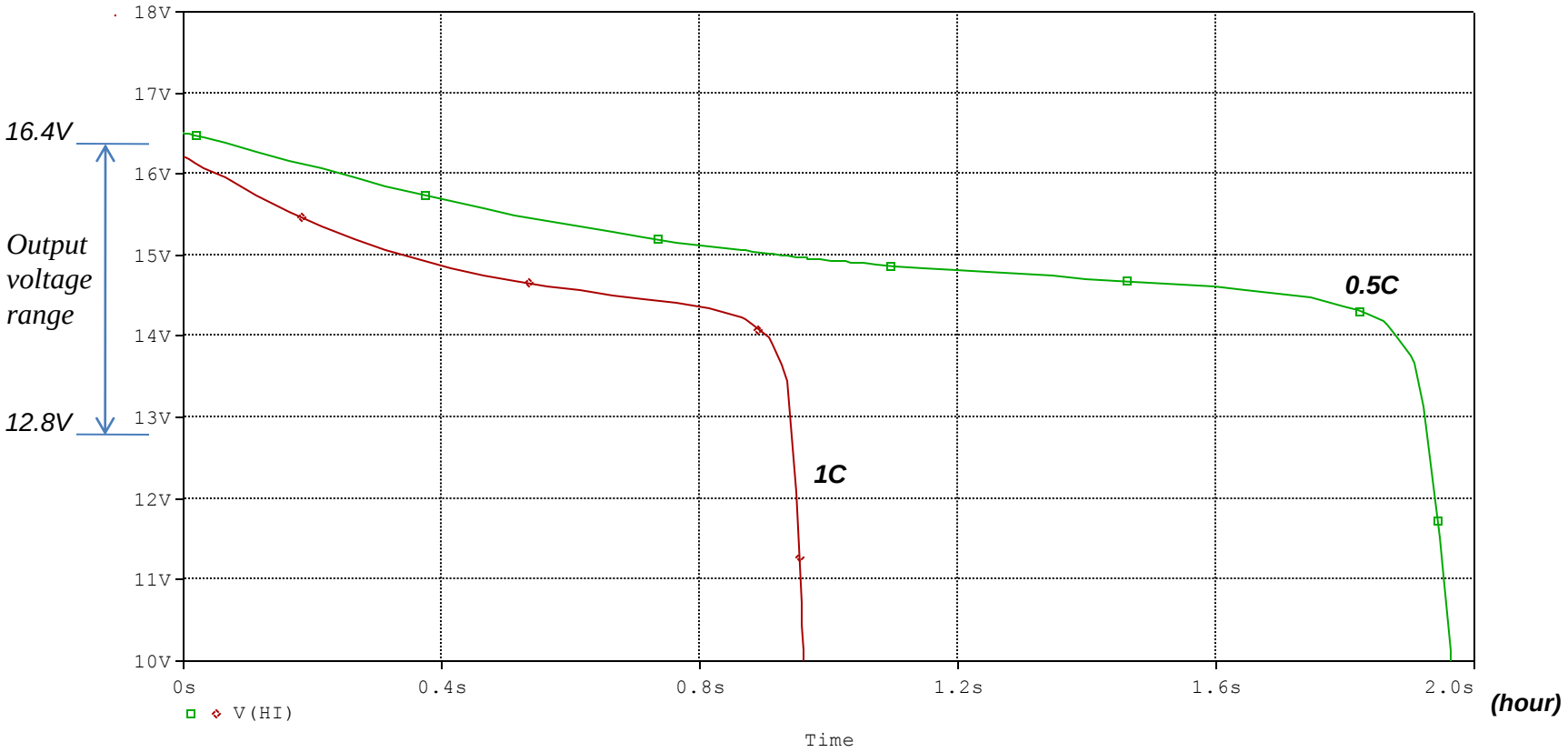
6.2 Discharge Time Characteristic, NS=4



- Charging Voltage: 16.8V
- Charging Current: 880mA (0.2 Charge)

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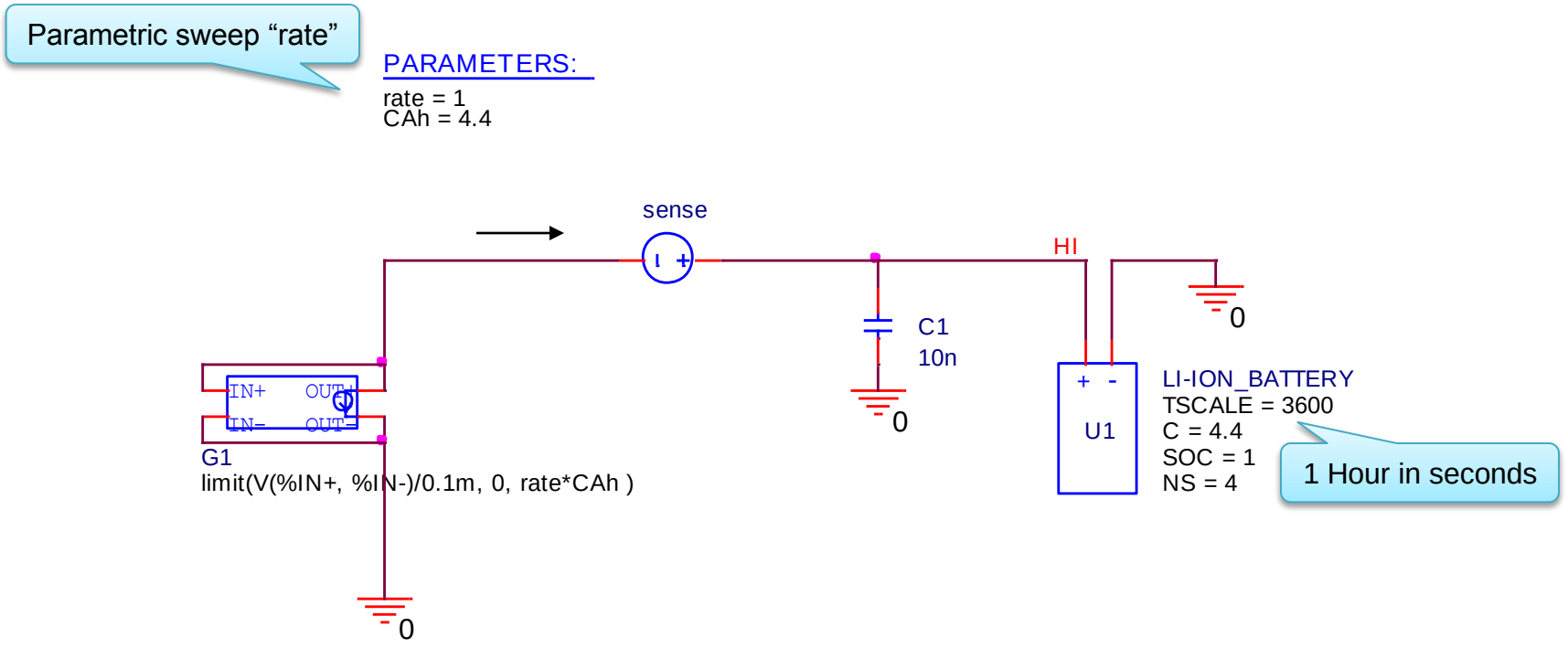
6.2 Discharge Time Characteristic, NS=4 – Simulation Circuit and Setting



*Analysis directives:
.TRAN 0 3 0 0.05
.STEP PARAM rate LIST 0.5,1
.PROBE V(*) I(*) W(*) D(*) NOISE(*)

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