Electric Vehicle (EE60082)

Lecture 14: BMS part4

DR. SHIMUL K. DAM

ASSISTANT PROFESSOR,
DEPARTMENT OF ELECTRICAL ENGINEERING,
INDIAN INSTITUTE OF TECHNOLOGY (IIT), KHARAGPUR.

Cell specsc

-SAMSUNG SDI Confidential Proprietary –

SAMSUNG SDI

Spec. No.	ICR18650-26F	Version No.	0.0

SPECIFICATION OF PRODUCT

for Lithium-ion Rechargeable Cell

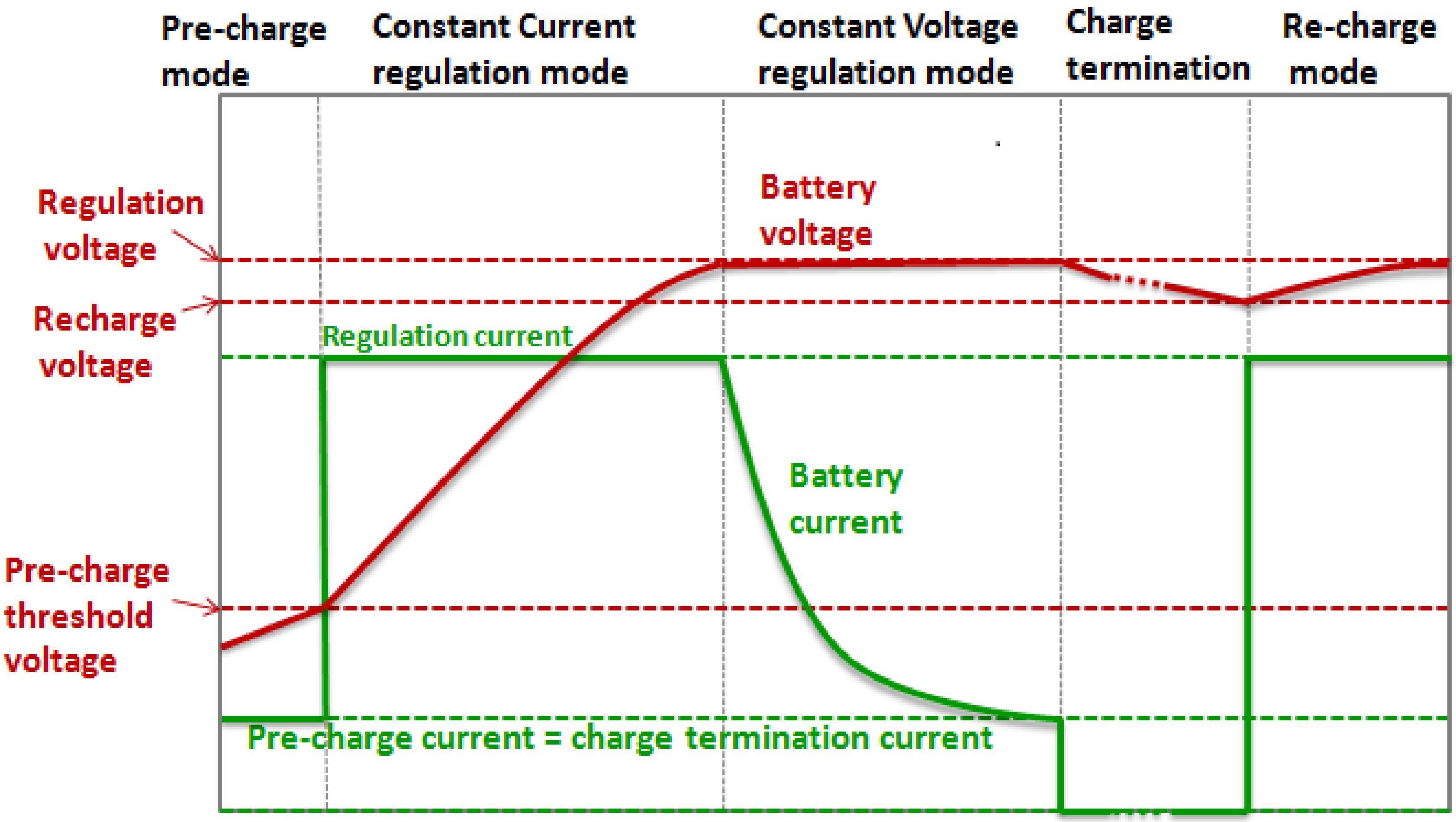
Model : ICR18650-26F

Cell specs (recap)

3. Nominal Specifications

Item	Specification
3.1 Nominal Capacity	2600mAh (0.2C, 2.75V discharge)
3.2 Minimum Capacity	2550mAh(0.2C, 2.75V discharge)
3.3 Charging Voltage	4.2 ±0.05 V
3.4 Nominal Voltage	3.7V
3.5 Charging Method	CC-CV (constant voltage with limited current)
3.6 Charging Current	Standard charge: 1300mA Rapid charge : 2600mA
3.7 Charging Time	Standard charge : 3hours Rapid charge : 2.5hours
3.8 Max. Charge Current	2600mA(ambient temperature 25℃)
3.9 Max. Discharge Current	5200mA(ambient temperature 25℃)
3.10 Discharge Cut-off Voltage	2.75V

CC-CV charging (recap)



Cell specs (recap)

7.6 Charge Rate Capabilities

Discharge capacity is measured with constant current 520mA and 2.75V cut-off after the cell is charged with 4.2V as follows.

	Charge Condition			
Current	0.2C (520mA)	0.5C (1300mA)	1.0C (2600mA)	2.0C (5200mA)
Cut-off	7h or 0.05C	2.5h or 0.05C	2.5h or 0.05C	2.5h or 0.05C
Relative Capacity	100%	95%	90%	80%

Note: Percentage as an index of the capacity at 25℃(=2550mAh) is 100%.

7.7 Discharge Rate Capabilities

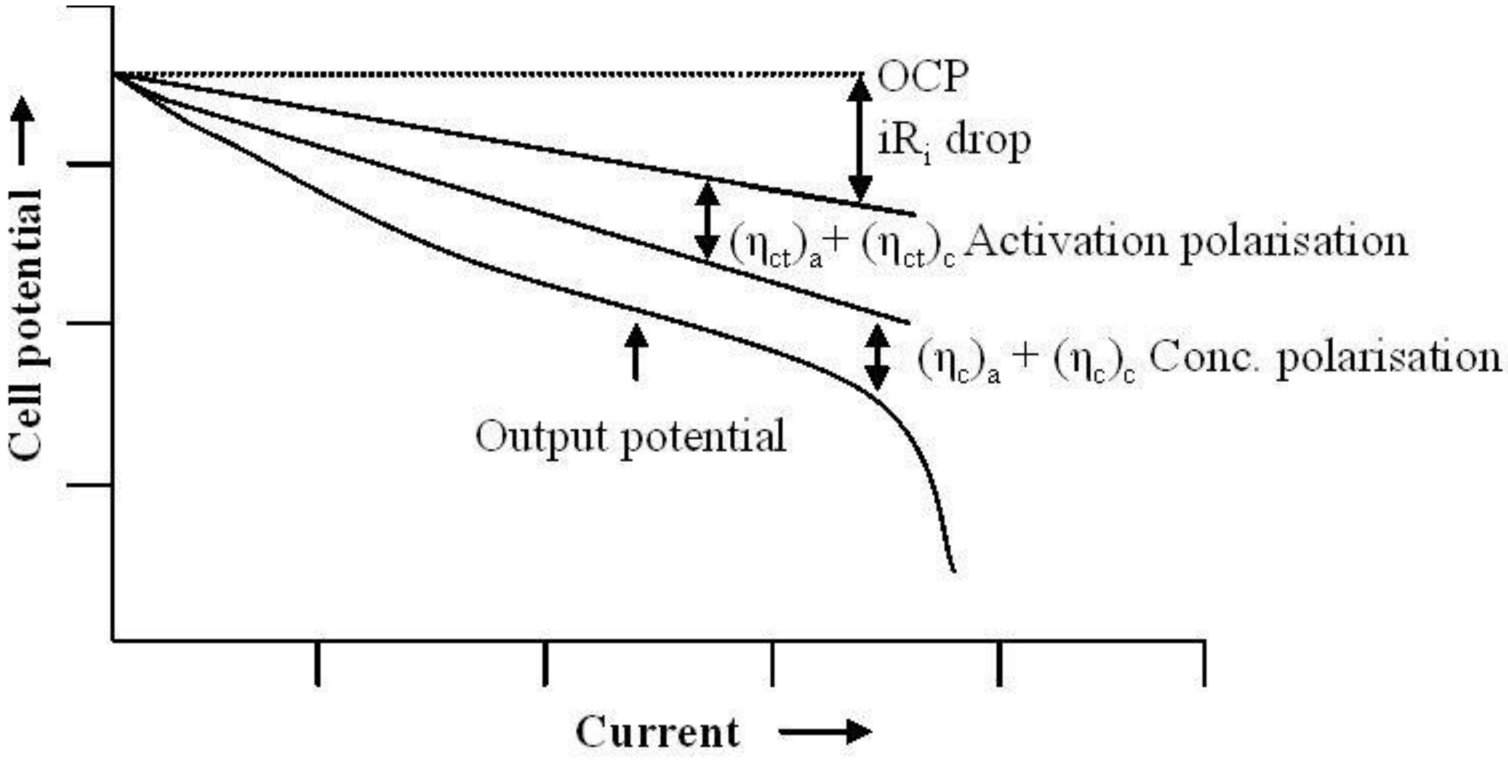
Discharge capacity is measured with the various currents in under table and 2.75V cut-off after the standard charge.

	Discharge Condition			
Current	0.2C (520mA)	0.5C (1300mA)	1.0C (2600mA)	2.0C (5200mA)
Relative Capacity	100%	95%	90%	80%

Note: Percentage as an index of the capacity at 25℃(=2550mAh) is 100%.

Cell voltage characteristics (recap)

- Whenever current flows in a cell, voltage drop is observed at the terminals



- Voltage drop is due to
  - Ohmic drop
  - Activation polarization
  - Concentration polarization

- Voltage drop increases with current
  - Not a linear relation

Example 2 (recap)

Three cells are series connected. Their SOCs are 90%, 80% and 70%, respectively. What is the overall SOC of the whole battery pack?

Depth of Discharge (recap)

DOD: a measure of the charge removed from the battery or cell. DOD could be expressed either in Ah or %.

In most cases: DOD(%) = 1-SOC. This description is not always true.

Example 3:

A battery with 100Ah rated volume could be further discharged even when its SOC is already 0 (not recommended though). This battery could discharged 105Ah, meaning over discharged. Using DOD(%) = 1-SOC, its SOC = 0% and its DOD is 100%, however although it actually released 105Ah charge.

Therefore for DOD, we prefer to using Ah instead of %.

State of Health (SOH) (recap)

Charge capacity: amount of charge in battery when it is fully charged.

SOH is defined to capture the impact of battery aging

- SOH is defined as,

$$SOC = \frac{Charge\ capacity\ now}{Charge\ capacity\ at\ the\ beginning\ of\ life}$$

- SOH is required for accurate estimation of available charge
  - Reduce range anxiety

End of life (EOL) (recap)

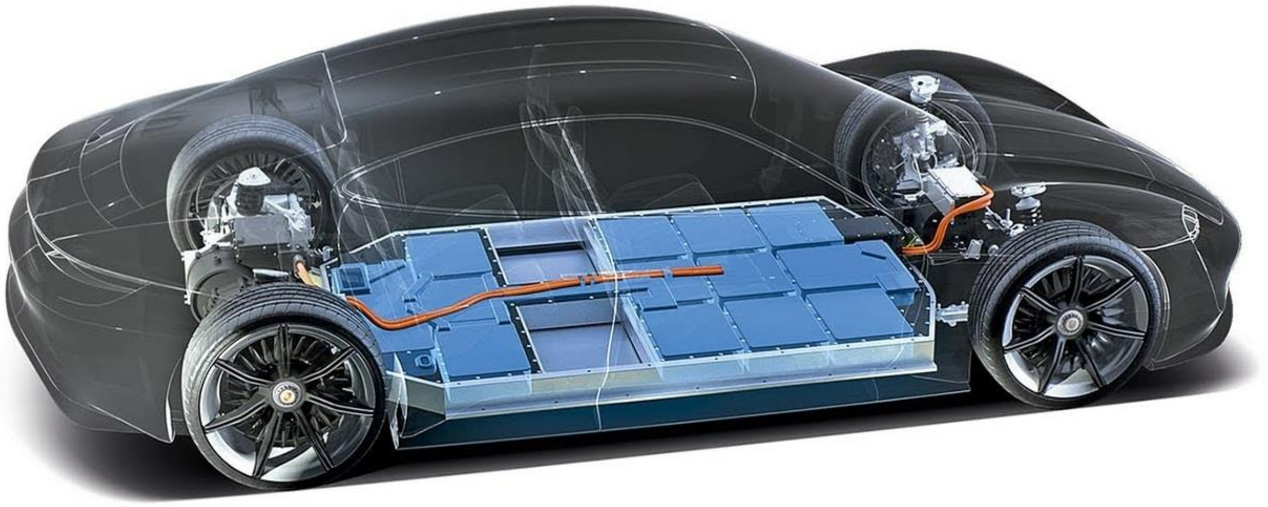
- End of life (EOL) definition:
  - SOH is below 80% or,
  - Cell resistance increases more than 50%

- For low power applications EOL criteria can be relaxed
  - example: energy storage applications, where energy and power density are not critical
  - Discarded EV battery pack can be reused
  - Called second life of battery

Sizing of battery pack (recap)

- How large should the battery pack be?

- Depends on several performance requirements
  - Energy requirement by the EV before it can recharge
  - Peak power requirement of the EV
  - Aging characteristics of the battery
  - Environmental impact



Battery pack sizing example (recap)

A BEV battery pack has the following requirements:

- eight years of operation, an average of S_{day}=48 km of driving per day
- daily charging
- an average battery output energy E_{km} = 180 Wh/km.
- Cycle limit index L = 1 and expected life $N_{100\%}$ = 1000.

Determine the beginning-of-life (BOL) kilowatt-hour storage required.

What are the vehicle ranges at BOL and EOL?

Battery pack sizing example (cont.) (recap)

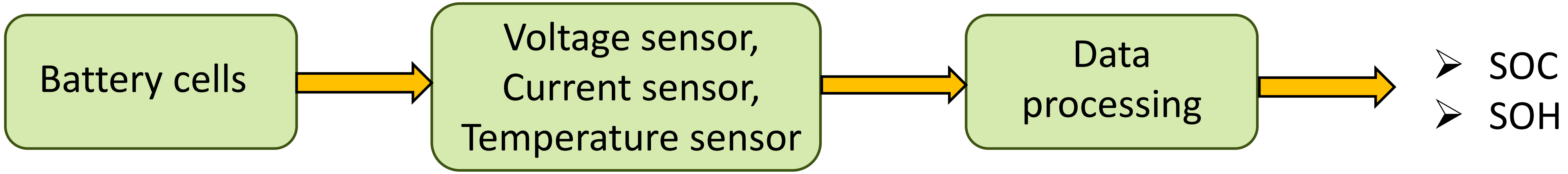
How to construct the required battery pack?

- cell specs: 3.7V nominal, 25Ah
- Pack specs: 350V nominal voltage

SOC Estimation

Accurate SOC estimation needed to-

- estimate available battery backup – reduce range anxiety



- SOC estimation methods,

  1. OCV method;
  2. Coulomb Counting method;
  3. Other methods: model based, data driven, etc.

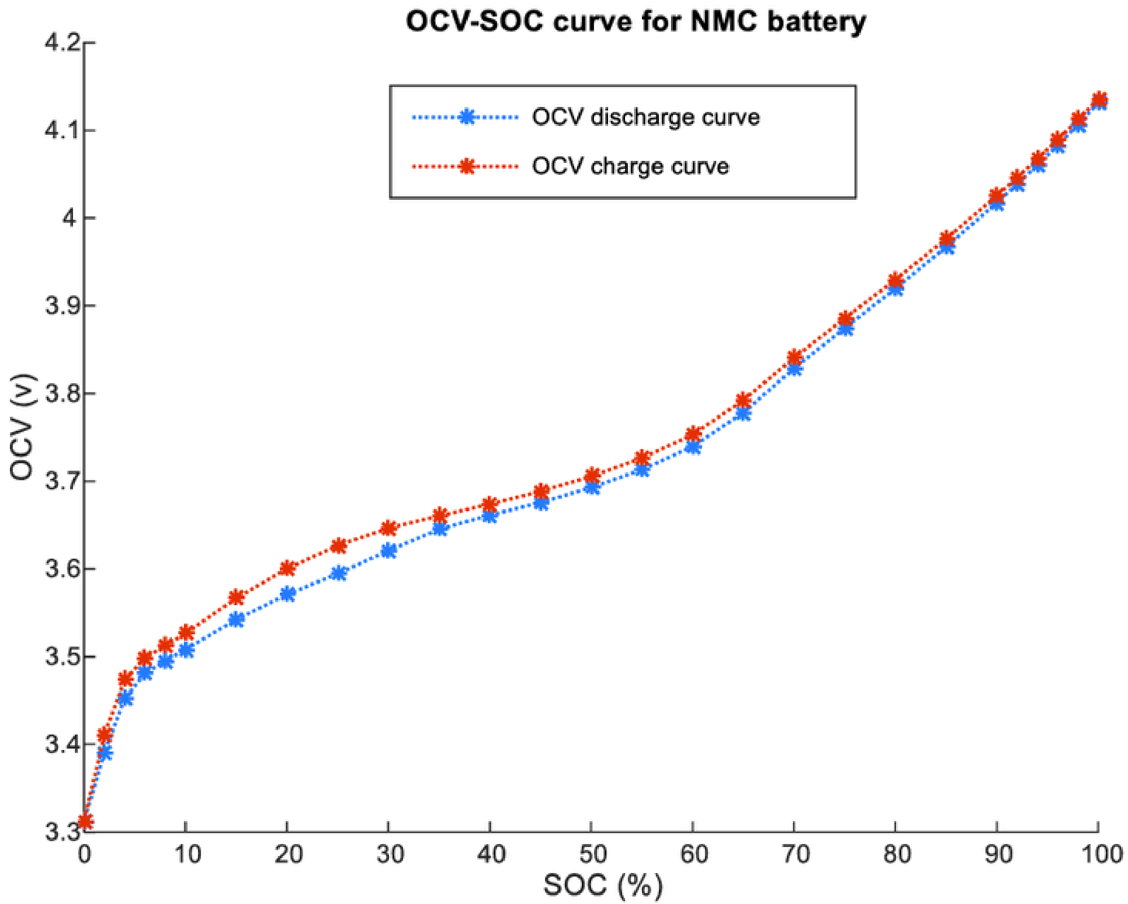
OCV Method (Look-up Table)

Pros:

- Most accurate method for new cell under rest condition;

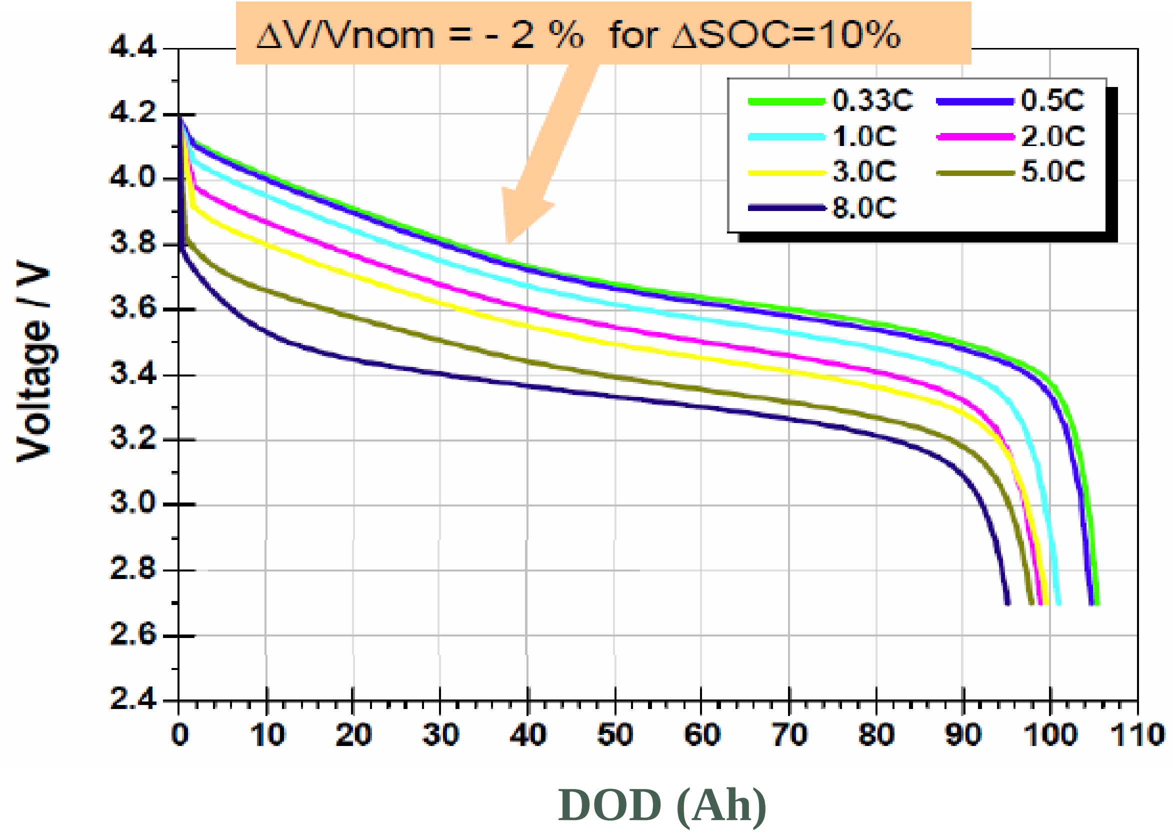
Cons:

- Not applicable in most applications;
- Not accurate for the aged cell;
- Can be difficult if the SOC curve is flat.



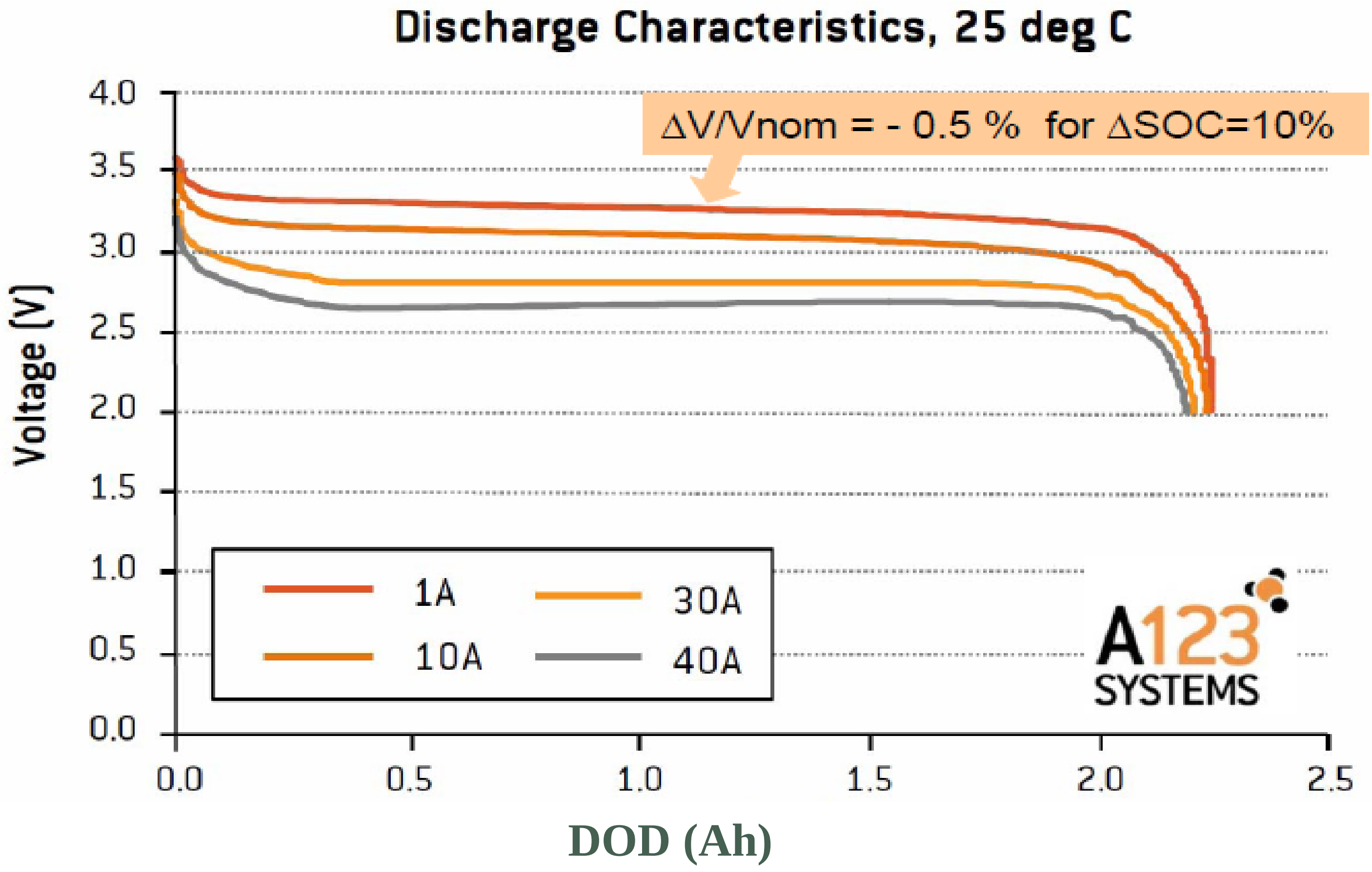
Case 1

Example of a NCM lithium cell (Lithium Nickel Cobalt Manganese)



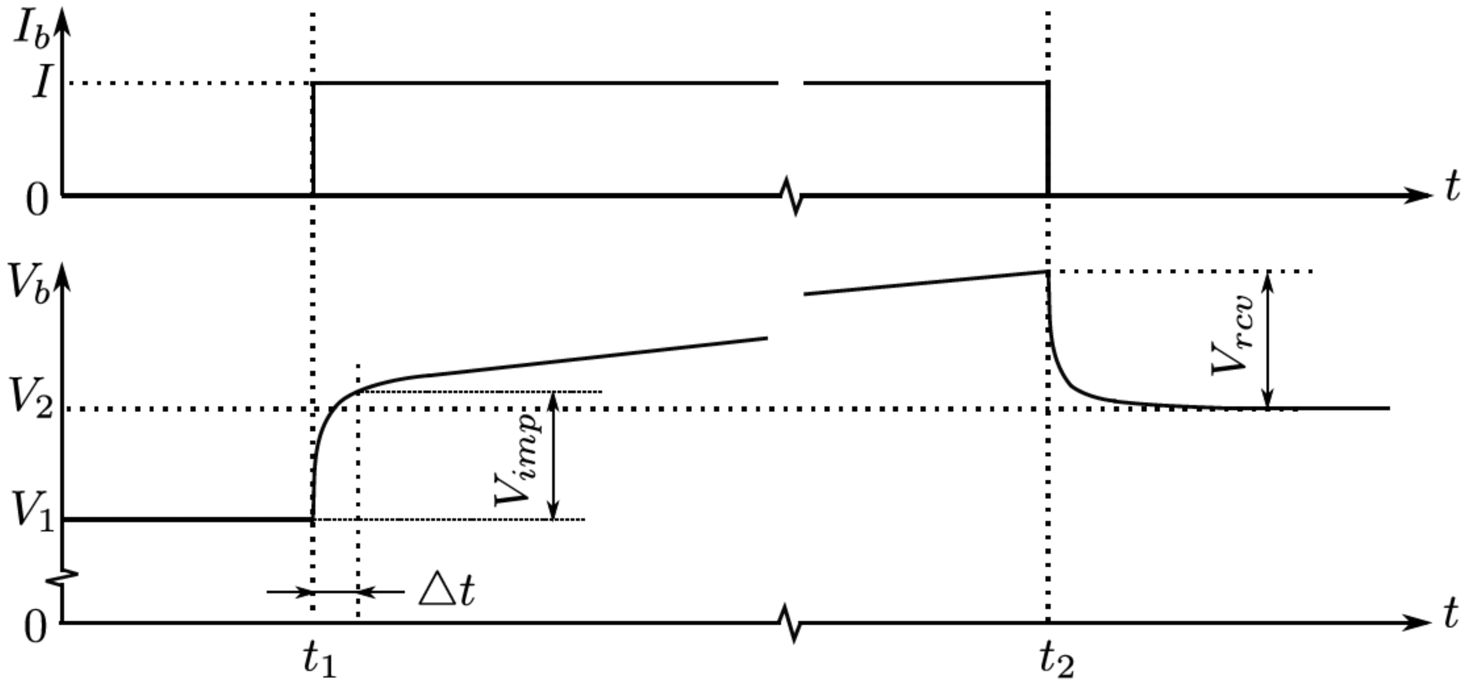
Case 2

Example of a LFP lithium cell (Lithium Iron Phosphate)



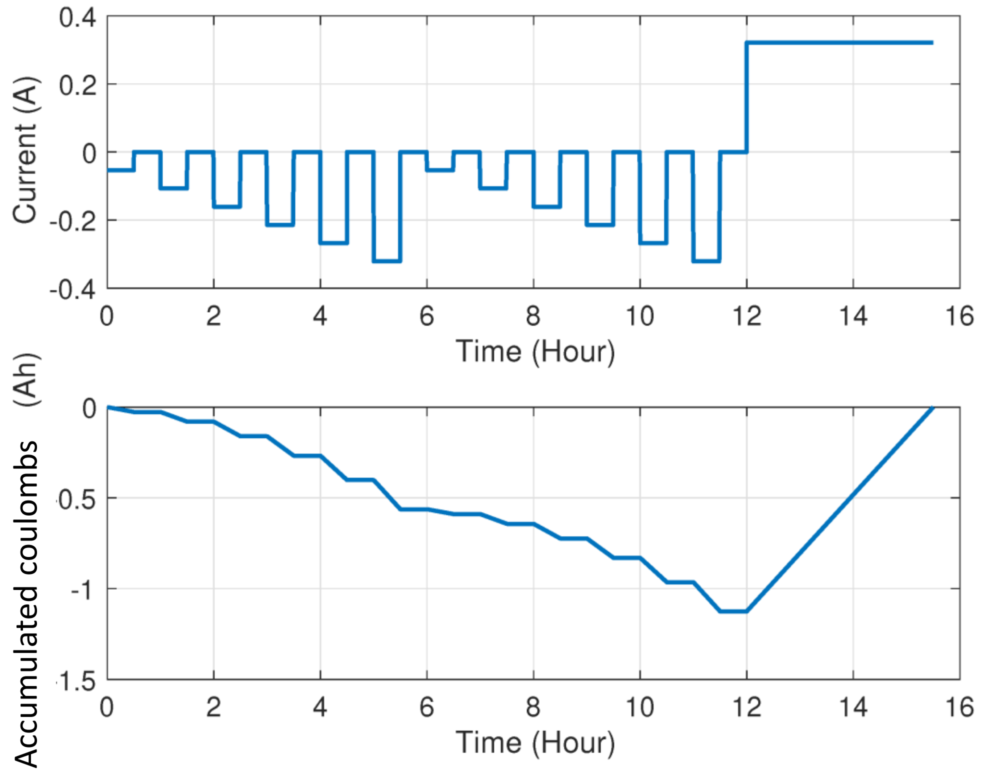
OCV Method: Limitations in practical conditions

- OCV measurement not possible when battery is in use
- Not feasible to use in EV application



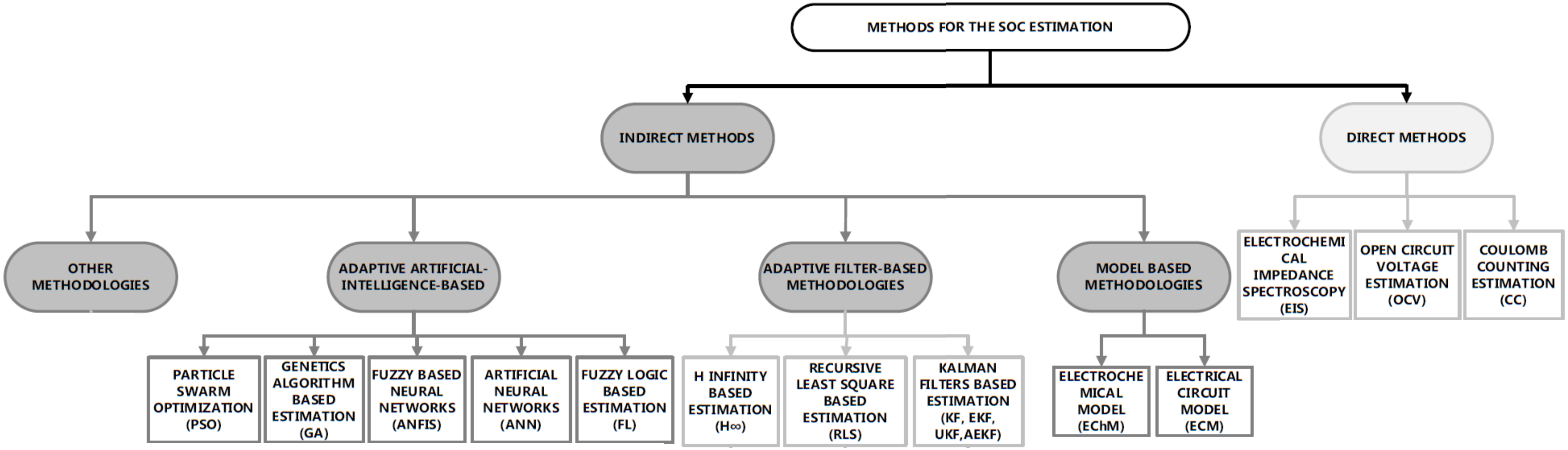
Coulomb Counting

- Method:
  - Integrate battery current over time
  - Calculate total charge spent from the integration of current
  - Estimate total spent charge from fully charged condition

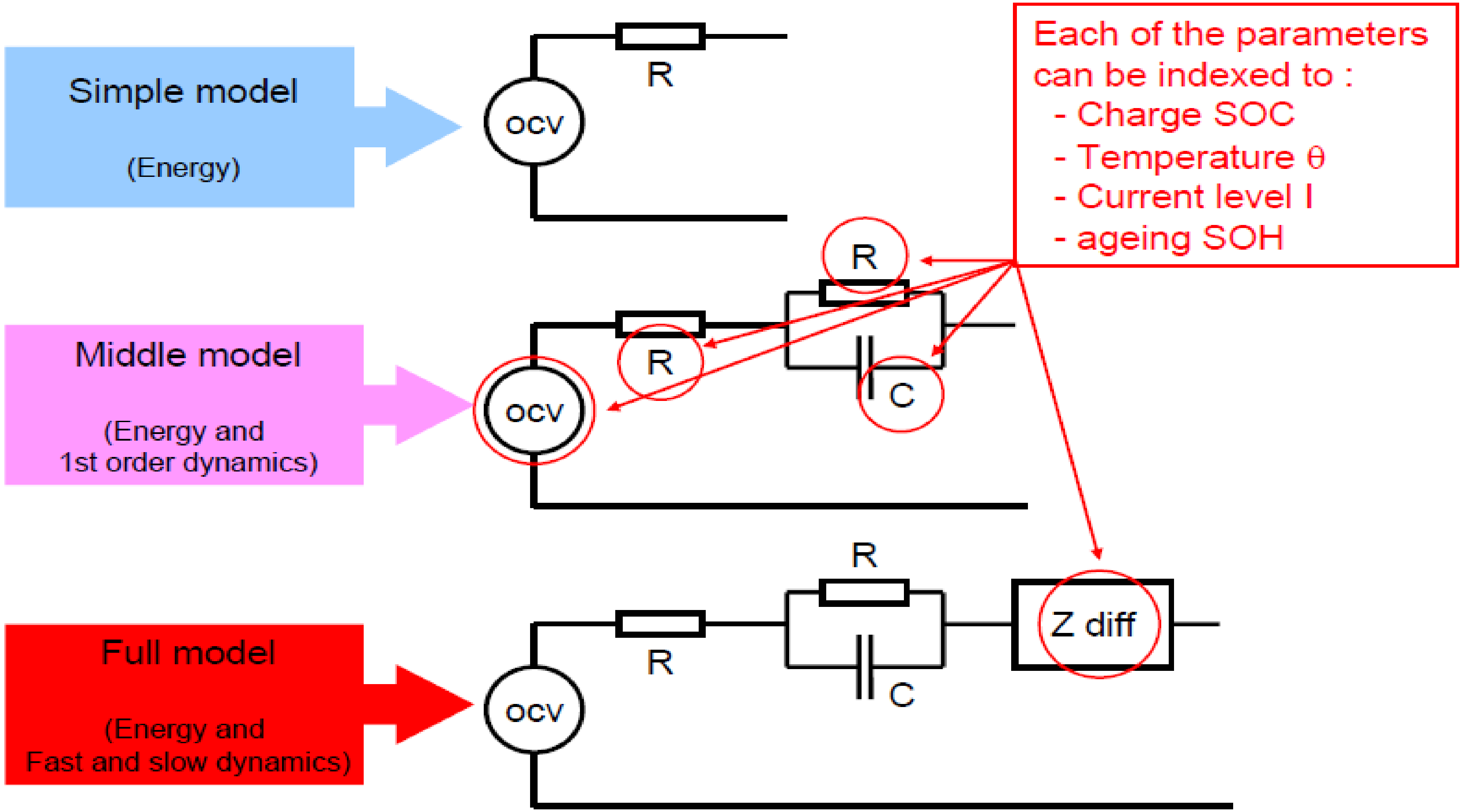


- Pros:
  - Simplest method among all.
- Cons:
  - Error accumulation if there is offset error in current sensor
  - Error accumulates over multiple cycles if battery is not fully charged
  - Can not accommodate for aging effect, temperature dependence, current dependance of SOC, etc.
  - Does not consider self-discharge

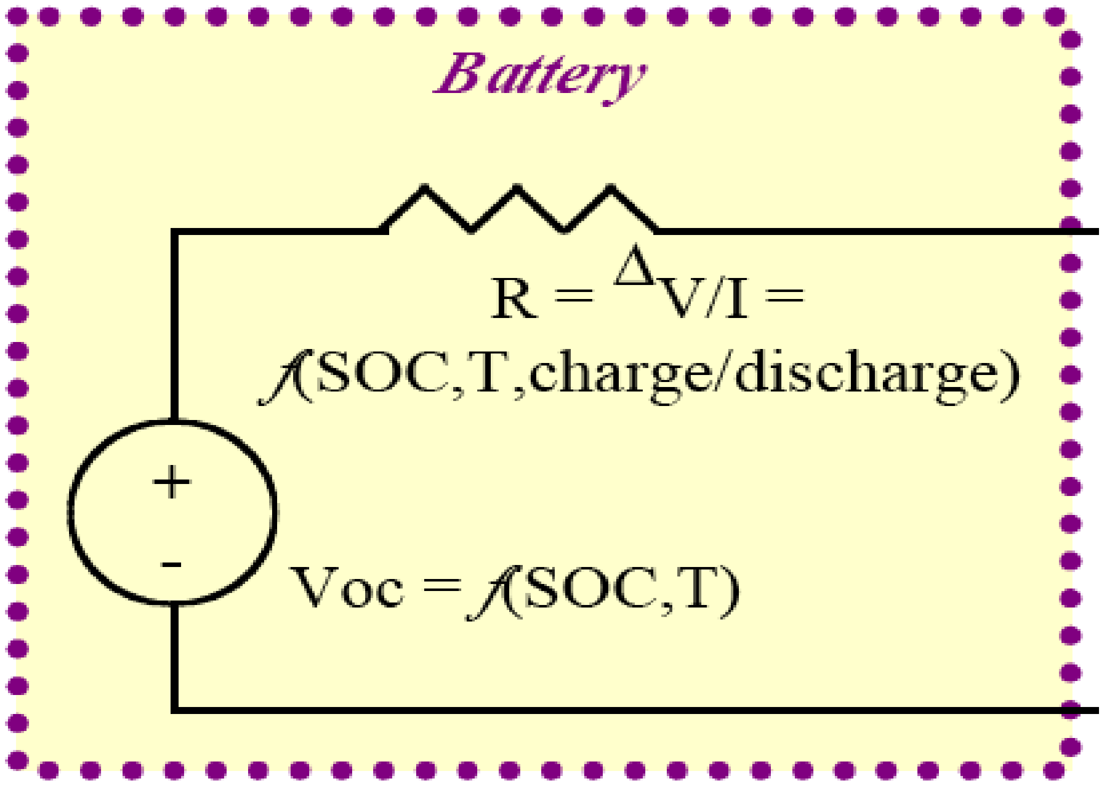
Other methods



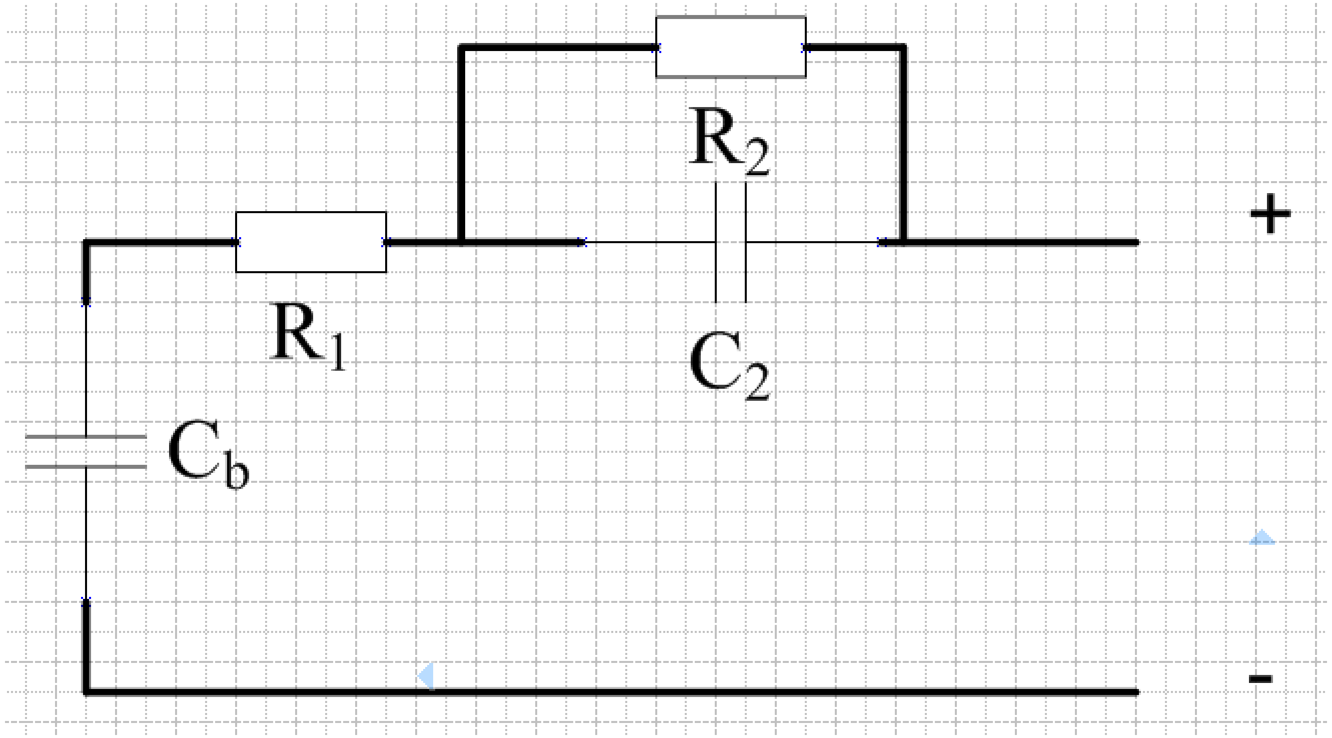
Electrical Circuit Model (ECM)



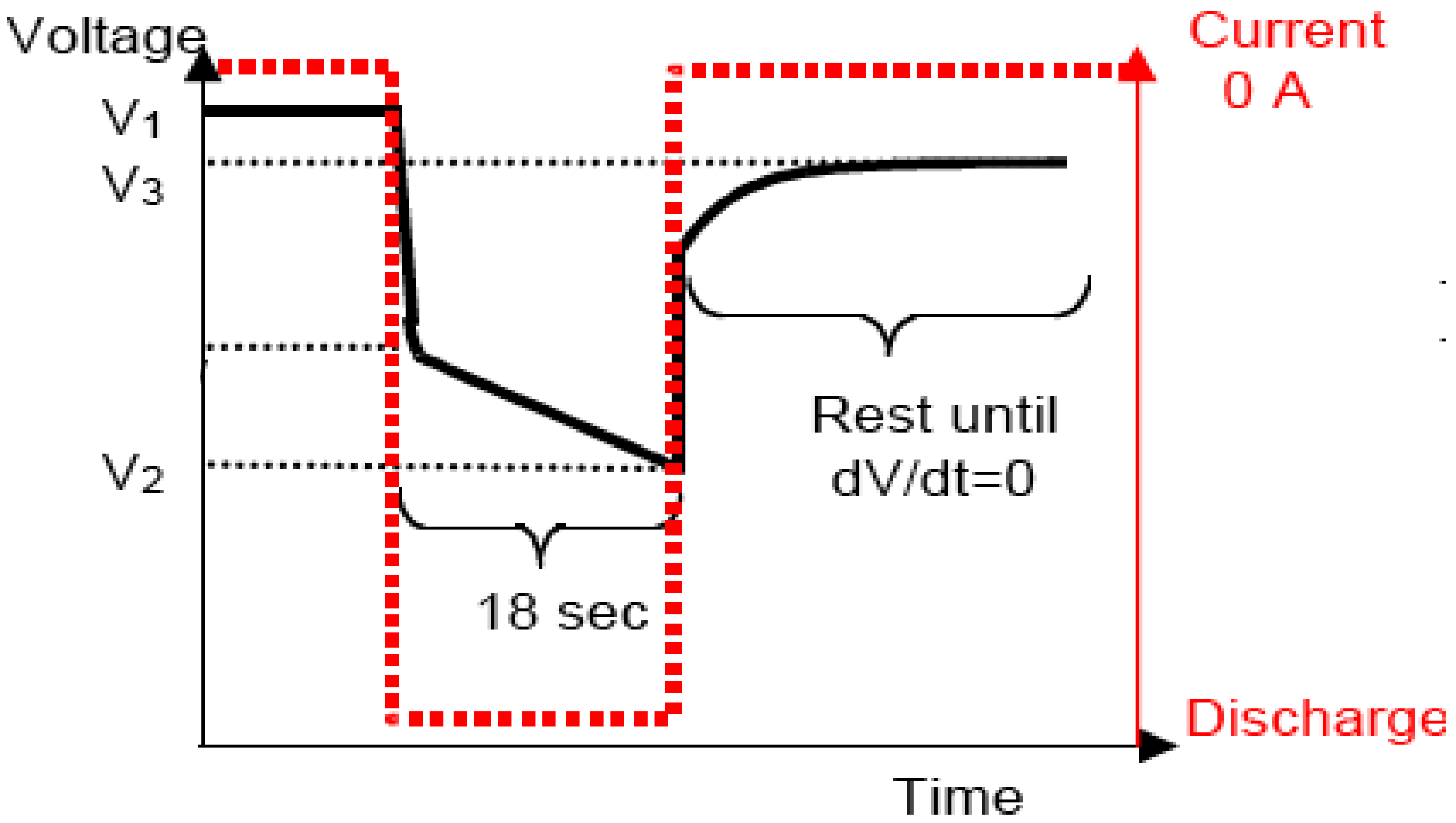
Simple Model



Middle Model



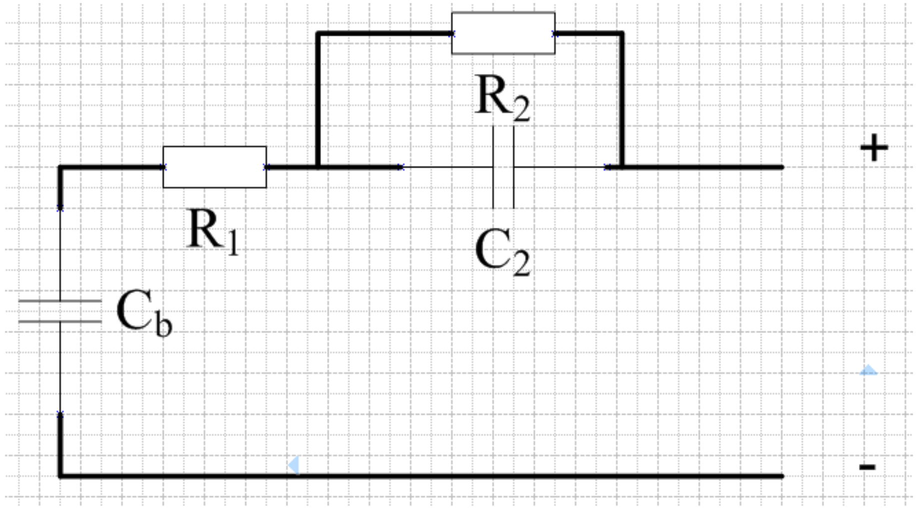
Pulse Testing for Middle Model

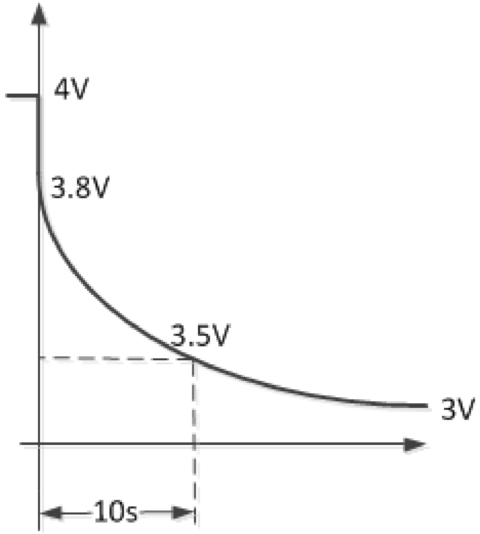


NREL / SAFT

Practice (1)

A battery is modeled as the left figure. At t=0 a 20A discharging current is imposed. The battery voltage sharply drops to 3.8V. After 10 seconds the battery voltage drops to 3.5V. At the end the battery terminal voltage settles at 3V. Calculate R_1, R_2 and C_2. Assume battery OCV does not change during this process.





Thank you!