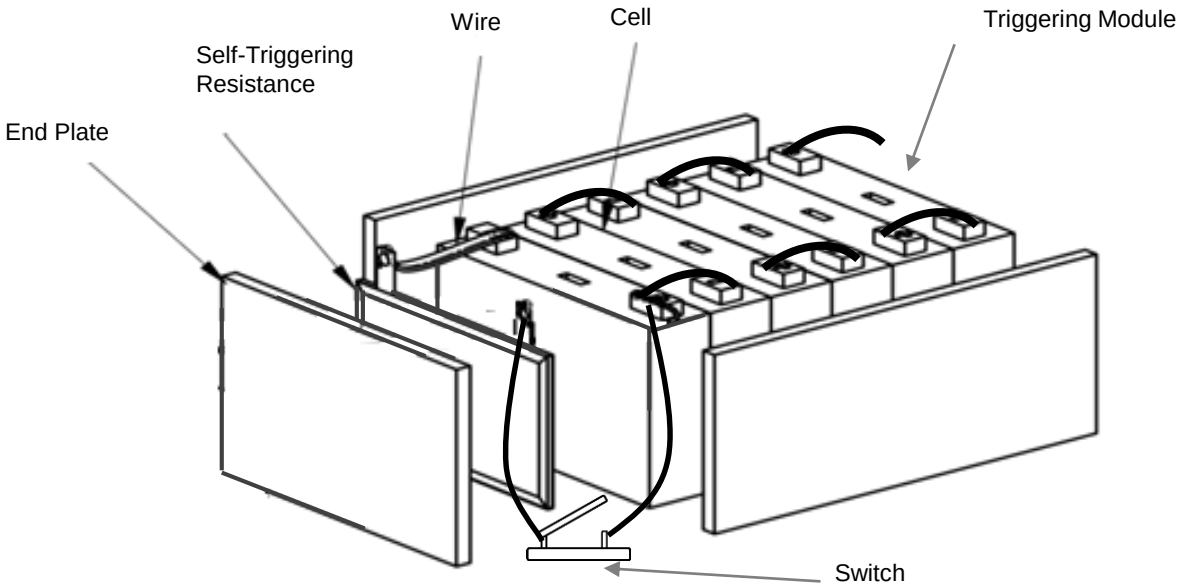
Self-Triggering Method Research Update

Date: 20191114

Self-Triggering Method

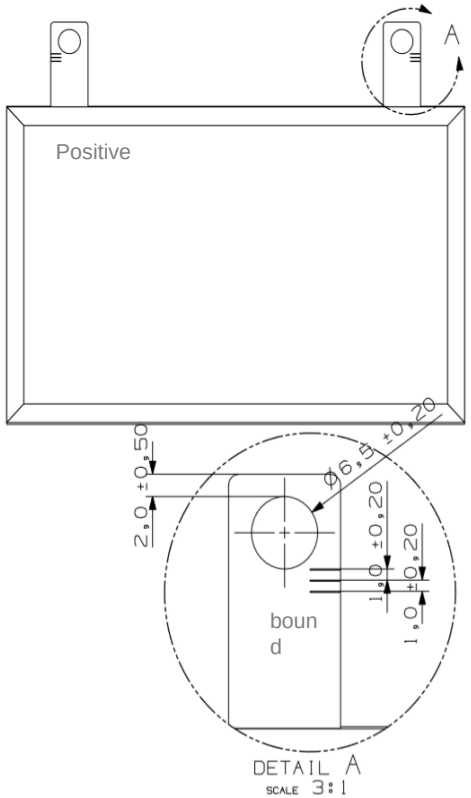
- Self-Triggering Module Constructional Sketch



Remark: trigger cell at the module telos

The Self-Triggering Resistance

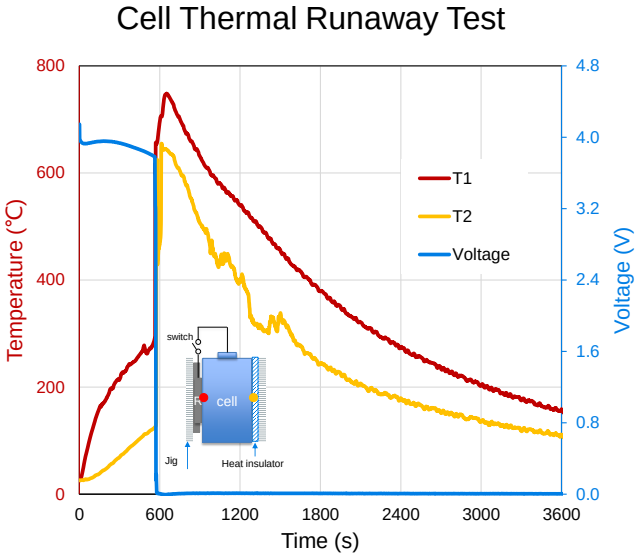
- Self-Triggering Resistance



		Ideal Conditions	Reasoning
Material		Metal	Fe_xCo_y alloy, Ag_xCu_y alloy, Ni_xCr_y alloy, et al.
Heater	Thickness	≤5mm	Thickness contained sealed materials and metal
	Area	not be larger than area of cell surface	Not include the positive and negative terminals
Shape		Planate or others	Covered with ceramics, metals or insulator
Heating Rate		1~10 (℃/s)	Depends on the voltage of the triggering cells and the resistance
Minimum heater temperature		>300℃	↑
Value of Resistance		30~100mΩ	/
Resistance acquisition accuracy		±2mΩ	/
Suitable Cell		/	Pouch & Prismatic

Energy Transformation

➢ **Use the energy by the battery itself, heating a physical resistance** to trigger the battery go to thermal runaway, without any additional energy.



➢ **Q : Energy release before cell thermal runaway**,

- $Q = \int_0^{t1} i dt$

➢ **Q_a : Total Energy absorbed by the heating resistance,**

- $Q_a = \int_{T0}^{T1} C_{p\_h} * m_h * dT$

➢ **Q_b : Dissipated heat with the environment,**

- $Q_b = \int_{T0}^{T1} h * A dT$ ， $h = 5\ W/(m^2*K)$

➢ **Q_c: Radiant Energy,**

- $Q_c = \varepsilon * A * \sigma * (T_1^4 - T_2^4)$ ， $\sigma = 5.67*10\text{-}8 W/(m^2*K^4)$

Sample	Q(kJ)	Q_a(kJ)	Q_b(kJ)	Q_c(kJ)	$(Q_a+Q_b+Q_c)/Q$
Example	~198.4	~5.1	~2.3	~1.9	~4.7%

Energy Appearance Self-Triggering Vs. Nail Penetration

- Purpose:
  - In order to analyze the ***failure SOC*** influence at the self-triggering method.

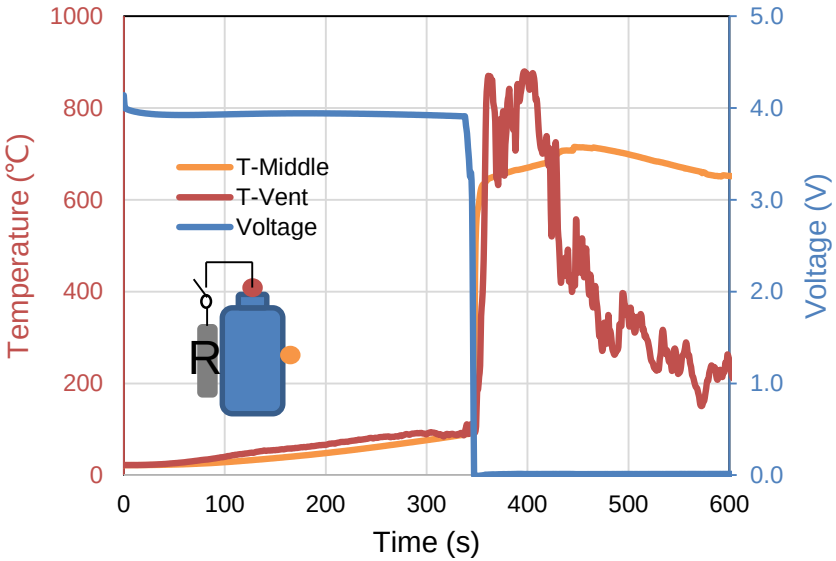
- Test Method:
  - Use the self-triggering method to trigger the cell into thermal runaway, calculate the failure SOC at cell thermal runaway, the cell ***initiation SOC*** (100%SOC)
  - Use other trigger method, like nail penetration, to trigger the cell into thermal runaway at ***failure SOC*** (from the self- trigger method) and ***initiation SOC*** (~100%SOC)

- Test :

No	Trigger Method		DUT		
	Method	Parameter	SOC	Type	Chemistry
Test1	Self-Triggering	40mohm resistance	100%	Prismatic	NCM/ Graphite
Test2	Nail penetration	3mm steel, 20~60° nail tip angle	TBD (Depending on the test1)	↑	↑
Test3	↑	↑	100%	↑	↑

Test 1 Self-Triggering method

- Test Procedure:
  - DUT: 100%SOC, NCM Vs. Graphite;
  - Temp. Room temperature as ambient temperature, like 25±3℃;
  - Procedure: Use 40mohm self-triggering resistance to trigger cell to thermal runaway

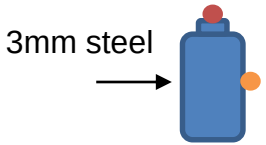


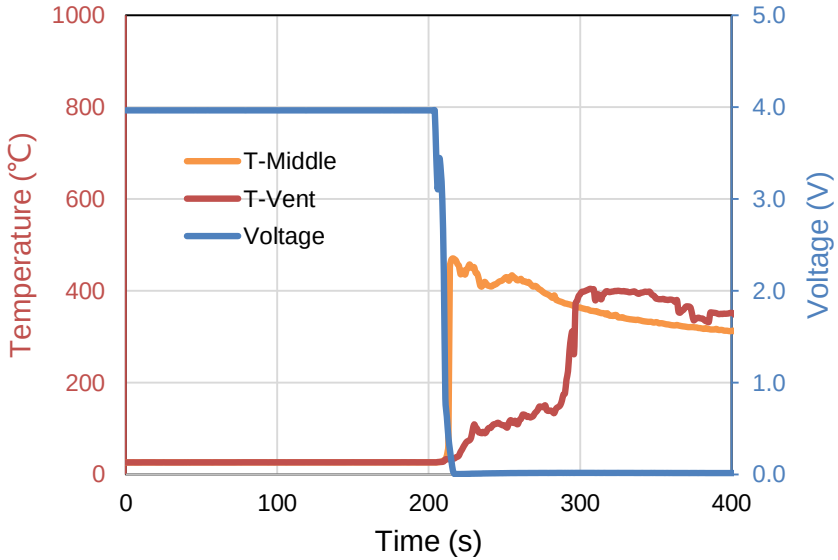
- **Y: Failure SOC of the cell**
  - C'_{cap} : failure state capacity of the cell
  - C_{cap}: Initiation capacity of the cell
    - $C'_{cap} = C_{cap} - \int_0^{t1} idt$
    - $Y = C'_{cap}/C_{cap}$

- Y≈***80%*** at this test

Test 2 Nail Penetration

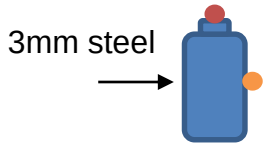
- Test Procedure:
  - DUT: ***80%SOC (refer to test 1),*** NCM Vs. Graphite;
  - Temp. Room temperature as ambient temperature, like 25±3℃;
  - Procedure: Use nail penetration to trigger cell to thermal runaway

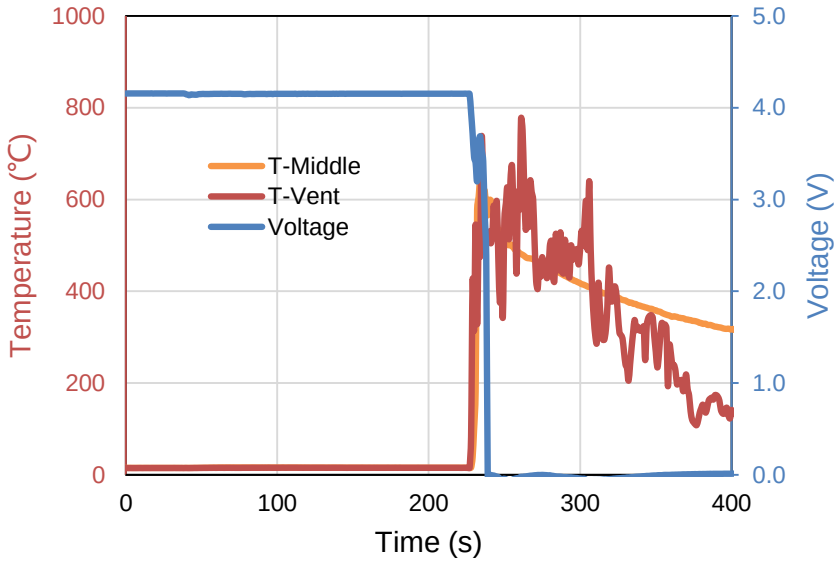




Test 3 Nail Penetration

- Test Procedure:
  - DUT: ***100%SOC***, NCM Vs. Graphite;
  - Temp. Room temperature as ambient temperature, like 25±3℃;
  - Procedure: Use nail penetration to trigger cell to thermal runaway



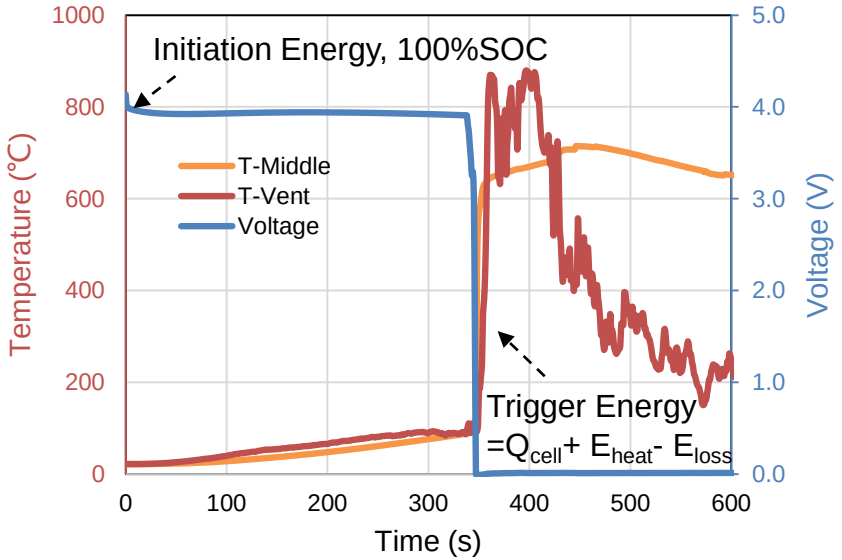


Energy Appearance Self-Triggering Vs. Nail Penetration

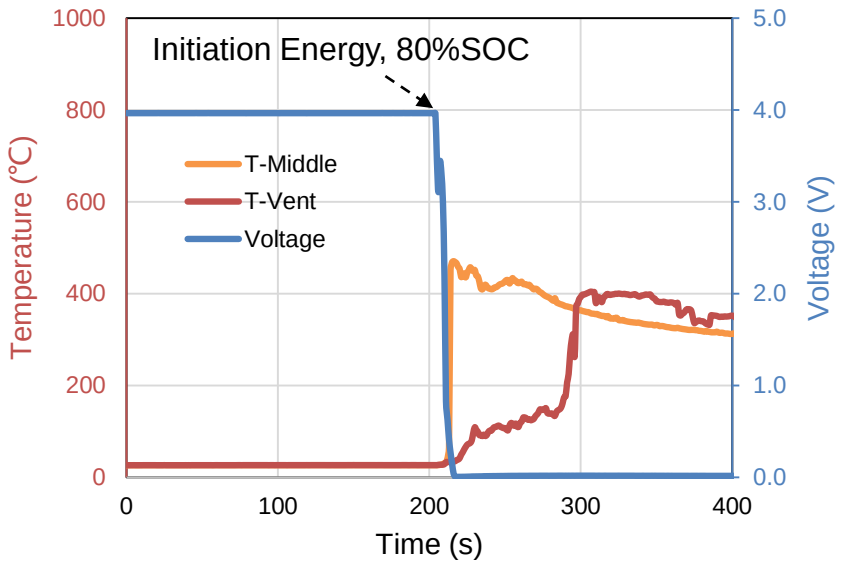
- ***Initiation energy*** is the key parameter for battery thermal runaway test.
  - Trigger energy ≈ Initiation energy for self-triggering method
  - Trigger energy<<Initiation energy at similar ***failure SOC*** of cell

Remark:
- Initiation Energy: The initiation energy for the battery
- Trigger Energy: Energy when battery thermal runaway
- Q_{cell}: battery energy
- E_{heat}: heater energy from the self-triggering resistance
- E_{loss}: loss energy, ≤ 5%

Self-Triggering Test



Nail Penetration Test_ ~***80%SOC***



Energy Appearance Self-Triggering Vs. Nail Penetration

- ***Initiation energy*** is the key parameter for battery thermal runaway test.
  - Trigger energy ≈ Initiation energy for self-triggering method
  - Trigger energy<<Initiation energy at similar ***initiation SOC*** of cell

Remark:
- Initiation Energy: The initiation energy for the battery
- Trigger Energy: Energy when battery thermal runaway
- Q_{cell}: battery energy
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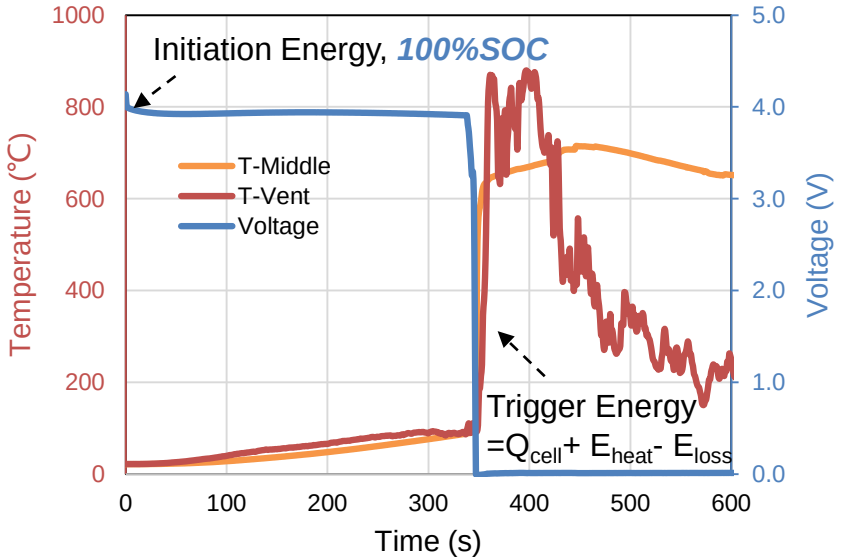
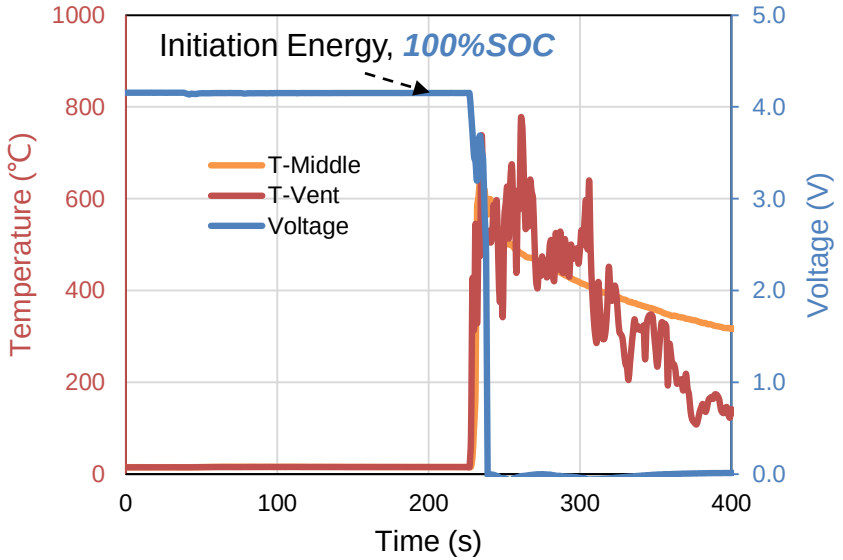
Self-Triggering Test

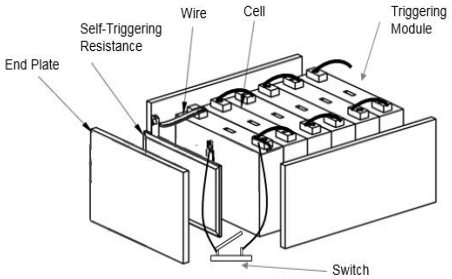


Nail Penetration Test_ ~***100%SOC***



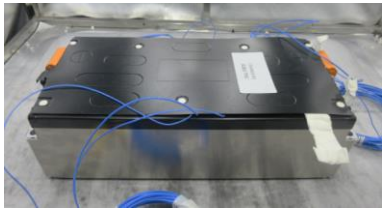
Pack level _Validation

- Device under test：
  - Prismatic module，1P4S；
  - SOC range，~95%SOC；



- Measured data include：
  - Cell and module voltage
  - Bottom temperature of the cell
  - Photographs before and after the test

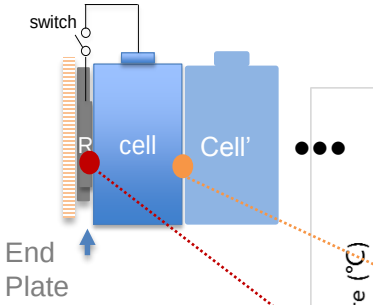
Before the test



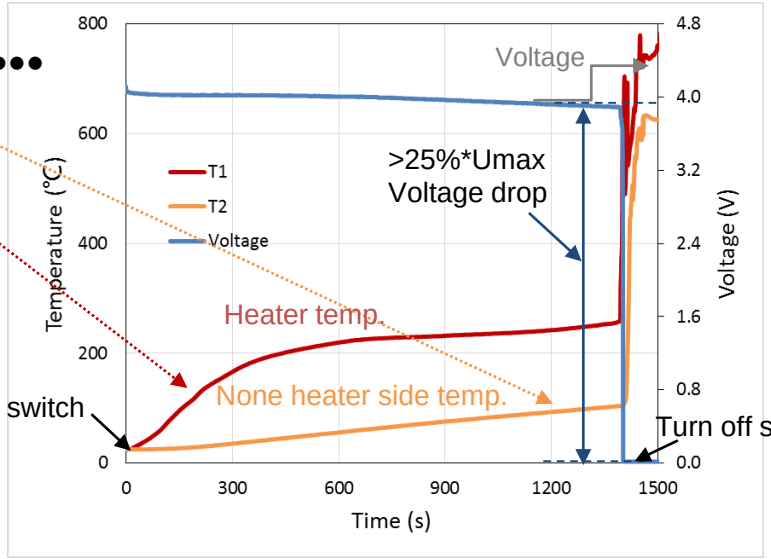
After the test

Pack level _Validation

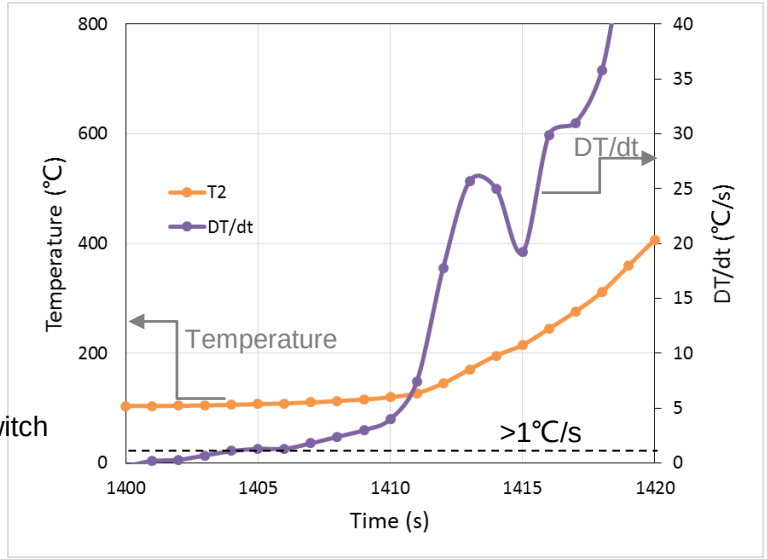
- Succeed trigger the cell into thermal runaway， and thermal runaway propagated to the other cells in Demo Pack



Voltage and temperature for initiation cell



Temperature and temperature rise rate for initiation cell



Pack level _Validation

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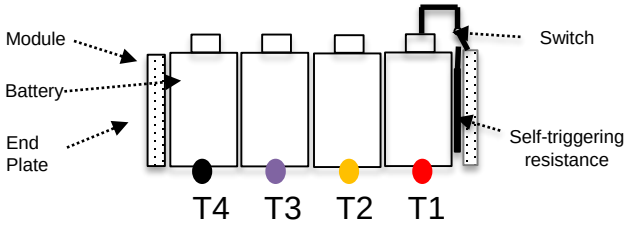
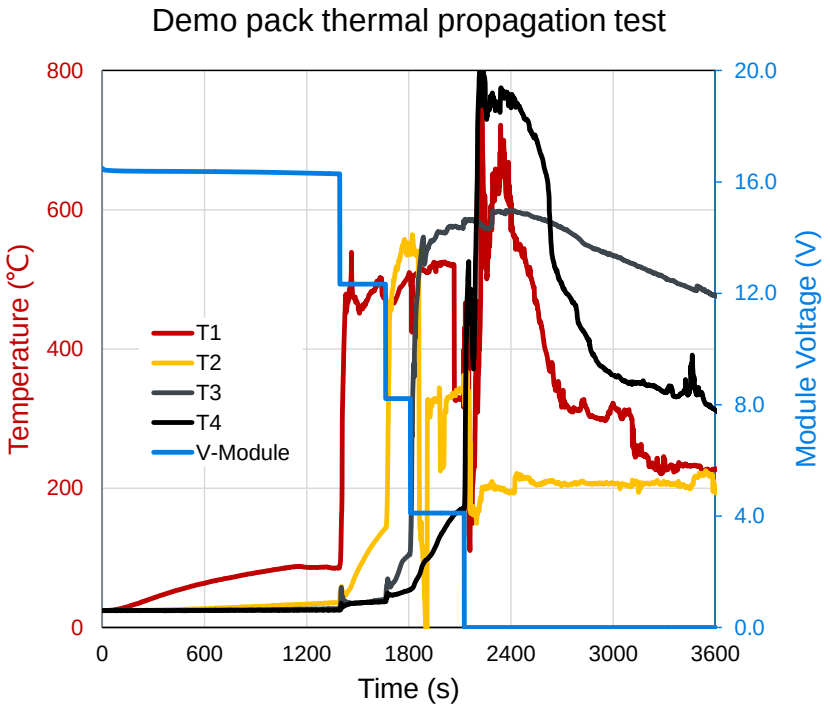
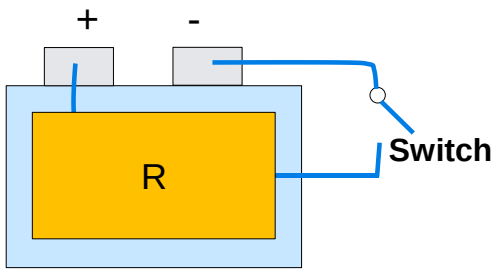




Pack level _Validation

➢ Energy transformation :



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- **Q_c: Radiant Energy,**
  - $Q_c=\varepsilon*A*\sigma*(T_1^4-T_2^4)$ ， $\sigma=5.67*10\text{-}8W/(m^2*K^4)$

Sample	Q(kJ)	Q_a(kJ)	Q_b(kJ)	Q_c(kJ)	$(Q_a+Q_b+Q_c)/Q$
Example	~431.9	~14.4	~1.2	~6.24	~5.0%

Thank You