





Li-ion battery testing

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Agenda

- Safety first
- Electrical testing
- Hardware
- Software
- System integration
- Related products

Safety first



Electric car explodes just like that in Enschede, does that wait for us more often?

ENSCHDEDE - What was a brand new BMW i3 a few hours earlier, lies like a blackened carcass on Wednesday morning in the parking lot at dealer Broekhuis Oost in Enschede. There is hardly a car in it anymore. The electric vehicle went up in flames due to a spontaneous explosion of the battery pack.



Replaced battery is cause fire Stella bikes Nunspeet

A replaced battery is the cause of the fire at the factory of Stella Fietsen in Nunspeet Thursday evening. As a result, 36 e-bikes and 80 bicycle batteries were destroyed. That is the conclusion of the fire brigade after investigation. The fire raged in the returns department where exchange bicycles and used batteries were stored.

Safety first



Apple recalls 15-inch MacBook Pro due to overheating



Tesla batteries caught fire again five days after accident



Safety first

Please take precautions for a safe test environment:

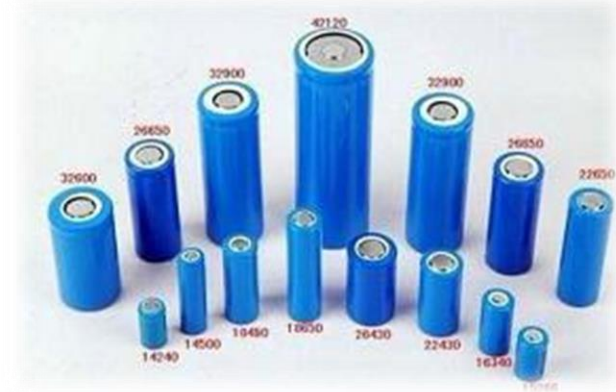


Electrical tests

Battery cel test

Battery module test

Battery pack test



Electrical tests

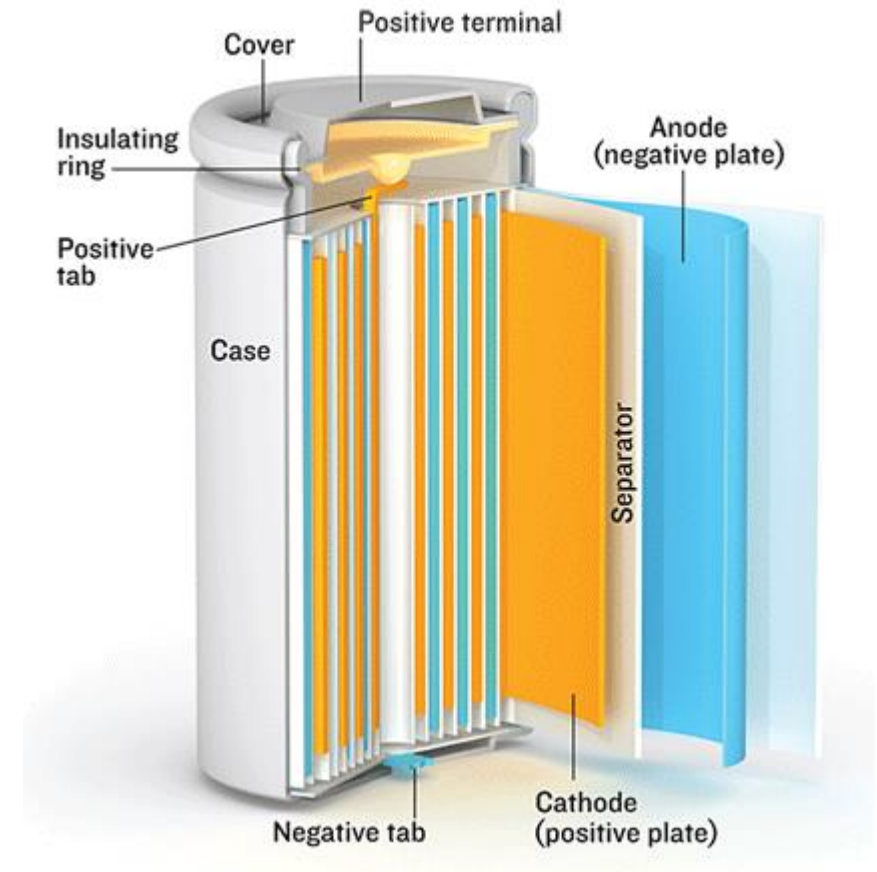
Battery cel isolation test

Battery cel impedance test

Battery capacity test

Lifetime test

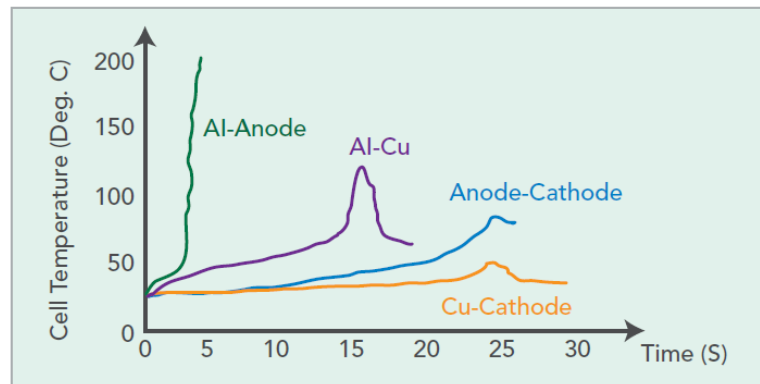
Overload test



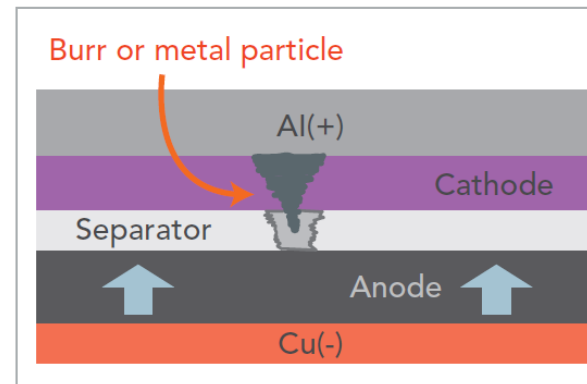
Electrical tests

Battery cell isolation test

- Isolation voltage up to 1KV(dc)
- Charging with mA.
- Leakage Current (LC) measurement (10pA ~ 20mA)
- Partial discharge/flashover detection



[Figure 1] Temperature rising of different internal short circuit scenarios



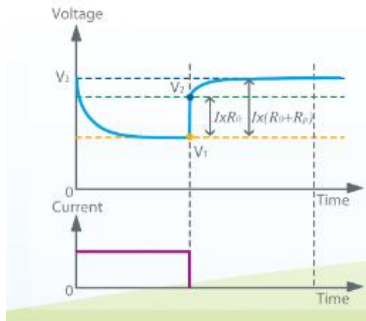
[Figure 2] A burr extruded from the positive electrode may touch the material coated on the negative electrode and eventually cause the disaster.

Electrical tests

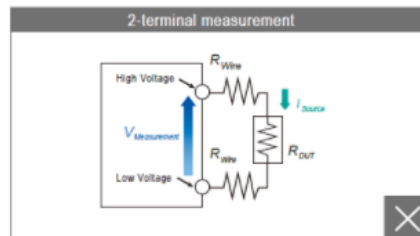
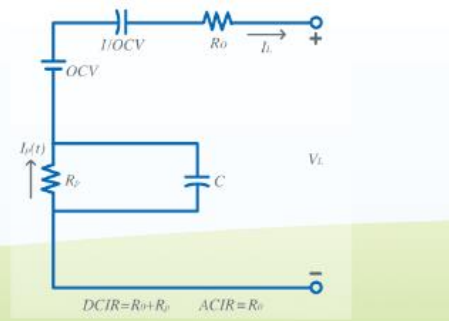
Battery impedance test

- AC impedance measurement
- Or DC step response

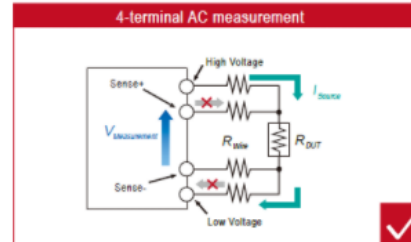
IR (Internal Resistance) Measurement



Lumped Parameter Model Circuit Diagram



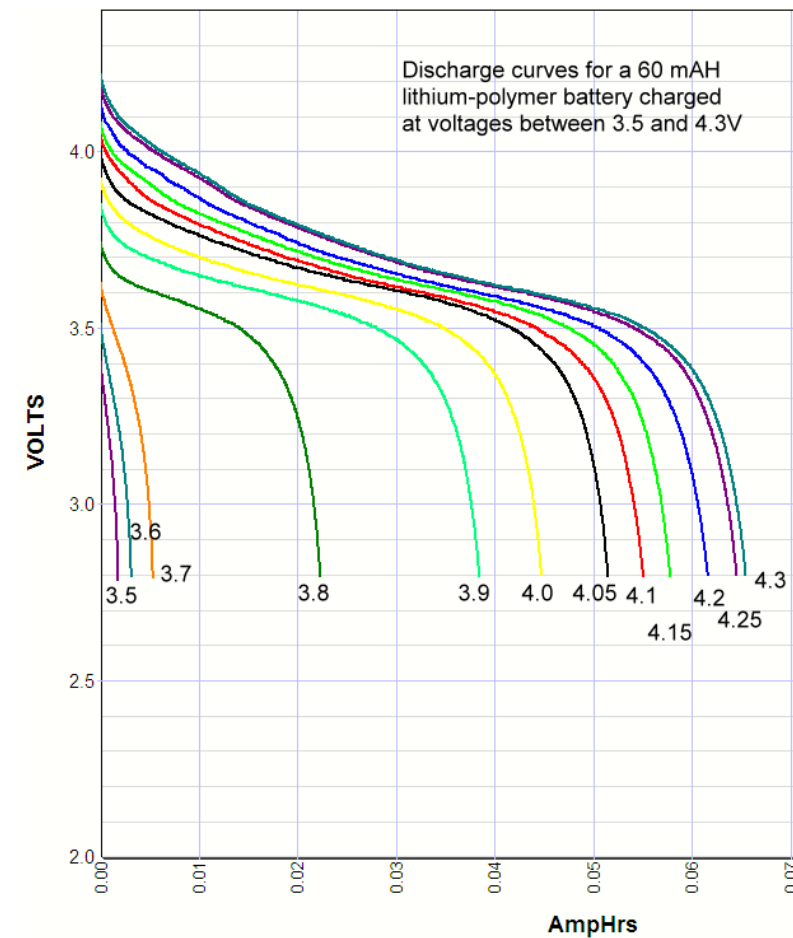
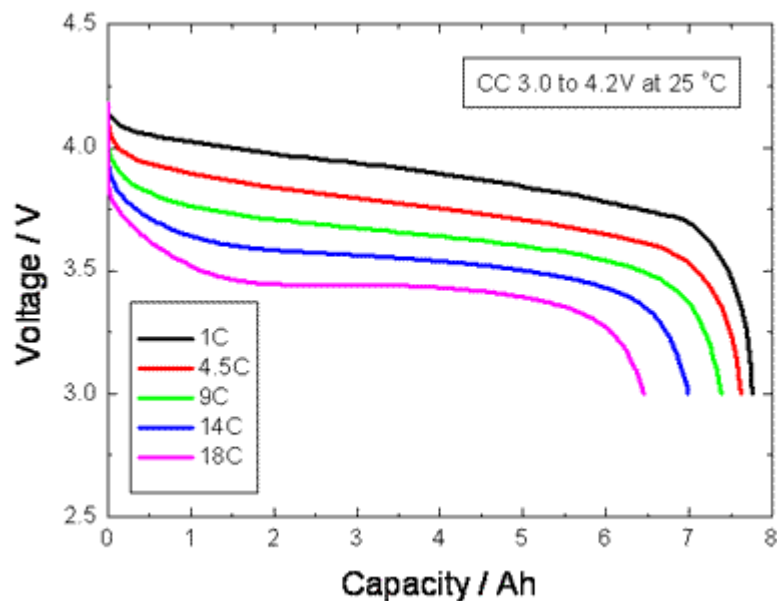
VS



Electrical tests

Battery capacitance test

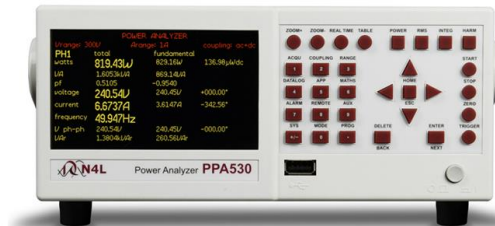
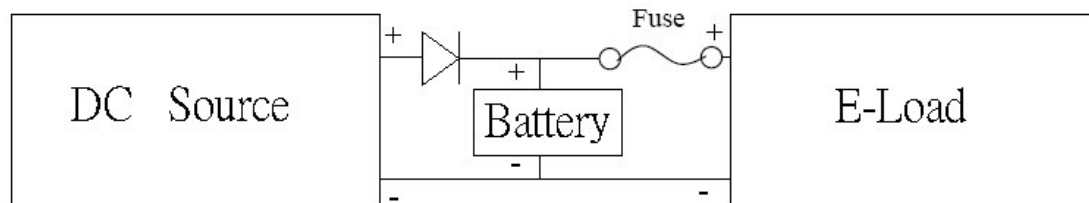
- Ah measurement
- Charging up to the max voltage level
- Discharge until min voltage level
- Multiple cycles.
- Depending on the temperature



Electrical tests

Battery capacitance test & Measurement equipment

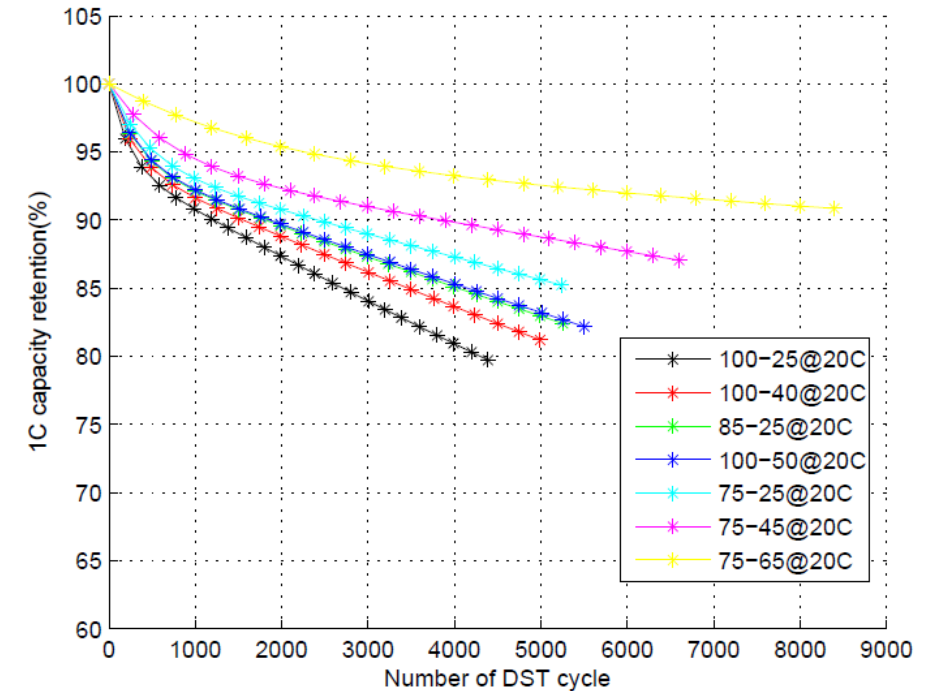
- DC power supply
- (Regenerative) DC load
- Temperature meter
- Ah meter
- software



Electrical tests

Lifetime test / Cycle test

- Capacitance test with many cycles.
- Measuring degrees in capacitance
- Depending on charge voltage
- Depending on the temperature
- Depending on discharge voltage
- Depending on charging level in %
- Depending on discharge level in %

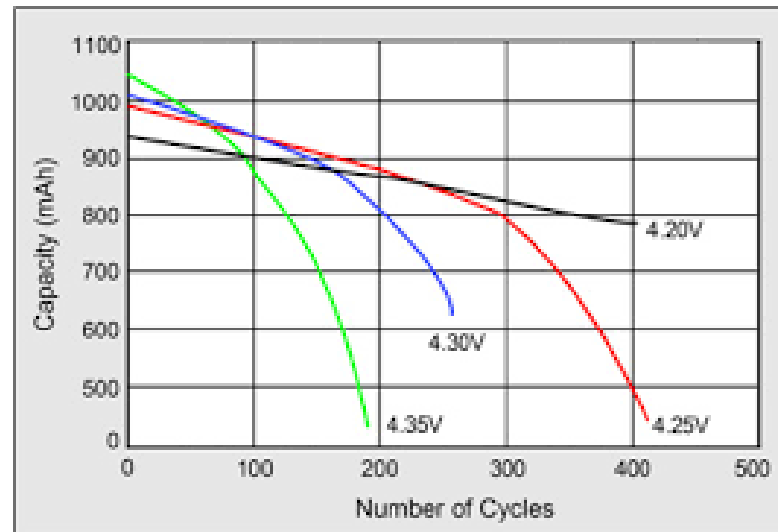


(b) Reproduced DST Data.

Electrical tests

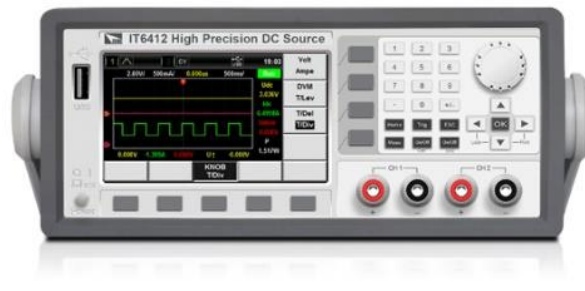
Overload test

- Charging up to a certain voltage level
- Depending on charge level you do get a wide range of charging cycles/ life time battery.



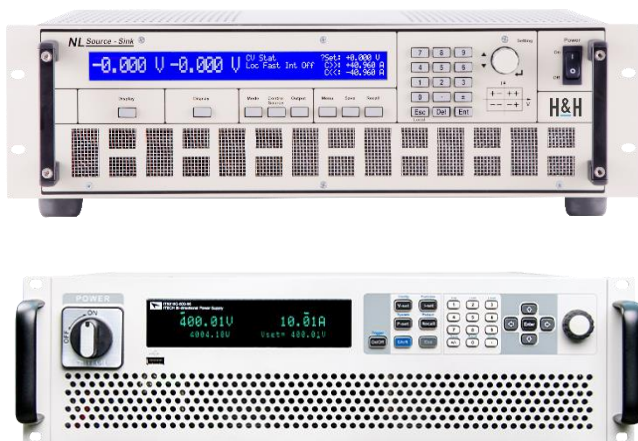
Battery Cell test

- Different models.
- 1, 2, 8, 12 and 16 channels per unit.
- Voltage range range normally low
- Current ranges 200 μ A to 4000A
- Some models regenerative
- High resolution for voltage and current



Battery Module test

- Single and multiple channel solutions
- Power Range: 600W up to 60KW per channel
- Voltage Range: 20V up to 800V
- Current Range: up tot 4000A
- Often regenerative units
- Driving cycle simulation



48CH

16CH

8CH

Battery Pack test

- 1 to 3 channels
- Voltage range : 60V to 1500V
- Current range : up to 4000A
- Power range : 15 to 1.280kW
- Regenerative(Eff. >92%, PF >0.98, THD <3%)
- Dynamic (current/power) driving profile simulatie tests voor NEDC, FUDS, HPPC
- Test channel parallel function



Software

- Loop & Cycle for Life Cycle Test
- Waveform for Drive Simulation, Certification
- CAN Write for BMS Control
- CV Source for Testing Protection Function of BMS
- DCIR measurement



Software

- Double layers testing cycle: Loop & Cycle
- Jump mode from step to step:
(a) Next (b) End (c) Jump to step (d) If-Else (e) Repeat Count

No.		Step Name	Setting			Cut-Off Condition		Jump		Loop			Cycle		
			V(V)	I(A)	P(W)	Parameter	Value	Mode	Value	Label	Loop To	Count	Label	Cycle To	Count
1	+	CC-CV Charge	54.6	6		Cut-off Time(sec)	>= 360000	Next			A	5		C	3
2	+	CC Discharge		10		Cut-off Time(sec)	>= 360000	Next							
3	+	DCIR Discharge				DCIR T1(ms)	>= 100	Next							
4	+	CC-CV Discharge	54.6	6		Cut-off Time(sec)	>= 360000	Next							
5	+	Waveform						Next							
6	+	DCIR Discharge				DCIR T1(ms)	>= 100	Next		A					
7	+	CC-CV Discharge	54.6	6		Cut-off Time(sec)	>= 360000	Next		B	8				
8	+	DCIR Discharge				DCIR T1(ms)	>= 100	Next							
9	+	CC Discharge		20		Cut-off Time(sec)	>= 360000	Next							
10	+	CC-CV Charge	54.6	6		Cut-off Time(sec)	>= 360000	Next							
11	+	CP Discharge			3000	Cut-off Time(sec)	>= 360000	End		B			C		

Waveform(W)					End			If
					If Repeat Count	>	10	Next
					Else			End
								Jump to Step
+	CC-CV Charge	4.2	10		Time(sec)	>=	7200	Rest(sec)
								If

Software

Waveform function can read .xls file, and download data to the memory of tester

UUT Setup **Waveform** UUT Test

Waveform file name: ...

Data Position

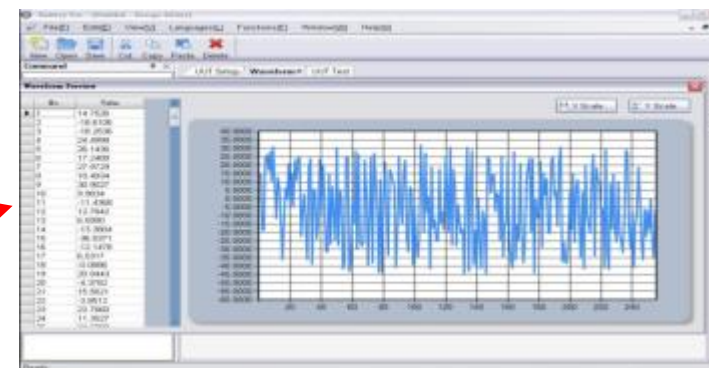
Sheet No.:

Start Column:

Start Row:

Number of Points:

Preview



No.	Step Name	Setting			Cut-Off Condition		Jump		Loop			Cy	
		V(V)	I(A)	P(W)	Parameter	Value	Mode	Value	Label	Loop To	Count	Label	Cyc
1	<div><div>+</div>Waveform</div>						Next						
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Software

The Battery Testing software allows advanced testing of batteries:

- charging
- discharging
- cycling

	Boost Voltage		Charging Current		Floating Voltage		Charging2Floating Current	
	Set Point	Actual Value	Set Point	Actual Value	Set Point	Actual Value	Set Point	Actual Value
Output U	20.00	1.00	0.00	0.00	20.00	1.00	0.00	0.00
Output V	20.00	1.00	0.00	0.00	20.00	1.00	0.00	0.00
Output W	20.00	1.00	0.00	0.00	20.00	1.00	0.00	0.00
Global	20.00	1.00	0.00	0.00	20.00	1.00	0.00	0.00

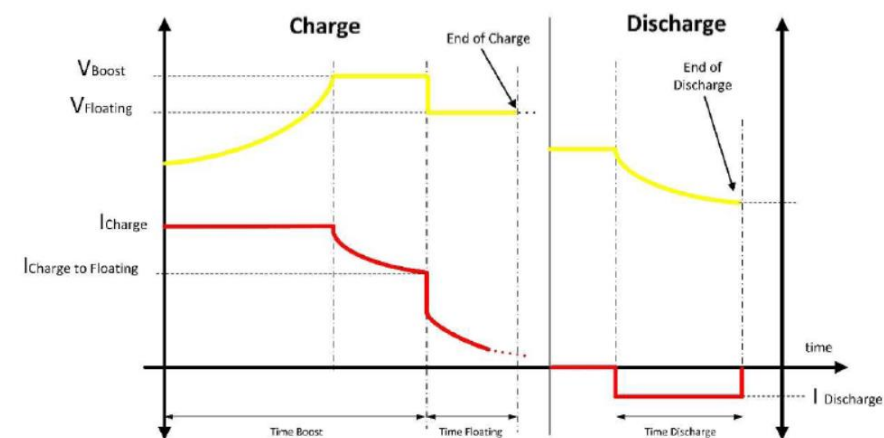
	Discharging Voltage		Discharging Current	
	Set Point	Actual Value	Set Point	Actual Value
Output U	20.00	-1.00	0.00	0.00
Output W	20.00	-1.00	0.00	0.00
Output V	20.00	-1.00	0.00	0.00
Global	20.00	-1.00	0.00	0.00

Save as CSVAdvanced Settings
Load CSV FileSend Set Points

	Boost Time		Floating Time		Time Transition		Time Discharge	
	Set Point	Actual Value	Set Point	Actual Value	Set Point	Actual Value	Set Point	Actual Value
Output U	3600.00	3600.00	60.00	60.00	10.00	10.00	3600.00	3600.00
Output V	3600.00	3600.00	60.00	60.00	10.00	10.00	3600.00	3600.00
Output W	3600.00	3600.00	60.00	60.00	10.00	10.00	3600.00	3600.00
Global	3600.00	3600.00	60.00	60.00	10.00	10.00	3600.00	3600.00

	Ah Stop Charge		Ah Stop Discharge	
	Set Point	Actual Value	Set Point	Actual Value
Output U	1000.00	1000.00	-1000.00	-1000.00
Output V	1000.00	1000.00	-1000.00	-1000.00
Output W	1000.00	1000.00	-1000.00	-1000.00
Global	1000.00	1000.00	-1000.00	-1000.00

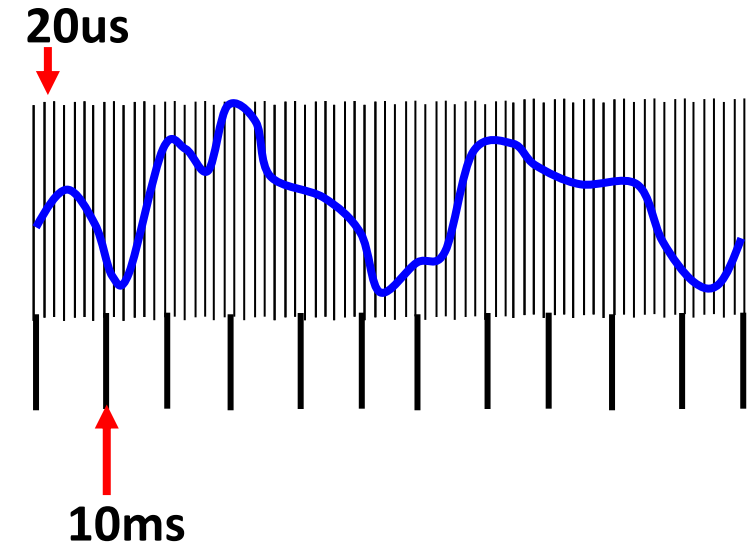
Save as CSVBasic Settings
Load CSV FileSend Set Points



Firmware protection

Download protection parameter to hardware

- Over/ Under voltage protection
Over current/ temperature/ capacity protection
- Wire loss protection
- Delta Protection: Protect internal short of battery cell
- ΔV /+ ΔV protection (V) & + ΔI /- ΔI protection (A)

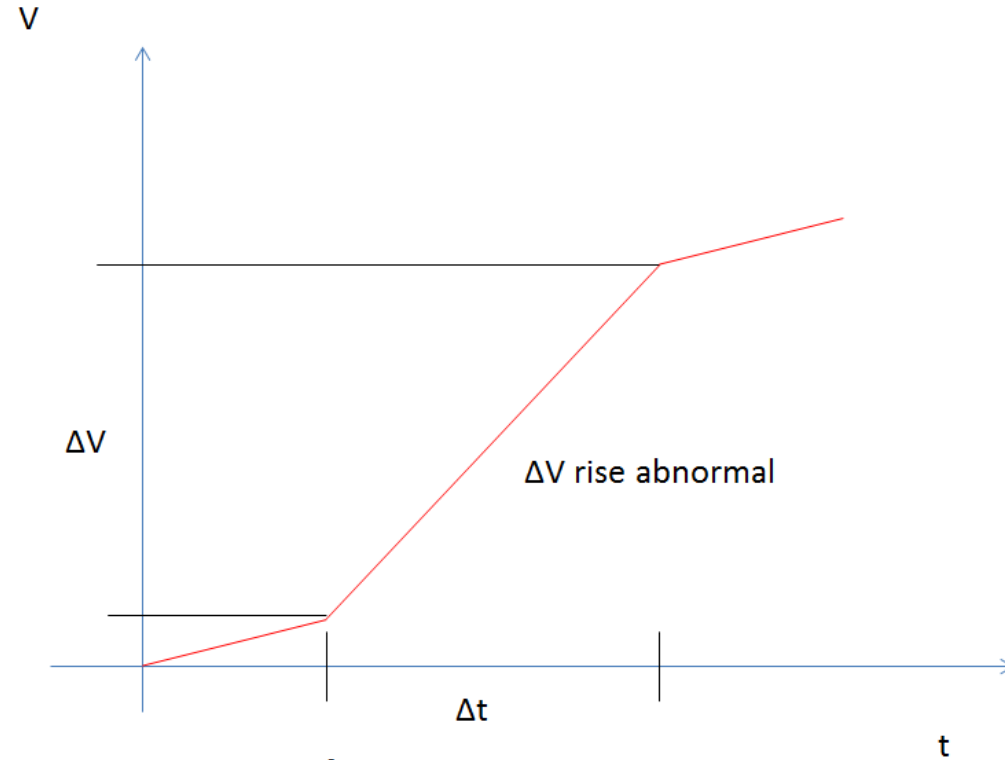


Firmware protection

Delta Protection:

Protect internal short of battery cell

- $-\Delta V$ / $+\Delta V$ protection (V)
- $+\Delta I$ / $-\Delta I$ protection (A)



Sample time < 1sec $\rightarrow \Delta t = 1$ sec.

Sample time > 1sec $\rightarrow \Delta t = \text{Sample time}$; Sample time = 10 sec $\Delta t = 10$ sec.

Software protection

Software



Regenerative Burn In Tester



Thermal/Multi-Function Data Logger



Thermal Chamber



CANBus



System integration



Related instrumentation

- Battery emulation
 - Which specifications battery do you need for your application?
- Battery Cell emulation
 - for testing BMS



Related norms

- Dutch standard
NEN-EN 50604-1

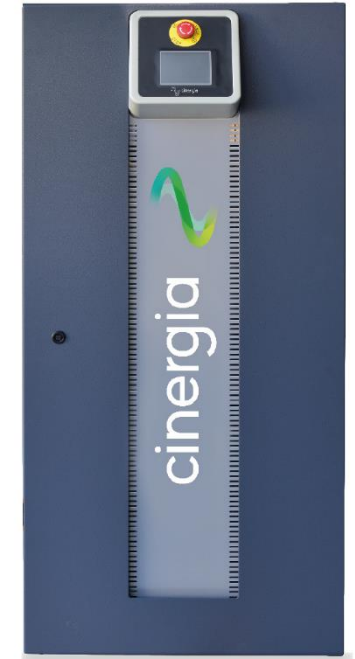
General safety requirements and test methods for small electric vehicles.
(2016 + supplement 2019)

- UN/DOT 38.3
test requirement from packaging industry

https://msc.ul.com/wp-content/uploads/2018/03/UL_WP_Safety-Issues-for-Lithium-Ion-Batteries.pdf

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https://obelics.eu/download/project_results/deliverables/OBELICS-D7.2-Evaluation-of-international-standards-for-lithium-ion-batteries.pdf





WHAT YOU DON'T MEASURE, YOU CAN'T IMPROVE.



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