



# Test solution for the Battery industry



GW Instek, founded in 1975, mainly produces electronic test and measurement instruments and it is the earliest and largest professional electronic test instrument manufacturer in Taiwan.

GW Instek started out as a power supply manufacturer, with test and measurement technology as its core, focusing on the research and development of precision electronic test and measurement instruments.

The operational locations are in Taiwan, China, the United States, Japan, South Korea, Malaysia and other countries, and the products are sold in more than 80 countries around the world.

The instrument product lineup is comprehensive, including more than 300 products such as oscilloscopes, spectrum analyzers, signal sources, power supplies, and general measurement instruments. It is a world-renowned company that provides various electronic test and measurement solutions.



## Headquarters and Global Subsidiaries



Headquarters & Plant



Suzhou Plant



China Subsidiary



India Subsidiary



Europe Subsidiary



Malaysia Subsidiary



Japan Subsidiary



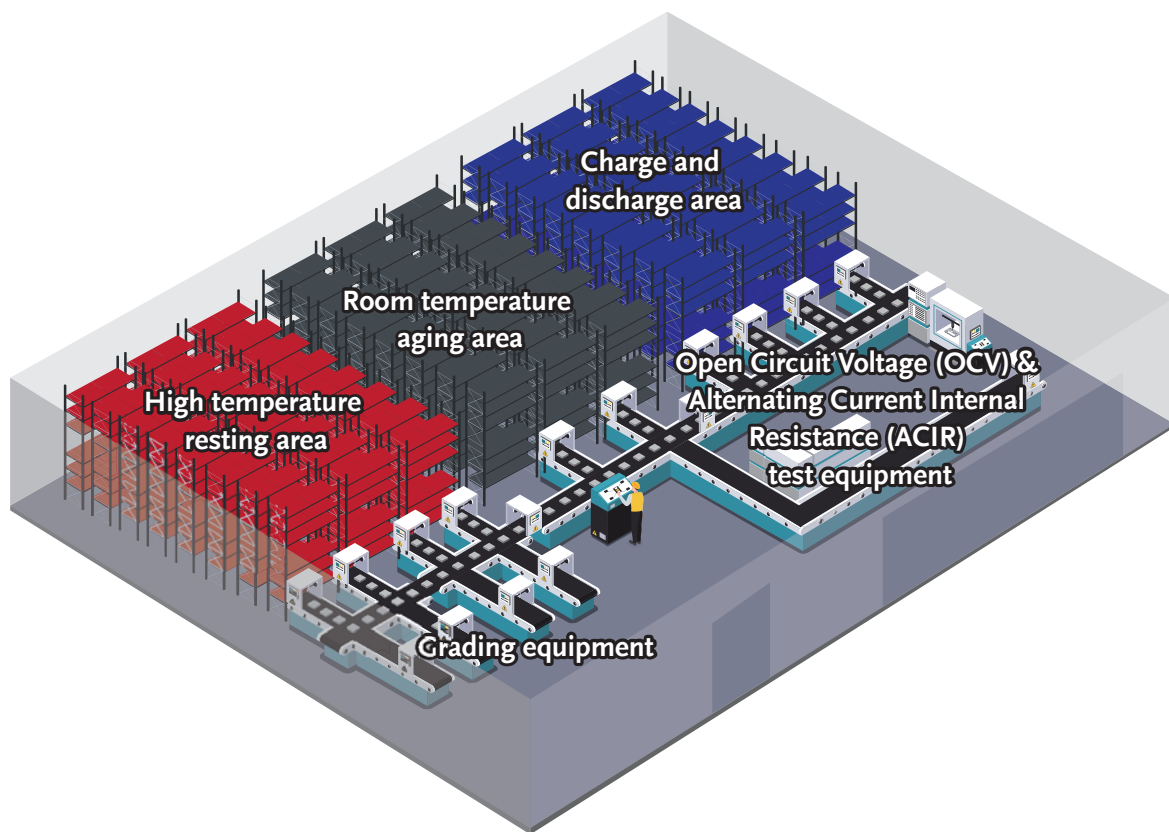
Korea Subsidiary



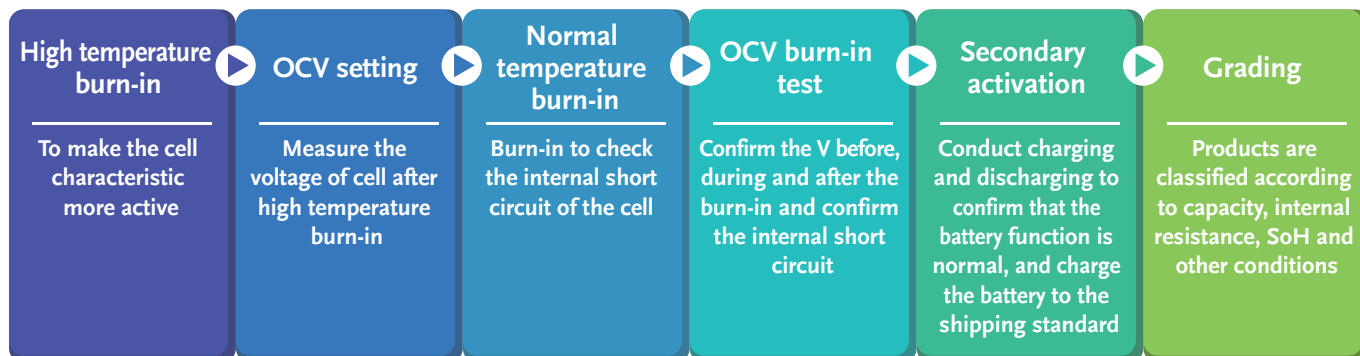
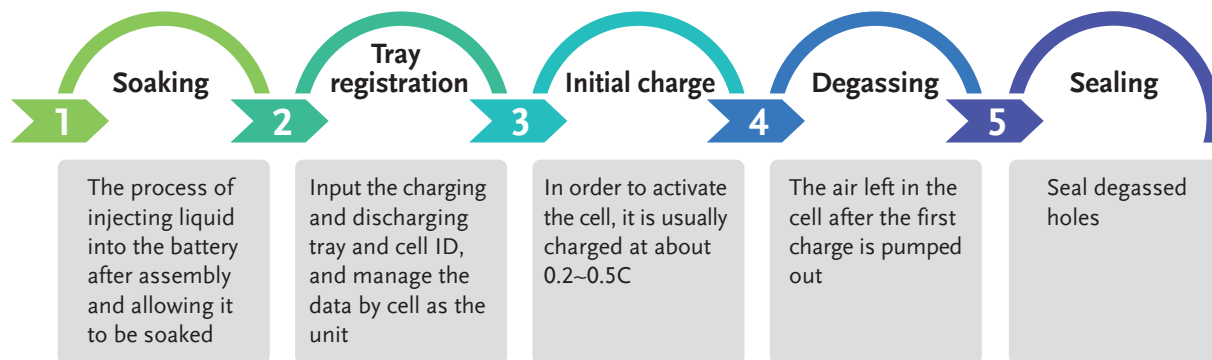
U.S.A. Subsidiary

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## Battery cell mid to final manufacturing process



## Voltage

- Open circuit voltage:**

Refers to the voltage of the battery when it is not connected to an external circuit (load).

The open circuit voltage has a certain relationship with the remaining energy of the battery, and the power display adopts this principle.

- Operating voltage:**

Refers to the potential difference between the positive and negative terminals of a battery when it is in an active state with current flowing in the circuit, also known as the load voltage.

In the operational state of battery discharge, when the current flows through the inside of the battery, it must overcome the resistance of the internal resistance, so the working voltage is always lower than the open circuit voltage.

- Discharge cut-off voltage:**

Refers to the voltage reached after the battery is fully charged and fully discharged (if it continues to discharge, it is over-discharged, which will affect the life cycle and performance of the battery)

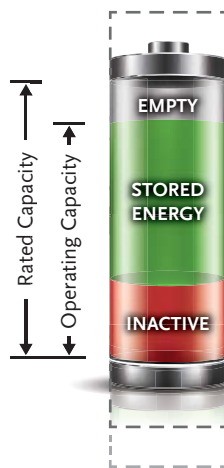
- Charge limit voltage:**

When reaching the Charge limit voltage, the charging mode changes from constant current to constant voltage.

	Open circuit voltage	Working voltage	Discharge cut-off voltage	Charge limit voltage
Lead-acid batteries	2.1V~2.2V	2.0V	1.7V	2.3V
Nickel-cadmium batteries	1.4V	1.2V	1.0V	
NiMH batteries	1.4V	1.2V	1.0V	
Lithium batteries	4.1~4.2V	3.6~3.7V	2.6~2.7V	4.2~4.3V

### Cylindrical lithium battery

model	Diameter	Height
10440	10mm	44mm
14500	14mm	50mm
16340	16mm	34mm
18350	18mm	35mm
18650	18mm	65mm
21700	21mm	70mm
26650	26mm	65mm
26700	26mm	70mm
32650	32mm	65mm
32700	32mm	70mm



- $V_{max\ pulse}$  ( applies only to short duration pulses ) **Fixed**
- $V_{max\ 100}$  ( 100% SOC at BOL ) **Fixed**
- $V_{max\ op}$  ( top of operating range at BOL ; fixed at BOL ) **Fixed**  
 $V_{max\ op}$  may be equal to  $V_{max\ 100}$  for EV application
- $V_{min\ op}$  ( Voltage corresponding to DOD condition from a C/3 rate at which the manufacturer's margin is met ) **Variable ( lowers as cell ages )**
- $V_{min\ 0}$  ( 0% SOC at BOL ) **Fixed**
- $V_{min\ pulse}$  ( applies only to short duration pulses ) **Fixed**
- $V_{min\ Low\ T}$  **Fixed**



### GDM-9061

#### 6½ Dual Measurement Multimeter

## Capacity makes greatness Relentless refinement

- The code is 100% compatible with that of 34401A  
System ID can also be changed to 34401A
- Best DC accuracy  
 $\pm(0.0035 + 0.0005)$ , which is better than that of 34460A
- The fastest measurement speed is 10 times faster than the industry benchmark  
10k reading/sec v.s. 1k reading/sec

For detailed specifications of the stand-alone unit, please click this link

## Internal resistance

- **DC internal resistance (DCIR) :**

According to the equivalent circuit of the battery, the DC measurement method is used, the capacitance is regarded as an open circuit, and the measured internal resistance is  $R_{\Omega} + R_{CT}$ .

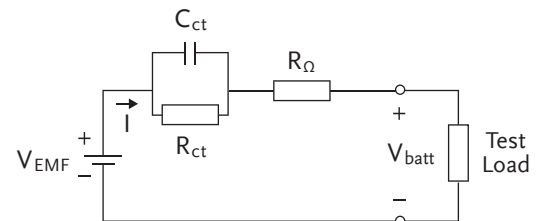
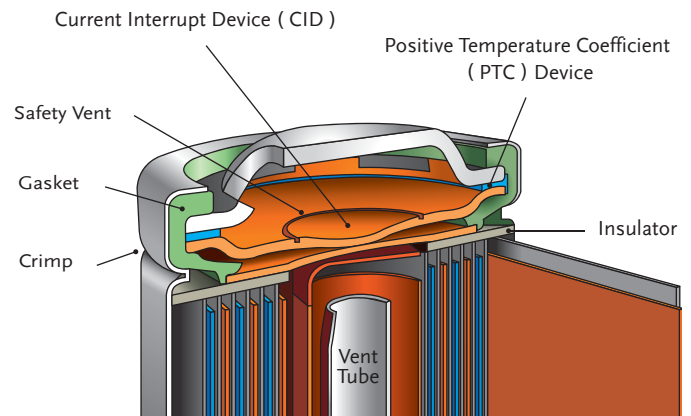
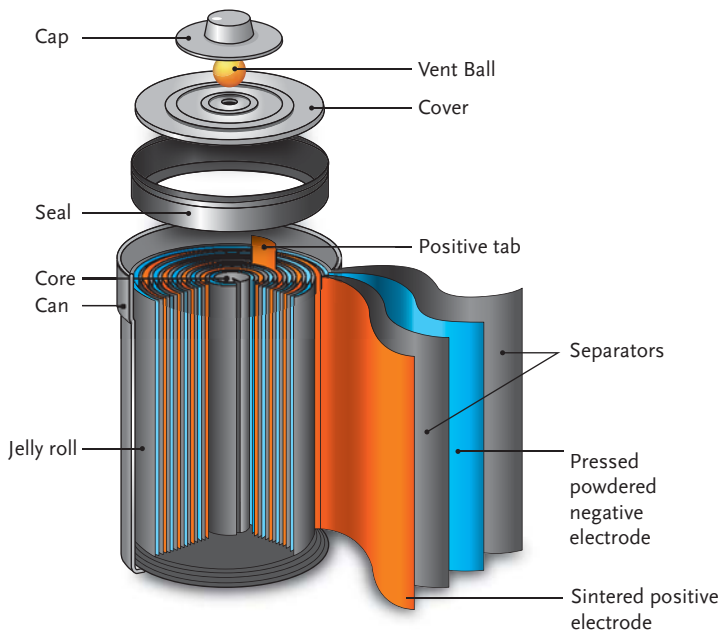
- **AC internal resistance (ACIR) :**

According to the equivalent circuit of the battery, the AC measurement method is used, the capacitance is regarded as a short circuit, and the measured internal resistance is  $R_{\Omega}$ .

- **Structural contact resistance**

- **EIS Electrochemical Impedance Spectroscopy :**

EIS can separate and quantify the cell resistance of the bulk ( $R_b$ ), interface layer ( $R_{SEI}$ ), charge transfer reaction ( $R_{ct}$ ), and diffusion process ( $W$ ) by a single experiment.



Standard accessory: GBM-01  
Kelvin Clip Test Lead

### GBM-3000 Series Dedicated Battery Tester

**All required functionalities in one  
Mighty testing capability**

**GBM-3300 ( 300V )**

**GBM-3080 ( 80V )**

- Features voltage and internal resistance measurements
- 3.5-inch LCD color screen: Intuitive settings and measurements
- Best resolution:  $0.1\mu\Omega$ ,  $10\mu V$
- Compatible with HIOKI dedicated BATTERY HiTESTER data acquisition software


For detailed specifications of the stand-alone unit, please click this link

### GOM-805 Milli-Ohm Meter

#### Pulse measurement

To eliminate the error caused by the thermal coupling effect of metal joints



For detailed specifications of the stand-alone unit, please click this link 

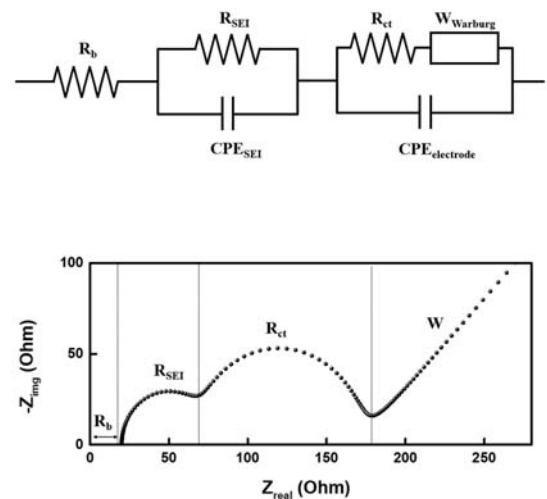
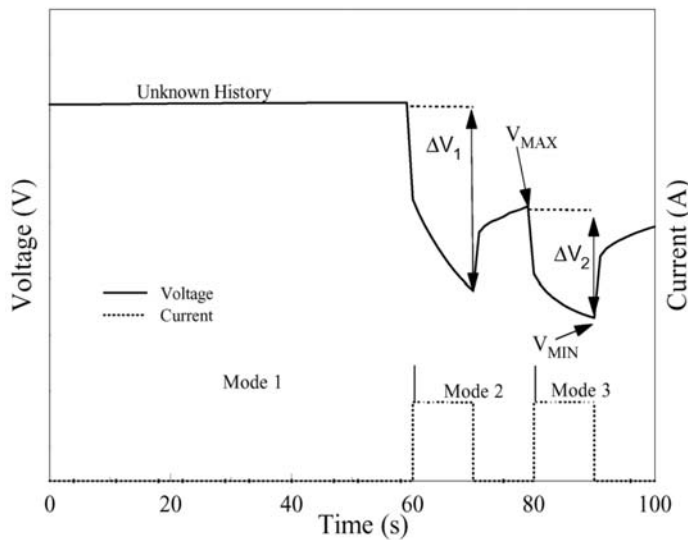
### Two-Pulse test method and EIS electrochemical impedance spectroscopy test method Battery Life Assessment

$$SOH = \frac{AHC_{aged}}{AHC_{Nom}}$$

$$AHC = \frac{I}{C_R}$$

$$C_R = \delta \Delta V_2 + \gamma$$

$$\delta = 1.868, \gamma = -0.2505$$



Source: IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 23, NO. 2, JUNE 2008  
An Improved Battery Characterization Method Using a Two-Pulse Load Test  
Martin Coleman, William Gerard Hurley, Fellow, IEEE, and Chin Kwan Lee

#### Recommended measurement methods:

- Applying the discharge test function of the GMC-1000 MetaView IoT Wizard solution, three steps : discharge → idle → discharge to test the voltage and current, record the readings to find out  $\Delta V_2$  and calculate it.
- Applying the PEL-3000 series or the PEL-2000B series, the stand-alone unit function can also be used to calculate after obtaining the record file through the battery test mode.
- Related EIS test functions are expected to be launched in 2023



## PCS-1000i Precision Current Shunt

### Battery pack current measurement



**GWInstek PCS-1000i**

For detailed specifications of the stand-alone unit, please click this link 



**Prodigit 7550A**



**Prodigit 1000A**



**Prodigit 2000A**

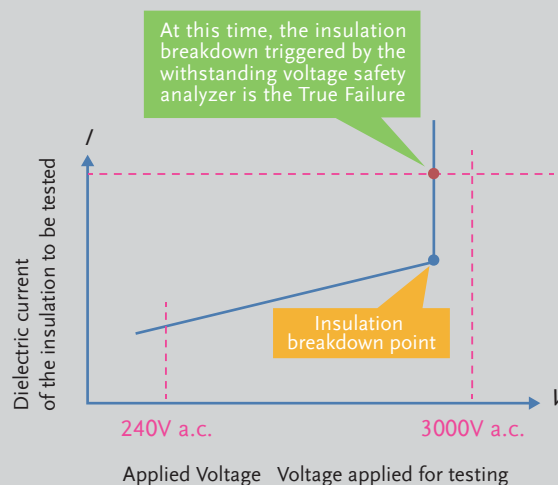
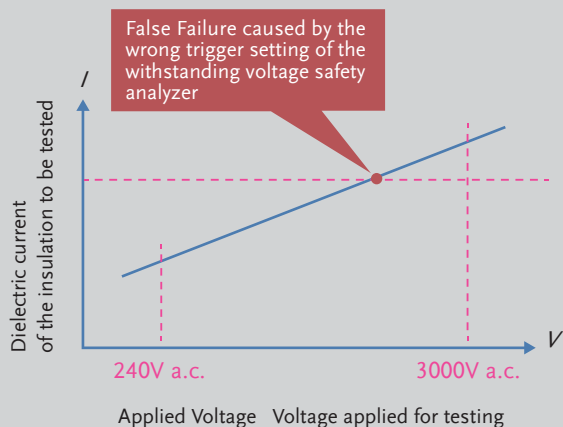
For detailed specifications of the stand-alone unit, please click this link 

Brand/Model	Current range	Interface	Input panel	Other functions
GWInstek PCS-1000i	0.01 $\mu$ A~300A	USB & GPIB	Front panel	6 1/2-digit voltage and current measurement resolution
Prodigit 7550A	1 $\mu$ A~750A	Performing remote testing with an external DVM	Front panel	
Prodigit 1000A	1 $\mu$ A~1000A	USB、RS-232、GPIB LAN (optional)	Front panel	
Prodigit 2000A	1 $\mu$ A~2000A	USB、RS-232、GPIB LAN (optional)	Front panel	
Prodigit 1000A-R	1 $\mu$ A~1000A	USB、RS-232、GPIB LAN (optional)	Rear panel	
Prodigit 2000A-R	1 $\mu$ A~2000A	USB、RS-232、GPIB LAN (optional)	Rear panel	

## GPT- 12000 / GPT- 15000 Series Insulation Material Analyzer



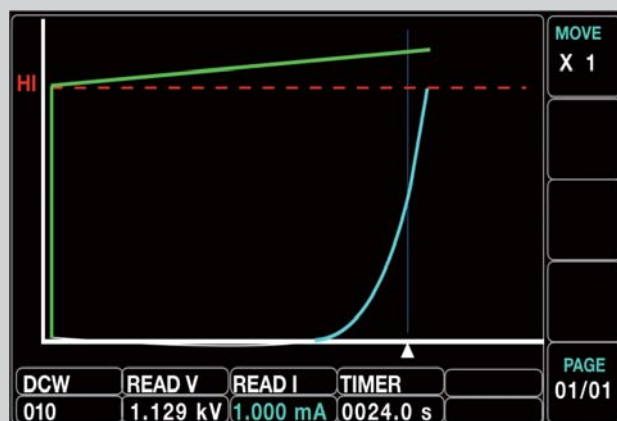
For detailed specifications of the stand-alone unit, please click this link 



### The determination of insulation breakdown is:

The current flowing through the insulation to be tested can already generate a corresponding current ( steep rise out of control ) with the increase of the test voltage, that is, the insulation to be tested can no longer effectively limit the increase of the current under the test electric field strength.

Therefore, only setting the upper limit of the leakage current will cause misjudgment. Insulation material analyzer must have the ability to display the VI curve in order to correctly determine the insulation breakdown.



## Battery pack charge and discharge test

### Methods to Construct a Battery Charging and Discharging System

	Entrust SI to purchase Turnkey	Self-construction	Construct independently through the suggested development platform
<b>Advantage</b>	Save time and energy Battery manufacturers only need to focus on material and formula research and process optimization, and all test issues are handled by SI	The self-constructed system can be adjusted according to the change of requirement, which is more flexible than the dedicated system.	With self-construction flexibility, the simple platform can quickly complete automated testing procedures without professional software engineers
<b>Disadvantage</b>	After the system is installed, it is dedicated, and there is no flexibility for adjustment	It is necessary to hire full-time and professional software engineers. If the engineer were to quit the job, it would cause system maintenance issues	None
<b>Solutions provided by GW Instek</b>	GW Instek and its subsidiary Prodigit can provide integrated solutions for charging and discharging test systems	GW Instek and its subsidiary Prodigit can provide power supplies, electronic loads and other instruments as well as sound after-sales services	GW Instek can provide the platform and the idle instruments in the required instrument field. Asset utilization can also be optimized through this open platform

### 9841 Battery Charge and Discharge Test System

#### Test functions:

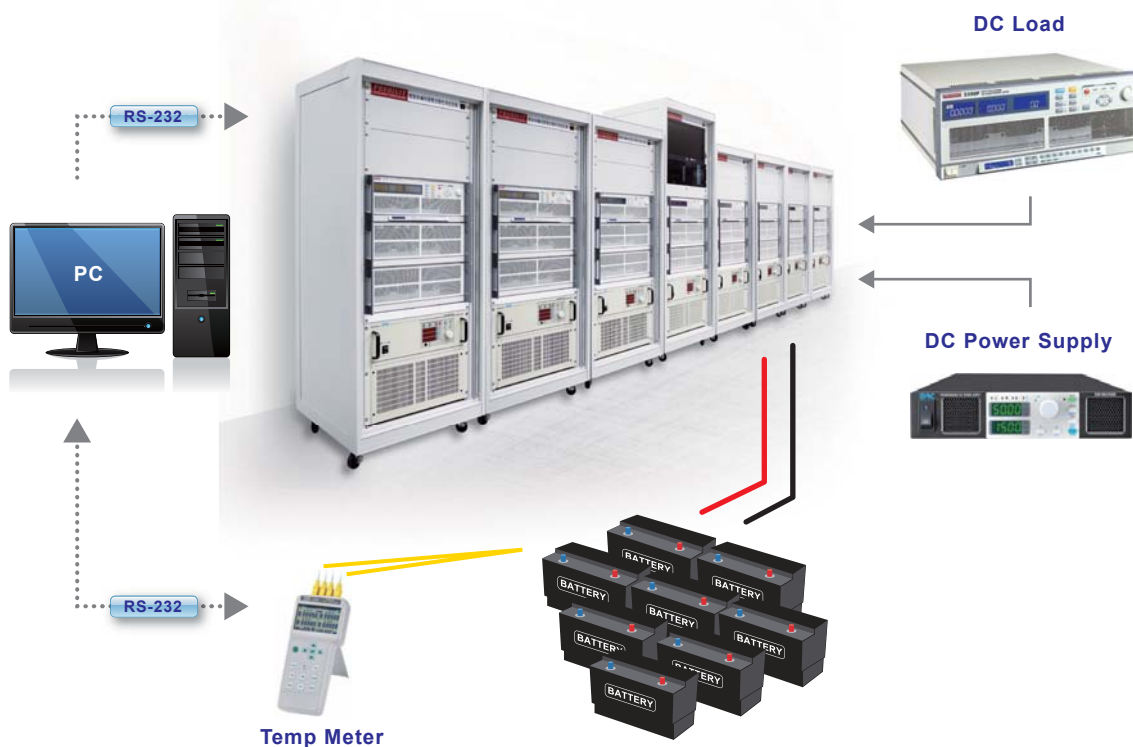
1. Charging test
2. CC/CV/CP charging test
3. Discharge test
4. Ramp on/off high-speed ramp discharge test
5. Pulse discharge test (>10C)
6. AC/DC internal resistance test
7. Temperature monitoring
8. SOC/SOH battery capacity/life test
9. Discharge test for imported customized discharge waveforms (CSV)
10. Large current/high voltage test control switching device to avoid leakage current discharge of test device
11. Up to 24 test channels

#### Features:

- Charging voltage (V), current (A), power (W) according to actual application planning
- Discharging voltage (V), current (A), power (W) according to actual application planning
- Allow users to self-defined edit test steps
- Measure voltage, current, power, KWH, AH, temperature, and easily observe the current test progress during the test, and provide the cycle test function
- Provide Charge, DisCharge, Suspend, FOR, LOOP modes to choose from. Each mode has a relative setting method, which is easy to set
- Set the stop current when charging, you can stop charging when fully charged to avoid battery damage caused by overcharging
- Set the stop voltage during DisCharge, which can stop the discharge when the discharge reaches the lowest level so as to avoid overdischarge discharge and battery damage
- More than 100 test steps can be set and test results can be saved in EXCEL CSV format files
- More than 1000 cycles of testing can be set.



## Hardware



## Test Example

### The Start Screen

The screenshot displays the Prodigit 9941-01 software interface, showing test parameters for 8 channels. Each channel has a table of steps and actions, and a set of measurement items.

Channel	Step	Action Mode	Mode / Volt	Value	Stop Time(m)	Stop Value	Stable(s)
Channel - 1	1	Suspend					
	2	DisCharge	CC	2.3	60	0	1
	3	Suspend					
Channel - 2	1	FOR			100		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	0
	5	Suspend					
	6	LOOP					
Channel - 3	1	FOR			500		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					
Channel - 4	1	FOR			250		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					
Channel - 5	1	FOR			250		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					
Channel - 6	1	FOR			250		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					
Channel - 7	1	FOR			250		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					
Channel - 8	1	FOR			250		
	2	Charge	1	0.1	1	0	1
	3	Suspend					
	4	DisCharge	CC	0.1	1	0	1
	5	Suspend					
	6	LOOP					

Additional Test Procedure

Addition Step - Channel 1  
 Action Mode : Charge  
 Charge Setup  
 Charge Voltage : 0 V  
 Charge Current : 0 A  
 Stop Time : 0 Minutes  
 Stop Current : 0 A  
 Stable Time : 0 Seconds

Modify Channel - 2 Step - 3  
 Action Mode : Suspend  
 Suspend Setup  
 Suspend Time : 0.1

Modify Channel - 3 Step - 4  
 Action Mode : DisCharge  
 DisCharge Setup  
 DisCharge Mode : CC  
 DisCharge Current : 0.1 A  
 Stop Time : 1 Minutes  
 Stop Voltage : 0 V  
 Stable Time : 1 Seconds

Modify Channel - 5 Step - 1  
 Action Mode : FOR  
 FOR Setup  
 Times : 250

Modify Channel - 4 Step - 2  
 Action Mode : CP-Charge  
 CP-Charge Setup  
 Charge Power : 30 W  
 Charge Current : 1 A  
 Stop Time : 1 Minutes  
 Stop Current : 0.1 A  
 Stable Time : 1 Seconds

Modify Channel - 6 Step - 6  
 Action Mode : LOOP  
 LOOP Setup

System Setup

System Setup

Test Channel Count : 8  
 Temperature Meter Count : 4  
 Device 1 COM : 18  
 Device 2 COM : 19  
 Device 3 COM : 20  
 Device 4 COM : 21

## Connection Setup

Connection Setup - Channel 1

Load - COM : 02 BaudRate : 115200

Power - COM : 14 BaudRate : 115200

Temperature CH -

01  02  03  04

05  06  07  08

09  10  11  12

13  14  15  16

OK

Cancel

## Start Test

Channel - 1 - Load Error

Step	Action Mode	Mode / Volt	Value	StopTime(m)	StopValue	Stable(s)
1	FOR				1500	
2	Charge	3.3	2.3	0.1	0	1
3	Suspend			0.1		
4	DisCharge	CC	2.3	0.1	0	1
5	Suspend			0.1		
6	LOOP					

SN : 201108291

Measurement Item

Voltage  KWH

Current  AH

Power  Temperature

MeasureTime : 1 S

## Review test data

Channel - 1

Step	Action Mode	Mod	Measurement Value
1	FOR		2011-08-29 15:43:59
2	Charge		Voltage 3.28862 Temperature 25.2 25.4
3	Suspend		Current 0.10975
4	DisCharge		Power 0.3609260
5	Suspend		KWH .36097357
6	LOOP		AH .17764000

SN : 201108291

Measurement Item

Voltage  KWH

Current  AH

Power  Temperature

MeasureTime : 1 S /

## Review test records

Prodigid CSV Viewer MainForm

Select CSV File

Filter

Action : Time Range : MAX MIN  Cycle View Show Count : 1

X - Scale Y - Scale Sub Y - Scale

Max MAX Min MIN

Max MAX Min MIN

Max MAX Min MIN

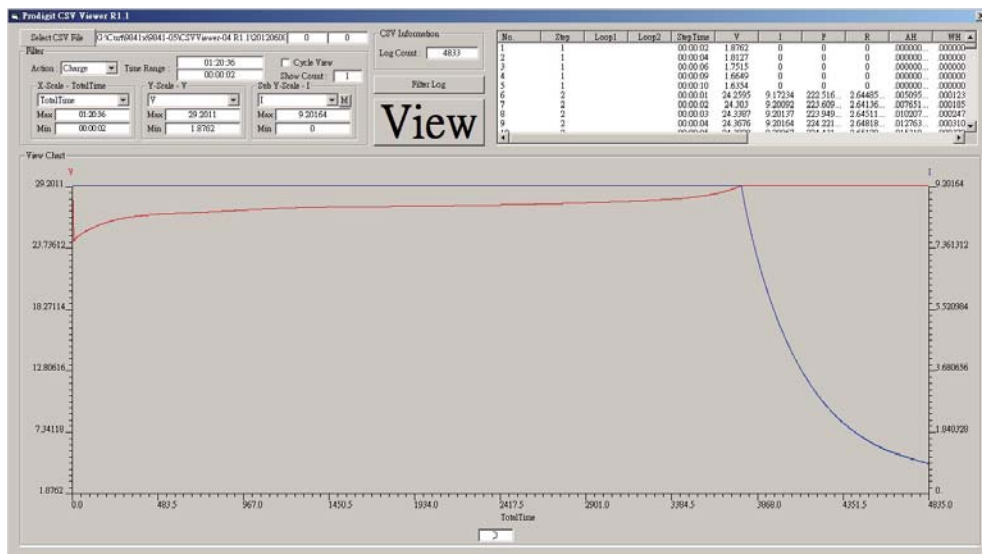
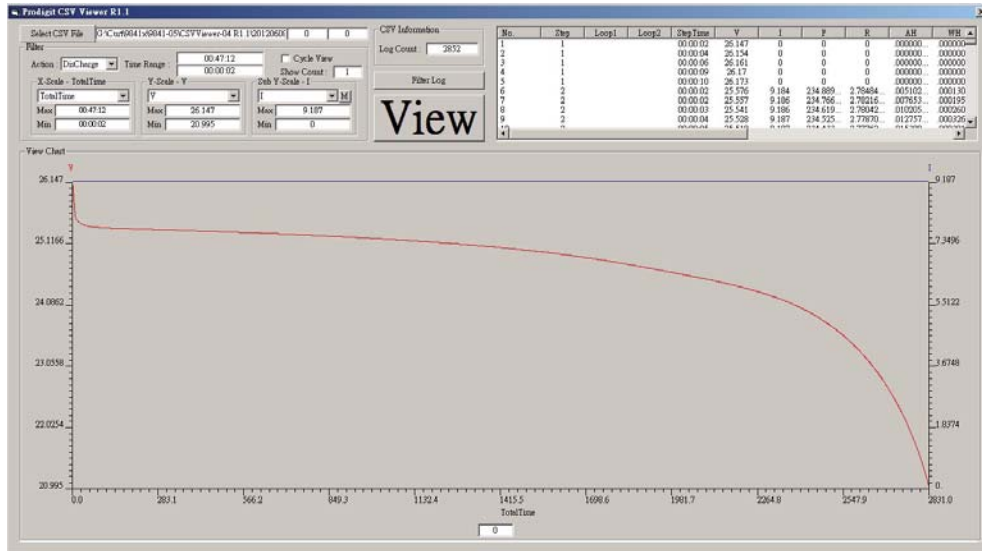
CSV Information

Log Count : 0

Print Wave

View

## Plotting the record waveform



## Power < 3kW

Battery pack applications Small energy storage, machine tool, mower, UPS, drone

GPP Series Power Supplies



PEL-500 Series and PEL-2000B Series Electronic Loads



PSW Series Power Supplies



PEL-3000 Series Electronic Loads



PSU Series Power Supplies



## Power > 3kW to 360kW

Battery pack applications Medium energy storage, Electric Vehicle

PHX Series Power Supplies  
6kW~120kW



PBW Series Bidirectional Recovery  
Power Supplies 5kW



PEL-5000C Series  
Electronic Load



There are also customized solutions for power supply and Prodigit solutions for electronic loads

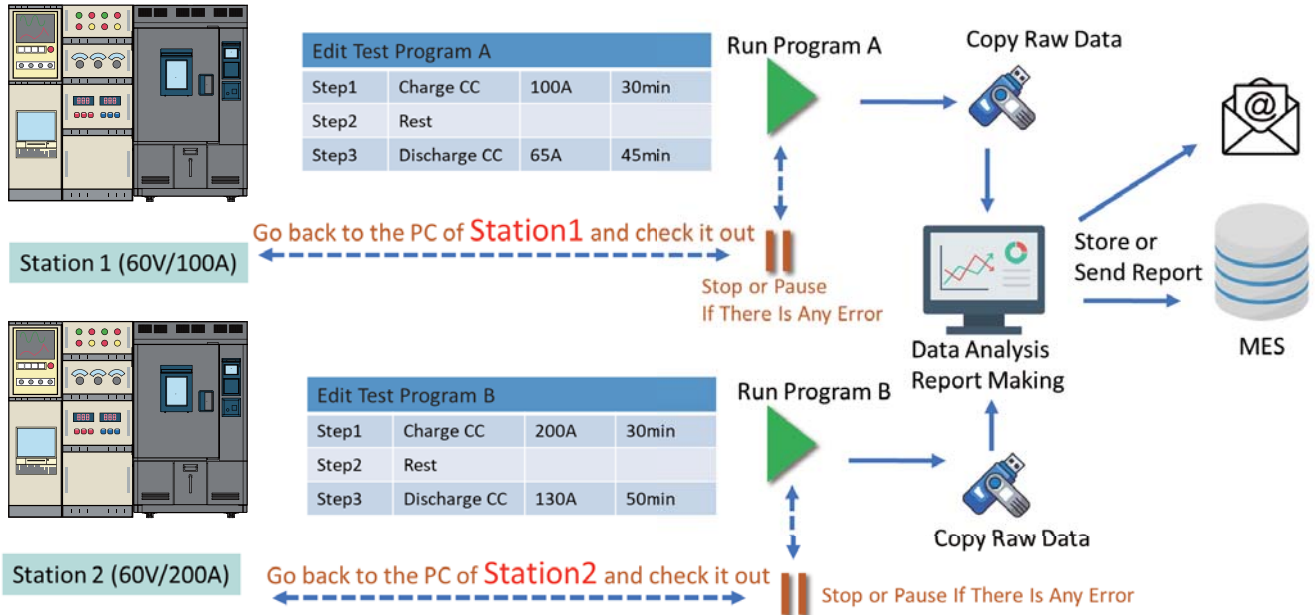


# Battery charge and discharge test

( Construct independently through the suggested development platform )

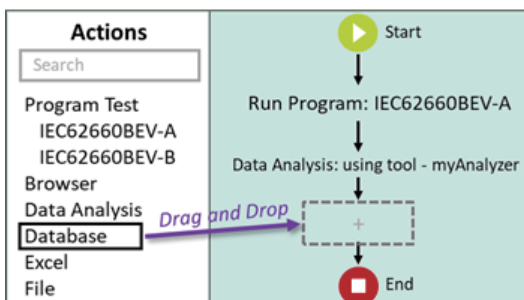
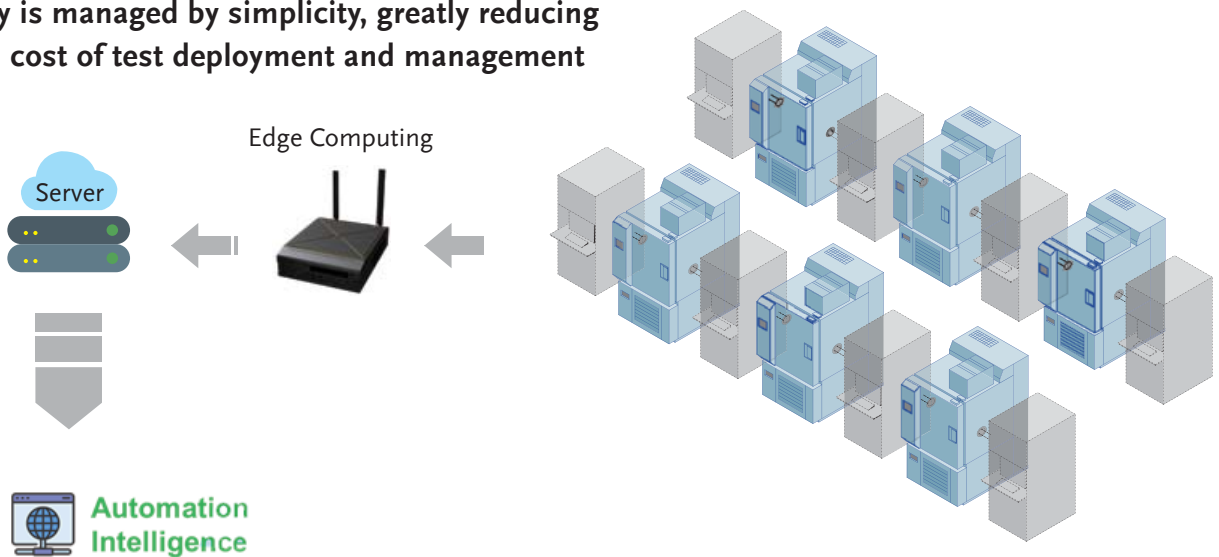
In the past, the equipment could not be connected to the Internet, and the process data had to rely on manual or semi-automatic collection of information

High time and labor costs for managing equipment and data



## Through GW Instek's MetaLab and MetaView metaverse solutions

Complexity is managed by simplicity, greatly reducing the overall cost of test deployment and management



VR Dashboard



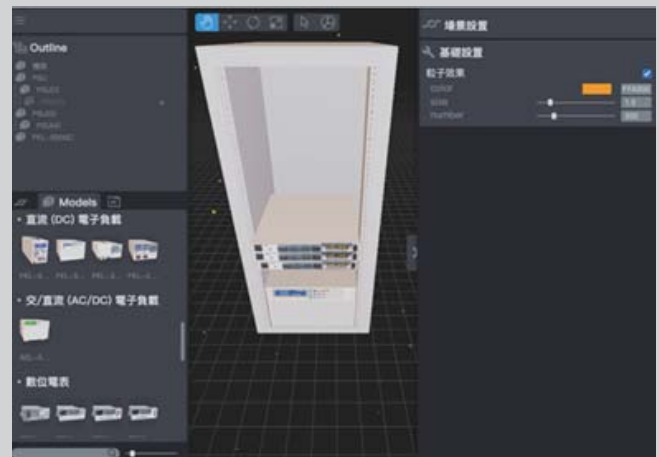
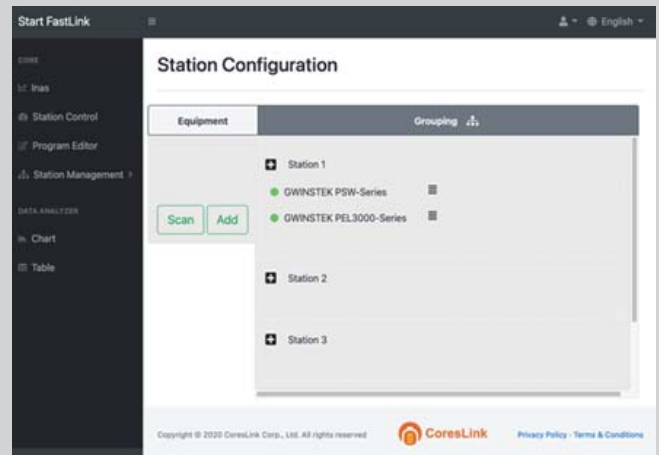
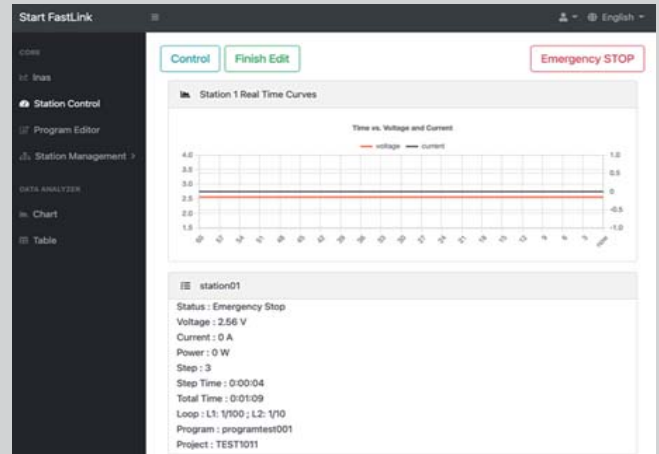
## MetaLab & MetaView new generation test field deployment platforms

### Advantages of MetaLab Application

- No need to install software, cross-platform/ cross-device usage
- One-key scanning function to quickly complete the instrument setting
- Quickly build automated tests through edge computing



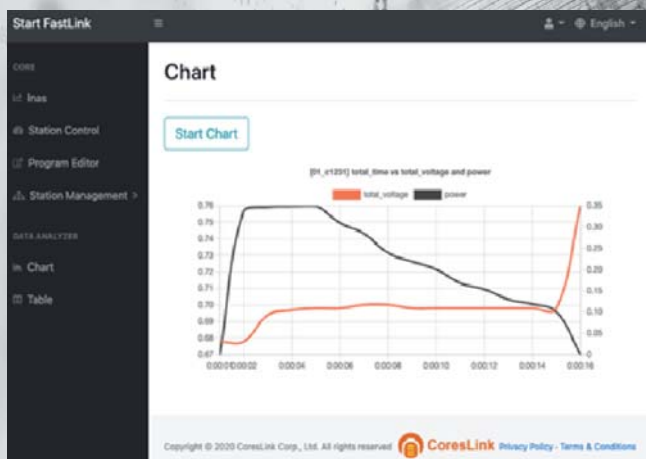
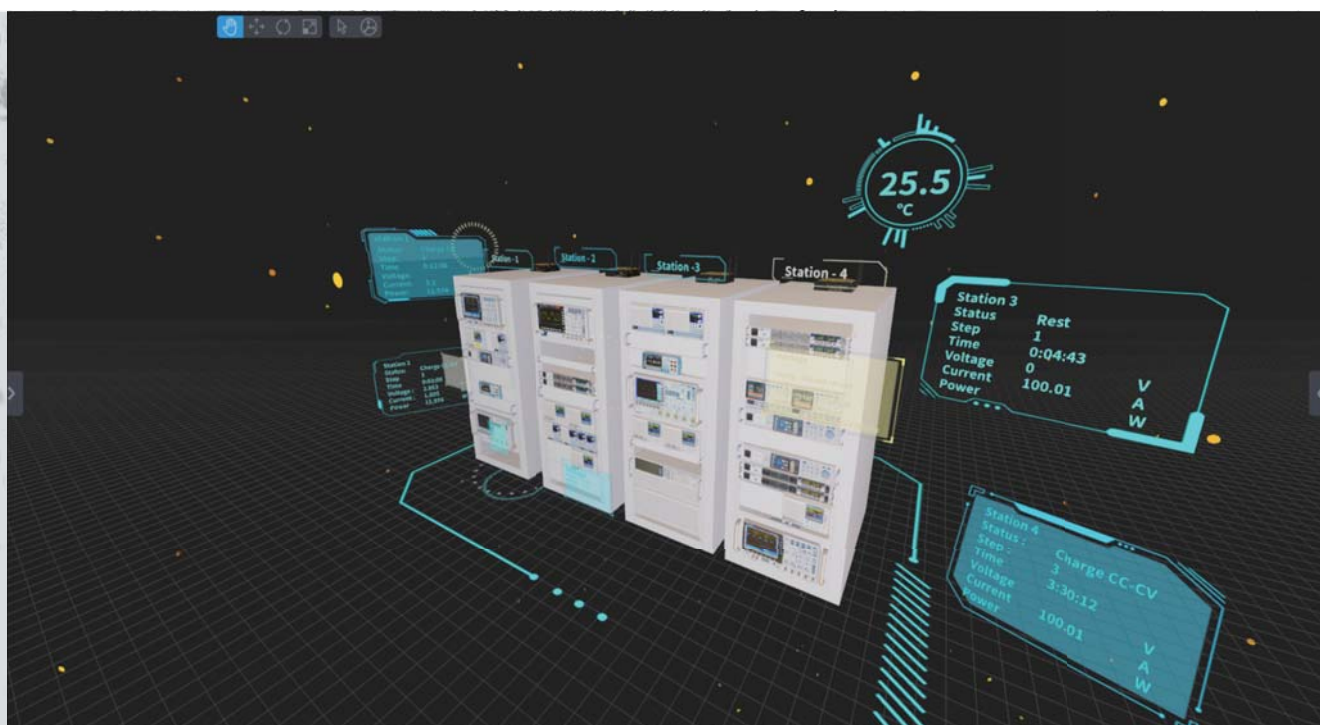
GMC-1000 MetaView IoT Wizard



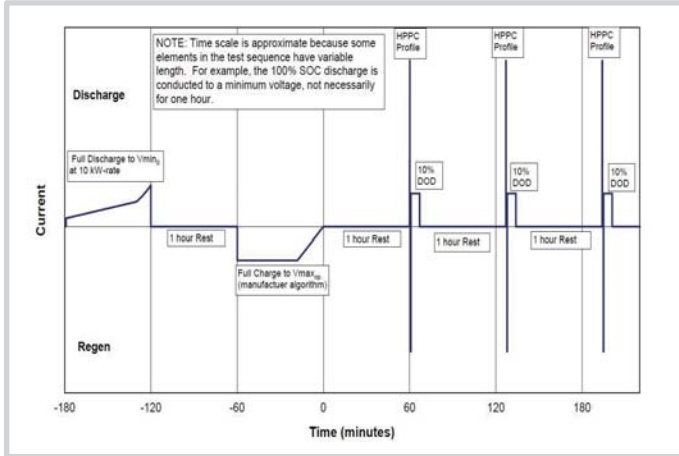
## MetaLab & MetaView new generation test field deployment platforms

### Advantages of MetaView application

- Manage the most devices with the least manpower
- Quickly establish a test network "metaverse test situation center (MetaView)"
- Augmented reality, on-site personnel can quickly obtain on-site test results through mobile phones or tablets



## Power battery road condition tests

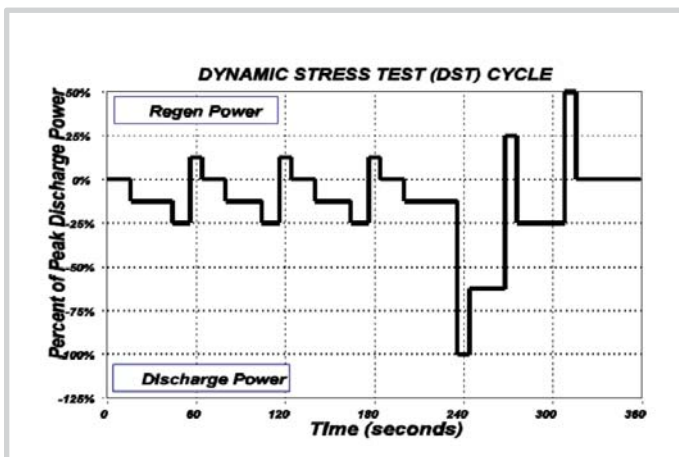
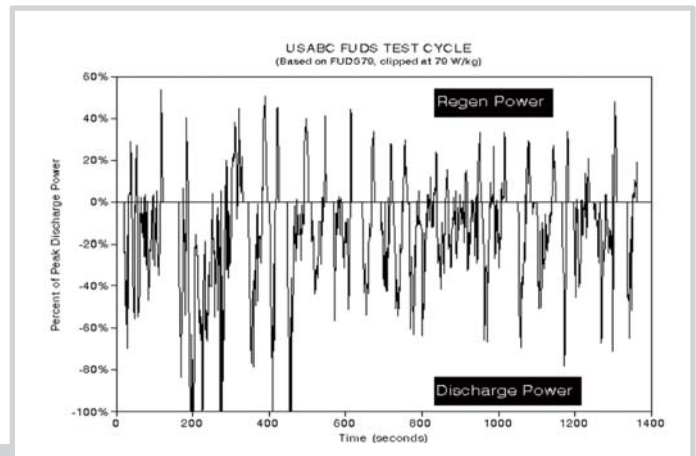


### Hybrid Pulse Power Characterization ( HPPC )

- Purpose: To test the dynamic power output capability of the battery
- USABC proposes to test the cells under different states of charge (SoC), perform short-term (10-30 seconds) high-rate pulse discharge and high-rate pulse charge, and measure the change of potential to calculate the internal resistance and power characteristics of the battery
- With every 10% of SoC as an interval, apply high-rate pulse charging and discharging current for 10~30 seconds, and calculate the internal resistance of charging and discharging

### Federal Urban Driving Schedule (FUDS) US Federal Urban Driving Distance

- Purpose: To simulate urban cruising
- Proposed by USABC, it is used for working condition simulation, using power loops to simulate actual load conditions and test battery performance during the process
- Continuous loop with 1372 seconds test profile ( end-to-end without resting )



### Dynamic Stress Test (DST)

- Purpose: Simulate start and stop
- Proposed by USABC, it is modified based on FUDS and is also used for working condition simulation, using power loops to simulate actual load conditions and test battery performance during the process
- Continuous loop with 360 seconds test profile ( end-to-end without resting )

GW Instek provides USABC related testing solutions

## 6020 BMS ATE Application Note

A growing number of portable devices and vehicles rely on Li-ion or Li-Polymer batteries for their power. Examples thereof are mobile phones, laptops, cordless vacuum cleaners, drones and vehicles such as electric bicycles, scooters, cars, buses or boats. Charging these types of battery chemistries requires careful monitoring of voltage, current, temperature and state of charge (SoC). This is accomplished by integrating a battery management system (BMS) in the battery charger. These BMS equipped battery chargers must be thoroughly tested to ensure customer safety.

Prodigit developed the battery BMS test verification tool for this purpose. The BMS system provides a dedicated test and verification platform for testing of single cell batteries as well as multiple cells.

In battery based system, major considerations include physical battery volume, operating temperature range, dust and waterproof resistance and environmental and safety parameters. The most important parameters are the performance of the battery system, including the battery capacity and energy, state of charge (SoC), voltage, Ampere Hour (AH) or Watt Hour (WH), internal resistance, energy efficiency, self-discharge and lifetime no of cycles. To ensure overall performance verification, it is necessary to test each single battery cell as well as the entire power battery system input / output (I / O).

The selection of the BMS chip is mainly related to the number of battery and cells in series which determines the battery voltage. At the current state of the art, a single BMS device's analog front-end can monitor from 1 through 16 cells or 16 channels.

The main objectives of a BMS are focused on: low power consumption, high reliability and product safety. Most batteries used today are lithium batteries. Unfortunately, the safety record for lithium is not stellar. Because the characteristic of lithium is more dynamic, it is easier to cause an explosion or fire, but it has higher energy density. Thus, the battery module manufacturer has to include a BMS design with a high emphasis on protection features. From a single battery, battery pack and then to the entire BMS, each function has to include a protection mechanism to ensure safe and secure operation under all conditions. In addition, the BMS is also used to monitor for protection related criteria. This same monitoring function can also assist in prolonging battery life. When the battery is charged and discharged, it is critical that the voltage balance between all cells is maintained to ensure that no individual cell overcharges or over-discharges.

The battery management system (BMS) is designed to protect the battery from damage, extend battery life and maintain battery performance. In other words, the battery management system plays an important role in achieving safety and performance requirements for rechargeable batteries.



BMS test board

### 1. The basic functions of the battery management system include

- Measure the battery voltage
- Measure the battery input current (when charging) and the output current (when discharging)
- Measure the cell voltage
- Measure the battery temperature (by NTC thermistor). The BMS needs to disconnect or limit the charge voltage or current with its protection delay. When there is an Over-Temperature or Under-Temperature condition, the BMS needs to reconnect the charge and/or discharge switch with a recovery time after the OTP or UTP condition is removed.
- When the measured values exceed the upper or lower limits, the battery should be disconnected, including over voltage (OV), under voltage (UV), over current (OCD), short circuit (SCD), etc.  
These steps also include protection recovery times for normal operation after protection is removed to meet design requirements
- When there are multiple battery cells, it is necessary to balance the power of battery stored in each battery pack
- Check the operating status of the system components to ensure the safety of the battery management system.
- Status of Charge (SoC), Status of Health (SoH), and Status of Function (SoF) of the battery are calculated and tested.
- Calibration of the above measured values, programming the setting parameters, and feedback the information to the system through the communication interface of BMS.

Whether the battery management system can perform the above functions well depends on the accuracy of the input data of the battery sensor. This sensor directly affects the user's safety, so it needs to be testing 100% as part of BMS test verification. Because the BMS is a custom assembly product that is in connection with a dedicated battery, the test verification project is quite complicated and needs to be checked and confirmed step by step in order to ensure correct operation. Therefore, an ATE test system is the best choice.

Since the battery BMS must be combined together with the battery and it is a highly customized device, the BMS parameters must be determined and set by the user. The ATE is just used to implement and confirm whether all condition meet the tools and platforms that can quickly and indeed do the verification. To avoid human error, the setting parameters for the BMS programming can only be applied to a specific lithium battery. for use, It does not apply to other, different specifications of lithium batteries. Thus, It is required to pair lithium batteries and BMS circuit board in order to bring performance into full play, which is different from other standardized single-type component. In other words, the user does not have to worry about BMS parameter settings during ATE operation, but only confirm that the BMS protection & security functions are performed without error.

## 2. Test Verification Solution

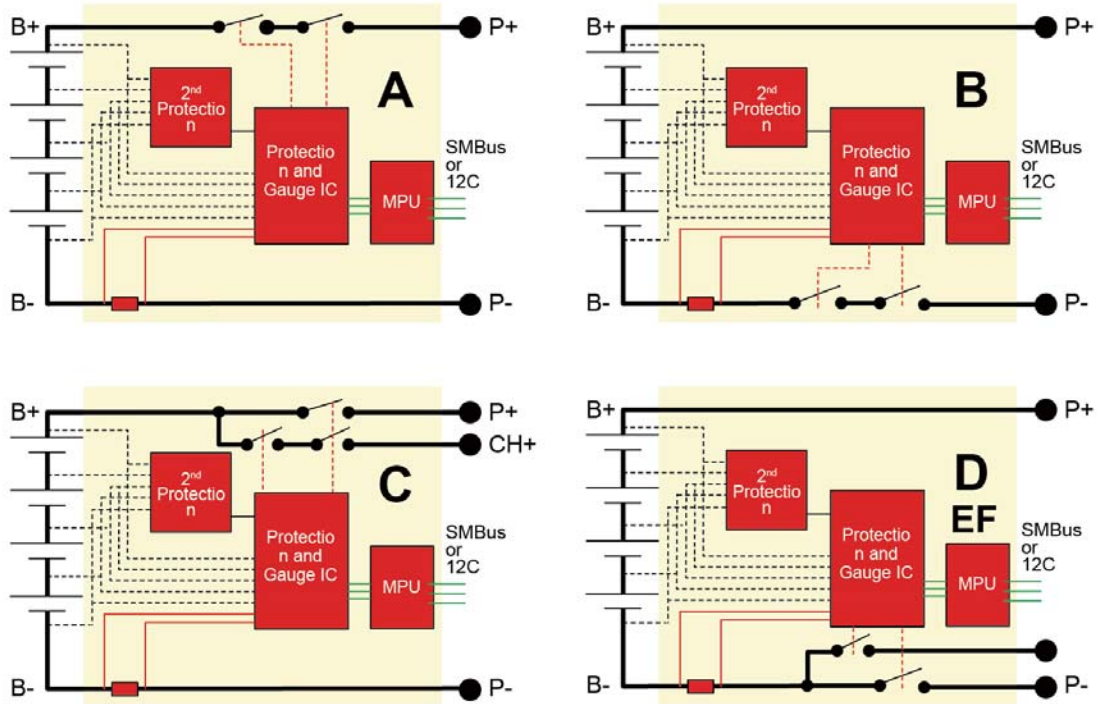
For the lithium battery, charger and battery BMS, Prodigit provides the corresponding test solution respectively, Prodigit provides the industry's most wide range of models of electronic load product line, the power up to 60KW, the voltage up to 1000V, and the current up to 1000A, by the way, Prodigit also has provided a variety of customized specifications (by request) and BMS Short/OCP test option to meet the requirements of various tests on the market.

## 3. 6020 BMS ATE Test Function Items

- ▶ TI management chip test, through the 99097 4 Channel communication adapter can simultaneously burn in and calibrate up to 4 BMS boards.
  - 12C data writing and checking
  - Automatically write production date and serial number
  - PCM Calibration
- ▶ OC No-load current consumption includes Normal working status, Sleep working status, Shout Down working status
- ▶ OV No-load voltage : after measuring the load voltage, whether the MOS is turned on normally
- ▶ CIR Charge impedance
- ▶ DIR Discharge impedance
- ▶ NTC Negative Temperature Coefficient Resistor (Thermistor)
- ▶ ID Identify resistance
- ▶ OVD Load voltage: the load capacity of measuring the protective board
- ▶ Charge control
  - Pack OVC Pack Overvoltage protection / recovery
  - OVC Overvoltage Charge protection / recovery
  - OTC Over temperature Charge protection / recovery
  - COC Charge overcurrent protection / recovery
- ▶ Discharge control
  - UVD Under Voltage discharge protection / recovery
  - OTD Over temperature Discharge protection / recovery
  - OCD Overcurrent Discharge protection / recovery (50A, 55A)
  - SCD Short circuit Discharge protection / recovery (90A)
- ▶ LDO Low-Dropout Regulator measurement
- ▶ OD Automatically discharge test
- ▶ EQ Single-cell balance function
- ▶ SMBus Communication verification



BMS test board



## BMS Discharge Test Diagram



Multi-Meter



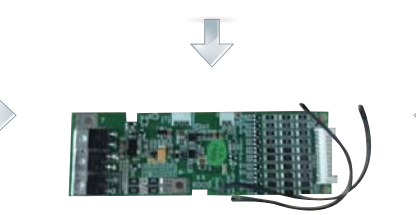
NTC Simulation



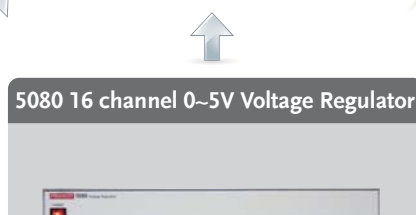
Communication



As Battery



BMS

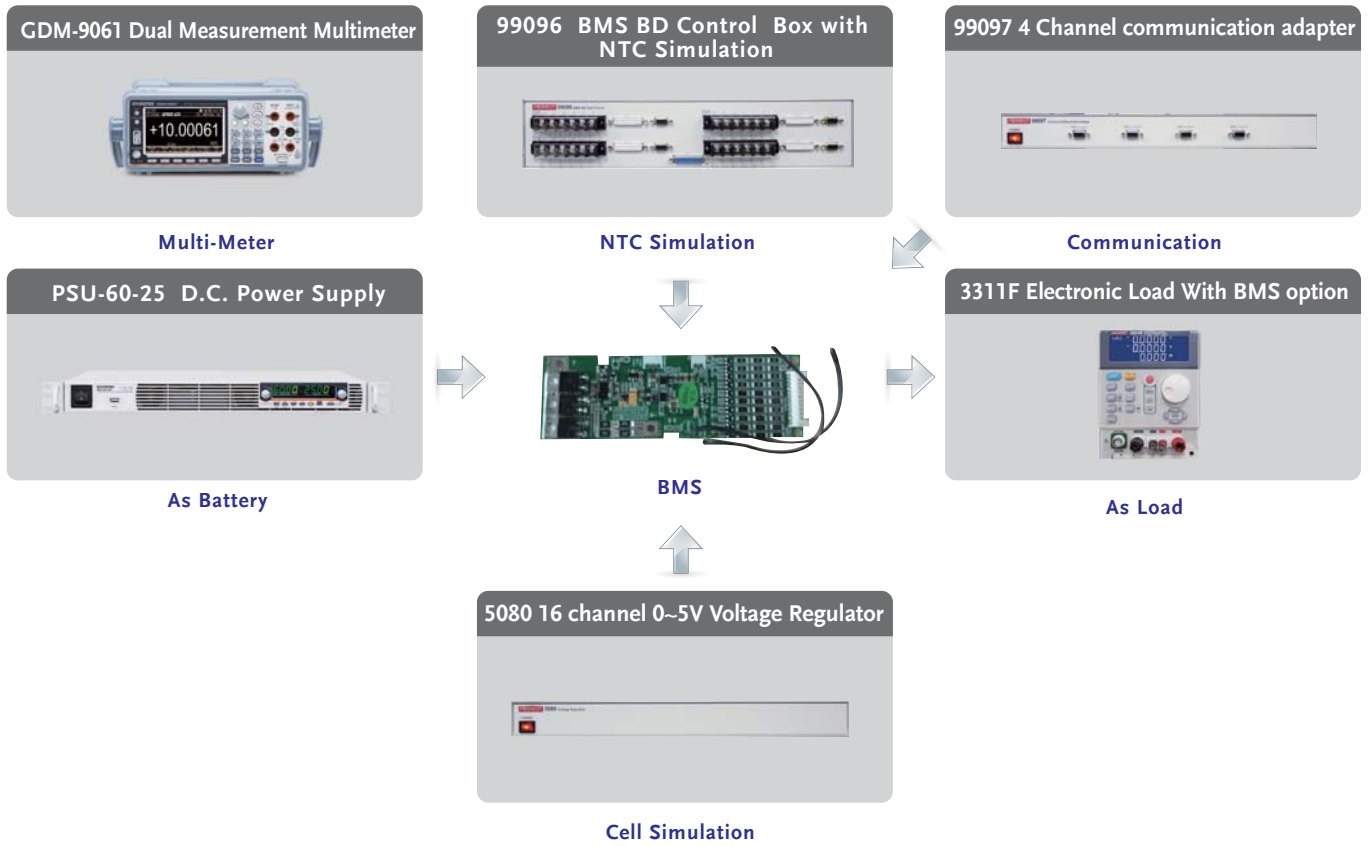


Cell Simulation

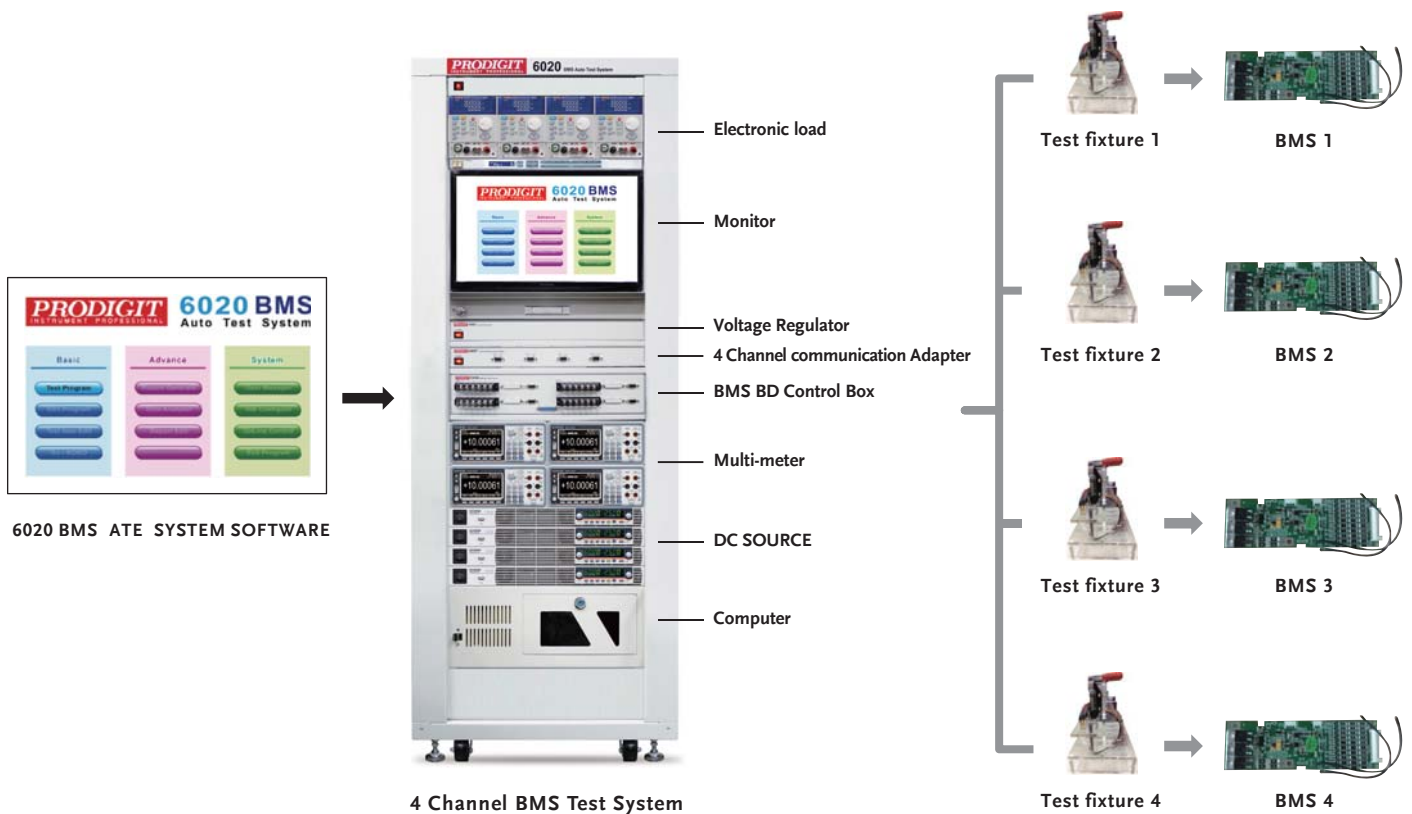


As Load

## BMS Charge Test Diagram



### 4. 6020 BMS ATE system architecture diagram





## 5. Feature

- **System Authority Assignment:**User Authority Management, which allows to assign different permissions for different users
- **High Extensibility:**for multi-string battery cell, 4 cells per channel, expandable from 1 to 16 cells per strings
- **High compatibility:**for a wide range of charge and discharge specifications, and with multi-level current protection test
- **Battery simulation device modular design:**Use one string 16 cells or four string 4 cells battery, simulation device can simulate 0.1 ~ 5V analog battery cell voltage, you can test the core specifications of the PCM product, such as:PCM OC sleep power self-consumption, each string CELL of the charge and discharge protection 13 pt and balance function.
- **The communication method between the device and the system is RS-232 communication.**
- **The Gauge IC communication protocol supports I2C, SMBUS and other customized communication protocol.**
- **The Pass / Fail test result:**the system can accurately measure the voltage and current changes. If the test result is NG, the system will automatically stop the test according to the protection setting conditions, and generate alarm function to remind the user.
- **Data processing and human-machine interface:**Test data can be converted into EXCEL files. The selected conversion data items include data such as test items, Pass / Fail conditions, and test procedures, and support batch query and convert data.
- **Powerful system functions:**it supports test solution import/export and manual modification, which is applicable for new products verification with modification. The test items can be edited by profile, which is convenient for profile editing in different test models.

## 6. 6020 BMS ATE practical application

- PC with 6020 BMS Auto Test System installed and IO control
- 3300F+3311F Electronic Load 60V/60A/300W, include BMS function, can sink the maximum load of 120A
- PSU-60-25 Programmable Switching D.C. Power Supply
- 99096 BMS Switch Box
- 99097 4 channel communication adapter
- BMS Battery Simulator model 5080 Voltage Regulator can be configured as 1pc 16 strings or 4pcs 4 strings battery simulator
- 34461A Digit Multi-meter
- Short/ OCP Source 5V/100A
- NTC Simulator

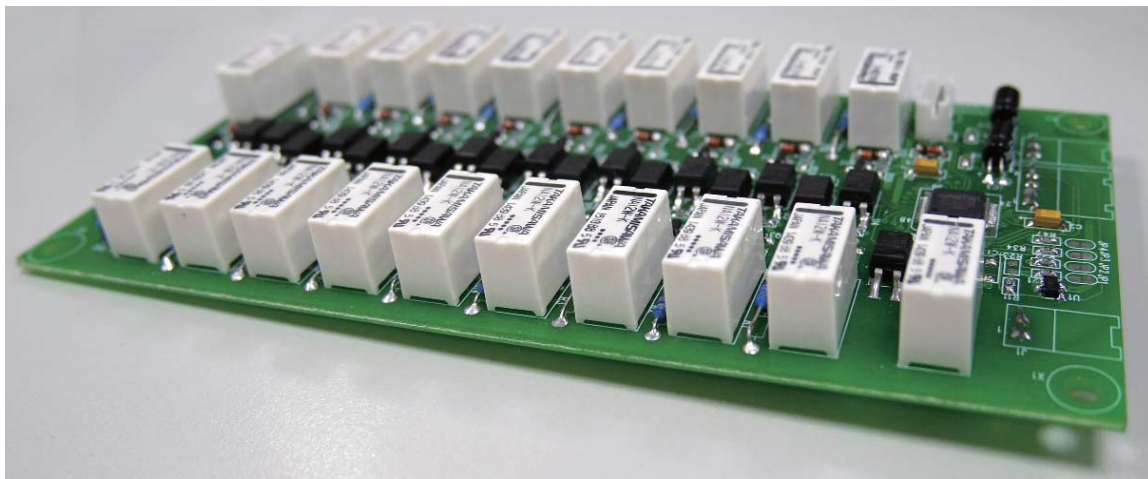
## 7. 6020 BMS ATE practical application

- Single Cell BMS
- Multiple Cell BMS
- R & D design verification test:
- A large number of rapid testing in manufacturing
- Battery Pack/battery module verification and testing

For the BMS over current protection functions, including the battery overcharge, over discharge, short circuit etc. abnormal conditions, the Prodigit electronic load (Model 3310F) with BMS option is able to measure the BMS peak protection current and protection response time. If needed, Prodigit can provide the corresponding models to meet the market requirement for up to 1000A protection current.

For the BMS temperature detection, including over or under temperature protection action and after temperature recovery and protection, Prodigit designed an NTC module that can simulate the battery BMS NTC resistance values. Using the 3302F with NTC Option or the 6020 BMS ATE NTC simulation mode, the BMS temperature protection operation can be verified and the reaction of the delay and recovery time can be checked.

For the BMS DC internal resistance, AC internal resistance, BMS consumption current, battery cell balance, NTC simulation and a variety of other protections, the 6020 BMS high-performance automatic test system can provide simultaneous testing of 1 to 4 BMS. Each BMS function is tested step by step and quickly. The 6020 BMS test system can be configured as a single BMS test system for design verification or quality testing. It can also be configured as four BMS simultaneous testing systems for rapid testing in mass production environments.



NTC module

For complete battery pack charge and discharge testing, Prodigit also provides the 9841 battery charge and discharge test system and software based on to the customer's specific requirements. Test systems are designed to match the required power and electronic load to perform the battery charge and discharge related testing.

The 6020 BMS ATE can be purchased the whole system (Hardware + Software) or dedicated hardware in the system. Prodigit provides the operation and programming instructions for the dedicated equipment. This means the dedicated hardware such as the 5080 voltage regulator for battery cell simulation and the 99096 Switch Box with NTC simulation can be added to your existing ATE system. The user can also build his own custom ATE system.

6020 BMS ATE Ordering Information:

Please contact Prodigit sales office or distributor in your area.

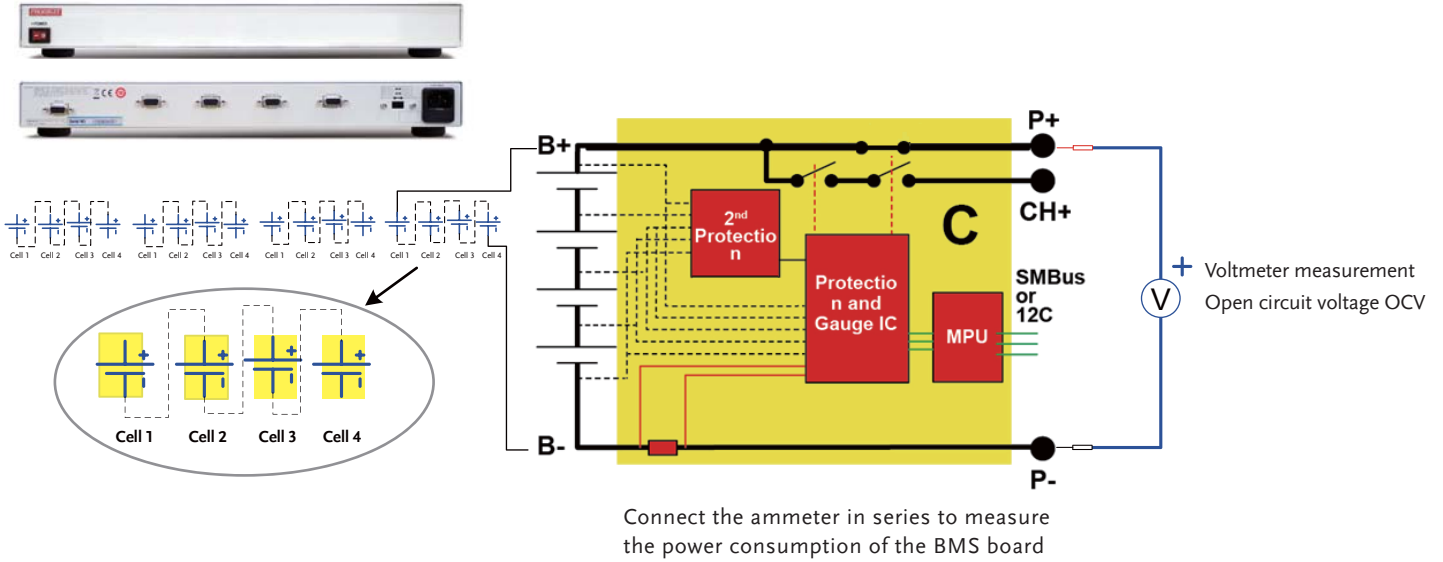
## 6020 Battery Management System Test Item Description

### Test items

- **OV:** Voltage test for no load output
- **OC:** Power consumption test for the sleep mode
- **DIR:** Discharging circuit impedance test
- **CIR:** Charging circuit impedance test
- **NTC:** Thermistor test
- **ID:** Identification resistance test
- **OVD:** On-load discharge voltage/current test
- **OVC:** Single-cell battery over-charge protection recovery test
- **UVD:** Single-cell battery over-discharge protection recovery test
- **OTC:** Over-temperature charge protection recovery test
- **OTD:** Over-temperature discharge protection recovery test
- **COC:** Over-charge current protection recovery test
- **Pack OVC:** Pack over-voltage protection recovery test
- **OCD:** Over-discharge current protection recovery test ( 60A )
- **OSD:** Discharge short circuit protection recovery test ( 120A )
- **LDO:** Testing
- **EQ:** Multi-cell battery balancing function test
- Burn code
- Calibration ( voltage, current )
- SMBus communications

## OV : Voltage test for no-load output

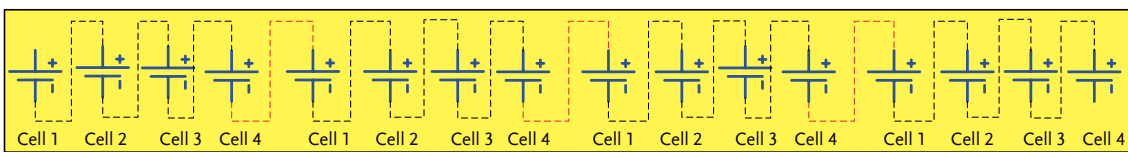
5080 Voltage Regulator to simulate Battery Cell 1~16



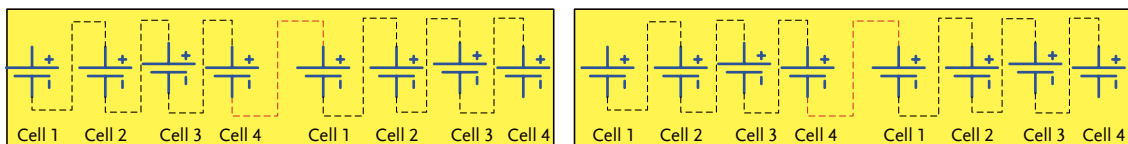
Prodigit developed the 5080 Voltage Regulator battery cell voltage simulator for the test and verification requirements of BMS. The 5080 contains 4 channels, and each channel has 4 sets of electrically isolated and independent 0~5V battery voltage simulators, therefore, it can form 4 sets of 1~4 cells, 2 sets of 1~8 cells or 1 set of 1~16 cells of battery simulation according to the requirements, as shown in the figures below



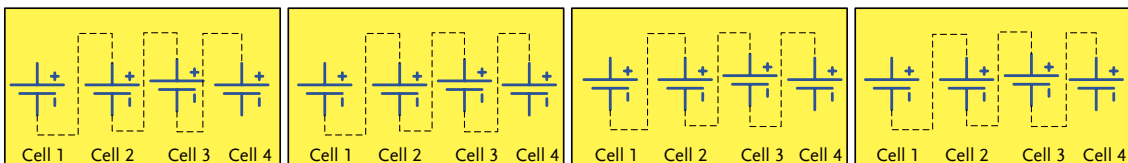
5080 Voltage Regulator to simulate Battery Cell 1 set of 16 cells



5080 Voltage Regulator to simulate Battery Cell 2 sets of 8 cells

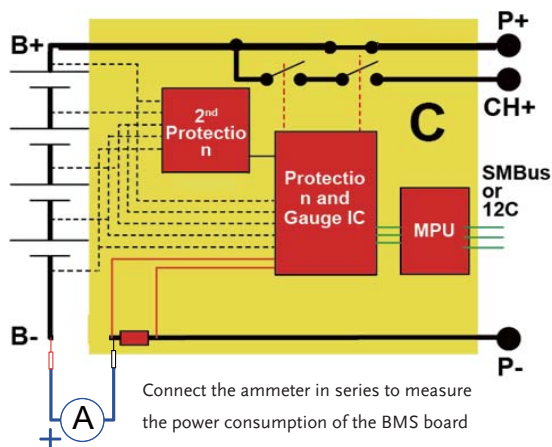


5080 Voltage Regulator to simulate Battery Cell 4 sets of 4 cells



## OC : Power consumption test for the sleep mode

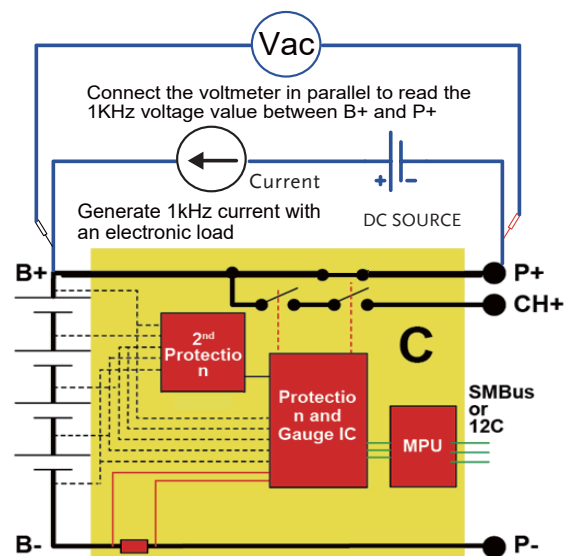
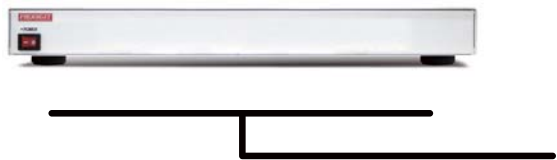
5080 Voltage Regulator to simulate Battery Cell 1~16



## DIR : Discharging circuit impedance test

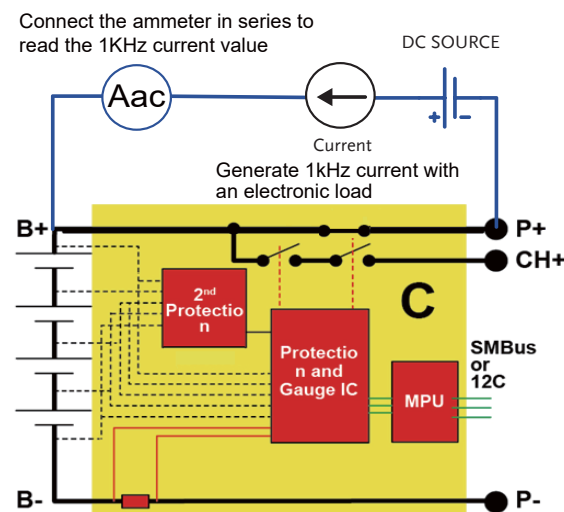
Step 1 ACV Meas.

5080 Voltage Regulator to simulate Battery Cell 1~16



Step 2 ACA Meas.

5080 Voltage Regulator to simulate Battery Cell 1~16

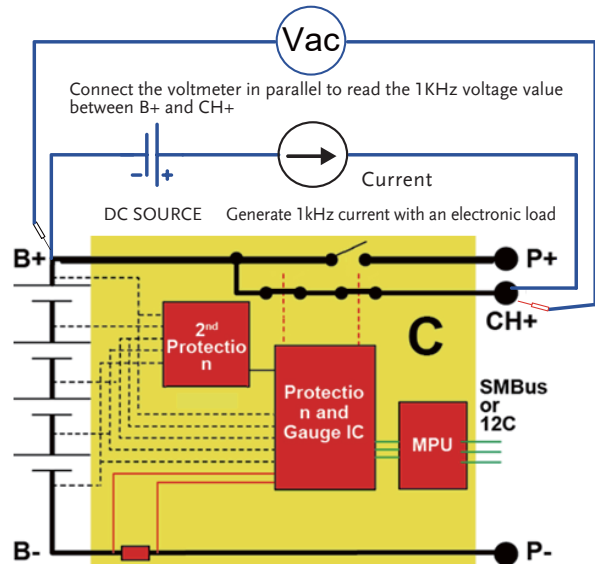
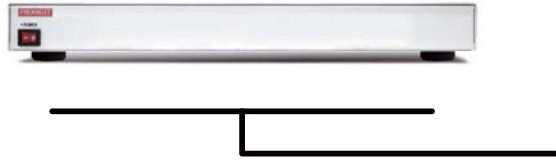


Step 3  $IR = Vac / Aac$  loop impedance = AC voltage reading / AC current reading

## CIR : Charging circuit impedance test

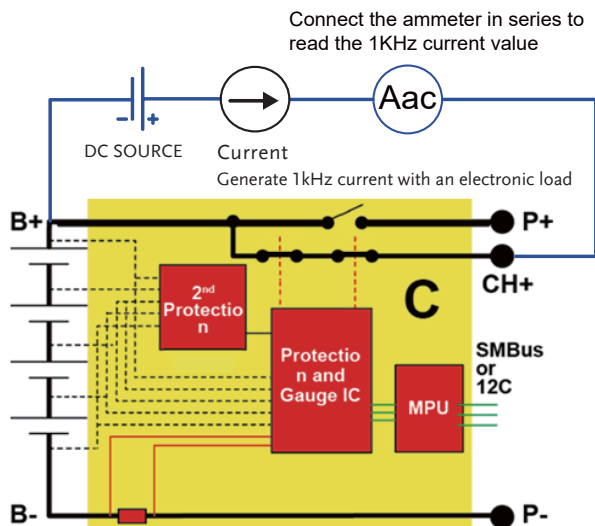
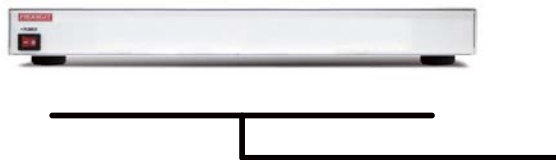
Step 1 ACV Meas.

5080 Voltage Regulator to simulate Battery Cell 1~16



Step 2 ACA Meas.

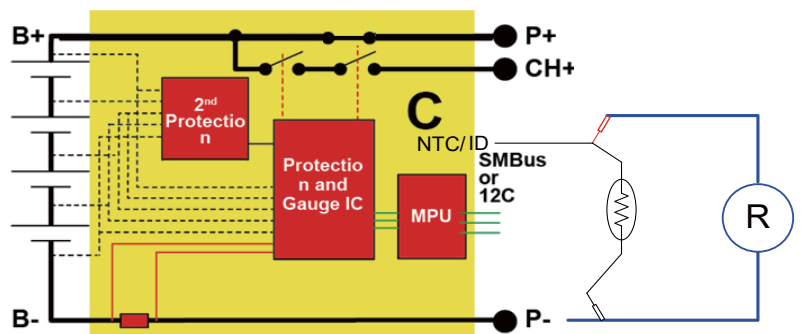
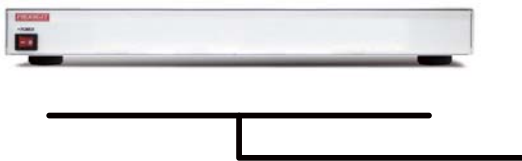
5080 Voltage Regulator to simulate Battery Cell 1~16



Step 3  $IR = V_{ac} / A_{ac}$  loop impedance = AC voltage reading / AC current reading

## NTC : Thermistor Test

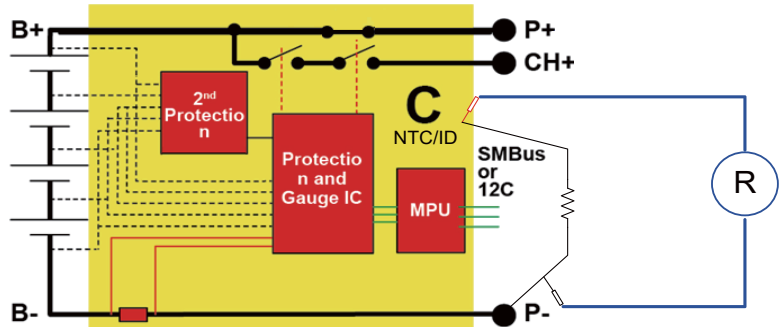
5080 Voltage Regulator to simulate Battery Cell 1~16



Ohmmeter measurement with a multimeter

## NTC : ID identification resistance test

5080 Voltage Regulator to simulate Battery Cell 1-16



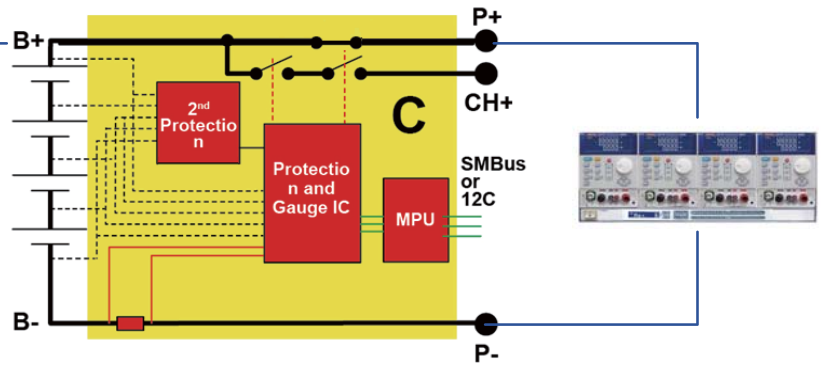
Ohmmeter measurement with a multimeter

## OVD : Discharge voltage with a load/current test

5080 Voltage Regulator to simulate Battery Cell 1-16



PSU Series Power Supplies

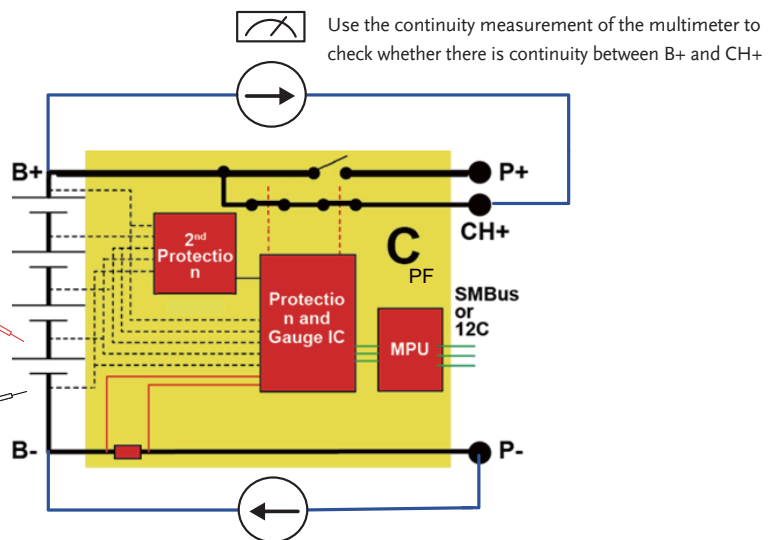


## OVC : Single cell battery overcharge protection recovery test

5080 Voltage Regulator to simulate Battery Cell 1-16



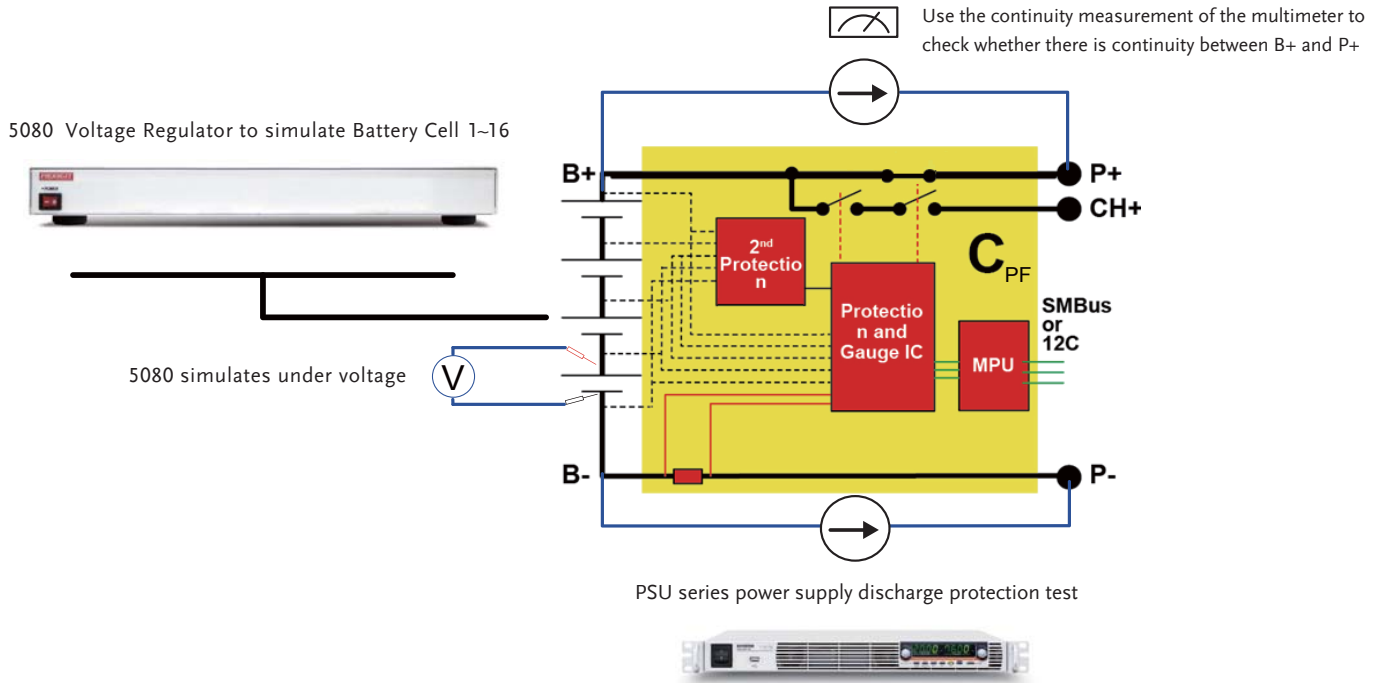
5080 simulates overvoltage



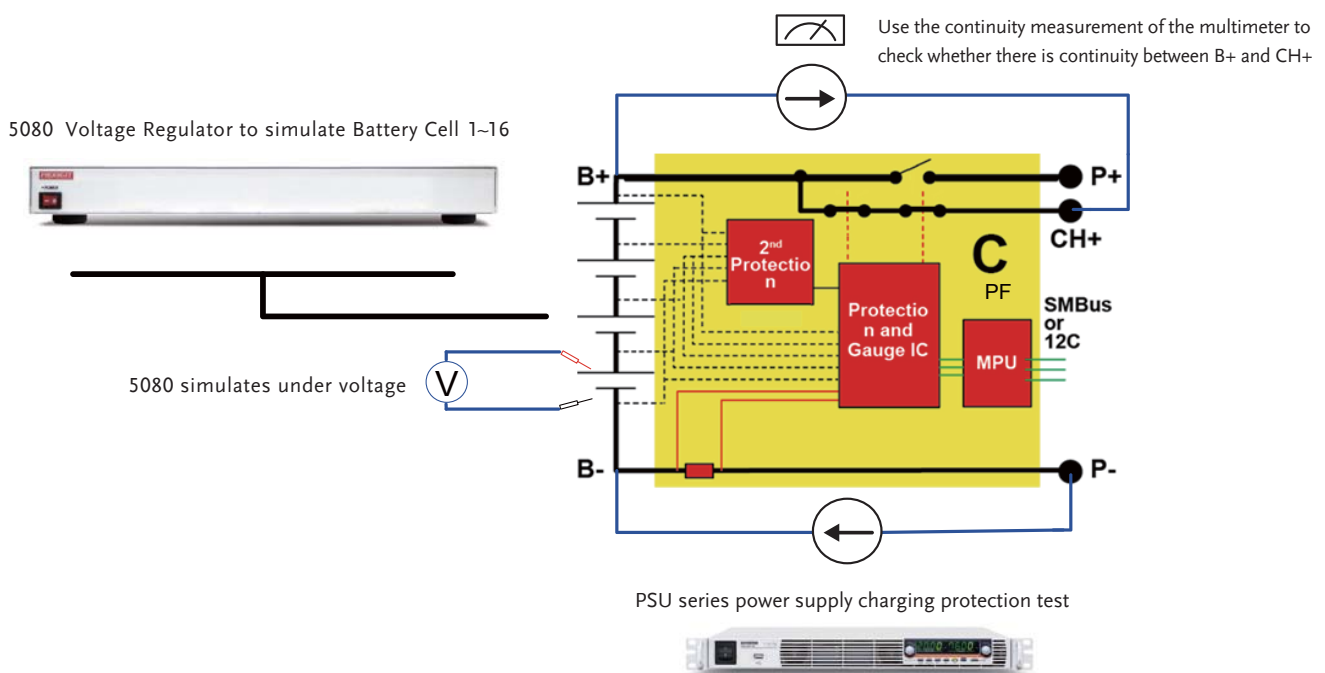
PSU Series Power Supplies



## UVD : Single cell battery over-discharge protection

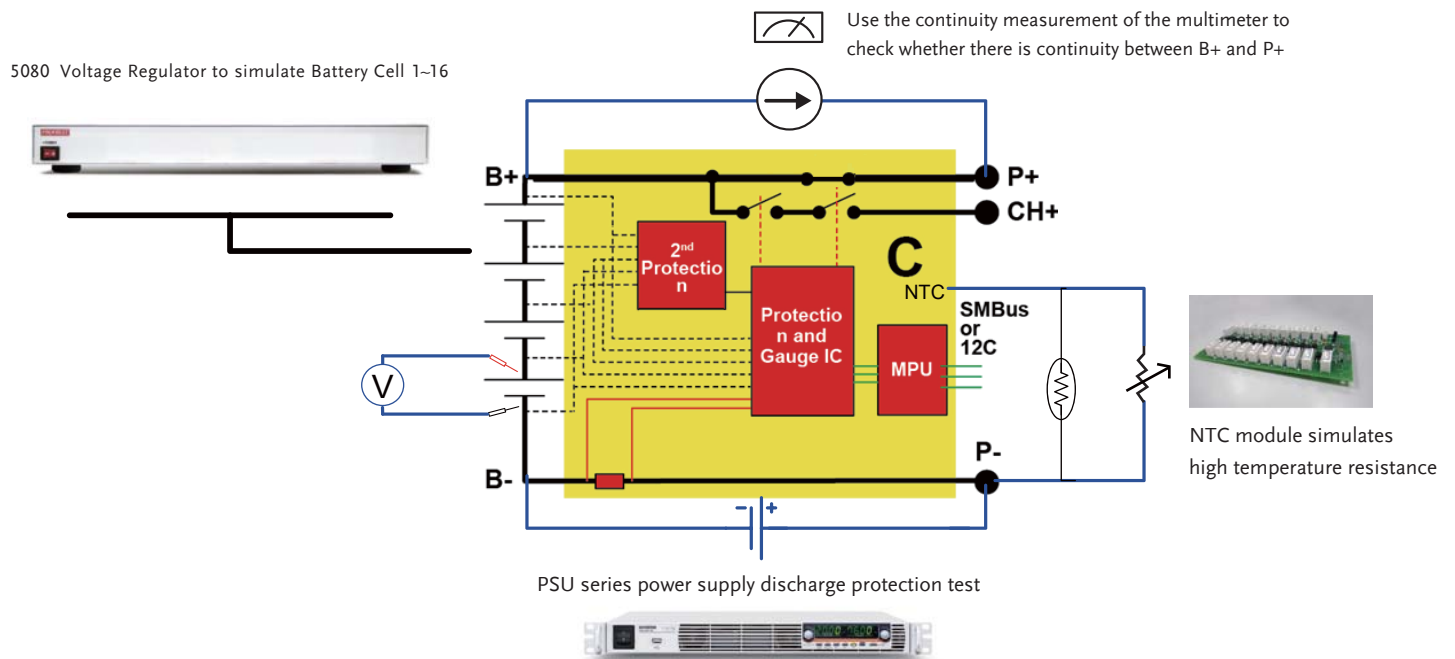
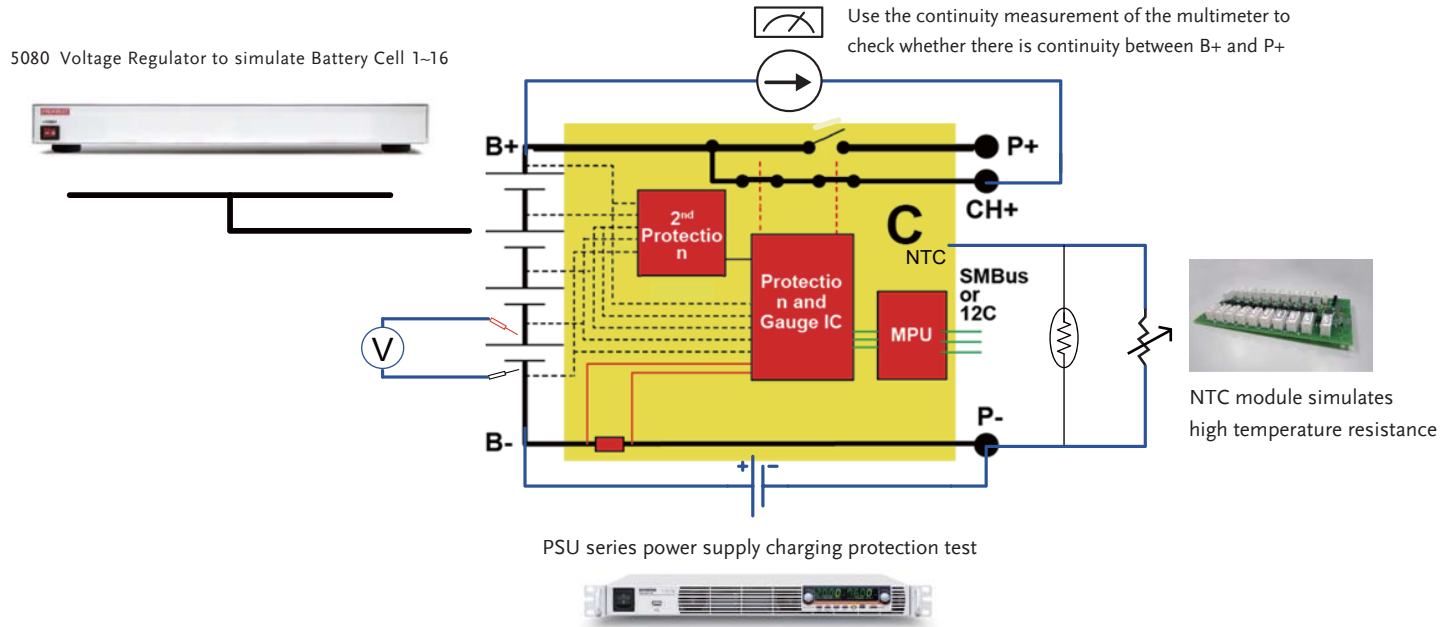


## OVC : Single cell battery overcharge protection recovery test





## OTC : Over-temperature charging protection recovery test

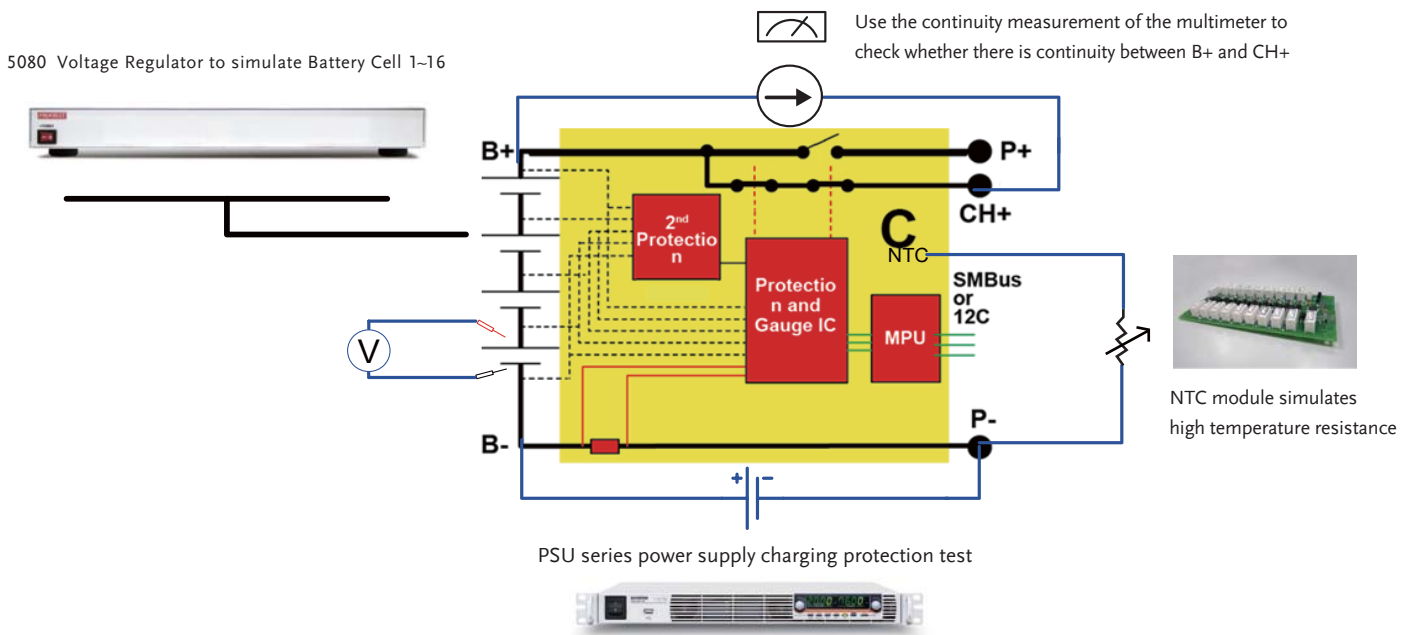


Prodigit developed an NTC simulation resistor for the temperature protection of BMS. Each NTC simulation resistor can simulate a resistance of  $10\Omega\sim 500K\Omega$ . For a  $10K\Omega$  thermistor at  $25^{\circ}C$ , it can simulate  $-40^{\circ}C\sim 120^{\circ}C$  temperature change.

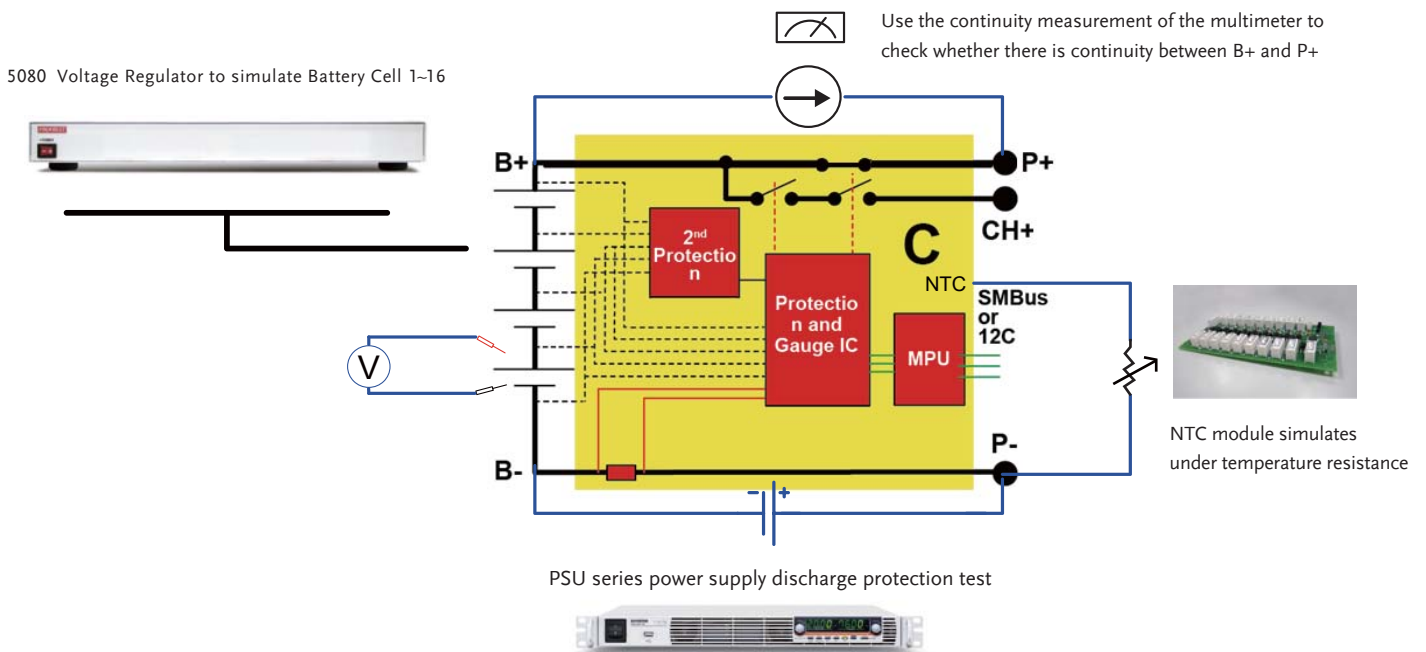
The NTC simulator is installed in the Switch Box of 6020 BMS ATS.

When BMS contains NTC resistors, you can use the NTC simulator of the 6010 system and connect it to the NTC resistor to reduce the resistance value to simulate the charge and discharge protection recovery test when the temperature is too high.

## UTC : Under temperature charging protection recovery test

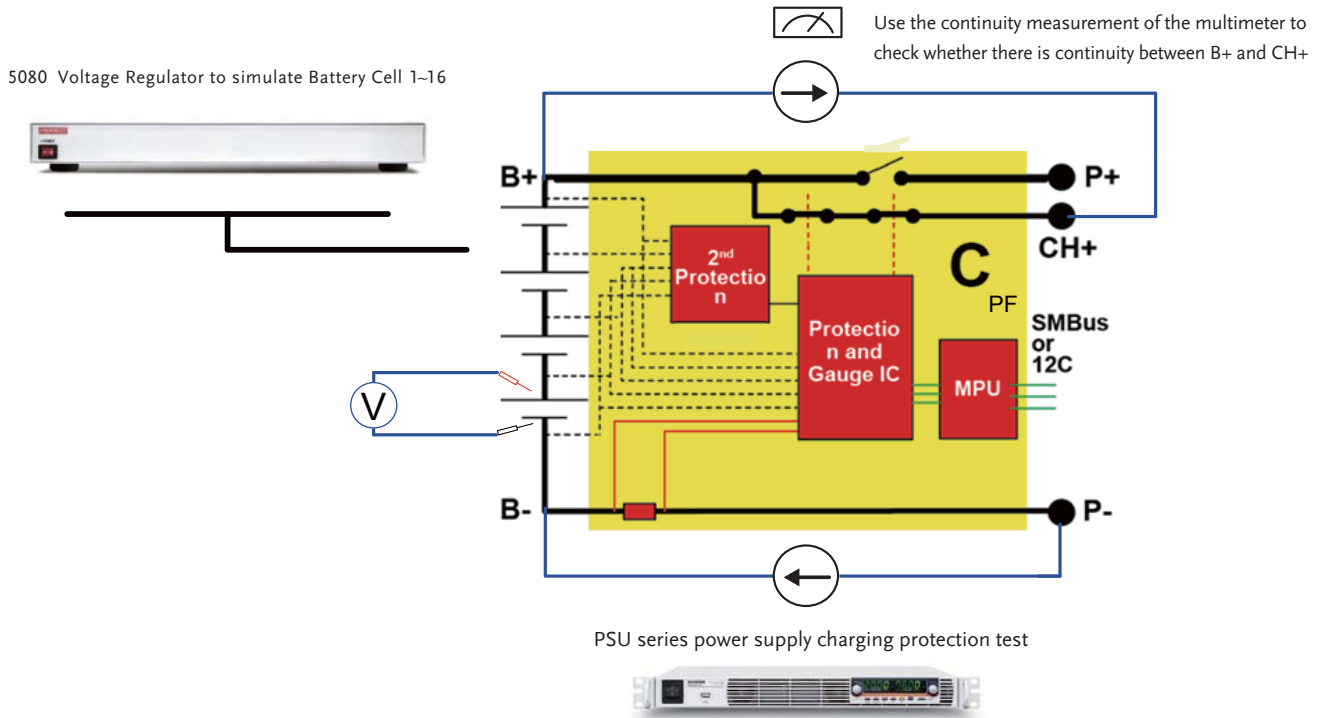


## UTD : Under temperature discharge protection recovery test

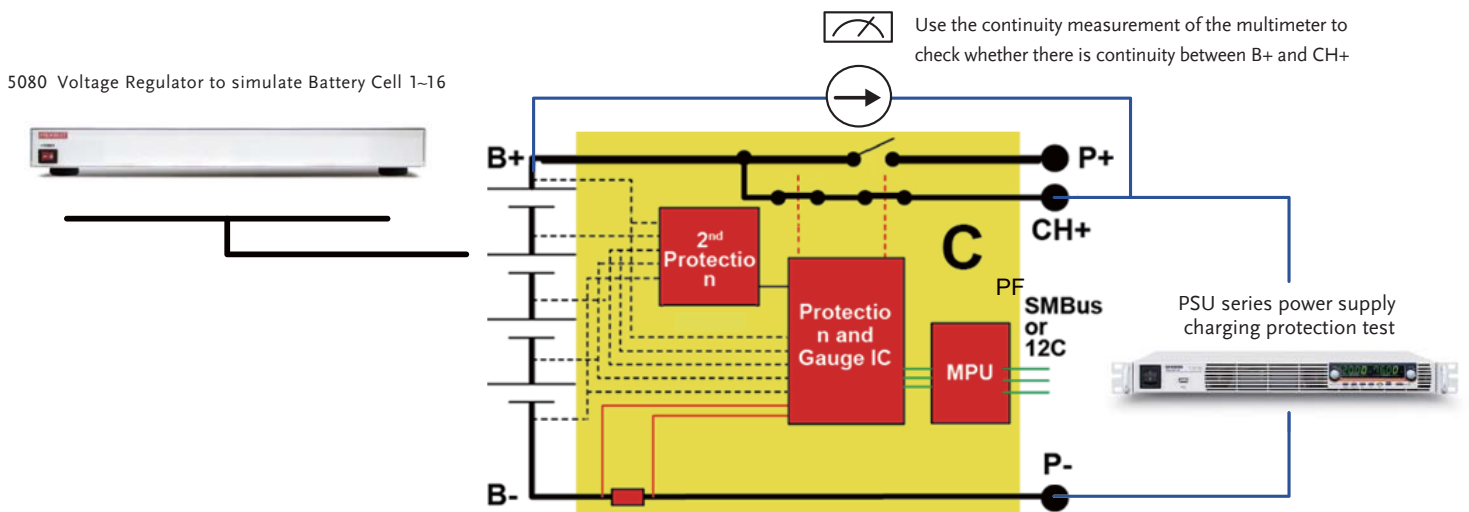


When BMS does not contain an NTC resistor, the NTC simulator of the 6010 system can be used to connect to the pin of the NTC resistor, and the resistance value can be set by the NTC simulator to simulate the charging and discharging protection recovery test under or various temperature conditions.

## COC : Overcharge current protection recovery test

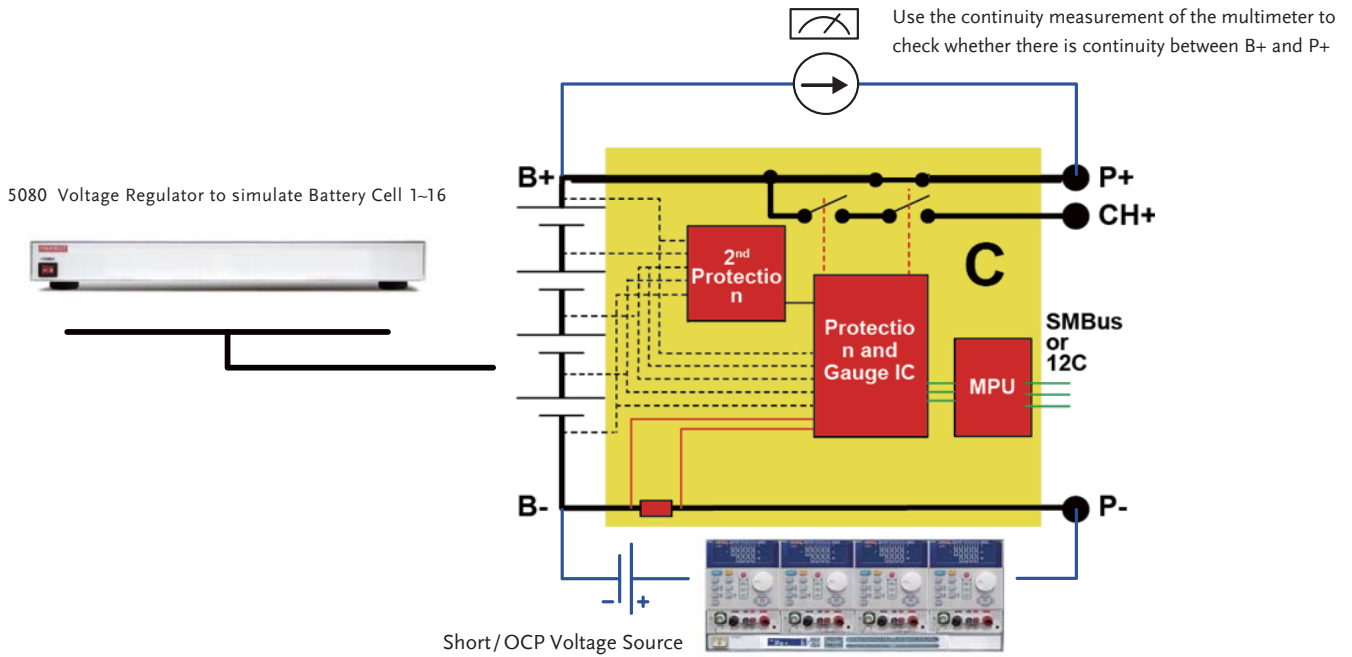


## Pack OVC : Pack overvoltage charging protection recovery test



## OCD : Over discharge current protection recovery test (60A)

## OSD : Discharge short circuit protection recovery test (120A)



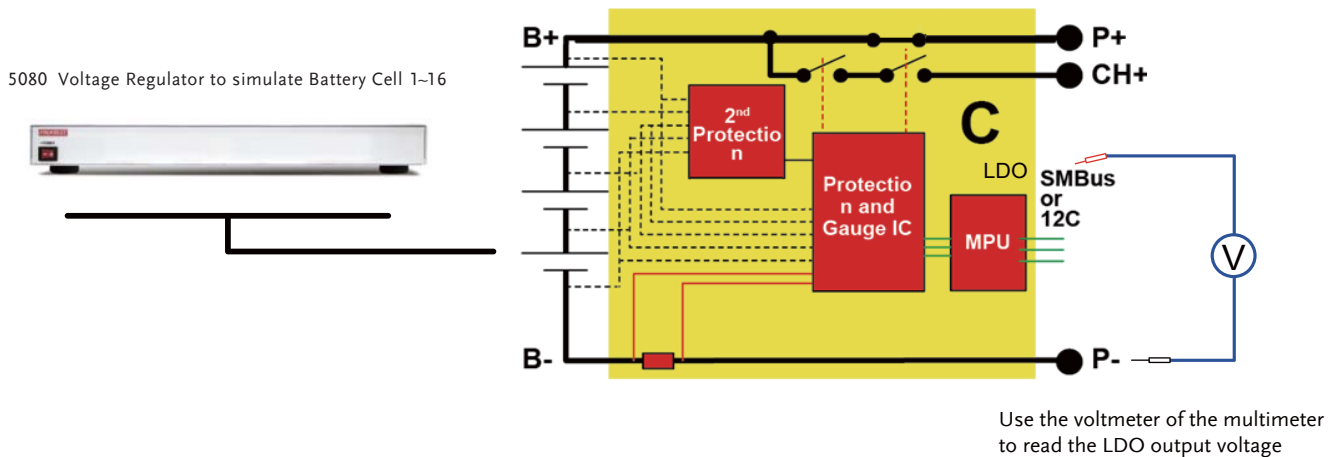
The BMS with the 3311F electronic load option can be used to measure:

The current value and protection action time of the overcurrent protection of the BMS board

The current value and protection action time of the discharge short-circuit protection of the BMS board

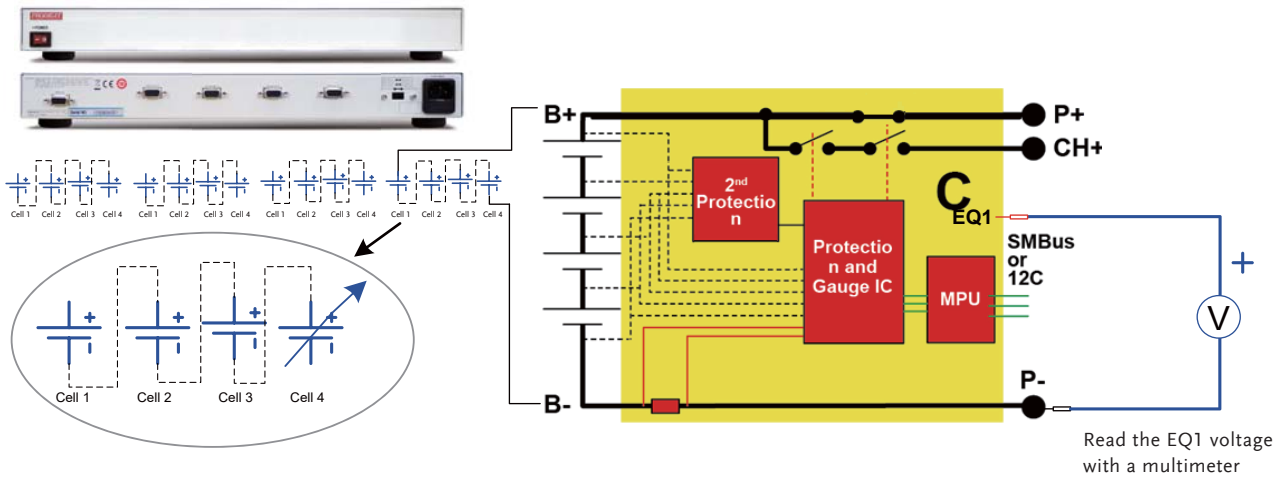
The BMS protection current of 3311F load can be increased from 60A to 120A

## LDO : Testing



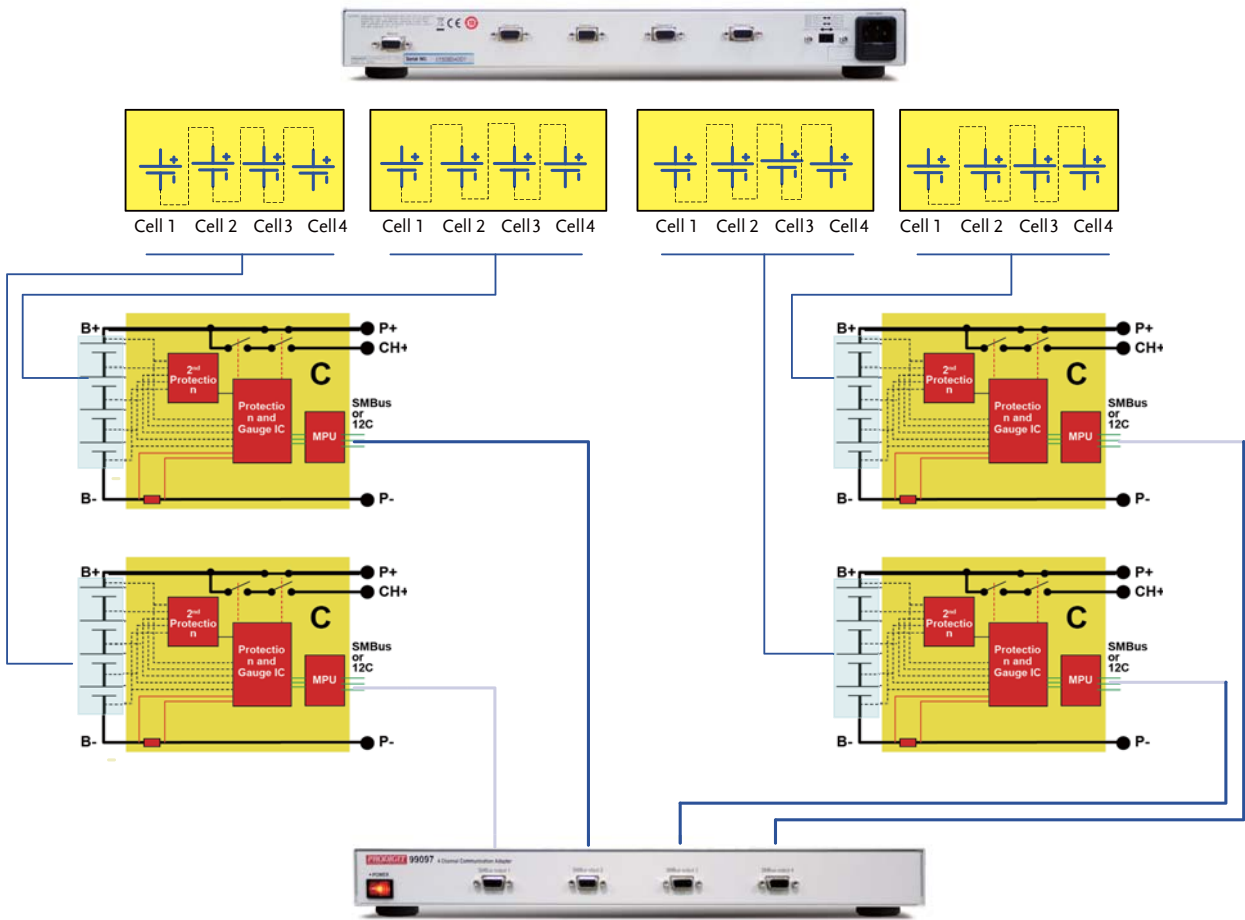
## EQ : Multi-cell battery balancing function test

5080 Voltage Regulator to simulate Battery Cell 1-16



## Burning code calibration can perform 4 sets of BMS board burning code calibrations at the same time

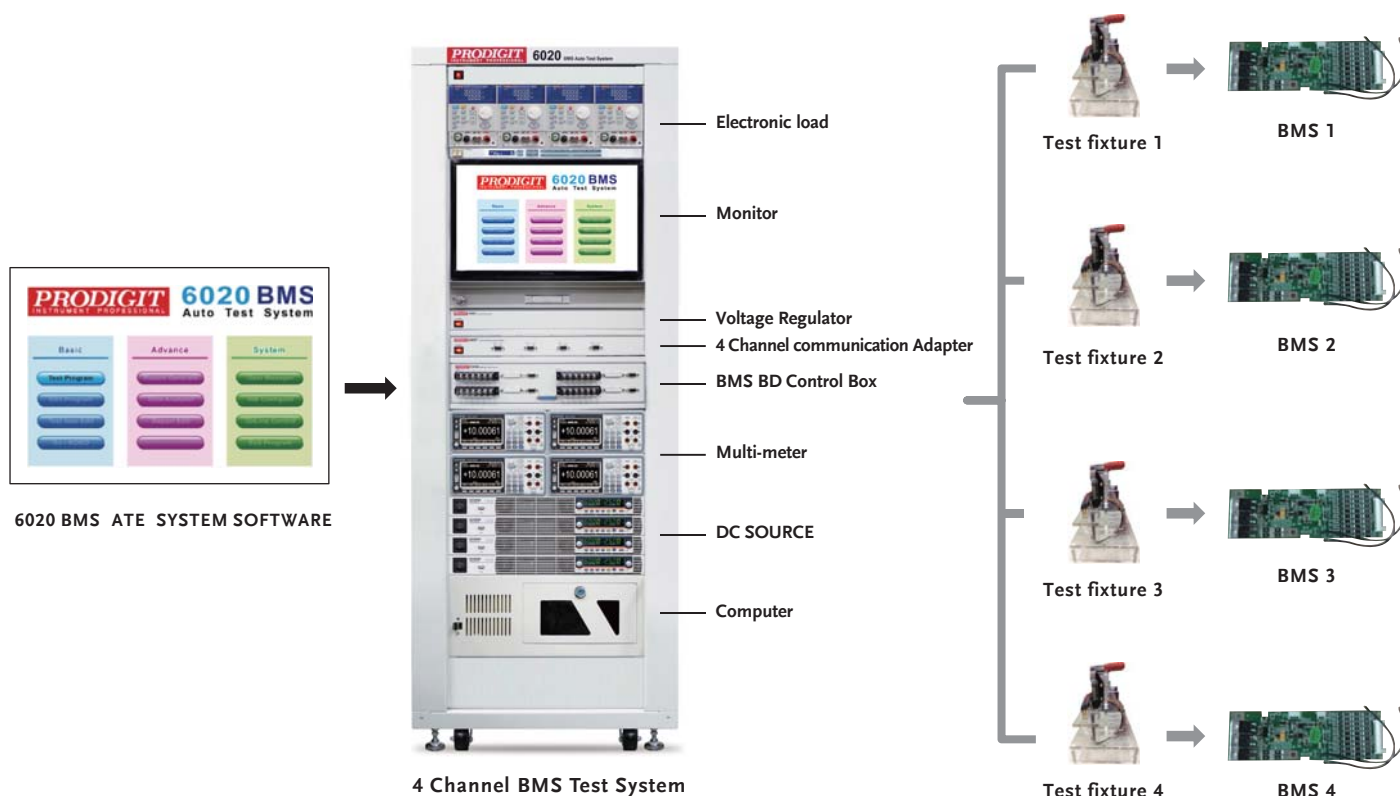
5080 Voltage Regulator to simulate Battery Cell



99097 4 CH. SMBus communications interfaces

99097 4 Channel Communication Adapter has 4 sets of SMBus communications interfaces, which are respectively connected to the SMBus or I2C interfaces of 4 BMS boards. It can write, read, and calibrate BMS boards. All data (.srec files) can be edited, burned into codes, compared, stored, and managed in 6020 BMS ATE. Since 4 sets of codes are burned or read at the same time, it can quickly complete the required actions so as to save a lot of precious time in the production process, and improve production capacity and productivity.

The appearance figure and system configuration are as follows



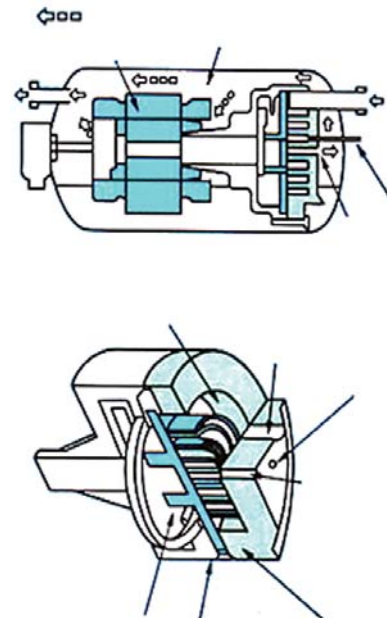
Configuration descriptions for 6020 BMS ATE

- DC electronic load module : 3311F ( 60V / 60A / 300W )**  
 The electronic load is used to simulate various conditions of the load change of the DUT when performing various tests, including discharge OCP, discharge short circuit protection, 1KHz loop current required for charging and discharging loop impedance, so that various tests can be closer to the real situation. The BMS function is included, which can sink up to 120A instantly.
- DC power supply**  
 The 5070 is used to provide the DUT with DC input power for trigger and charging function tests.
- 99096 BMS Board Control Box**  
 Model 99096 is an automatic switching device for various test items developed by Prodigit for BMS. It can be used to test 4 DUTs at the same time to save test time, and can control the output terminal or input terminal to be completely disconnected. An optional NTC module can be used for temperature simulation.
- NTC simulator ( applied to temperature simulation )**  
 The NTC simulator can simulate the change of NTC resistance value and provide a resistance value of 10~500K, which is equivalent to a temperature change of -46 degrees Celsius to +179 degrees Celsius that is similar to a standard resistance box, which is composed of multiple precise resistors and can automatically output the resistance value of the required temperature according to the need. Connecting it to the NTC interface of the charger can simulate whether the electrical appliance can operate according to the design under low or high temperature so as to make the simulation of the DUT faster and more complete. This device needs to be used in combination with 99096.
- 5080 voltage regulator**  
 The 5080 can provide 4 sets of 4 cells or 1 set of 16 cells of 0~5V battery cell simulation voltage at the same time.
- 99097 4 Channel Communication Adapter**  
 Model 99097 4 channel communication adapter is a code burning device developed by Prodigit for BMS, which supports TI battery management chip to control 4 BMS boards at the same time, including data writing and verifying, production date and serial number writing, voltage and current calibration, etc.
- GDM-9061 6½-digit dual measurement digital multi-meter**  
 It is used to measure BMS current consumption, voltage, NTC resistance, and conduct protection function testing.
- Short/OCP Source 5V/100A**  
 It is used to provide a large transient current when BMS conducts testing on Short or OCP.

Note : The above instruments are applicable equipment and are based on actual shipment content.

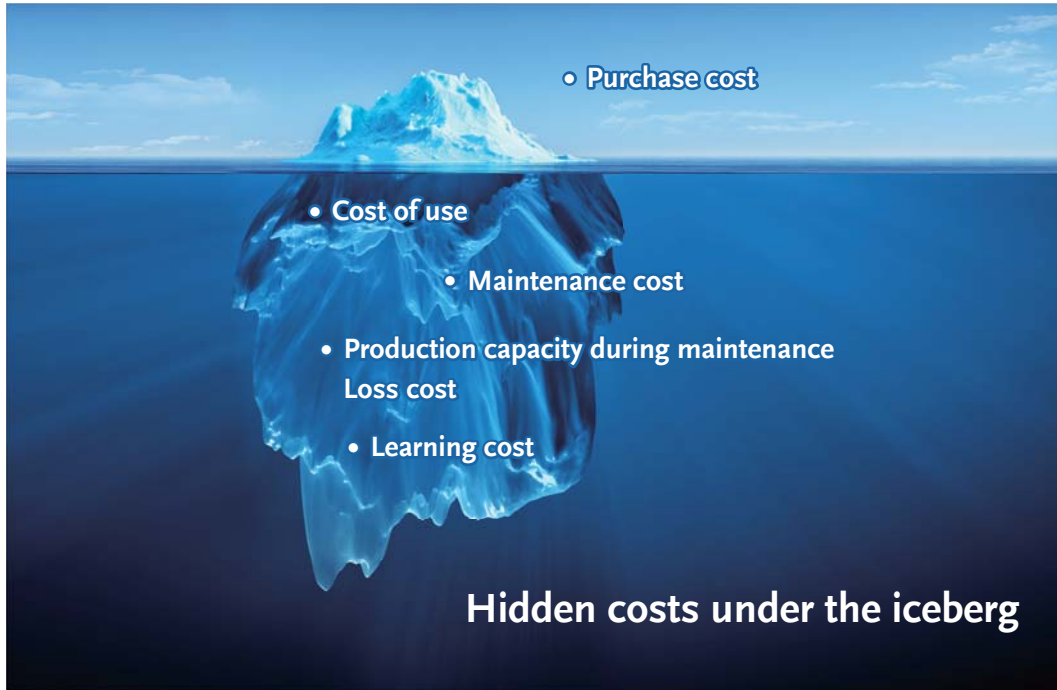


HITACHI



## Advantages of scroll compressors

Item	Scroll	Piston	Screw
<b>Efficiency</b>	<ul style="list-style-type: none"> <li>• Less leakage inside the compressor from high pressure to low pressure, high efficiency</li> <li>• When compressing refrigerant, there is no compression gap</li> </ul>	Compressed refrigerant, there is a compression gap, and the efficiency is low It is easy to leak from the inside of the compressor during high pressure to low pressure	
<b>Reliability</b>	<ul style="list-style-type: none"> <li>• No intake and discharge valves</li> <li>• Using injection cooling compressor</li> <li>• Few internal parts</li> </ul>	Many internal parts	Large number of internal parts
<b>Vibration</b>	<ul style="list-style-type: none"> <li>• During the operation of the compressor, the torque change is small and the vibration is small</li> </ul>	Piston reciprocating motion, large vibrations	During operation, there are torque changes and large vibrations
<b>Noise</b>	<ul style="list-style-type: none"> <li>• No discharge valves, low noise</li> </ul>	There are reciprocating and discharging valve movements, and the noise is relatively large	There are discharging valve movements, and the noise is loud



## Comprehensive cost assessment suggestion Total Cost of Ownership



**Cost of use = electricity fee + space + management**

\* Hitachi constant temperature and constant humidity chambers only utilize one compressor and electronic expansion valves to increase frequency converter efficiency by more than **25%**.

Taking 800 liters as an example, Hitachi only utilizes one 1.5kW compressor, while other manufacturers use a cascade refrigeration structure, requiring two or even three 1.5kW compressors. Hitachi scroll compressors can generally save electricity and only require 1/3 of the electricity fee of other brands.



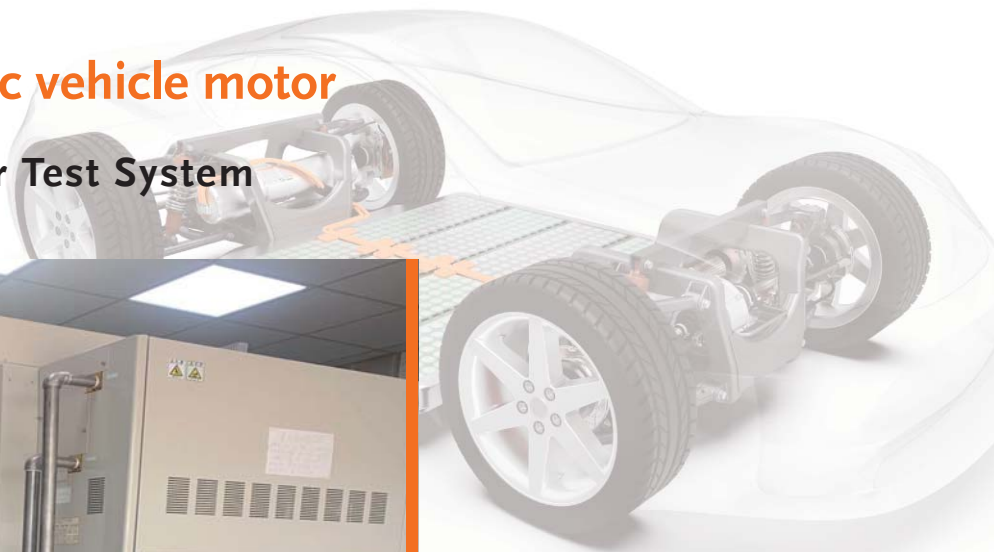
## Recognized by world-renowned brands



The above customer trademarks are owned by the above companies

## Test product: Electric vehicle motor

Tested with AVL Power Test System



- The entire chamber can be moved by the track and a hole is opened on the side to cover the motor to be tested
- Temperature/humidity range : -40 ~ 130°C ; 20 ~ 98%RH
- Doors open front and rear for easy access to install motors
- Preserve original performance while no temperature control is required
- Chamber can be moved



## Power battery test

Both testing and safety must be considered



### Countermeasures against battery fire

Cooling by water injection ; smoke exhaust ; explosion-proof

- The internal positive electrode and negative electrode of the power battery may short-circuit and catch fire under overcharging or low temperature environment, and the fire cannot be extinguished. The safest and most effective way is to inject water to cool down until the energy of the battery is exhausted.
- Water injection may generate hydrogen gas. When injecting water, it will automatically open the smoke exhaust to avoid the accumulation of hydrogen. If it detects the generation of combustible gas, it will alarm and automatically open the smoke exhaust.
- In case of explosion, the roof is equipped with a large area of explosion-proof openings to reduce disasters.



## Explosion-proof power battery energy storage cabinet

Both testing and safety must be considered



## Explosion-proof power battery energy storage cabinet

Cooling by water injection ; smoke exhaust; explosion-proof

- -40~100 degrees
- Fire temperature sensor to activate the automatic sprinkler for cooling
- Smoke detection alarm
- The roof is equipped with a large area of explosion-proof openings to reduce gas explosion damage
- When the alarm is triggered, the upper explosion-proof pressure relief port is automatically opened



# HITACHI

model MT

## Cosmopia C Constant temperature chamber

Cables for measuring instruments can be connected to the left and right sides of the test chamber

Applicable evaluation test system for secondary batteries

( Secondary batteries are often referred to as rechargeable batteries and storage batteries, batteries that can be charged and discharged repeatedly. )

**Test chamber capacity 392L**  
 ( Optional accessories are included in the photo )  
 Cable hole  
 EC-45MTB



Grade	Test chamber capacity ( L )	Temperature control range ( °C )	Test chamber size ( mm )
EC-45MTB	392	-40 ~ +100	(W) 630 x (D) 720 x (H) 900
EC-85MTB	784	-40 ~ +100	(W) 1000 x (D) 800 x (H) 1000

### Model with holes on both sides

The cables for evaluation and testing can be pulled out from the left and right sides arbitrarily, which improves the practicality.

Setting operations using the touch panel



**Standard**

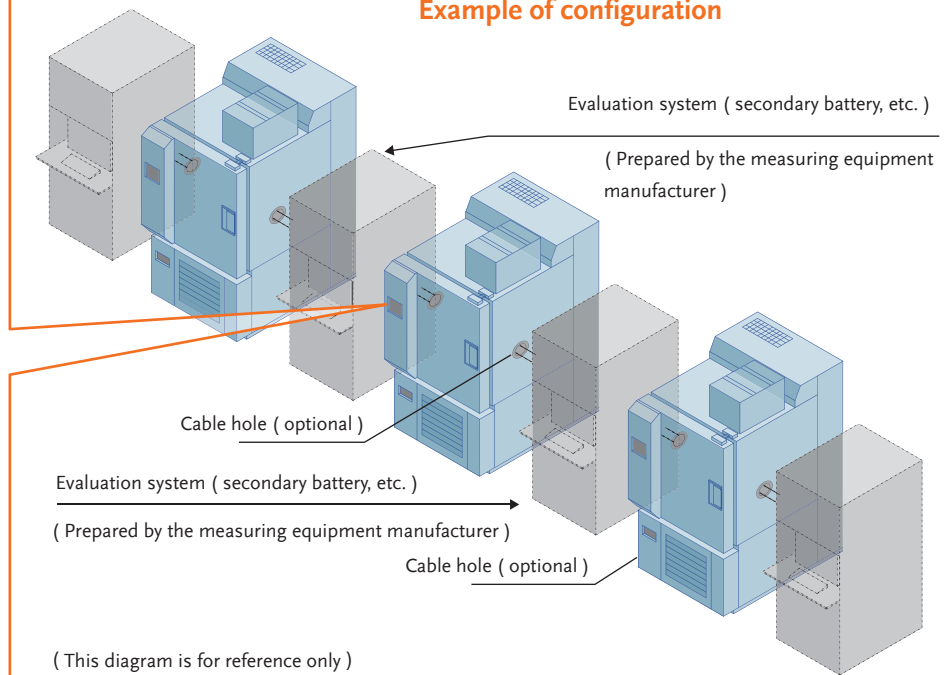
If it is not used in the secondary battery evaluation system, it can also be used for independent constant temperature testing.



**Option**

Optional color touch panel for procedure operations.

### Example of configuration



### Model with holes on both sides

Equipped with the necessary functional configuration of the secondary battery evaluation system

<p><b>Pressure discharge Adjustment baffle</b></p>	<p><b>Stainless steel sheathed heater</b></p>	<p><b>Door lock mechanism</b></p>	<p><b>Emergency stop switch</b></p>	<p><b>Communication interface ( RS-485 )</b></p>
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Note : The cable hole is an optional accessory

## Appendix A

- Anode: The anode represents the electrode where the oxidation reaction occurs. Indicates that this electrode accepts electrons provided by an external circuit.  
When charging, the anode is the negative pole; when discharging, the anode is the positive pole.
- AHC: Ampere hour capacity
- BMS: Battery Management System
- BOL: Beginning-of-Life
- BSF: Battery Size Factor
- Cathode: The cathode represents the electrode where the reduction reaction occurs. Indicates that this electrode provides electrons to the external circuit. When charging, the cathode is positive; when discharging, the cathode is negative.
- Cell: Single battery
- C Rate: Capacity rate, the battery charge or discharge current divided by the total capacity of the battery
- DOD: Depth-of-Discharge
- Electrode: The electrodes include positive electrodes and negative electrodes.
- Electrolyte: The electrolyte, between the positive and negative electrodes, provides the necessary ionic conductivity for the positive and negative electrodes.
- EIS: EIS Electrochemical Impedance Spectroscopy
- EOL: End-of-Life
- EV: Electric Vehicle
- Formation: Formation, after the battery is made, it needs to be activated. The activation method is the process of activating its internal positive and negative active materials through a certain charge and discharge method to improve the comprehensive performance of the battery such as charge and discharge performance, self-discharge and storage. Only after the battery is formed can it reflect its true performance. At the same time, the sorting process in the formation process can improve its consistency when it is integrated into a battery pack, so that the performance of the final battery pack can be improved.
- FreedomCAR: Freedom Cooperative Automotive Research
- HPPC: Hybrid Pulse Power Characterization
- OCV: Open-Circuit Voltage. The voltage of the battery when no external circuit (load) is connected
- PNGV: Partnership for a New Generation of Vehicles
- RPT: Reference Performance Test
- Separator: It is a non-conductor that can only pass necessary ions, and can avoid short circuits inside the positive and negative electrodes.
- SOC: State of Charge
- SOH: State of Health
- USABC: United States Advanced Battery Consortium
- W
- Wh: Battery energy, which is used to indicate the electrical energy that a battery can store. Watt-hour
- Wh/kg: Mass energy density, the amount of electrical energy a battery can store per unit mass
- Wh/L: Volumetric energy density, the amount of electrical energy a battery can store per unit volume

## Appendix B: Battery Related Standards

- IEC 61982-1:2006, Secondary batteries for propulsion of electric road vehicles-Part 1:Test parameters
- CNS15369-1:Secondary battery packs for electric vehicle propulsion - Part 1: Test parameters (September 2010)
- IEC 61982-2:2002, Secondary batteries for propulsion of electric road vehicles-Part 2:Dynamic discharge performance test and dynamic endurance test
- CNS15369-2:Secondary battery packs for electric vehicle propulsion - Part 2: Dynamic discharge performance test and dynamic durability test (September 2010)
- IEC 61982-3:2001, Secondary batteries for propulsion of electric road vehicles-Part 3:Performance and life testing (traffic compatible, urban use vehicles)
- CNS15369-3:Secondary battery packs for electric vehicle propulsion - Part 3: Performance and life cycle tests for urban transport vehicles ( September 2010 )
- IEC 62660-1:2010, Secondary lithium-ion cells for the propulsion of electric road vehicles-Part 1:Performance testing
- CNS15391-1:Secondary battery packs for electric vehicle propulsion - Part 1: Performance testing of a single lithium-ion cell ( September 2010 )
- IEC 62660-2:2010, Secondary lithium-ion cells for the propulsion of electric road vehicles- Part 2:Reliability and abuse testing
- CNS15391-2:Secondary battery packs for electric vehicle propulsion - Part 1: Reliability and abnormal use effect tests of a single lithium-ion cell (September 2010)
- IEC 63056:2020 Secondary cells and batteries containing alkaline or other non-acid electrolytes- Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems
- CNS63056:2021 Secondary batteries and battery packs containing alkaline or other non-acid electrolytes - safety requirements for a single secondary lithium cell and battery packs used in electric energy storage systems ( single batteries and battery systems should meet the safety requirements of the test in CNS 62619 )
- IEC 63057:2020 Secondary cells and batteries containing alkaline or other non-acid electrolytes- Safety requirements for secondary lithium batteries for use in road vehicles not for the propulsion
- CNS63057:2021 Secondary batteries and battery packs containing alkaline or other non-acid electrolytes - safety requirements for secondary lithium batteries used in road vehicles other than propulsion

### References:

<https://www.jecst.org/journal/view.php?doi=10.33961/jecst.2019.00528>

IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 23, NO. 2, JUNE 2008 An Improved Battery Characterization Method Using a Two-Pulse Load Test Martin Coleman, William Gerard Hurley, Fellow, IEEE, and Chin Kwan Lee

Domestic and foreign standards

<https://news.yiche.com/hao/wenzhang/33658110>

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