

Temperature Profiling a Battery During Charging and Discharging Using a DAQ

DAQ techniques

Charge and discharge currents increase the temperature of batteries. And, temperature directly affects the lifespan and storage capacity of batteries. Batteries tend to be efficient and have a normal life span at room temperatures. However, when batteries are subjected to hot or cold temperatures, their lifespan is greatly reduced.

At extreme temperatures, batteries can even break down. The breakdown typically happens in several stages: leakage, smoke, fire and explosion. It's important to perform abuse tests to determine the temperatures present for each of the stages of breakdown. Knowing the temperatures for each breakdown stage tell you how close you are to experiencing issues and allows you to manage your device accordingly.

When batteries fail spectacularly (smoke and fire) it is typically due to a short causing a rapid discharge and greatly increased heat. So newer batteries have an extra protection that acts as a fuse to avoid an external short circuit.

Lithium-ion (Li-ion) based batteries are very popular as they can hold a lot of energy in a small package and be quickly charged and discharged. Lithium-ion battery cells come in standard or custom configurations. Standard configurations are cylindrical with standard diameters and lengths. Custom configurations are designed to fit into compact devices such as mobile phones and tablets.

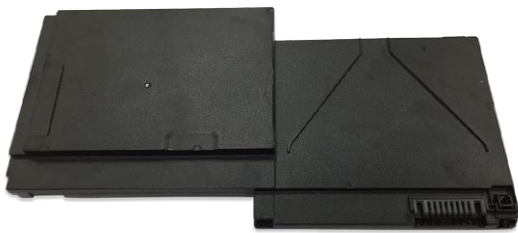
Combine the latest precision of the DAQ970A / DAQ973A multi- channel Data Acquisition (DAQ) system with the BenchVue programming capability to get:

- Fast reading measurements scan rates up to 450 channels/sec
- Ability to measure high voltages up to 300 Volts
- Ability to measure wide temperature range from -200 °C to 1800 °C
- Speed your development process by providing test automation without programming

Learn more by downloading the DAQ970A / DAQ973A Data Sheet, [5992-3168EN](#).

Here are some examples of Li-ion configurations:

- Most mobile devices: 1 serial cell by 1 parallel cell (1s X 1p)
- Tablet devices: 1s X 2p, 1s X 3p
- Notebook and laptop PCs: 2s X 2p, 2s X 3p
- Driving electric motors, power tools, lighting, electric vehicles, hybrid electric vehicles, and so on: multiple serial x multiple parallel



Flat multi-cell Li-ion battery pack for laptops



Li-ion battery pack for power tools



Standard 18650 single cell Li-ion used in battery packs.
The bump at the end of the teal battery provides added electrical protection against rapid current draw



Flat single cell Li-ion battery for mobile phones

Temperature Profiling Setup for Battery Charging

Instrument 1: A DAQ instrument

Monitoring and measuring simultaneously across multiple points is necessary for accurate and effective temperature characterization during a battery performance test. A data acquisition (DAQ) instrument can be used, such as the Keysight DAQ970A / DAQ973A DAQ data logger switch unit with the DAQM901A general-purpose multiplexer card, which has the capability to measure temperature, current, voltage and frequency. You'll also need a common J-type thermocouple sensor at least 2-feet in length, and a pair of wires to measure voltage across the Li-ion battery.

The diagram in Figure 1 illustrates the simple setup and connection to the DUT, PC and power supply.

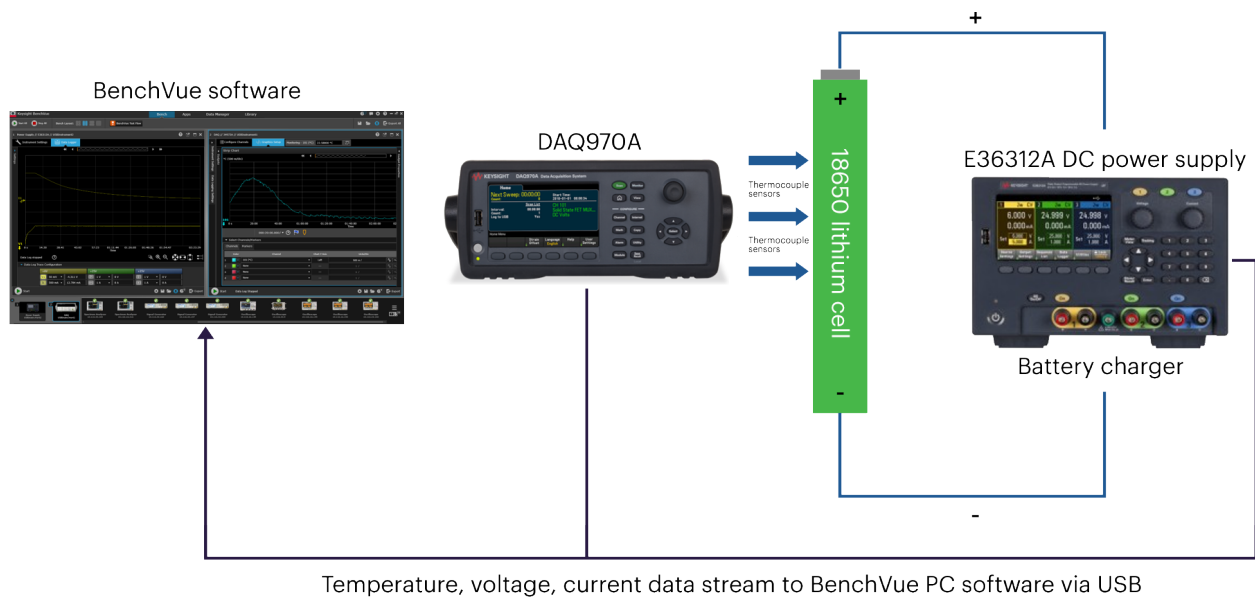


Figure 1. Temperature profiling of the Li-ion battery while charging, using the Keysight DAQ970A, E36312A DC Power Supply and BenchVue software.

Instrument 2: A DC power supply

Depending on the Li-ion battery charging characteristic, you need to use a DC power supply with sufficient voltage and current coverage to charge the device-under-test (DUT), in this case, the battery. In our test setup, we used the Keysight E36312A Programmable DC Power Supply because of its broad current range and ability to log current data down to 1 mA.

For the setup, be sure to set the current limit anywhere between half and the maximum charging rate (0.5 C -1 C). Set the voltage limit to the acceptable final float charge voltage level. As the battery DUT charges, the constant current will automatically transition to constant voltage once the set voltage level is reached. The charge current will automatically taper down as the battery continues to get more saturated with charge. Charge termination takes place when the charge current drops to about 3% of the full charge current value.

See Figure 2 for the Li-ion battery DUT charging characteristics.

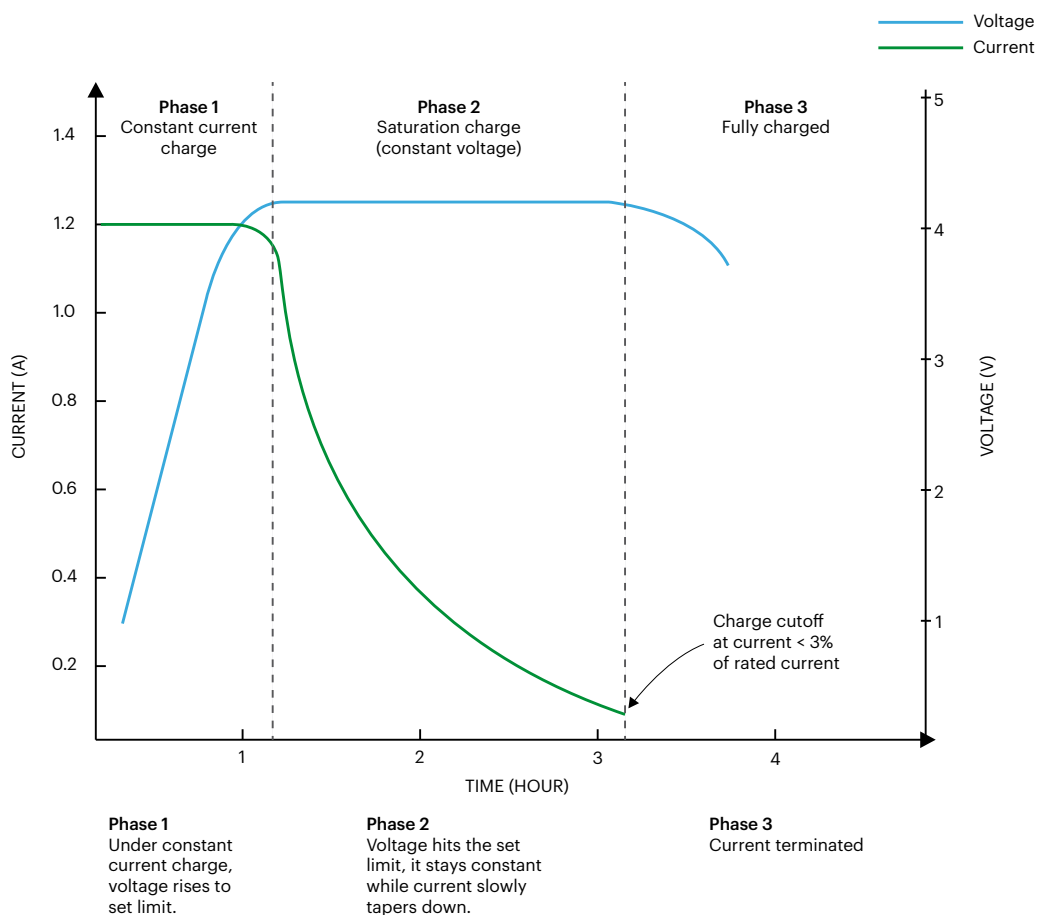


Figure 2. Lithium-ion battery charging characteristics.

What is a battery charging rate symbolized by "C"?

- C is charge rate (also discharge rate). It is measured in Ah per hour
- C is a measure of the rate at which a battery is charge/discharged relative to its maximum capacity
- 14 Ah cell charged at 1 C means it is charged with current of 14 A

Recording and Data Analysis Software

You may want to monitor and record measurement data, real time, for future analysis. Traditionally, this meant writing a program from scratch. Keysight made this easier with applications like the Keysight BenchVue software. In fact, BenchVue does more than ease data logging and visualization of measurements. In addition to its simple point-and-click usage for multiple instrument controls, BenchVue also automatically detects instruments connected to your PC and launches the respective instrument apps. With BenchVue, there is no need for programming and you can easily build your own automated tests with the Test Flow feature.

You will need the following BenchVue instrument apps for profiling temperature while the battery is charging:

BenchVue DAQ app

The BenchVue Data Acquisition Control and Analysis App (BenchVue DAQ app) and a J-type thermocouple can be used to measure the temperature of the battery. Simply connect the J-type thermocouple to the DAQM901A multiplexer card. For the purposes of this example, the multiplexer card is in slot 1, and the measurement channel is 101. Open the BenchVue DAQ app and configure channel 101 to measure temperature using a J-type thermocouple. A single temperature point should be sufficient for measurements on a single cell battery. A complex battery packaging may require measurements over multiple temperature points.

Next, set another channel for DC voltage measurement across the battery DUT. Figure 3 shows the channel configurations on the BenchVue DAQ app.

BenchVue Power Supply app

The BenchVue Power Supply Control and Automation App can be used to set the voltage to the maximum charging voltage of the Lithium-ion cell, in this case, 4.2 V, and the current at 1.2 A limit (approximately 0.5 C). Figure 4 shows the channel configuration on the BenchVue Power Supply app.

Channel			Measurement				Scaling (Mx + B)			Alarm Limits					
Scan	Number	Name	Function	Range	Res	More	Scale	Gain (M)	Offset (B)	Units	Test	Low	High	HW Alarm	More
34901A:20-Channel Armature Multiplexer															
<input checked="" type="checkbox"/>	101	Temp (Type J)	None	C	...		1	0	C	Off	0	0	Alarm 1	...	
<input checked="" type="checkbox"/>	102	DC Voltage	+/- 10 V	5.5	...		1	0	Vdc	Off	0	0	Alarm 1	...	
<input checked="" type="checkbox"/>	103	DC Voltage	Auto	5.5	...		1	0	Vdc	Off	0	0	Alarm 1	...	
<input type="checkbox"/>	104	DC Voltage	Auto	5.5	...		1	0	Vdc	Off	0	0	Alarm 1	...	
<input type="checkbox"/>	105	DC Voltage	Auto	5.5	...		1	0	Vdc	Off	0	0	Alarm 1	...	
<input type="checkbox"/>	106	DC Voltage	Auto	5.5	...		1	0	Vdc	Off	0	0	Alarm 1	...	

Figure 3. BenchVue DAQ app channel configuration.

+6V CC On

Measure (V): **4.090 V** Measure (I): **1.200 A**

Voltage Setting: Current Limit:

Voltage Range: Current Range:

Show Advanced Options

Enable OVP Enable OCP

Log voltage Log current

Figure 4. BenchVue Power Supply app channel configuration.

Temperature Profiling Setup for Battery Discharging

Instrument 1: A DAQ instrument

As with the battery charging setup, we recommend a DAQ instrument for battery discharging. In this exercise, we will use the same Keysight DAQ970A / DAQ973A DAQ/Data Logger Switch Unit with the DAQM901A general-purpose multiplexer card, J-type thermocouple sensors and wires across the Li-ion battery.

Figure 5 illustrates the simple setup and connection to the DUT, PC, DAQ and electronic load.

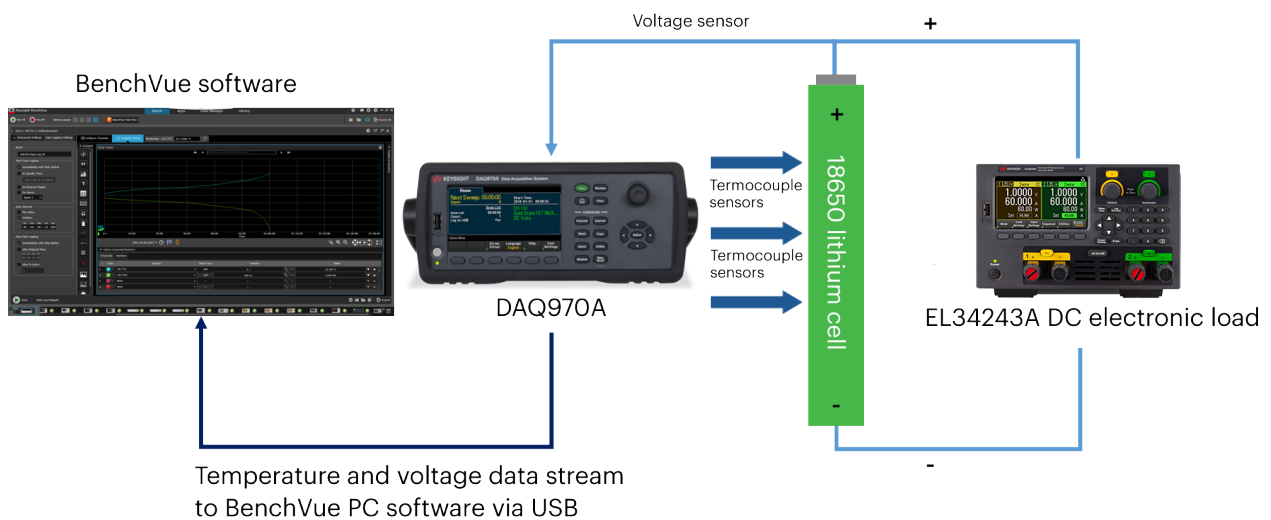


Figure 5. Temperature profiling while battery is discharging, using the Keysight DAQ970A, EL34243A DC Electronic Load and BenchVue software.

Instrument 2: A DC electronic load

The electronic load functions as a battery discharger for the DUT, simulating real applications that can drain battery power. Set the mode to constant current at 0.5 C (half of the full charge rate per hour).

You need to be aware of the end of discharge voltage, 3.0 V in this case. Beyond the 3.0 V cutoff, the voltage rolls off very quickly.

Software: A data logging application

As with profiling temperature for battery charging, applications that aid data recording and visualization are a tremendous help in reducing program development and test times. We recommend the same Keysight BenchVue software because of its useful features and ease of use. You will need the following BenchVue instrument apps for profiling temperature while the battery DUT is discharging:

BenchVue DAQ app

Utilize the same setup as shown for profiling temperature on a charging battery as shown on Figure 3.

BenchVue Electronic Load app

The BenchVue Electronic Load Control & Automation App can be used to set the EL34243A as a constant current load at 1.2 A (approximately 0.5C). Figure 6 shows the channel configuration on the BenchVue Electronic Load app.



Figure 6. BenchVue Electronic Load app configuration.

Analyzing the Results: Temperature Profile of Battery While Charging and Discharging

With BenchVue's intuitive graphical user interface (GUI) and various graphical visualization options – including strip charts, XY charts, histograms and more – you can quickly validate your tests and further troubleshoot or test the next DUT. Where reporting is necessary, you can also export measurement data and screen images easily with just a few clicks.

Figure 7 shows two strip chart results with BenchVue. On the left is the current and voltage profiles, as data logged with the E36312A DC Power Supply. On the right is the temperature profile of the battery while charging, as recorded with the DAQ970A DAQ/Data Logger Switch Unit.

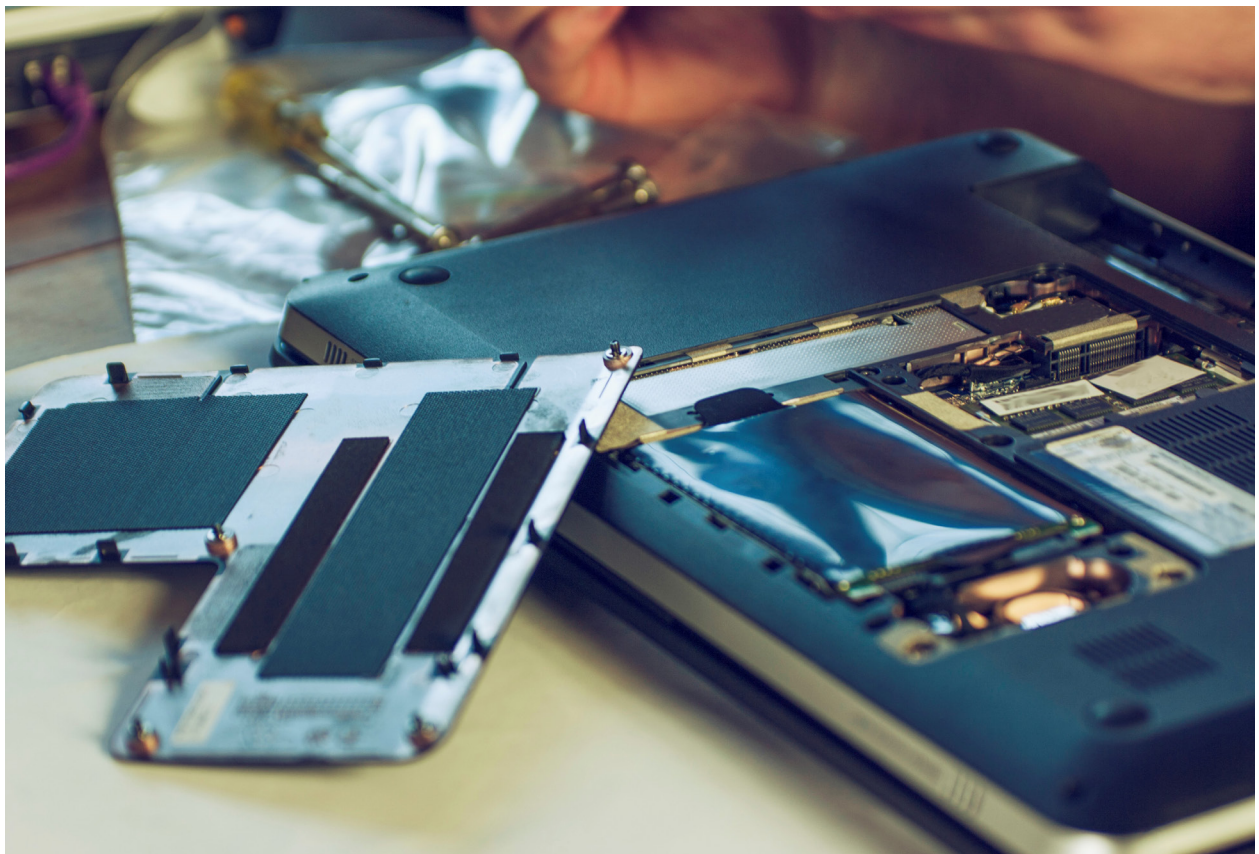




Figure 7. Temperature, voltage and current profiles shown in strip chart format on the BenchVue software while battery is charging.

Figure 8 shows the battery temperature and voltage across it while discharging, as data logged with the DAQ970A DAQ/Data Logger Switch Unit.

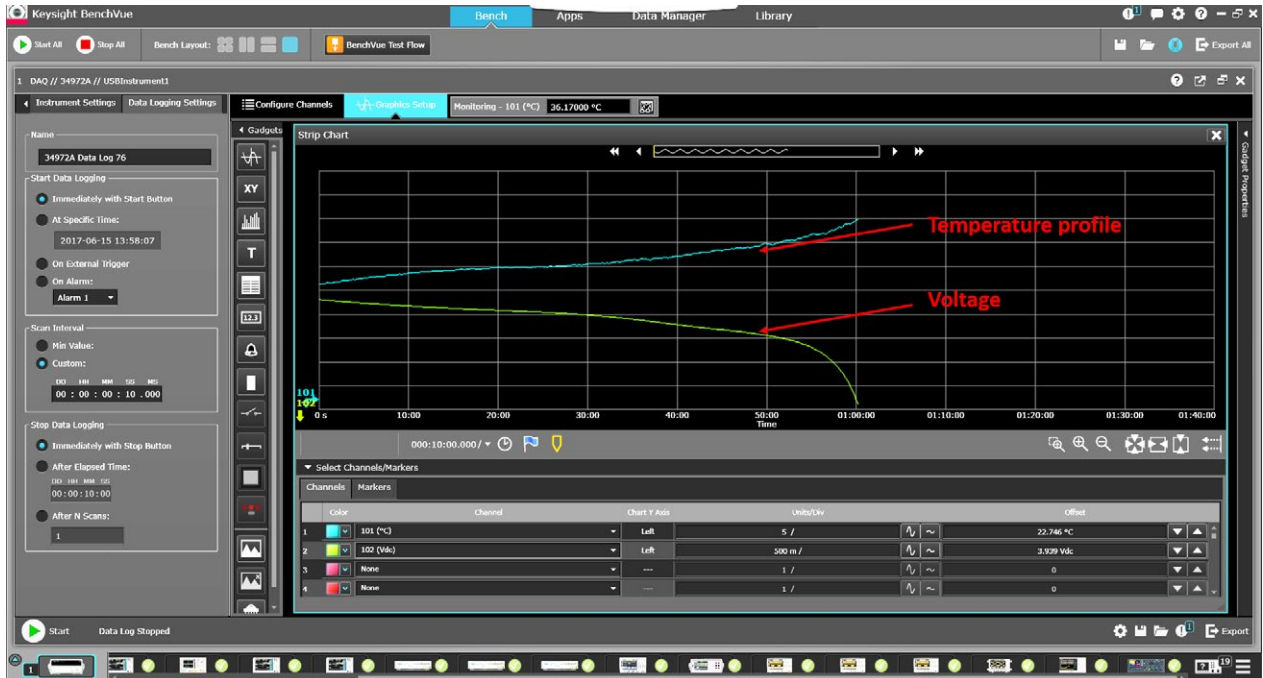


Figure 8. Temperature and voltage profiles shown in strip chart format on the BenchVue software while battery is discharging

Other Related Tests

We've covered the basics on how you can easily characterize temperature during a battery performance test using just a handful of instruments with sufficient specifications that meet your test requirement. The DAQ instrument can be a scalable investment beyond the application we've covered, as you can see in the table below.

Scalability needs	Keysight DAQ970A DAQ/Data Logger Switch Unit Features and Module/Card Specifications
Number of temperature test points	The DAQ mainframe has 3 slots. Each slot can take up to 40 test points.
Data logging scanning speed	The DAQM900A multiplexer input card can scan up to 450 channels per second, with 20 channels per card. The DAQM908A multiplexer input card can scan up to 100 channels per second with 40 channels per card.
Universal inputs	The DAQ and its modules/cards have incredible flexibility to measure across various input types including temperature (supports 8 types of thermocouples, 2/4 wire RTD, Thermistor), AC/DC voltage, AC/DC current, 2/4-wire Ohm, Frequency and Period.
Switches	Besides the scanning multiplexer cards, this general purpose DAQ has switching features for more complex test solutions. The DAQM903A card has 20 channel actuator/general-purpose switch.
High voltage depending on usage	The multiplexer input cards and switching cards can measure a maximum voltage of 300 V.