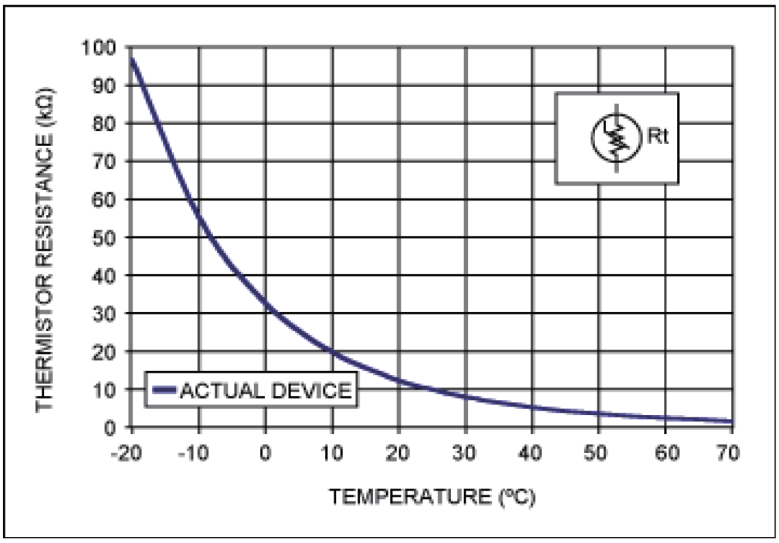
DC Electronic Loads simulate NTC devices for temperature monitoring in battery test applications

This application note discusses the use of programmable DC loads to simulate temperature sensors used in battery management systems.

Li-ion batteries are widely used in hand-held device such as notebook computers, mobile phones and tablets as well as electric bicycles, scooters and electric cars. The products have become very popular and are growing in numbers. Many of these run on Li-Ion batteries which offer higher power density those other battery chemistries. However, if a Li-ion battery is overcharged at either high or low temperatures, it may represent a serious safety issue. Due to widely reported battery fires in these devices and vehicles, the safety of battery charging has become one of the most important design regulations of battery powered portable devices. The Japanese electronics and information technology industry association (JEITA) has published standards to enhance battery charging security. The following sections introduce and describe the JEITA safety-compliant battery charger solutions in effect for notebook computer and single-cell hand-held applications.

To support JEITA battery safety standard testing, Prodigit has developed a complete high and low temperature simulation solution for temperature monitoring of battery packs that use thermistors as part of their battery management system (BMS). Thermistors are negative temperature coefficient resistors (Negative Temperature Coefficient is abbreviated as NTC). NTC's provide battery management system of the charging system with very accurate, fast and convenient temperature data.

A Negative Temperature Coefficient (NTC) is a resistor which resistive properties change with temperature. The negative aspect means the resistance value will decrease with increasing temperature, as shown in the graph below. By measuring the resistance value of an NTC embedded in a battery pack, the temperature change of battery can be monitored closely. Battery manufacturer's generally use an NTC with a 10 K ohm resistance value at 25 ℃ to sense the internal battery temperature. The NTC resistors are installed in the battery pack the most sensitive location and is used by the BMS to sense the internal temperature of the battery at all times. This allows the BMS to effectively control the battery charge and discharge, ensuring that the battery remains in its safe operating range.



The NTC resistance varies with temperature Graph

Battery Charger Safety and JEITA specification

As stated before, lithium batteries are widely used in mobile phones and notebook computers as well as many other consumer electronic products. Among the available rechargeable battery chemistry types, lithium possesses one of the highest capacity and weight energy density. It also has no memory effect over time and can meet constant system power demand.

Several news stories have come out over the past few year concerning exploding laptop and smart phone batteries, resulting in a number of widely publicized product- recalls by manufacturers.
These battery explosion and subsequent fires are all the result of thermal runaway conditions, which means the battery chemistry is out of control. During this thermal runaway condition, the internal temperature of the battery is as high as about 175 °C and a highly exothermic, irreversible reaction occurs that causes a fire when the battery is being charged. Figure 1 shows the charge current and charge voltage as a function of-temperature, which are often used in early lithium battery charging systems. These battery charging systems are prone to thermal runaway. At a battery temperature from 0 to 45 ° C, the battery charge current and charge voltage are constant. Higher battery temperatures can accelerate battery aging and increase the risk of battery failure.

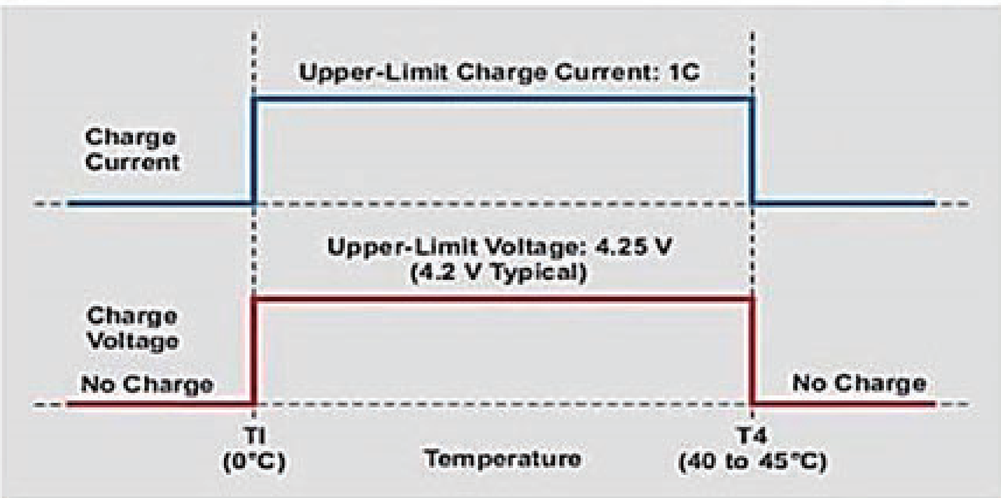


Figure 1 is charging current limit and charging voltage in early lithium battery charging system.

In an effort to improve the safety of lithium battery charging systems, JEITA and Battery Association of Japan issued safety regulations on April 20, 2007. This regulation emphasizes the need to avoid using high charging currents and high charging voltages in certain low and high temperature ranges. The JEITA believes that lithium battery problems are occur under high charge voltage and high battery temperature conditions. Figure 2 shows the JEITA regulation of the charge current and charge voltage at the battery temperature limits used in the notebook computer.

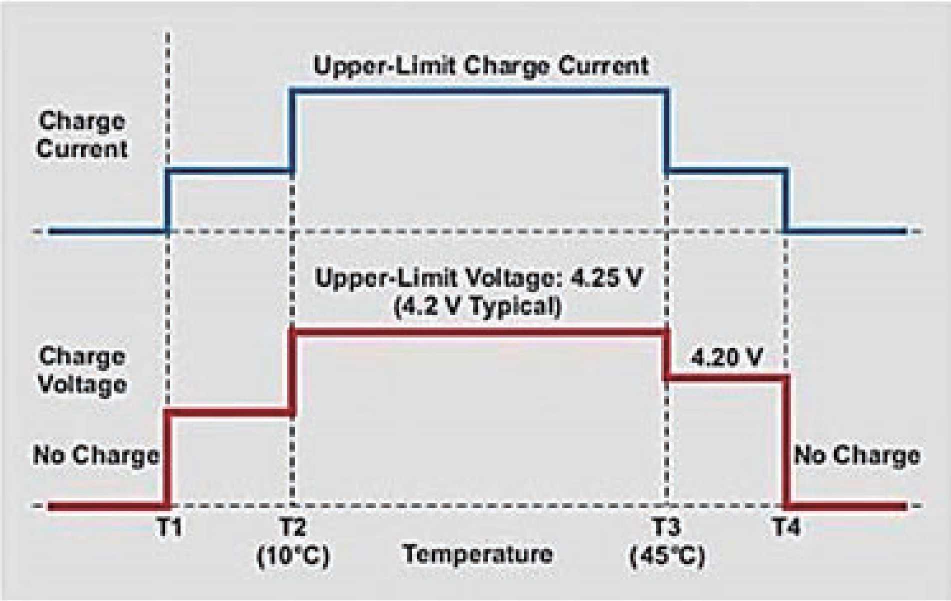


Figure 2 Is the JEITA regulation of the lithium-ion battery charge current and charge voltage used in Notebook computer

Over the standard charge temperature range (T2 to T3), the user can safely charge the lithium battery using the upper limit charge voltage and upper limit charge current under optimum conditions recommended by the battery manufacturer.

Low temperature charge

If the surface temperature of the battery during charging is lower than T2, the chemical reaction inside the lithium battery will generate excess thermal energy, resulting in thermal runaway. Therefore, at low battery temperatures, the charge current and charge voltage must be reduced. If the temperature drops to T1 (e.g. 0 ° C), the system should no longer allow any charging at all.

High temperature charge

If the battery surface temperature rises above T3 (e.g. 45 ° C) during charging, a chemical reaction with the electrolyte occurs as the battery voltage rises. If the battery temperature continues to rise further to T4, the BMS system should stop charging. If the battery temperature is allowed to reach 175 ° C at 4.3 V battery voltage, a thermal runaway condition may occur and the battery may explode.

Likewise, Figure 3 shows the JEITA regulation for lithium battery charging in a single-cell hand-held application where the charge current and charge voltage are also a function of battery temperature. The 4.25 V maximum charge voltage represents the maximum output voltage of the battery charger. Users can charge up to 60 ° C with a low charge voltage to ensure safety.

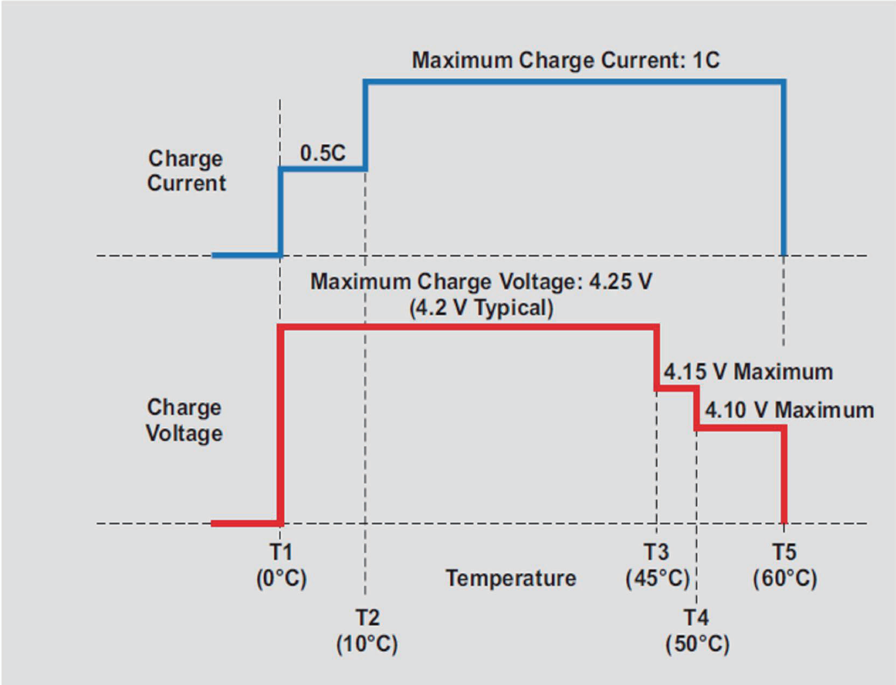


Figure 3 The JEITA regulation for lithium battery charging in a single-cell hand-held application

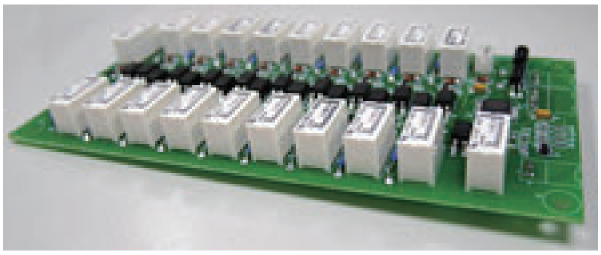
JEITA-compliant battery charger solution

Smart battery packs contain fuel gauges and protection circuits that are often used in laptops. Fuel gauges provide information such as battery voltage, charge and discharge current, battery temperature, remaining capacity, and executable time provided through the SMBus to optimize system performance. Based on JEITA regulations for battery charging current and charging voltage, the temperature threshold can be programmed by the user to meet various regulations of different applications.

A battery pack for a single cell type as used in portable devices typically has a battery and safety protection circuit that uses a charger to monitor the battery temperature and adjust the charge voltage and current.

Single-cell linear battery chargers are designed to meet the JEITA regulations of handheld devices. When the battery temperature is between 0 ° C and 10 ° C, the charge current can be reduced by half and when the battery temperature is between 45 ° C and 60 ° C the charge voltage can be reduced to 4.06 V. The charger monitors the battery temperature through the thermistor (TS) pin and adjusts the charge current and voltage when the temperature reaches the threshold.

Lithium battery safety charging is essential and important. It has become one of the key specifications for battery charger designs. According to the JEITA recommendations, reduced charge current and voltage under low temperature and high temperature conditions can greatly improve the safety of battery charging.



NTC analog circuit output is Pin 9 and Pin 11 of the connector

NTC Module

(Left image) is installed in the 3302F/G frame

Prodigit's new NTC simulator can simulate NTC resistance values change. Available ranges is from 100 Ω to 500 KΩ, which is equal to - 46 ℃ to + 179 ℃ temperature range changes. The NTC simulator acts like a standard resistance box, consisting of a number of precision resistors. It can automatically output the required temperature resistance value. Thus, if the NTC simulator is connected to the NTC interface of the charger, it can simulate low temperature (0 ℃) or high temperature charging conditions. This enabled checking to see if the unit under test can stop charging according to the design criteria. Furthermore, it can also simulate when the temperature returns to the available temperature, such as from 0 ℃ back to 5 ℃ and return to charge normal charging. The following table shows the required general charger test items for temperature changes.

The typical verification tests of battery charger using a thermistor temperature input are shown below, where 10 KΩ is for normal temperature, 33 KΩ is used to simulate low temperature（about zero degree）, and 4.7 KΩ is used to simulate high temperature （about 45 degrees）.

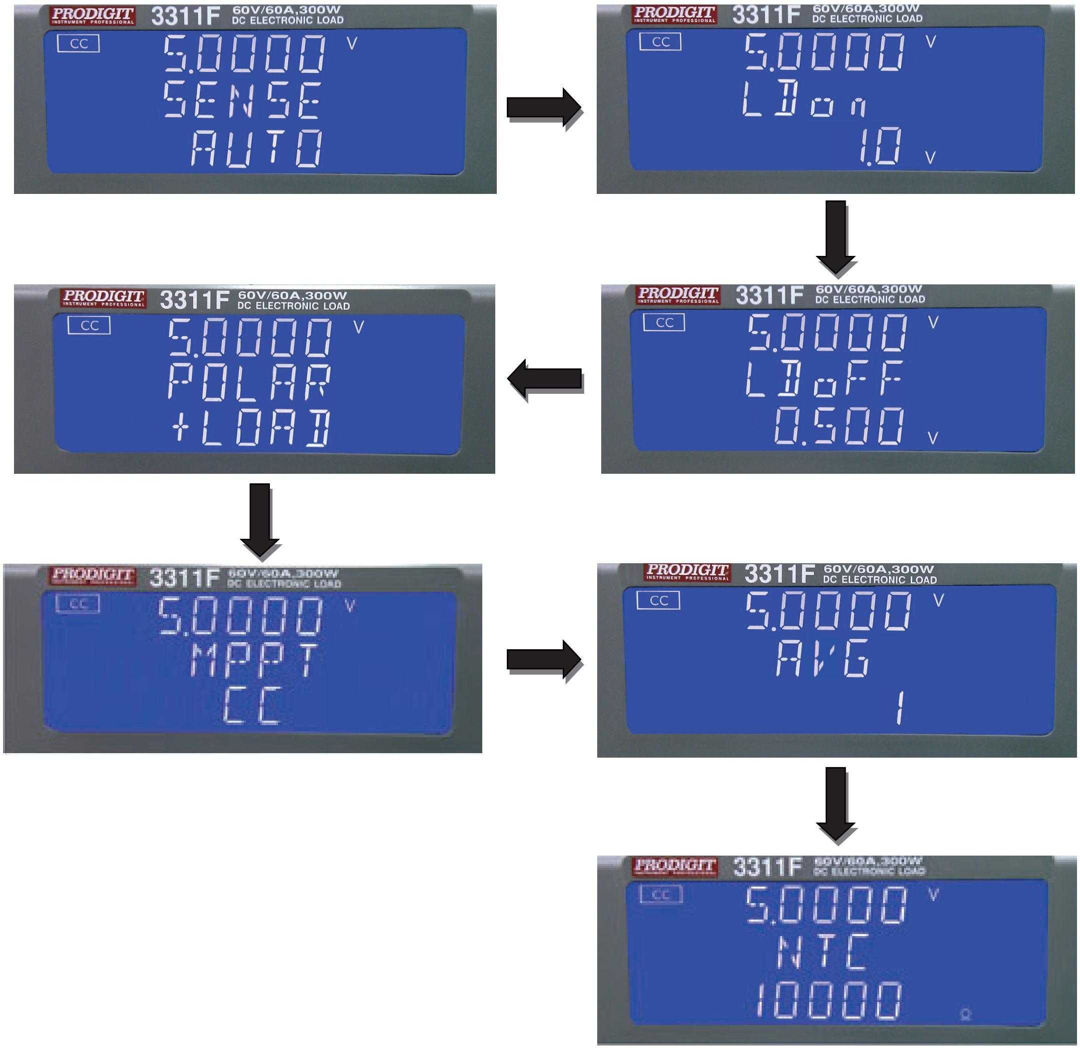
Test Project Proposal

Test Items		Test Setup	Judgment	Reference Range
No Load condition		Stable 5 V, 1 A output, no battery placement or no load	1. Blue LED constant lit, red, yellow, green three LED off	
			2. The test standby voltage is established	
Output voltage / current test		Stable 5 V, 1 A output, no battery placement or load generation		
Working condition	The battery is fully charged	TS Pin and GND Pin connect 10 k resistor	Green LED light	>8.2 V,<8.5 V
	Normal charge	TS Pin and GND Pin connect 10 k resistor, BAT Pin and GND	Green LED off, yellow LED light, load current 300 mA	270 mA to 330 mA
		Access to 7 V constant voltage electronic load		
	Low temperature alarm	Connected BAT, replace the 10k resistor of the TS pin is 33 k (about zero degree)	Only the red LED is on and the load current is zero	<=10 μA
	High temperature alarm	Connected BAT, replace the 10 k resistor of the TS pin is 4.7 k (about 45 degrees)	Only the red LED is on and the load current is zero	<=10 μA
Average efficiency test		TS Pin and GND Pin connect 10 k resistor, BAT pin and GND	Green LED off, yellow LED light, load current 300mA	>60 %
		Access to 7 V constant voltage electronic load (at CC mode)		
Ripple test		TS Pin and GND Pin connect 10k resistor, BAT pin, and GND		
		7 V constant voltage electronic load (at CC mode) is measured by the BAT pin		<=160 mA
Leakage current		Stable 5 V input, TS Pin and GND Pin then 10 k resistor	Green LED light, 8.5V supply current is less than 10 uA	
		BAT Pin to 8.5 V power input	(Current direction is 8.5V power flow into the circuit board)	<=10 μA
Boost circuit test		Stable 5 V, 1 A output, 12 V termination constant current 300 mA load test voltage	12 V with load voltage	11 V to 13 V

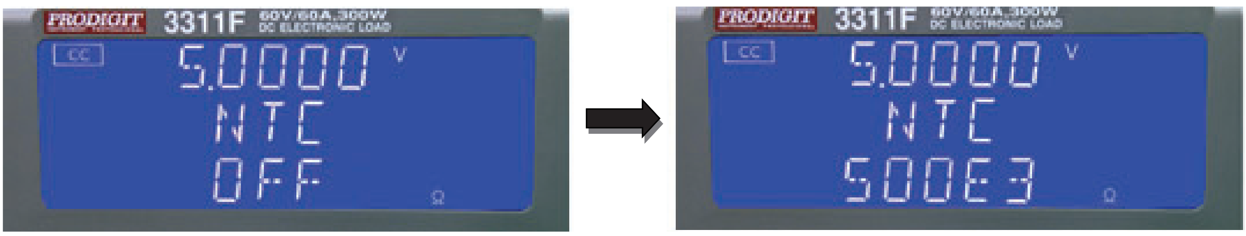
The following descriptions show how to program the NTC resistor option installed in 3302F/G mainframe. All operations are performed from the front panel of 3310F/G series electronic load :

Config and LED display

Press the Config key to enter the Config mode, LED indicator ON, the operation of the order to set the NTC as shown below :



- The NTC values sets the resistance value. The initial value is 10 KΩ. When the setting is change, the set number will flash. Press the Knob Up key to increase the setting value. Press the Knob Down key to decrease the setting value, or use the knob to vary the setting from OFF to 500 KΩ. The minimum resistance setting for the NTC parameter is 100 Ω. The adjustment interval of the knob and button is 10 Ω.



- Set the NTC resistance value to 10 KΩ. The NTC output for the DSUB-15PIN connector is located on the rear panel of 3302F/G electronic load chassis. Use a DMM meter to measure the resistance value between PIN9 and PIN11 at both ends of the DSUB-15PIN connector. The set value shown as (Figure left) and the actual measured value shown as (Figure right).

3302F/G frame with NTC module set NTC resistance is 10.00KΩ

Three meter resistance measurement NTC's resistance is 10.00 KΩ

- Set the NTC resistance value to 500 Ω. The NTC output for the DSUB-15PIN connector is located on the rear panel of 3302F/G electronic load chassis. Use a DMM meter to measure the resistance value between PIN9 and PIN11 at both ends of the DSUB-15PIN connector. The set value shown as (Figure left) and the actual measured value shown as (Figure right).

3302F/G frame with NTC module set NTC resistance is 500 KΩ

Three meter resistance measurement NTC's resistance is 0.50 KΩ

A test project example based on the following table is shown here. The original test steps required changing out resistors. However, when using the 3302F/G and 3311F/G with NTC function, there is no need to manually replace any resistors. The test steps are as follows.

1. Set Config. NTC 10 K ohm, (battery is full charge) store to memory 1.
2. Set Config. NTC 10 K ohm, CV 7 V, Load ON, (normal charge) store to memory 2.
3. Set Config. NTC 33 K ohm, CV 7 V, Load ON, (low temperature alarm) store to memory 3.
4. Set Config. NTC 4.7 K ohm, CV 7 V, Load ON, (high temperature alarm) store to memory 4.
5. Set Config. NTC 10 K ohm,CV 7 V, Load ON, (Average efficiency test & ripple test) store to Memory 5.
6. Set Config. NTC 10 K ohm, (Leakage current test) store to memory 6.
7. Set Config. NTC 10 K ohm, CC 300 mA,Load ON (Boost circuit test) store to memory 7.
8. Recall 1, 2, 3, 4, 5, 6, 7 you can complete a variety of temperature NTC resistance simulation test.

Test Project Proposal

Test Items		Test Setup	Judgment	Reference Range	Test Procedure
No Load condition		Stable 5 V, 1 A output, no battery placement or no load	1. Blue LED constant lit, red, yellow, green three LED off		
			2. The test standby voltage is established		
Output voltage / current test		Stable 5 V, 1 A output, no battery placement or load generation			
Working condition	The battery is fully charged	TS Pin and GND Pin connect 10k resistor	Green LED light	>8.2 V,<8.5 V	1
	Normal charge	TS Pin and GND Pin connect 10k resistor, BAT Pin and GND	Green LED off, yellow LED light, load current 300mA	270 mA to 330 mA	2
		Access to 7 V constant voltage electronic load			
	Low temperature alarm	Connected BAT, replace the 10 k resistor of the TS pin is 33 k (about zero degree)	Only the red LED is on and the load current is zero	<=10 μA	3
	High temperature alarm	Connected BAT, replace the 10 k resistor of the TS pin is 4.7 k (about 45 degrees)	Only the red LED is on and the load current is zero	<=10 μA	4
Average efficiency test		TS Pin and GND Pin connect 10 k resistor, BAT pin and GND	Green LED off, yellow LED light, load current 300 mA	>60 %	5
		Access to 7 V constant voltage electronic load (at CC mode)			
Ripple test		TS Pin and GND Pin connect 10 k resistor, BAT pin, and GND			
		7 V constant voltage electronic load (at CC mode) is measured by the BAT pin		<=160 mA	
Leakage current		Stable 5 V input, TS Pin and GND Pin then 10 k resistor	Green LED light, 8.5 V supply current is less than 10 uA		
		BAT Pin to 8.5 V power input	(Current direction is 8.5 V power flow into the circuit board)	<=10 μA	6
Boost circuit test		Stable 5 V, 1 A output, 12 V termination constant current 300 mA load test voltage	12 V with load voltage	11 V to 13 V	7

Table of test items and test steps of NTC resistance test

When requiring NTC simulation testing for the battery chargers or BMS test applications, you can purchase the 3302F/G frame and add the option NTC module that can meet the above test requirements.