**Customer Project XXXX**

**nSnP Battery Pack**

**Electric test requirement**

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| **Customer:** | XXX |
| **Project Name:** | xxxx |
| **Inventus Project Number:** | xxxx |
| **Prepared by:** | EE |
| **Checked by:** | EE Manager |
| **Date:** | Mon-DD-YYYY |

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1. Introduction

This document specifies the electrical performance testing requirements for battery packs used in various applications, such as electric vehicles, stationary energy storage, and portable electronics. These tests are designed to ensure the safety, reliability, and performance of the battery packs.

1. Testing Equipment

* DC power source
* E-load
* Multimeter
* Oscilloscope
* Environmental chamber

1. PCBA Electrical Performance Tests
   1. Gauge IC measurement accuracy of cell voltage and pack voltage

* **Test Objective**: Verify the measurement accuracy of gauge IC’s cell and pack voltage sensing.
* **Test Procedure**:
  1. Use the DC and e-load to simulate the cells stack. Set the voltage as battery’s nominal voltage.
  2. Read the cell voltage and pack voltage from gauge IC and compare them with the actual measurements by multimeter.
* **Acceptance Criteria**:
  + The voltage accuracy should be within 5mV/cell.
  1. Gauge IC current measurement accuracy
* **Test Objective**: Verify current measurement accuracy of gauge IC.
* **Test Procedure**:
  1. Discharge the battery with 2A (or 1A, per IPS) and the requested max loading via e-load.
  2. Compare the actual current reading on the meter and the current value read from gauge.
  3. Charge the battery with max current.
  4. Compare the actual current reading on the meter and the current value read from gauge.
* **Acceptance Criteria**:
  + The current accuracy should meet <1%.
  1. Battery shelf-life calculation
* **Test Objective**: Verify the battery shelf life.
* **Test Procedure**:
  1. Measure the battery’s average leakage in ship mode.
  2. Use the [“Battery Storage Life Analysis Template.xlsx” on Duoke](http://10.210.120.33:8091/doc?ownerid=101&folderid=133781) to make the calculations.
  3. The beginning SOC level should refer to the min. voltage value of shipment OCV check in the IPS.
* **Acceptance Criteria**:
  + If the shelf life is less than 12 months, remind customers to do charge/discharge cycle to prevent battery exhausting when 2/3 of shelf life lose.
  + If the shelf life is more than 12 months, remind customers to do charge/discharge cycle every year, remain 20%~30% after recharge.
  1. Over voltage protection test
* **Test Objective**: Verify over voltage protection function.
* **Test Procedure**:
  1. Use DC and e-load to simulate cells stack. Use another DC to charge the battery, limit the charge current to 100mA.
  2. Gradually increase the simulated cell voltage from the voltage which is lower than the lower limit of OVP (make sure the test starts from normal state) until it triggers the over voltage protection.
  3. Use oscilloscope to catch the waveform of Vgs voltage of charge MOSFET, cell voltage and charge current.
* **Acceptance Criteria**:
  + The trigger voltage and delay time should in the range of design value.
  + The recovery conditions should meet expectations.
  1. Under voltage protection test
* **Test Objective**: Verify under voltage protection function
* **Test Procedure**:
  1. Use DC and e-load to simulate cells stack. Use another e-load to discharge the battery, limit the discharge current to 100mA.
  2. Gradually decrease the simulated cell voltage from the voltage which is higher than the upper limit of UVP (make sure the test starts from normal state) until it triggers the under-voltage protection.
  3. Use oscilloscope to catch the waveform of Vgs voltage of discharge MOSFET, cell voltage and discharge current.
* **Acceptance Criteria**:
  + The trigger voltage and delay time should in the range of design value.
  + The recovery conditions should meet expectations.
  1. 0V charge forbidden function and low voltage charge(pre-charge) test
* **Test Objective**: Verify the 0V charge forbidden function and low voltage charge(pre-charge) function
* **Test Procedure**:
  1. Use DC and e-load to simulate cells stack. Use another DC to charge the battery.
  2. Set the simulated cell voltage in 0V and the charge current should be 0A.
  3. Increase the cell voltage beyond the 0V charge threshold (per IC spec), the charge function should recover.
* **Acceptance Criteria**:
  + Battery should have the 0V charge forbidden function.
  + The battery should be charged while cell voltage ≥1.55V.
  + The low voltage (pre-charge) current should meet the design requirement.
  + The gauge should report the properly charge voltage and current.
  1. Over current protection test
* **Test Objective**: Verify the over current protection.
* **Test Procedure**:
  1. Use DC and e-load to simulate cells stack. Use another DC and e-load for charging and discharging.
  2. Adjust the charge/discharge current to trigger the over current protection.
  3. Test all levels over current protection.
  4. Use oscilloscope to catch the waveform of Vgs voltage of MOSFET and current.
* **Acceptance Criteria**:
  + Both the trigger current in charge and discharge, and the delay time should in the range of design value.
  + The recovery conditions should meet expectations.
  1. Over and under temperature protection
* **Test Objective**: Verify the over and under temperature protection and the temperature accuracy.
* **Test Procedure**:
  1. The test unit should be covered by a shell to minimize the fan effect in the chamber.
  2. Place the fully discharged battery at 25’C chamber, then charge it with small current.
  3. Place thermal couple to the cell surface where close to the NTC.
  4. Place thermal couple next to the NTC.
  5. Place thermal couple for the ambient temperature.
  6. Adjust the chamber temperature to OTP temperature + 5’C and wait until the battery internal temperature is consistent with the ambient temperature.
  7. Adjust the chamber temperature to UTP temperature - 5’C and wait until the battery internal temperature is consistent with the ambient temperature.
  8. Prepare the fully charged battery and verify the OTP and UTP in discharging as well.
  9. Record the Gauge communication data each second if there is gauge IC inside.
* **Acceptance Criteria**:
  + The cell’s surface temperature (T1) and NTC temperature (T2) should meet |T1-T2|≤3℃.
  + The OTP and UTP temperature should in the range of ±3℃ of the designed temperature.
  + The protection delay should be in the range of +/- 2s of the designed value.
  1. I2C/ SMBUS communication waveform test
* **Test Objective**: Verify the waveform whether it can meet the I2C/ SMBUS criteria.
* **Test Procedure**:
  1. Use oscilloscope to catch SDA & SCL waveform.
  2. Check the logic level, rise time, fall time of the waveform.
* **Acceptance Criteria**:
  + Standard mode：Trise≤1us，Tfall≤300ns.
  + Fast mode：Trise≤300ns，Tfall≤300ns
  + Logic level: VH≥0.7VDD, VL≤0.3VDD.
  1. Capacity test
* **Test Objective**: Verify the battery capacity
* **Test Procedure**:
  1. Use the standard charge method to fully charge battery.
  2. Use the standard discharge current to discharge battery.
  3. Record the gauge data and monitor the battery voltage and current.
* **Acceptance Criteria**:
  + The capacity should meet the label capacity.
  + The SOC curve should be smooth and without jumping or dropping.
  1. Burn-in test in high/ low/ room temperature
* **Test Objective**: Verify the components rating.
* **Test Procedure**:
  1. Charge and discharge battery with max current at high/ low/ room temperature.
  2. Monitor the temperature rise data of the critical components, such as gauge IC, MCU, charge and discharge FETs, sense resistor, cell, fuse, PTC.
  3. Monitor the pack voltage and current.
* **Acceptance Criteria**:
  + The components temperature should be within the rating specified in datasheet.
  + The battery should be fully charged within the customer’s requested time.
  + The battery should be discharged to empty without triggering OTP.
  1. Short circuit test
* **Test Objective**: Verify components’ rating and setting of OCP under short circuit conditions.
* **Test Procedure**:
  1. Connect the pack+ and pack- with a low resistance wire.
  2. Perform the short test fully charged battery.
  3. Use oscilloscope to catch the current, pack voltage, FET’s Vds and Vgs.
  4. Repeat the short test 100 times.
  5. Generate the max current according to the setting of OCP to test the worst-case short current in micro-second and milliseconds. Repeat the test step c and d.
* **Acceptance Criteria**:
  + The battery should be able to recover to its normal state after the short test.
  + Calculate the power loss and the result should be within the MOSFET rating.
  + The spike voltage on pack+ pack- should be lower than IC voltage rating.
  1. Inrush current test
* **Test Objective**: Verify the battery would not trigger the OCP while inserted into system.
* **Test Procedure**:
  1. Confirm the inrush current or capacity of system from customer.
  2. The OCDP should not be triggered with the inrush current. Perform following tests If inrush current is unknown.
  3. Prepare a fully charged battery and a capacitors group with low ESR capacitors, and the capacity should be 1.5x customer’s request.
  4. Use width and short wires to connect the battery to the capacitors group.
* **Acceptance Criteria**:
  + No protection should be triggered during the test.
  1. LED functions test
* **Test Objective**: Verify the LED functions.
* **Test Procedure**:
  1. Use PCBA to test LED display in different states. Include the normal mode, SOC indication, error indication and charge indication.
* **Acceptance Criteria**:
  + The display should meet customer requests.
  + Check the LED brightness should not below 50lux.
  1. Reverse-charge protection test
* **Test Objective**: Verify the reverse-charge protection function if the protection circuit is included.
* **Test Procedure**:
  1. Use DC to reverse-charge the battery.
* **Acceptance Criteria**:
  + The reverse-charge protection circuit should stop charging.
  + No components break and function loss after the test.
  1. Leakage current test
* **Test Objective**: Verify the leakage current in different operation modes.
* **Test Procedure**:
  1. Use PCBA for the test.
  2. Place the PCBA in the chamber and perform the test in the high, low, room storage temperature and different mode (such as sleep, shutdown).
* **Acceptance Criteria**:
  + The leakage current should meet the IC spec.
  + The leakage current in different temperatures should be similar.
  1. PCBA Cell balance circuit test
* **Test Objective**: Evaluate the performance of the cell balancing circuit functionality and logic.
* **Test Procedure**:
  1. Connect the PCBA with a multi-channel DC power supply.
  2. Change the cell voltage to meet the cell balancing circuit on condition (EX △V>20mV).
  3. Change the cell voltage to meet the cell balancing circuit OFF condition (EX △V<10mV)
  4. Keep the cell balancing circuit ON and test the temperature rise.
* **Acceptance Criteria**:
  + The cell balancing circuit should be turned on based on the voltage condition set in parameter list.
  + The cell balancing circuit should be turned off based on the voltage condition set in parameter list.
  + The temperature rise should be in the range of component datasheet.
  1. Unit Cell balance circuit test
* **Test Objective**: Evaluate the performance of the cell balancing circuit functionality and logic.
* **Test Procedure**:
  1. Charge the battery pack to be full.
  2. Discharge one cell for more than 10% capacity.
  3. Let the battery pack enter rest statues.
  4. Record each cell voltage information by FW.
  5. Record the thermal rise of cell balance resistors and AFE/Fuel gauge IC.
* **Acceptance Criteria**:
  + The voltage bouncing value should not be higher than 5mV.
  + The thermal rise of components should meet the derating requirements.
  + The cell balance should be balanced in a time.

Revision History

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| --- | --- | --- | --- | --- |
| **Revision** | **Description of Change** | **Changed by** | **Approved by** | **Date** |
| X1 | New release | Jacky | Kyle/Kylin/CYW/XJJ | Mar-26-2025 |
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