# LITHIUM ION BATTERY SAFETY TESTING REPORT

| | |
|---|---|
| ***Applicant:*** | **Panasonic Industrial Devices Corporation of America**<br>**3461 Plano Parkway, The Colony, TX 75056**<br>**Tel: 469-362-5600; E-mail: RBG-Regulatory@us.panasonic.com;**<br>**Website: https://na.industrial.panasonic.com** |
| ***Manufacturer:*** | **Sanyo Energy (Suzhou) Co., Ltd.**<br>**No.86 Sunwu Road, Xukou Town, Wuzhong District, Suzhou City, Jiangsu, P.R. China** |
| ***Product:*** | **Rechargeable Li-ion Battery** |
| ***Model:*** | **ABL-F** |
| ***Rating:*** | **14.4 Vdc, 4460 mAh, 64.2 Wh** |
| ***Test method & Criterion*** | **UNITED NATIONS "Recommendations on the TRANSPORT OF DANGEROUS GOODS" Manual of Tests and Criteria ST/SG/AC.10/11/Rev.7** |
| ***Appearance*** | **Plastic enclosure** |
| ***Verification Issuing Office Name*** | **AnTek Certification Inc.**<br>**7F, No.351, Yangguang St. Taipei, 11491 Taiwan**<br>**Tel: +886-2-8752-3779; Website: www.atclab.com.tw;**<br>**E-mail: atc@atclab.com.tw** |
| ***Date Received*** | **Jan. 03, 2022** |
| ***Test Performed Date:*** | **Jan. 12, 2022– Feb. 16, 2022** |
| ***Conclusion:*** | **The sample has passed the test items of UN 38.3** |
| ***Date of Issued:*** | **Mar. 02, 2022** |
| ***Comment:*** | **Internal cell source: Panasonic / UR1865ZP**<br>**MOSFET Source Model: SP8009E** |

**Prepared by:**

**Ann Kuo**
**Project handler**

**Approved by:**

**Nick Wu**
**Technical reviewer**

# TEST ITEMS

| No. | Name of Test Items | Conclusion | Remark |
|---|---|---|---|
| **T1.** | **Altitude Simulation** | Passed | -- |
| **T2.** | **Thermal Test** | Passed | -- |
| **T3.** | **Vibration** | Passed | -- |
| **T4.** | **Shock** | Passed | -- |
| **T5.** | **External Short Circuit** | Passed | -- |
| **T6.** | **Impact** | N/A | -- |
| | **Crush** | N/A | -- |
| **T7.** | **Overcharge** | Passed | -- |
| **T8.** | **Forced Discharge** | N/A | -- |
| **Test Environment Condition** | Ambient Temperature: 22.1 °C~23.2 °C<br>Ambient Humidity: 52 %~63% | | |

**General remarks**

The report relates only to the object tested and uncertainty of measurement will not be evaluated.

This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.

# SAMPLES FOR TYPE TESTS:

| Test Number | Cell / Battery Type | Test Samples |
|---|---|---|
| T1 ~ T5 | ☐ Primary Cells | Ten cells in undischarged states<br>Ten cells in fully discharged states |
| | ☐ Primary Batteries (Small Type) | Four batteries in undischarged states<br>Four batteries in fully discharged states |
| | ☐ Primary Batteries (Large Type) | Four batteries in undischarged states<br>Four batteries in fully discharged states |
| | ☐ Rechargeable Cells | Five cells at first cycle, in fully charged states<br>Five cells after 25 cycles ending in fully charged states |
| | ☐ Single Cell type Battery | Five cells at first cycle, in fully charged states<br>Five cells after 25 cycles ending in fully charged states |
| | ☒ Rechargeable Batteries (Small Type) | Four batteries at first cycle, in fully charged states<br>Four batteries after 25 cycles ending in fully charged states |
| | ☐ Rechargeable Batteries (Large Type) | Two batteries at first cycle, in fully charged states<br>Two batteries after 25 cycles ending in fully charged states |
| T6 | ☐ Primary cells | Five cells in undischarged states<br>Five cells in fully discharged states |
| | ☐ Component cells of primary batteries | Five cells in undischarged states<br>Five cells in fully discharged states |
| | ☐ Rechargeable cells | Five cells at first cycle at 50% of the design rated capacity<br>Five cells after 25 cycles ending at 50% of the design rated capacity |
| | ☐ Component cells of rechargeable batteries | Five cells at first cycle at 50% of the design rated capacity<br>Five cells after 25 cycles ending at 50% of the design rated capacity |
| T7 | ☒ Rechargeable Batteries (Small Type) | Four batteries at first cycle, in fully charged states<br>Four batteries after 25 cycles ending in fully charged states |
| | ☐ Rechargeable Batteries (Large Type) | Two batteries at first cycle, in fully charged states<br>Two batteries after 25 cycles ending in fully charged states |
| T8 | ☐ Primary cells | Ten cells in fully discharged states |
| | ☐ Primary component cells | Ten cells in fully discharged states |
| | ☐ Rechargeable cells | Ten cells, at first cycle in fully discharged states<br>Ten cells after 25 cycles ending in fully discharged states |
| | ☐ Rechargeable component cells | Ten cells, at first cycle in fully discharged states<br>Ten cells after 25 cycles ending in fully discharged states |

# T1: Altitude Simulation

## Test procedure:

Test cells and batteries shall be stored at a pressure of 11.6 kPa or less for at least six hours at ambient temperature (20 ± 5 °C).

## Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

## Results:

| Sample No | Sample State | Before Test | | After Test | | Mass Loss (%) | Residual Voltage (%) | Phenomenon |
|---|---|---|---|---|---|---|---|---|
| | | Mass (g) | Open-Circuit Voltage (V) | Mass (g) | Open-Circuit Voltage (V) | | | |
| 01 | A | 451.433 | 16.43 | 451.422 | 16.42 | 0.00 | 99.94 | O |
| 02 | A | 451.366 | 16.49 | 451.357 | 16.49 | 0.00 | 100.00 | O |
| 03 | A | 451.046 | 16.47 | 451.039 | 16.46 | 0.00 | 99.94 | O |
| 04 | A | 451.103 | 16.45 | 451.095 | 16.44 | 0.00 | 99.94 | O |
| 05 | B | 451.231 | 16.48 | 451.219 | 16.48 | 0.00 | 100.00 | O |
| 06 | B | 451.544 | 16.49 | 451.535 | 16.49 | 0.00 | 100.00 | O |
| 07 | B | 450.985 | 16.48 | 450.974 | 16.47 | 0.00 | 99.94 | O |
| 08 | B | 450.981 | 16.40 | 450.961 | 16.40 | 0.00 | 100.00 | O |

**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

# T2: Thermal Test

## Test procedure:

Test cells and batteries are to be stored for at least six hours at a test temperature equal to 72 ± 2 °C, followed by storage for at least six hours at a test temperature equal to - 40 ± 2 °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated until 10 total cycles are complete, after which all test cells and batteries are to be stored for 24 hours at ambient temperature (20 ± 5 °C). For large cells and batteries the duration of exposure to the test temperature extremes should be at least 12 hours.

## Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

## Results:

| Sample No | Sample State | Before Test | | After Test | | Mass Loss (%) | Residual Voltage (%) | Phenomenon |
|---|---|---|---|---|---|---|---|---|
| | | Mass (g) | Open-Circuit Voltage (V) | Mass (g) | Open-Circuit Voltage (V) | | | |
| 01 | A | 451.422 | 16.42 | 451.377 | 16.24 | 0.01 | 98.90 | O |
| 02 | A | 451.357 | 16.49 | 451.326 | 16.26 | 0.01 | 98.61 | O |
| 03 | A | 451.039 | 16.46 | 451.014 | 16.28 | 0.01 | 98.91 | O |
| 04 | A | 451.095 | 16.44 | 451.028 | 16.23 | 0.01 | 98.72 | O |
| 05 | B | 451.219 | 16.48 | 451.187 | 16.28 | 0.01 | 98.79 | O |
| 06 | B | 451.535 | 16.49 | 451.495 | 16.29 | 0.01 | 98.79 | O |
| 07 | B | 450.974 | 16.47 | 450.922 | 16.27 | 0.01 | 98.79 | O |
| 08 | B | 450.961 | 16.40 | 450.914 | 16.25 | 0.01 | 99.09 | O |

**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

# T3: Vibration

## Test procedure:

Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell. One of the directions of vibration must be perpendicular to the terminal face.

The logarithmic frequency sweep shall differ for cells and batteries with a gross mass of not more than 12 kg (cells and small batteries), and for batteries with a gross mass of more than 12 kg (large batteries).

For cells and small batteries: from 7 Hz a peak acceleration of 1 gn is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 gn occurs (approximately 50 Hz). A peak acceleration of 8 gn is then maintained until the frequency is increased to 200 Hz.

For large batteries: from 7 Hz to a peak acceleration of 1 gn is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 2 gn occurs (approximately 25 Hz). A peak acceleration of 2 gn is then maintained until the frequency is increased to 200 Hz.

## Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire during the test and after the test and if the open circuit voltage of each test cell or battery directly after testing in its third perpendicular mounting position is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

## Results:

| Sample No | Sample State | Before Test | | After Test | | Mass Loss (%) | Residual Voltage (%) | Phenomenon |
|---|---|---|---|---|---|---|---|---|
| | | Mass (g) | Open-Circuit Voltage (V) | Mass (g) | Open-Circuit Voltage (V) | | | |
| 01 | A | 451.377 | 16.24 | 451.265 | 16.23 | 0.02 | 99.94 | O |
| 02 | A | 451.326 | 16.26 | 451.259 | 16.26 | 0.01 | 100.00 | O |
| 03 | A | 451.014 | 16.28 | 450.926 | 16.27 | 0.02 | 99.94 | O |
| 04 | A | 451.028 | 16.23 | 450.921 | 16.22 | 0.02 | 99.94 | O |

| Sample No | Sample State | Before Test | | After Test | | Mass Loss (%) | Residual Voltage (%) | Phenomenon |
|---|---|---|---|---|---|---|---|---|
| | | Mass (g) | Open-Circuit Voltage (V) | Mass (g) | Open-Circuit Voltage (V) | | | |
| 05 | B | 451.187 | 16.28 | 451.064 | 16.28 | 0.03 | 100.00 | O |
| 06 | B | 451.495 | 16.29 | 451.404 | 16.28 | 0.02 | 99.94 | O |
| 07 | B | 450.922 | 16.27 | 450.847 | 16.27 | 0.02 | 100.00 | O |
| 08 | B | 450.914 | 16.25 | 450.802 | 16.24 | 0.02 | 99.94 | O |

**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

# T4: Shock

## Test procedure:

Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test battery.

Each cell shall be subjected to a half-sine shock of peak acceleration of 150 gn and pulse duration of 6 milliseconds. Alternatively, large cells may be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds.

Each battery shall be subjected to a half-sine shock of peak acceleration depending on the mass of the battery. The pulse duration shall be 6 milliseconds for small batteries and 11 milliseconds for large batteries. The formulas below are provided to calculate the appropriate minimum peak accelerations.

| Battery | Minimum peak acceleration | Pulse duration |
|---|---|---|
| Small batteries | 150 $g_n$ or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{100850}{mass^a}\right)}$ whichever is smaller | 6 ms |
| Large batteries | 50 $g_n$ or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{30000}{mass^a}\right)}$ whichever is smaller | 11 ms |

[a] Mass is expressed in kilograms.

The relationship between minimum peak acceleration and mass is illustrated in Figure 38.3.4.1 for small batteries and Figure 38.3.4.2 for large batteries.

Each cell or battery shall be subjected to three shocks in the positive direction and to three shocks in the negative direction in each of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks.

## Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

## Results:

| Sample No | Sample State | Before Test | | After Test | | Mass Loss (%) | Residual Voltage (%) | Phenomenon |
|---|---|---|---|---|---|---|---|---|
| | | Mass (g) | Open-Circuit Voltage (V) | Mass (g) | Open-Circuit Voltage (V) | | | |
| 01 | A | 451.265 | 16.23 | 451.255 | 16.23 | 0.00 | 100.00 | O |
| 02 | A | 451.259 | 16.26 | 451.252 | 16.26 | 0.00 | 100.00 | O |
| 03 | A | 450.926 | 16.27 | 450.913 | 16.26 | 0.00 | 99.94 | O |
| 04 | A | 450.921 | 16.22 | 450.904 | 16.22 | 0.00 | 100.00 | O |
| 05 | B | 451.064 | 16.28 | 451.056 | 16.28 | 0.00 | 100.00 | O |
| 06 | B | 451.404 | 16.28 | 451.392 | 16.27 | 0.00 | 99.94 | O |
| 07 | B | 450.847 | 16.27 | 450.838 | 16.27 | 0.00 | 100.00 | O |
| 08 | B | 450.802 | 16.24 | 450.791 | 16.23 | 0.00 | 99.94 | O |

**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

# T5: External Short Circuit

## Test procedure:

The cell or battery to be tested shall be heated for a period of time necessary to reach a homogeneous stabilized temperature of 57 ± 4 °C, measured on the external case. This period of time depends on the size and design of the cell or battery and should be assessed and documented. If this assessment is not feasible, the exposure time shall be at least 6 hours for small cells and small batteries, and 12 hours for large cells and large batteries. Then the cell or battery at 57 ± 4 °C shall be subjected to one short circuit condition with a total external resistance of less than 0.1 ohm.

This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 57 ± 4 °C, or in the case of the large batteries, has decreased by half of the maximum temperature increase observed during the test and remains below that value.

The short circuit and cooling down phases shall be conducted at least at ambient temperature.

## Requirement:

Cells and batteries meet this requirement if their external temperature does not exceed 170 °C and there is no disassembly, no rupture and no fire during the test and within six hours after the test.

## Results:

| Sample No | Sample State | External Highest Temperature (°C) | Initial Voltage(V) | External resistance(mΩ) | Phenomenon |
|---|---|---|---|---|---|
| 01 | A | 57.1 | 16.23 | 82.27 | O |
| 02 | A | 57.2 | 16.26 | 76.09 | O |
| 03 | A | 56.8 | 16.26 | 78.58 | O |
| 04 | A | 57.2 | 16.22 | 78.35 | O |
| 05 | B | 56.9 | 16.28 | 77.69 | O |
| 06 | B | 57.0 | 16.27 | 83.68 | O |
| 07 | B | 56.9 | 16.27 | 75.60 | O |
| 08 | B | 56.9 | 16.23 | 78.11 | O |

**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

# T7: Overcharge

## Test procedure

The charge current shall be twice the manufacturer's recommended maximum continuous charge current. The minimum voltage of the test shall be as follows:

(a) when the manufacturer's recommended charge voltage is not more than 18V, the minimum voltage of the test shall be the lesser of two times the maximum charge voltage of the battery or 22V.

(b) when the manufacturer's recommended charge voltage is more than 18V, the minimum voltage of the test shall be 1.2 times the maximum charge voltage.

Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.

## Requirement

Rechargeable batteries meet this requirement if there is no disassembly and no fire during the test and within seven days after the test.

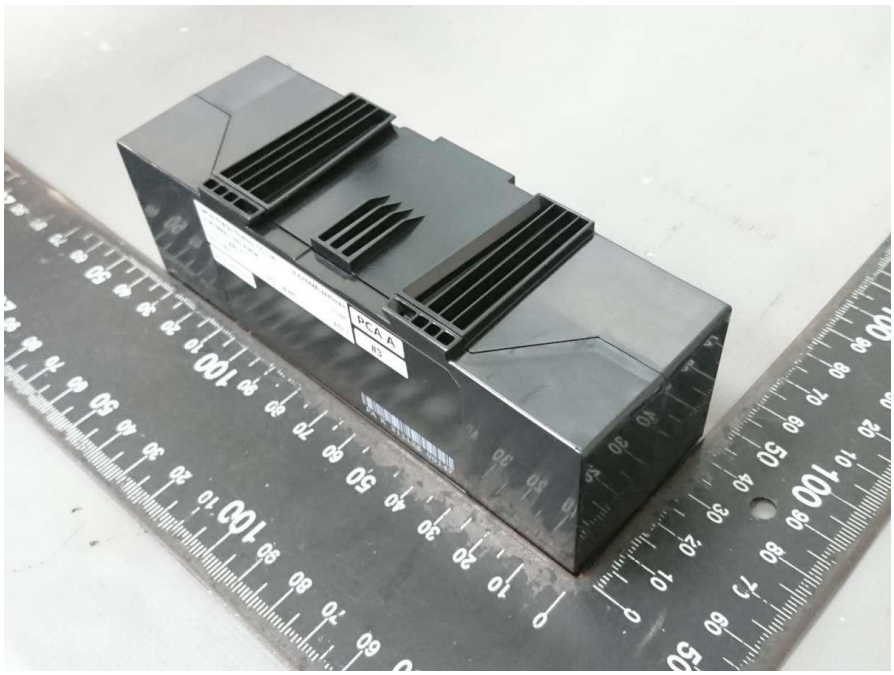
## Results:

| Sample No | Sample State | During Test | | Phenomenon |
|---|---|---|---|---|
| | | Charge Current | Charge Voltage | |
| 09 | A | 2.8 A | 22 V | O |
| 10 | A | 2.8 A | 22 V | O |
| 11 | A | 2.8 A | 22 V | O |
| 12 | A | 2.8 A | 22 V | O |
| 13 | B | 2.8 A | 22 V | O |
| 14 | B | 2.8 A | 22 V | O |
| 15 | B | 2.8 A | 22 V | O |
| 16 | B | 2.8 A | 22 V | O |

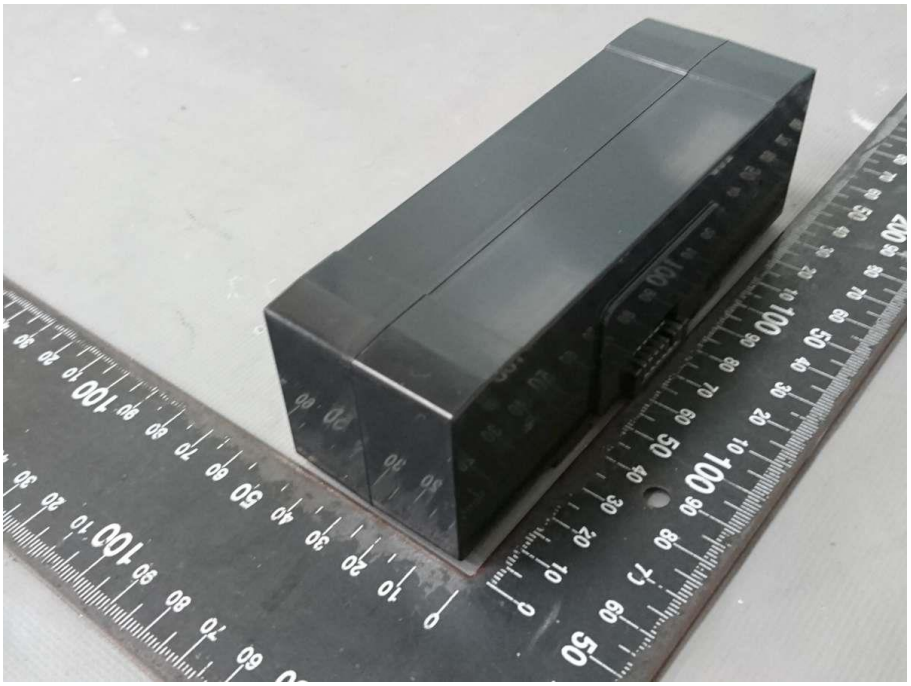
**Sample state:**
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
**Phenomenon:**
D – Disassembly; F – Fire; O - No disassembly and no fire.

# Photographs

<Fig. #1>



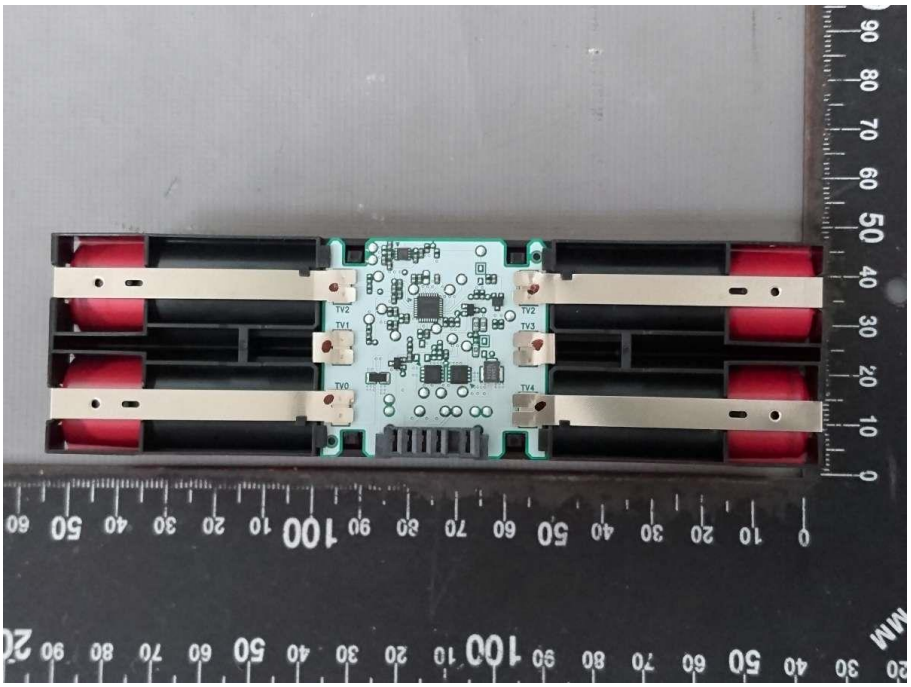
<Fig. #2>



# Photographs

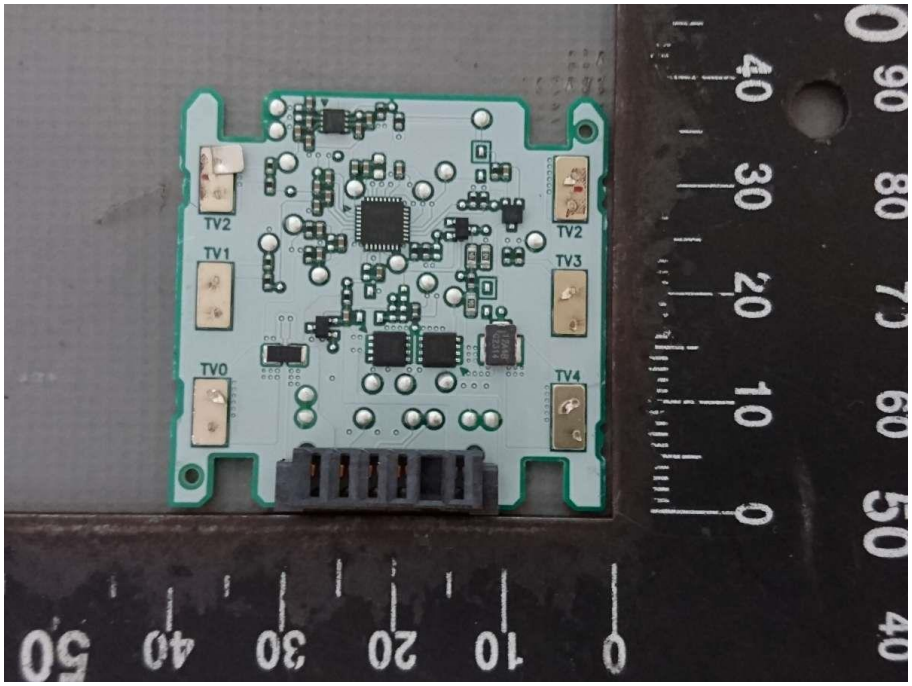
<Fig. #3>

<Fig. #4>

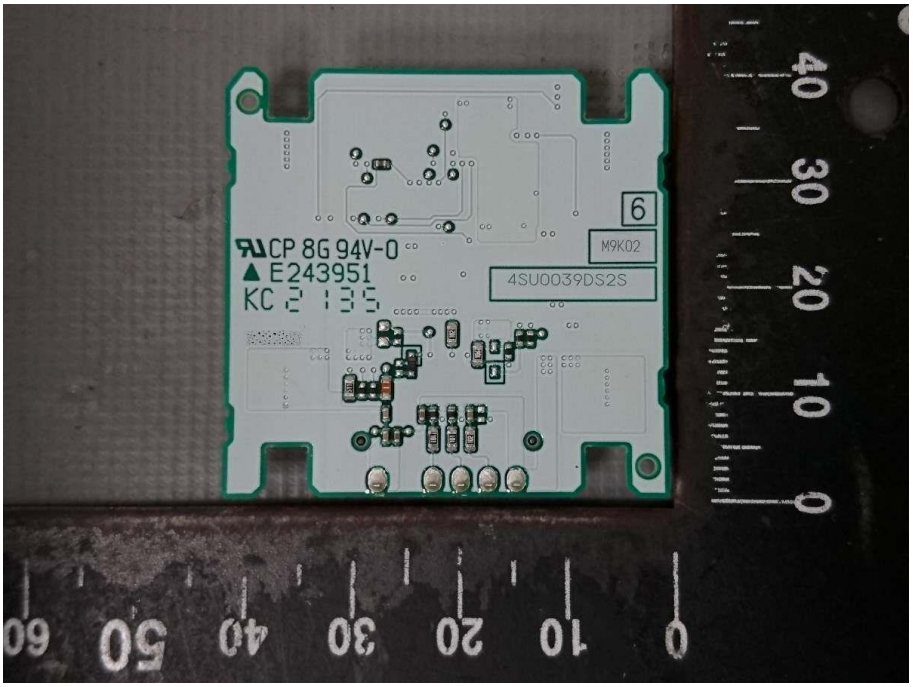


# Photographs

<Fig. #5>




<Fig. #6>



# Photographs

<Fig. #7> Label drawing