



Part Number

LSCU 002R7C 3000F EA

TEST REPORT

- 1) Electrical Properties
- 2) Thermal Characteristics
- 3) Temperature Characteristics
- 4) Reliability / Safety



TEST REPORT

Electrical/ Thermal/ Temperature/ Reliability & Safety test

1. Introduction

- 1) Characterization testing establishes the baseline performance and include capacitance, power characterization, leakage current, self-discharge, temperature performance.
- 2) Life testing establishes behavior over time at specific temperature, states of charge and other stress conditions and includes both cycle-life and load-life testing.
- 3) And also, Other reliability test, Safety test and vibration test was performed based on standard.

2. Product Specification

2.1 Product type : LSUC series (Electric double layer capacitor)

2.2 Part number : LSUC 002R7C 3000F EA ST01 / LSUC 002R7C 3000F EA LT01

3. The Measurement condition of Performance

Test was performed based on "IEC 62391-1", "QC/T 741-2006" and etc.

TEST REPORT

Electrical/ Thermal/ Temperature/ Reliability & Safety test

| No. | Type of test | Test item | Standard | Results |
|-----|---------------------|--------------------|--------------|---|
| 1 | | Appearance | QC/T741-2006 | No appearance defect  |
| 2 | Physical Dimensions | Polarity | QC/T741-2006 | Distinct polarity mark  |
| 3 | | Dimension / weight | QC/T741-2006 | Ø 60 X 138mm / 0.525kg |

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| No. | Type of test | Test item | Standard | Results | | | | | | |
|-------------|-----------------------|--|--|--|-------------|-----------------|-----------|----|--------|--------------------|
| 4 | Electrical Properties | Capacitance (F) | IEC62391-1 | <table border="1"> <thead> <tr> <th>Current (A)</th> <th>Capacitance (F)</th> <th>Ratio (%)</th> </tr> </thead> <tbody> <tr> <td>30</td> <td>3054.1</td> <td>102% of spec value</td> </tr> </tbody> </table> | Current (A) | Capacitance (F) | Ratio (%) | 30 | 3054.1 | 102% of spec value |
| Current (A) | | Capacitance (F) | Ratio (%) | | | | | | | |
| 30 | | 3054.1 | 102% of spec value | | | | | | | |
| 5 | | ESR (mΩ) | IEC62391-1 | Measured value 0.148mΩ(±10%) (Spec value 0.230 mΩ) | | | | | | |
| 6 | | Maximum specific Power (kW/kg) | LS Mtron Engineering Spec. | 15 kW/kg $(= \frac{V^2}{4*ESR*weight})$ | | | | | | |
| 7 | | Stored energy (Wh) | LS Mtron Engineering Spec. | 3.04 Wh $(= \frac{0.5*C*V^2}{3600})$ | | | | | | |
| 8 | Leakage current (mA) | IEC62391-1, LS Mtron Engineering Spec. | < 5 mA (72hr charging @ 2.7V) | | | | | | | |
| 9 | Self discharge (V) | IEC62391-1, LS Mtron Engineering Spec | 2.387 V (12hr charging, 100hr rest) | | | | | | | |

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| No. | Type of test | Test item | Standard | Results |
|-----|-----------------------------|----------------------------------|--|---|
| 10 | Thermal Characteristics | Thermal Resistance Test | Duty cycle test based on free convection cooling | 2.67 °C/W |
| 11 | Temperature Characteristics | Temperature Characteristics Test | QC/T741-2006, LS Mtron Engineering Spec. | 3064F, 0.148mΩ(±10%) @ 65 °C |
| 12 | | Low Temperature Measurement | QC/T741-2006, LS Mtron Engineering Spec. | 2992F, 0.220mΩ @ -40 °C |
| 13 | Reliability | Seal Test | LS Mtron Engineering Spec. | No visible damage, legible marking and No electrolyte leakage at interconnected parts with Al case body except safety vent |
| 14 | | Damp Heat Test | LS Mtron Engineering Spec., UL810A | No visible damage, legible marking and No electrolyte leakage at interconnected parts with Al case body except safety vent |
| 15 | | Rapid change of Temperature | IEC62391, LS Mtron Engineering Spec., UL810A | No visible damage, legible marking and No electrolyte leakage at interconnected parts with Al case body except safety vent |





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Electrical/ Thermal/ Temperature/ Reliability & Safety test

| No. | Type of test | Test item | Standard | Results |
|-----|--------------|------------------------------------|---|--|
| 16 | Reliability | Vibration and Shock test | IEC61373, IEC 60068 | $\Delta C/C \leq 10\%$ of value measured $\Delta ESR/ESR \leq 100\%$ of value measured (No visible damage/ No electrolyte leakage, There is no degradation of performance.) |
| 17 | | Temperature Load life test | IEC62391-2, LS Mtron Engineering Spec. | $\Delta C/C \leq 20\%$ of value measured @ 65°C, 1500hr $\Delta ESR/ESR \leq 100\%$ of value measured @ 65°C, 1500hr |
| 18 | | High Temperature Storage life Test | IEC62391-2, LS Mtron Engineering Spec. | No visible damage No electrolyte leakage $\Delta C/C \leq 10\%$ of measured value @ 100hr $\Delta ESR/ESR \leq 100\%$ of value measured @ 100hr |
| 19 | | Cycle life test | LS Mtron Engineering Spec. | $\Delta C/C \leq 20\%$ of value measured @ 25°C, 1,000K cycles $\Delta ESR/ESR \leq 100\%$ of value measured @ 25°C, 1,000K cycles (1cycle : 20sec charging → 10s CV → 20s discharging, 10s rest) |

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Electrical/ Thermal/ Temperature/ Reliability & Safety test

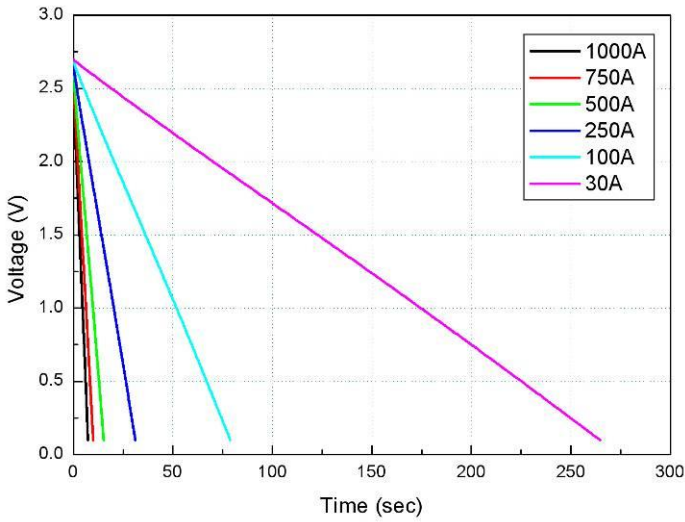
| No. | Type of test | Test item | Standard | Results |
|-----|--------------|---------------------------------------|--|---|
| 20 | Safety | Over - Discharge Test | SAND99-0497 (Electrochemical Storage System Abuse Test Procedure Manual), UL810A | No explode, No flame (Discharge to -2.7V) ↓  |
| 21 | | Over Charge Test | | No explode, No flame (Charge to 5.4V) ↓  |
| 22 | | Thermal Shock Test | | No explode, No flame (-40 ~ 80°C)  Photographs of sample after thermal shock cycling test |
| 23 | | Heating Test (Thermal Stability Test) | | No explode, No flame (30~ 200°C, rate 5°C/min)  |
| 24 | | Fall (Impact/ Shock test) | | UL810A |

TEST REPORT

Appendix 1. Test results

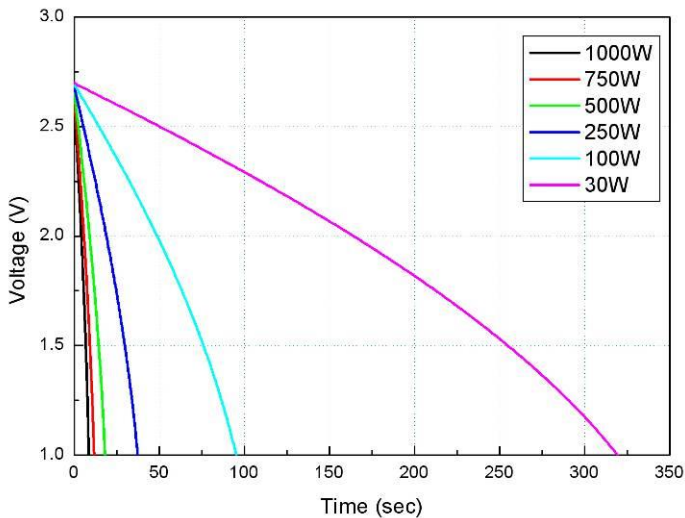
1. Electrical Properties

1) Discharging Constant Current Test



| Current (A) | Capacitance (F) | Ratio (%) |
|-------------|-----------------|-----------|
| 30 | 3054.1 | 100% |
| 100 | 3032.8 | 99% |
| 250 | 2991.3 | 98% |
| 500 | 2931.4 | 96% |
| 750 | 2870.3 | 94% |
| 1000 | 2810.7 | 92% |

2) Discharging Constant Power Test



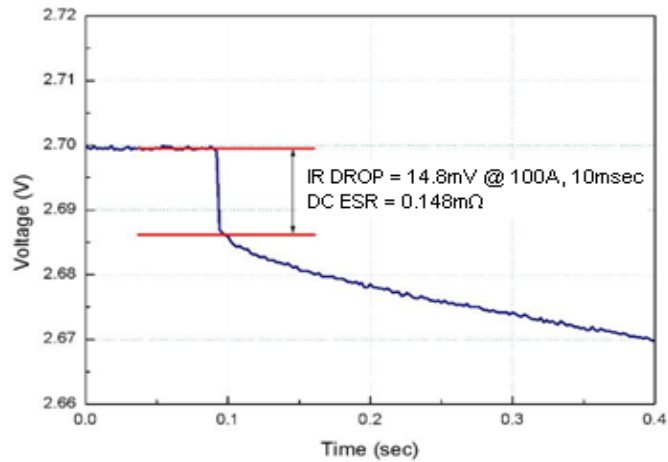
| Power (W) | Energy (Wh) | Ratio (%) |
|-----------|-------------|-----------|
| 30 | 2.67 | 100% |
| 100 | 2.65 | 99% |
| 250 | 2.64 | 99% |
| 500 | 2.52 | 94% |
| 750 | 2.44 | 91% |
| 1000 | 2.39 | 89% |

TEST REPORT

Appendix 1. Test results

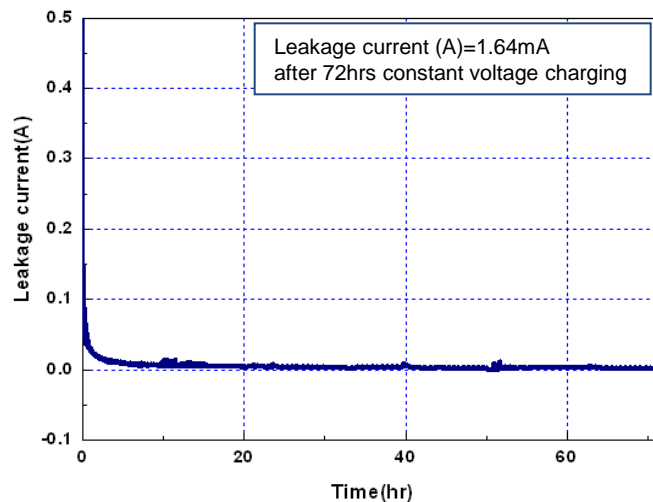
1. Electrical Properties

3) DC ESR test



4) Leakage current test

: The leakage current shall be measured using the direct voltage appropriate to the test temperature(25°C) for 72hrs.



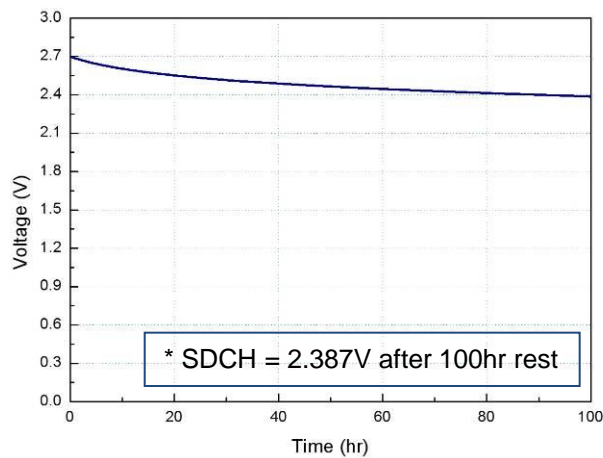
TEST REPORT

Appendix 1. Test results

1. Electrical Properties

5) Self Discharge test

Self discharge voltage shall be measured after charging up for 12hrs, disconnect the capacitor terminals from the voltage source. The capacitor shall be kept under standard condition for 100hrs.



TEST REPORT

Appendix 1. Test results

2. Thermal Characteristics

1) Thermal resistance (Case to ambient)

Generated heat:

$$\dot{Q} = I^2 R_{DC} \quad \text{with } I = \text{constant}$$

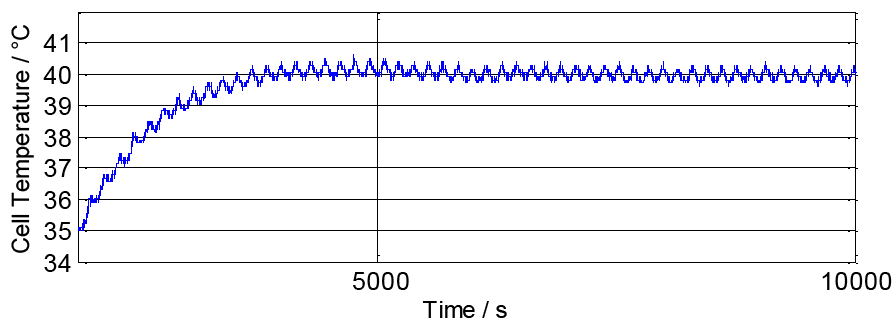
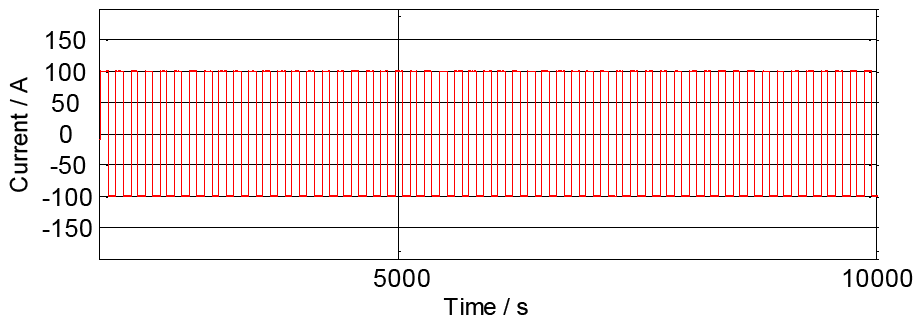
Temperature rise at cell surface can be estimated by: $T_{end} = \dot{Q} \cdot R_{th} + T_{start}$

The temperature characteristics can be calculated by using the following formula:

$$T(t) = (T_{end} - T_{start}) \cdot (1 - e^{-\frac{t}{\tau}}) + T_{start} \quad \text{with } \tau = R_{th} \cdot C_{th}$$

<Temperature ripples measured at cell surface at charging/discharging with 100 A>

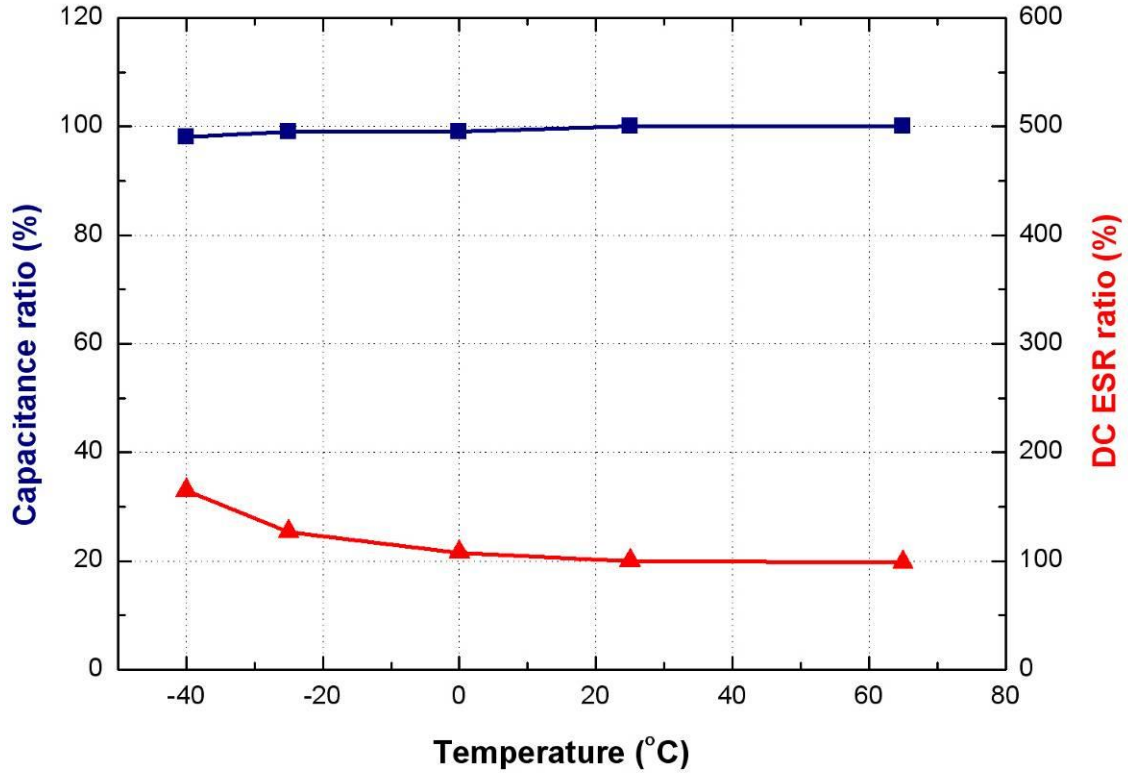
| | T1 | T2 | R _{th} |
|-------|---------|---------|-----------------|
| 100 A | 25.9 °C | 32.1 °C | 2.67 K/W |
| | 30.1 °C | 36.2 °C | 2.65 K/W |
| | 33.7 °C | 39.6 °C | 2.57 K/W |
| | 34.9 °C | 40.5 °C | 2.43 K/W |
| | 39.4 °C | 45.2 °C | 2.52 K/W |



TEST REPORT

Appendix 1. Test results

3. Temperature Characteristics



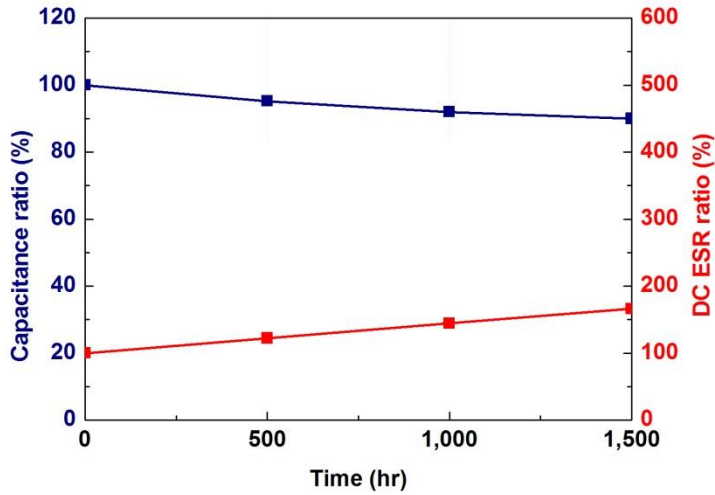
| Temp. | Capacitance ratio (%) | DC ESR ratio (%) |
|--------|-----------------------|------------------|
| 65 °C | 100 % | 100 % |
| 25 °C | 100 % | 100 % |
| 0 °C | 99 % | 108 % |
| -25 °C | 99 % | 127 % |
| -40 °C | 98 % | 158 % |

TEST REPORT

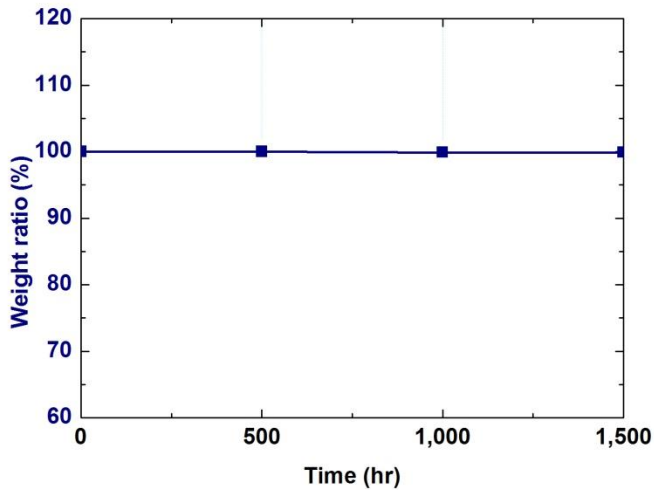
Appendix 1. Test results

4. Reliability

1) Seal test (add life test at high temperature)



<Figure A: 65°C, 2.7V life test>



<Figure B: Weight change monitoring @ 65°C, 2.7V life test>



<Appearance after test>

TEST REPORT

Appendix 1. Test results

4. Reliability

2) Vibration and shock test

Capacitance and DC ESR have been measured before and after test. There is no visible defect.

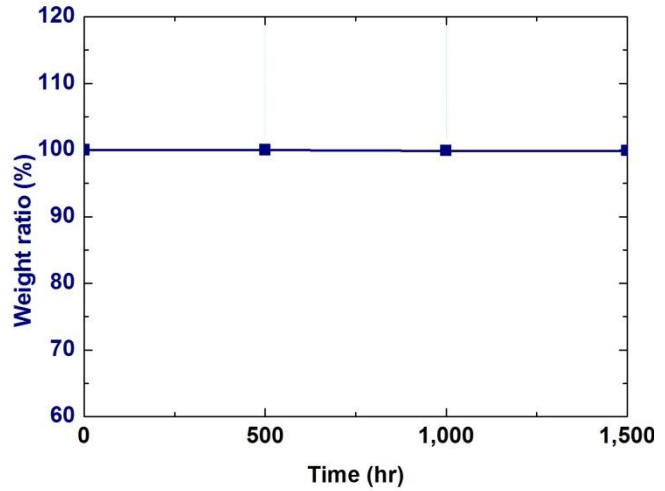
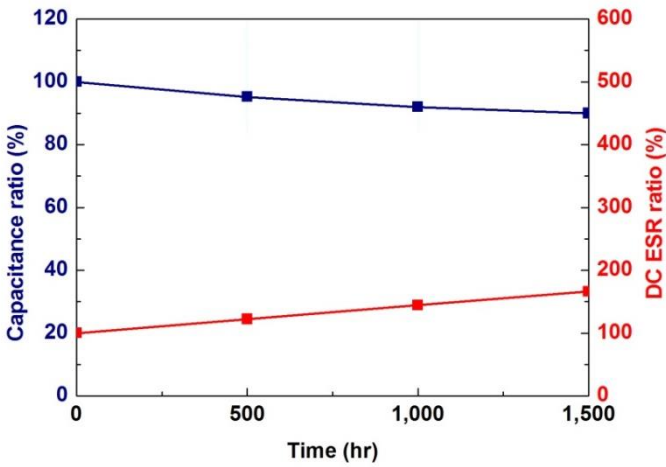
| 구분 | Before test | | | After test IEC 60068 | | | After test (IEC 61373) | | |
|------|-------------|-------------|-------------|-------------------------|-------------|-------------|---------------------------|-------------|-------------|
| | CAP (F) | ESR (mΩ) | SDCH (V) | CAP (F) | ESR (mΩ) | SDCH (V) | CAP (F) | ESR (mΩ) | SDCH (V) |
| Ref. | 3268 | 0.148 | 2.472 | 3279 | 0.140 | 2.482 | 3279 | 0.140 | 2.473 |

TEST REPORT

Appendix 1. Test results

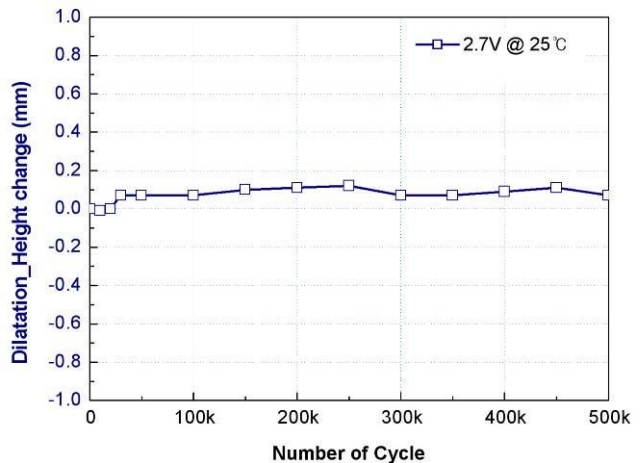
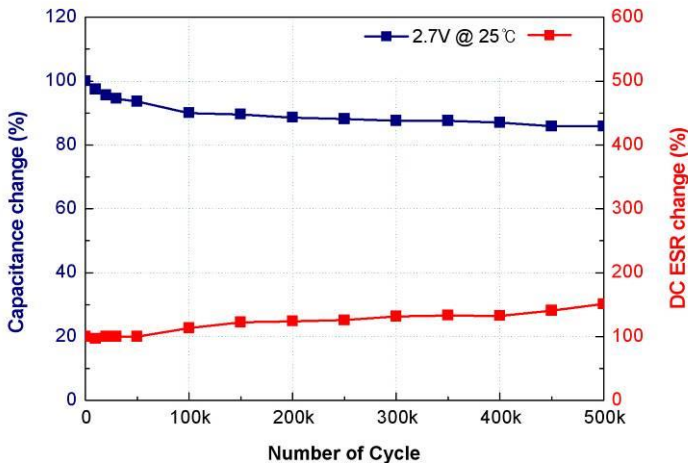
4. Reliability

3) Load life test @ 2.7V, 65°C



4) Cycle life test @ 25°C

*Actual cycle value can be subject to various application conditions.



TEST REPORT

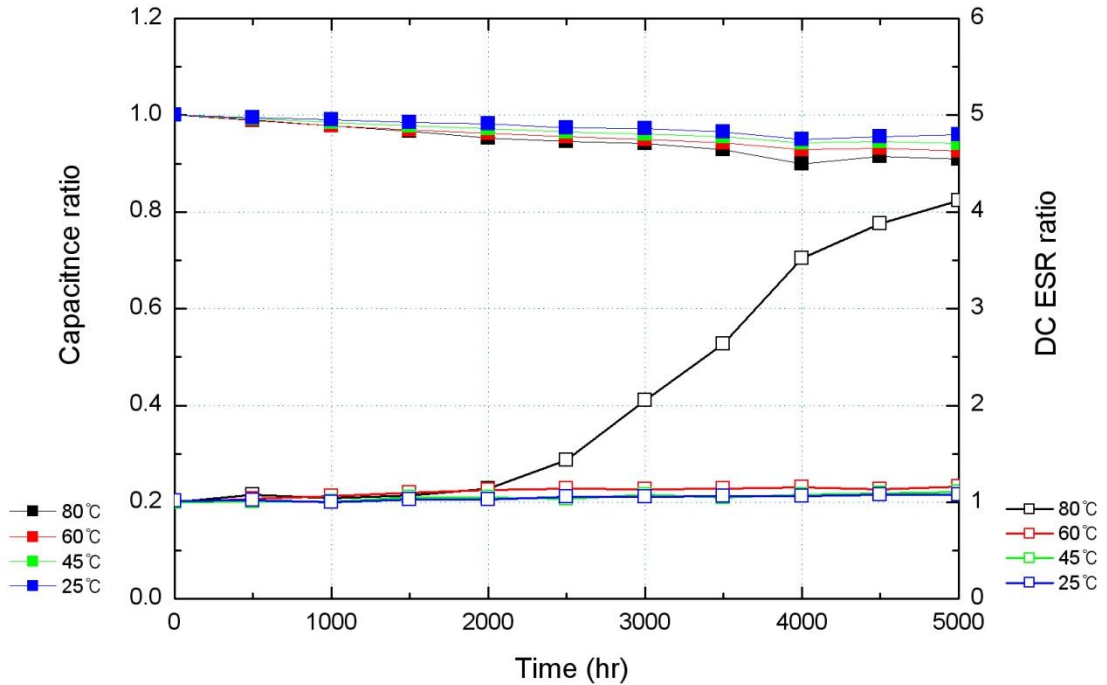
Characterization Test

4. Reliability

5) Shelf life test @ 25 ~ 85 °C

Storage test samples at 25 ~ 80 °C after initial characterization test (Capacitance & DC ESR).

Capacitance and DC ESR have been measured for around 7 months (5000hrs). There is no visible defect.



Technical Information (1)

How to calculate specification value

1. The Measurement Methods

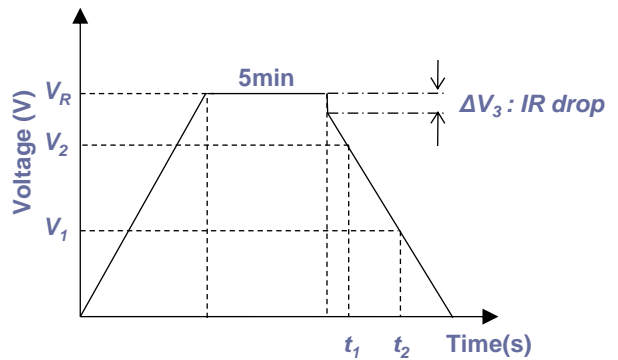
1-1 Capacitance

Apply rated voltage and charge for 5min after the constant current / constant voltage power supply has achieved the rated voltage. After a charge for 5min has finished, discharge with 10mA/F to 0.1V.

Measure the time t_1 to t_2 where the voltage between capacitor terminals at the time of discharge reduces from V_1 to V_2 as shown figure and calculate the capacitance value by the following formula:

- 1) Constant current charge with 10mA/F to V_R
- 2) Constant voltage charge at V_R for 5min
- 3) Constant current discharge with 10mA/F to 0.1V

$$C = \frac{I \times (t_2 - t_1)}{V_2 - V_1}$$



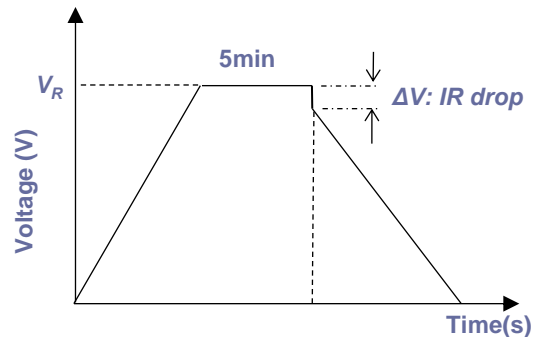
1-2 Resistance

The AC and DC resistance of a capacitor shall be calculated by the following formula;

$$R_{AC} = \frac{V}{I_{AC}} \quad (\text{The frequency of the measuring voltage shall be 100Hz})$$

$$R_{DC} = \frac{\Delta V}{I_{DC}}$$

- Where
- R_{AC} is the AC internal resistance (Ω);
 - R_{DC} is the DC internal resistance (Ω);
 - V is the effective value of AC voltage (V);
 - ΔV is the drop voltage for 10ms (V);
 - I_{AC} is the effective value of AC current (A);
 - I_{DC} is the discharge current (A);



Technical Information (2)

1-3 Leakage current & Self discharge

The leakage current shall be measured using the direct voltage appropriate to the test temperature(25 °C) for 72hrs. Self discharge voltage shall be measured after charging up for 12hrs, disconnect the capacitor terminals from the voltage source. The capacitor shall be kept under standard condition for 100hrs.

1-4 Maximum current

Current for 1sec discharge from the rated voltage to the half of it in constant current discharge,

$$I_{Max} = \frac{V_R - 0.5*V_R}{\Delta t / C + R_{DC}}$$

Where I_{Max} is the Maximum current (A);

Δt is the discharge time (sec), 1 sec in this case ;

C is the capacitance (F);

R_{DC} is the DC resistance (Ω);

V_R is the rated voltage (V).

1-5 Maximum stored energy (E_{MAX})

$$E_{MAX} (Wh) = \frac{\frac{1}{2} CV_R^2}{3600}$$

2. The Standard Atmospheric Condition for Measurement

All test and measurements shall be made under standard atmospheric conditions for testing. Before the measurements are made, the capacitor shall be stored at the measuring temperature for a time sufficient to allow the entire capacitor to reach this temperature. The period as prescribed for recovery at the end of a test is a normally sufficient for this purpose.

Temperature : 15~35 °C

Relative humidity : 25~75%

Air Pressure : 86~106 kPa