LS Ultracapacitor
New-generation Energy Storage Devices with Great Power and Great Reliability

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Leading Solution

LS Mtron, LS Cable & System, LSIS, LS-Nikko Copper, Gaon Cable, E1 and Yesco
Vision Statement

In order to become a leader in the competitive global market, LG has been divided into three business groups based upon their core competencies, Industrial Electric-Electronic, Energy & Materials (LS), Electronic & Chemical (LG), and Energy & Retail (GS).

INNOVATIVE TECHNOLOGY PARTNER - LS Mtron

LS Mtron’s mission is to grow into a company that provides market leading solutions while developing a workplace where its employee can achieve their dreams. All employees of LS Mtron stand behind the vision of becoming an Innovative Technology Partner and work tirelessly to make LS Mtron a world-class company.

LS Mtron will secure world-class core technologies to find and implement the most efficient solutions based on a market knowledge that can meet the challenges of our today’s markets. We will work hand-in-hand with our customers in order to grow into a global leader.

Business of LS Mtron

<table>
<thead>
<tr>
<th>Component</th>
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<tbody>
<tr>
<td>Ultracapacitor</td>
</tr>
<tr>
<td>Electronic Parts</td>
</tr>
<tr>
<td>Connectors / Antenna’s</td>
</tr>
<tr>
<td>Circuit Material</td>
</tr>
<tr>
<td>Copper Foils / FCCL</td>
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<tr>
<td>Vehicle Parts</td>
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<tr>
<td>Automotive Rubber Hose</td>
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<tr>
<td>Machinery</td>
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<tr>
<td>Tractor</td>
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<tr>
<td>Injection Molding Machine</td>
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<tr>
<td>Track Shoes</td>
</tr>
</tbody>
</table>
Overview

LS Ultracapacitor energy storage devices are positioned between conventional electrolytic capacitors and rechargeable batteries. LS Ultra capacitors feature high power, high energy, reliability and long life which enables use in a variety of applications such as back-up power, auxiliary power, instantaneous power compensation and peak power compensation.

- Rated voltage: up to 3.0V
- High power performance (vs. Battery)
- High energy performance (vs. Conventional electrolytic capacitor)
- Environmentally friendly
- Maintenance-free
- Wide operating temperature range (-40°C ~ +65°C)
Introduction to LS Ultracapacitor Technology

Structure
An Ultracapacitor consists of two electrodes immersed in an electrolyte and a separator which prevents the charge from moving between two electrodes of opposite polarity.

LS Mtron provides optimal package design to provide the best in performance and reliability.

Operating Principle
Ultracapacitors store energy based on electrostatic charges on opposite electrode surface of the electric double layer which is formed between the electrodes and the electrolyte. Randomly distributed ions in the electrolyte move toward the electrode surface of opposite polarity under electric field when charged. It is a purely physical phenomenon rather than a chemical reaction and is a highly reversible process. This results in a high power, high cycle life, long shelf life and maintenance-free product.
High Energy & High Power

Ultracapacitors are unique energy storage devices offering high power and high energy simultaneously, compared with conventional electrolytic capacitors and batteries. The high energy stored by Ultracapacitors in comparison to conventional electrolytic capacitors is derived from activated carbon electrode material having the extremely high surface area and the short distance of charge separation created by the opposite charges in the interface between electrode and electrolyte.

High power, long shelf and cycle life performance of Ultracapacitors originate in the energy storage mechanism differing from batteries. With batteries, energy is stored and released via chemical reaction inside electrode material that causes degradation of the entire system. On the other hand, Ultracapacitors use physical charge separation phenomena between the charge on an electrode and ions in electrolyte at the interface. Since the charge and discharge processes are purely physical and highly reversible, Ultracapacitors can release energy much faster and with more power compared to batteries which rely on slow chemical reactions and can be cycled hundreds of thousands of times without significant effect on performance.

Charge & Discharge

Ultracapacitors possess different charge and discharge characteristics compared with rechargeable batteries. Batteries have a voltage plateau region but Ultracapacitors have a linear relationship with voltage during charge and discharge. This linear relationship with voltage can change to constant voltage by simply utilizing a DC-DC converter. The amount of energy stored in an Ultracapacitor can be easily calculated by measuring voltage.

Formulas for calculating energy in a capacitor

The different units used between Ultracapacitors (Farad) and batteries (Ampere hour) can be confusing to users when adopting Ultracapacitors in their system. The amount of energy stored in an Ultracapacitor can be easily calculated by using following equation.

\[ \text{Energy (Joule)} = \frac{1}{2} \times \text{Capacitance (Farad)} \times \text{Voltage}^2 \] (Volt)

This can be converted from Farad for Ultracapacitors to Watt hour unit which is normally used for conventional rechargeable batteries.

\[ \text{Energy (Watt hour)} = \frac{\text{Energy (Joule)}}{3600} \] (sec)

LS Mtron recommends discharging Ultracapacitors from 100% of their rated voltage to 50% of their rated voltage in order to deliver 75% of their total energy.
LS Ultracapacitor Cells

Specifications

<table>
<thead>
<tr>
<th>Series</th>
<th>Part No.</th>
<th>Capacity</th>
<th>Rated Voltage</th>
<th>Max. ESR (DC)</th>
<th>Max. Current (Non-repeated)</th>
<th>Leakage Current</th>
<th>Max. Stored Energy</th>
<th>Weight</th>
<th>Operating Temperature Range</th>
<th>Type</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snap-in &amp; Lug Type</td>
<td>LSUC 002R8S 0100F EA</td>
<td>100F</td>
<td>2.8V</td>
<td>9mΩ</td>
<td>&lt;0.3mA</td>
<td>0.10Wh</td>
<td>0.023kg</td>
<td>-40~65°C</td>
<td>Snap-in</td>
<td>Φ32 X L46mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSUC 002R8S 0120F EA</td>
<td>120F</td>
<td>2.8V</td>
<td>9mΩ</td>
<td>&lt;0.4mA</td>
<td>0.13Wh</td>
<td>0.026kg</td>
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<td>Snap-in</td>
<td>Φ32 X L46mm</td>
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<tr>
<td></td>
<td>LSUC 002R8L 0200F EA</td>
<td>220F</td>
<td>2.8V</td>
<td>2mΩ</td>
<td>273A</td>
<td>&lt;1mA</td>
<td>0.078kg</td>
<td>-40~65°C</td>
<td>Lug</td>
<td>Φ35 X L61mm</td>
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<tr>
<td></td>
<td>LSUC 002R8L 0350F EA</td>
<td>350F</td>
<td>2.8V</td>
<td>3.2mΩ</td>
<td>231A</td>
<td>&lt;1mA</td>
<td>0.072kg</td>
<td>-40~65°C</td>
<td>Lug/Snap-in</td>
<td>Φ35 X L61mm</td>
<td></td>
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<tr>
<td></td>
<td>LSUC 002R8L 0400F EA</td>
<td>400F</td>
<td>2.8V</td>
<td>3mΩ</td>
<td>255A</td>
<td>&lt;1mA</td>
<td>0.080kg</td>
<td>-40~65°C</td>
<td>Lug/Snap-in</td>
<td>Φ35 X L66mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSUC 003R8S 0100F EA</td>
<td>100F</td>
<td>3.0V</td>
<td>9mΩ</td>
<td>&lt;0.3mA</td>
<td>0.12Wh</td>
<td>0.023kg</td>
<td>-40~65°C</td>
<td>Snap-in</td>
<td>Φ22 X L46mm</td>
<td></td>
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<tr>
<td></td>
<td>LSUC 003R8L 0300F EA</td>
<td>300F</td>
<td>3.0V</td>
<td>3.2mΩ</td>
<td>257A</td>
<td>&lt;1mA</td>
<td>0.072kg</td>
<td>-40~65°C</td>
<td>Lug/Snap-in</td>
<td>Φ35 X L61mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSUC 003R8L 0400F EA</td>
<td>400F</td>
<td>3.0V</td>
<td>3mΩ</td>
<td>282A</td>
<td>&lt;1mA</td>
<td>0.080kg</td>
<td>-40~65°C</td>
<td>Lug/Snap-in</td>
<td>Φ35 X L66mm</td>
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<tr>
<td></td>
<td>LSUC 003R8L 0450F EA</td>
<td>450F</td>
<td>3.0V</td>
<td>3mΩ</td>
<td>295A</td>
<td>&lt;1.2mA</td>
<td>0.088kg</td>
<td>-40~65°C</td>
<td>Lug/Snap-in</td>
<td>Φ35 X L71mm</td>
<td></td>
</tr>
</tbody>
</table>

• Endurance time (65°C, V/W) : 1500 hours (ΔC<20% decrease, ΔESR<100% increase of initial specified value)
• Projected life time (25°C, V/W) : 10 years (ΔC<20% decrease, ΔESR<100% increase of initial specified value)
• Projected cycle life time (25°C, V/W) : 500,000 cycles (ΔC<20% decrease, ΔESR<100% increase of initial specified value)

Actual cycle life time and value can be subject to various application conditions.

Prismatic Type | LSUC 002R8P 3000F EA | 3000F | 2.8V | 3.0mΩ | 2019A | <0.3mA | 3.26Wh | 0.650kg | -40~65°C | Prismatic | W65 X D55 X L155mm |

• Endurance time (65°C, V/W) : 1500 hours (ΔC<30% decrease, ΔESR<150% increase of initial specified value)
• Projected life time (25°C, V/W) : 10 years (ΔC<30% decrease, ΔESR<150% increase of initial specified value)
• Projected cycle life time (25°C, V/W) : 500,000 cycles (ΔC<30% decrease, ΔESR<150% increase of initial specified value)

Actual cycle life time and value can be subject to various application conditions.

Products

Terminal Type

- Snap-in (100F ~ 120F)
- Lug (300F ~ 600F)
- Snap-in (4pin, 350F ~ 600F)

- 2.8/3.0V Lug & Snap-in Type Cell
- Prismatic Type Cell
Specifications

<table>
<thead>
<tr>
<th>Series</th>
<th>Part No.</th>
<th>Capacitance</th>
<th>Rated Voltage</th>
<th>Max. ESR (DC)</th>
<th>Max. Current</th>
<th>Leakage Current</th>
<th>Max. Stored Energy</th>
<th>Weight</th>
<th>Operating Temperature Range</th>
<th>Type</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSUC 002R7C 0650F EA</td>
<td>650F</td>
<td>2.7V</td>
<td>0.57mΩ</td>
<td>640A</td>
<td>&lt;1.5mA</td>
<td>0.69Wh</td>
<td>0.200kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L51.5mm</td>
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<tr>
<td>LSUC 002R7C 1200F EA</td>
<td>1200F</td>
<td>2.7V</td>
<td>0.23mΩ</td>
<td>1160A</td>
<td>&lt;2.7mA</td>
<td>1.21Wh</td>
<td>0.280kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L74mm</td>
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<tr>
<td>LSUC 002R7C 1500F EA</td>
<td>1500F</td>
<td>2.7V</td>
<td>0.28mΩ</td>
<td>1426A</td>
<td>&lt;3.0mA</td>
<td>1.51Wh</td>
<td>0.320kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L85mm</td>
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<tr>
<td>LSUC 002R7C 2000F EA</td>
<td>2000F</td>
<td>2.7V</td>
<td>0.28mΩ</td>
<td>1753A</td>
<td>&lt;4.0mA</td>
<td>2.02Wh</td>
<td>0.380kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L102mm</td>
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<tr>
<td>LSUC 002R7C 3000F EA</td>
<td>3000F</td>
<td>2.7V</td>
<td>0.29mΩ</td>
<td>2396A</td>
<td>&lt;5.0mA</td>
<td>3.03Wh</td>
<td>0.513kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L138mm</td>
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<tr>
<td>LSUC 002R85C 3400F EA</td>
<td>3400F</td>
<td>2.85V</td>
<td>0.23mΩ</td>
<td>2719A</td>
<td>&lt;8.0mA</td>
<td>3.83Wh</td>
<td>0.513kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L138mm</td>
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</tr>
<tr>
<td>LSUC 003R0C 3000F EA</td>
<td>3000F</td>
<td>3.0V</td>
<td>0.23mΩ</td>
<td>2663A</td>
<td>&lt;5.0mA</td>
<td>3.75Wh</td>
<td>0.513kg</td>
<td>-40~65°C</td>
<td>Cylindrical</td>
<td>Φ60 X L138mm</td>
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</tr>
</tbody>
</table>

- Endurance time (65°C, 0.4C) : 1500 hours (ΔC<20% decrease, ΔESR<100% increase of initial specified value)
- Projected life time (25°C, 0.4C) : 10 years (ΔC<20% decrease, ΔESR<100% increase of initial specified value)
- Projected cycle life time (25°C, 0.4C) : 1,000,000 cycles (ΔC<20% decrease, ΔESR<100% increase of initial specified value)
- Actual cycle life time and value can be subject to various application conditions.

Products

Terminal Type
- Short Screw
- Weldable
- Long Screw (L T01)
- Long Screw (L T02)

Cell/Module Part No. Rule

<table>
<thead>
<tr>
<th>LS</th>
<th>R</th>
<th>F</th>
<th>(</th>
<th>)</th>
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</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Capacitance</td>
<td>Internally Control Code</td>
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<tr>
<td>Product(Cell) - Code C</td>
<td>Cell Type(Prismatic) - Code P</td>
<td>Electrolyte(AN) - Code EA</td>
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<tr>
<td>Product(Module) - Code M</td>
<td>Cell Type(Radial) - Code R</td>
<td>Electrolyte(PC) - Code EP</td>
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<tr>
<td>Series(AN Series, PC Series) - Code U</td>
<td>Cell Type(Snap-in) - Code S</td>
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<tr>
<td>Series(Hybrid Series) - Code H</td>
<td>Cell Type(Lug) - Code L</td>
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<tr>
<td>Cell Type(Cylindrical) - Code C</td>
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</tbody>
</table>
LS Ultracapacitor Modules provide the optimal solution for high voltage and current requirements by connecting Ultracapacitor unit cells in series. Higher voltage and capacitance modules can be built simply by connecting the modules. Low internal resistance and high working voltage features of LS Mtron modules maximize the available energy while keeping maintenance free, high reliability and wide operating temperature features of LS Ultracapacitor unit cell.

**Features**

- Low Internal Resistance
- Balancing and Overvoltage Protection
- Easy Build-up Design for High Voltage Module
- Efficient Heat Transfer to Outside
- Pressure / Moisture Control

LS Ultracapacitor modules are suitable energy storage systems for a wide variety of applications.

**Specifications**

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<tr>
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</thead>
<tbody>
<tr>
<td>LSUM 016R8L 0058F EA</td>
<td>58F</td>
<td>16.8V</td>
<td>22mΩ</td>
<td>20A</td>
<td>&lt;11mA</td>
<td>3.2Wh/kg</td>
<td>0.7kg</td>
<td>Active or Passive</td>
<td>Temperature (PTC) / Over Voltage</td>
<td>-40 ~ 65°C</td>
<td>L245 x W147 x H76.6mm</td>
</tr>
<tr>
<td>LSUM 162R4L 0015F EA</td>
<td>15.5F</td>
<td>162.4V</td>
<td>110mΩ</td>
<td>12A</td>
<td>&lt;25mA</td>
<td>3.0Wh/kg</td>
<td>18.5kg</td>
<td>Passive</td>
<td>Temperature (PTC) / Over Voltage</td>
<td>-40 ~ 65°C</td>
<td>L202 x W184 x H183.5mm</td>
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<tr>
<td>LSUM 168R8L 0005F EA</td>
<td>5.1F</td>
<td>168V</td>
<td>240mΩ</td>
<td>12A</td>
<td>&lt;25mA</td>
<td>3.5Wh/kg</td>
<td>6.5kg</td>
<td>Passive</td>
<td>Temperature (NTC) / Half Voltage Terminal</td>
<td>-40 ~ 65°C</td>
<td>L235 x W367 x H79mm</td>
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<td>LSUM 038R8L 0002F EA</td>
<td>2.5F</td>
<td>380.8V</td>
<td>650mΩ</td>
<td>12A</td>
<td>&lt;25mA</td>
<td>2.7Wh/kg</td>
<td>18.4kg</td>
<td>Passive</td>
<td>Temperature (PTC) / Over Voltage</td>
<td>-40 ~ 65°C</td>
<td>L750 x W191 x H163mm</td>
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<td>LSUM 016R2C 0250F EA AG</td>
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<td>16.2V</td>
<td>2mΩ</td>
<td>150A</td>
<td>&lt;3mA</td>
<td>2.3Wh/kg</td>
<td>3.9kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC)</td>
<td>-40 ~ 65°C</td>
<td>L311 x W166 x H70mm</td>
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<tr>
<td>LSUM 016R2C 0500F EA</td>
<td>500F</td>
<td>16.2V</td>
<td>1.7mΩ</td>
<td>200A</td>
<td>&lt;5mA</td>
<td>3.3Wh/kg</td>
<td>5.6kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC)</td>
<td>-40 ~ 65°C</td>
<td>L67.2 x W162 x H175.9mm</td>
</tr>
<tr>
<td>LSUM 016R2C 0500F EA AG</td>
<td>500F</td>
<td>16.2V</td>
<td>1.7mΩ</td>
<td>200A</td>
<td>&lt;5mA</td>
<td>3.1Wh/kg</td>
<td>5.9kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC)</td>
<td>-40 ~ 65°C</td>
<td>L47.0 x W166 x H70mm</td>
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<td>LSUM 022R6C 0250F EA</td>
<td>250F</td>
<td>32.4V</td>
<td>3.3mΩ</td>
<td>150A</td>
<td>&lt;11mA</td>
<td>3.6Wh/kg</td>
<td>10kg</td>
<td>Passive</td>
<td>-</td>
<td>-40 ~ 65°C</td>
<td>L137.1 x W426.6 x H184mm</td>
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<tr>
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<td>166F</td>
<td>48.6V</td>
<td>5mΩ</td>
<td>130A</td>
<td>&lt;5mA</td>
<td>3.9Wh/kg</td>
<td>14kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC) / Over Voltage</td>
<td>-40 ~ 65°C</td>
<td>L194.5 x W181.5 x H175.4mm</td>
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<tr>
<td>LSUM 048R6C 0166F EA YJ166F</td>
<td>166F</td>
<td>48.6V</td>
<td>5mΩ</td>
<td>200A</td>
<td>&lt;5mA</td>
<td>3.2Wh/kg</td>
<td>17.2kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC)</td>
<td>-40 ~ 65°C</td>
<td>L67.1 x W181 x H171mm</td>
</tr>
<tr>
<td>LSUM 051R3C 0166F EA</td>
<td>166F</td>
<td>51.3V</td>
<td>5mΩ</td>
<td>100A</td>
<td>&lt;28.5mA</td>
<td>5.1Wh/kg</td>
<td>12kg</td>
<td>Active &amp; Passive</td>
<td>Temperature (PTC) / Over Voltage</td>
<td>-40 ~ 65°C</td>
<td>L590.4 x W136 x H181mm</td>
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<tr>
<td>LSUM 086R4C 0093F EA</td>
<td>93F</td>
<td>86.4V</td>
<td>11.3mΩ</td>
<td>80A</td>
<td>&lt;120mA</td>
<td>3.6Wh/kg</td>
<td>27kg</td>
<td>Passive</td>
<td>Temperature (PTC)</td>
<td>-40 ~ 65°C</td>
<td>L517 x W265 x H210.5mm</td>
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<tr>
<td>LSUM 129R6C 0062F EA</td>
<td>62F</td>
<td>129.6V</td>
<td>13.2mΩ</td>
<td>250A</td>
<td>&lt;5mA</td>
<td>2.6Wh/kg</td>
<td>55kg</td>
<td>Active or Passive</td>
<td>Temperature (NTC) / Over Voltage (CAN2.0B)</td>
<td>-40 ~ 65°C</td>
<td>L720 x W405 x H226mm</td>
</tr>
</tbody>
</table>

- Leakage Current (1) can be changed by Balancing method
- NTC Thermistor & Group voltage monitoring via CAN2.0B
- Customized module can be supplied under the customer’s requirement

LS Ultracapacitor

New-generation Energy Storage Devices with Great Power and Great Reliability
Size Scalable (Up or Down)
Markets for LS Ultracapacitors

**HEV (Hybrid Electric Vehicle)**
- Auxiliary power
  - Recapture braking energy and compensate peak power load
  - Increase energy efficiency of vehicle
- Emergency backup power for brake
  - Increase reliability of safety system

**FCEV (Fuel Cell Electric Vehicle)**
- Output load compensation for fuel cell
  - Provide peak power compensation
    - (Fuel cell has constant power performance)

**Locomotives**
- Auxiliary power
  - Regenerate energy while braking
  - Provide peak power compensation
  - Installed in vehicle or station
  - Increase energy efficiency

**Hybrid Harbor Crane**
- Auxiliary power
  - Regenerate the energy while lowering the container
  - Provide output load compensation during lifting container
  - Reduce size of ICE
  - Increase energy efficiency of crane

**Photovoltaic & Solar light**
- Energy storage
  - Photovoltaic
    - Provide energy for motor used in heliostats
  - Solar light
    - Store energy generated from the sun light during daytime
    - Provide energy for light during night time
    - Increase service life of solar light product

**Power Quality Solution (UPS)**
- Instantaneous power compensation
  - Suitable for short time backup (~30 sec)
  - Fast reacting time could prevent voltage sag
  - Increase power quality for delicate process

**Wind Turbine**
- Emergency backup power
  - Provide emergency power for pitch system
  - Increase reliability of pitch system

**Hybrid Construction & Distribution Equipment**
- Auxiliary power
  - Recapture the energy from equipment operation
    - Excavator: Boom movement, Upper part rotation etc
    - Forklift: Lowering goods, braking forklift etc
  - Provide peak power compensation

- Output load compensation for fuel cell
- Increase reliability of pitch system
- Increase service life of solar light product
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