Construction and Characteristics of FPCAP

Construction of FPCAP

FPCAP is roughly the same construction as an aluminum electrolytic capacitor, and uses rolled aluminum foils in its capacitor element.

Manufacturing Process of FPCAP
Equivalent Circuit of Capacitor

\[ |Z| = \left( \frac{R_s + \frac{R_p}{1 + \omega^2 C_p^2 R_p^2}}{1 + \omega^2 C_p^2 R_p^2} \right)^2 + \left( \frac{\omega L - \frac{\omega C_p R_p^2}{1 + \omega^2 C_p^2 R_p^2}}{1 + \omega^2 C_p^2 R_p^2} \right)^2 \]

Feature of Functional Polymer

- Electrolyte (Aluminum Electrolytic Capacitor)
- Manganese dioxide (Tantalum Solid Electrolytic Capacitor)
- TCNQ Complex salt (Organic Semiconductive Capacitor)
- PPY by Chemical Polymerization
- PPY by Electrolytic Polymerization

**Conductive Polymer (PEDOT)**

FPCAP differs from the aluminum electrolytic capacitor in that in place of the electrolyte, functional polymer is impregnated.
**Typical Electrical Characteristics of Capacitors**

**Frequency Dependence**

FPCAP has excellent frequency characteristic nearly equal to the film capacitor. Using the high conductivity of the Functional polymer with an electrolyte, and adopting the winding element for layer thinness of electrolyte, the ESR is improved greatly and has the frequency characteristic that is nearly equal to the film capacitor.

**Typical Temperature Dependence of Capacitors**

The temperature dependence of the FPCAP is that it features little change in temperature for the ESR.

Since ESR is dominant at high range of impedance (near resonance point), the ESR value greatly affects Noise clearing capacity.

What ESR changes little against temperature means that Noise clearing ability changes little against temperature as well.
**Frequency Dependence**

L8 series 2.5V 560µF (φ8×8L)
NU series 6.3V 1000µF (φ8×11.5L)
NU series 16V 270µF (φ8×11.5L)
Resistance to Soldering Heat

Test condition: 260°C, 30sec

<table>
<thead>
<tr>
<th>Current (Arms)</th>
<th>ΔCc/C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
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<tr>
<td>2</td>
<td>0</td>
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<tr>
<td>3</td>
<td>0</td>
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<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Current (Arms)</th>
<th>ESR (Ω) at 100kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.01</td>
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<tr>
<td>1</td>
<td>0.1</td>
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<td>2</td>
<td>1</td>
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<td>3</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
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</table>

Fevering Temperature by Ripple Current

\[ \Delta T = \frac{I^2 R}{\alpha \beta S} \]

\[ \log \Delta Tc = \log \left( \frac{I^2 R}{\alpha \beta S} \right) \]

\[ = \log I^2 + \log R - \log \alpha \beta S \]

\[ = 2 \times \log I + (\log R - \log \alpha \beta S) \]

\[ = 2 \times \log I + A \]

Where,

- \( I \) : Ripple Current (Arms)
- \( R \) : ESR (Ω)
- \( \Delta T \) : Fevering Temp. at Outside Wall of Capacitor (°C)
- \( \Delta Tc \) : Fevering Temp. at Inside of Capacitor (°C)
- \( \beta \) : Heat Radiation coefficient (W/ °C×cm²)
- \( S \) : Surface Area of Aluminum Case(cm²)
- \( \alpha \) : Ratio of \( \Delta Tc / \Delta T \)
Reliability at 105°C

### Change of Capacitance

- **NS series 6.3V 47µF (φ6.3×7L)**
- **L8 series 2.5V 560µF (φ8×8L)**
- **NS series 4.0V 1200µF (φ10×12.5L)**

### Change of Tangent of Loss Angle

### Change of Leakage Current

### Change of Equivalent Series Resistance
Calculation Formula of Lifetime
For FPCAP

In general, calculation formula of lifetime of capacitors is appeared as follows.
The calculation formula of lifetime on FPCAP is same as usual Aluminum capacitor.

\[ L_X = L_0 \times 10^{(T_0 - T_x)/20} \]

Where,
- \( L_X \) (Hrs) = Life expectancy in actual use
- \( L_0 \) (Hrs) = Life time
- \( T_0 \) (105°C) = Maximum operating temperature (105°C)
- \( T_x \) (°C) = Temperature of capacitor in actual use

On the other hand, temperature \( T_x \) adds the circumference temperature \( T \) as the capacitor temperature and the generating temperature \( \Delta T \) by ripple current.

\[ T_x = T + \Delta T \]

- \( T \) (°C) = Ambient temperature
- \( \Delta T \) (°C) = generating temperature

Furthermore, the generating temperature \( \Delta T \) by the ripple current is proportional to ripple current, and is shown by the following formula.

\[ \Delta T = (I / I_0)^2 \times \Delta T_0 \]

- \( I \) (A rms) = Ripple current in actual use
- \( I_0 \) (A rms) = Maximum permissible ripple current
- \( \Delta T_0 \) (°C) = Generated temperature value by maximum permissible ripple current
  [About 20 (°C)]
**DC/DC Converter Primary, Secondary Side Smoothing**

**Input side**
- For Primary Side Smoothing

**Output side**
- For Secondary Side Smoothing
- For Secondary Side Smoothing

**Back-up Capacitor for Variable Load (1)**
- Input side: 12V
- Output side: 3.3 to 5V
- Capacitors: FPCAP 16V, FPCAP 6.3V, FPCAP 2.5 to 4V

**Back-up Capacitor for Variable Load (2)**
- Input side: 3.3 to 5V
- Output side: 1.6 to 1.8V
- Capacitors: FPCAP 6.3V, FPCAP 2.5 to 4V

**Noise Filters**
- Input side: 3.3 to 5V
- Output side: 1.6 to 1.8V
- Capacitors: FPCAP 6.3V
Ripple Removal Capability

We measured ripple voltage by oscilloscope for output capacitor change on the typical chopper type DC-DC converter. (described below)

Examination of Same Level Residual Ripple Voltage

To obtain same level of ripple voltage to FPCAP, Low Impedance Aluminum capacitor needs 16V3300uF, even Low ESR tantalum capacitor needs 4 pcs. of same capacitance.

Comparison Between FPCAP and Other Capacitors with Same Capacitance

Low Impedance Aluminum Capacitor
16V100uF (φ6.3x11L)
ΔV=156mV

Low ESR Tantalum Capacitor
16V100uF (7.3x4.3x2.9)
ΔV=76mV

FPCAP
16V100uF (φ8x11.5L)
ΔV=58mV

Examining Same Level Residual Ripple Voltage

To obtain same level of ripple voltage to FPCAP, Low Impedance Aluminum capacitor needs 16V3300uF, even Low ESR tantalum capacitor needs 4 pcs. of same capacitance.
Spice Model for Simulation Circuits with Computer

Spice Model of Radial lead type (L8 and S8 Series)

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Cp (μF)</th>
<th>Rs (mΩ)</th>
<th>L (nH)</th>
<th>LC (μA)</th>
<th>Rp (kΩ)</th>
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<tbody>
<tr>
<td>RL80E821MDN1</td>
<td>820</td>
<td>4.2</td>
<td>2.9</td>
<td>100</td>
<td>25</td>
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<tr>
<td>RL80G561MDN1</td>
<td>560</td>
<td>4.2</td>
<td>2.9</td>
<td>100</td>
<td>40</td>
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<td>RL80J561MDN1</td>
<td>560</td>
<td>5.0</td>
<td>2.9</td>
<td>100</td>
<td>63</td>
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<tr>
<td>RS80E331MDN1</td>
<td>330</td>
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<td>RS80E471MDN1</td>
<td>470</td>
<td>5.3</td>
<td>2.0</td>
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<td>RS80E561MDN1</td>
<td>560</td>
<td>5.3</td>
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<td>100</td>
<td>25</td>
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</table>

Typical ESL by Case Size

<table>
<thead>
<tr>
<th>Classification</th>
<th>Case Size (mm)</th>
<th>ESL (nH, 40MHz)</th>
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<tbody>
<tr>
<td>Radial lead type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>φ6.3×8L (S8)</td>
<td>1.8 to 2.2</td>
<td></td>
</tr>
<tr>
<td>φ6.3×10L</td>
<td>2.8 to 3.0</td>
<td></td>
</tr>
<tr>
<td>φ8×8L (L8)</td>
<td>2.7 to 3.1</td>
<td></td>
</tr>
<tr>
<td>φ8×11.5L</td>
<td>3.9 to 4.1</td>
<td></td>
</tr>
<tr>
<td>φ8×11.5L (R7)</td>
<td>4.6 to 4.9</td>
<td></td>
</tr>
<tr>
<td>φ10×12.5L</td>
<td>5.4 to 5.6</td>
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</tr>
<tr>
<td>SMD type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>φ4×5.2L</td>
<td>1.0 to 1.2</td>
<td></td>
</tr>
<tr>
<td>φ6.3×5.7L</td>
<td>2.5 to 2.7</td>
<td></td>
</tr>
<tr>
<td>φ8×11.7L</td>
<td>3.1 to 3.3</td>
<td></td>
</tr>
<tr>
<td>φ10×12.4L</td>
<td>4.5 to 4.7</td>
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</tbody>
</table>

Equivalent Circuit of Capacitor

\[
|Z| = \sqrt{\left(\frac{R_p}{1 + \omega^2 C_p R_p^2}\right)^2 + \left(\omega L - \frac{\omega C_p R_p^2}{1 + \omega^2 C_p R_p^2}\right)^2}
\]

* It is available to present the spice model of other parts for customers.