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**

- **Etched Al Foil**
- **Forming**
- **Slitting**
- **Winding**
- **Forming**
- **Polymerization**
- **Sealing**
- **Aging and Inspection**
- **Shipping**
- **Tab Terminal**
- **Separator Sheet**
- **Functional Polymer**
- **Assembling Parts**
**Equivalent Circuit of Capacitor**

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

**Feature of Functional Polymer**

- **100** Electrolyte (Aluminum Electrolytic Capacitor)
- **10** Manganese Dioxide
  (Tantalum Solid Electrolytic Capacitor)
- **1** TCNQ Complex Salt
  (Organic Semiconductive Capacitor)
- **0.1** PPY by Chemical Polymerization
- **0.01** 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)

HS series 6.3V 390µF (φ8×6.7L)
SA series 6.3V 220µF (φ6.3×5.7L)
SL series 6.3V 220µF (φ6.3×4.2L)

VA series 16V 33µF (7.3×4.3×2.8)
UA series 16V 27µF (7.3×4.3×1.9)
**Resistance to Soldering Heat**

Test Condition: 260°C, 30sec

<table>
<thead>
<tr>
<th>I (Arms)</th>
<th>ΔC/C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<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>
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<tr>
<td>5</td>
<td>0</td>
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</tbody>
</table>

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

**Fevering Temperature by Ripple Current**

\[ I^2 R = \Delta T \times \beta \times S = \Delta T_c \times \alpha \times \beta \times S \]

\[ \Delta T_c = \frac{(I^2 R)}{(\alpha \times \beta \times S)} \]

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

Where,
- I: Ripple Current (Arms)
- R: ESR (Ω)
- ΔT: Fevering Temp. at Outside Wall of Capacitor (°C)
- ΔTc: Fevering Temp. at Inside of Capacitor (°C)
- β: Heat Radiation Coefficient (W/°C×cm²)
- S: Surface Area of Aluminum Case (cm²)
- α: Ratio of ΔTc/ΔT

L8 series 2.5V 560µF (φ8×8L)
R7 series 2.5V 820µF (φ8×11.5L)
R7 series 4.0V 820µF (φ10×12.5L)
VB series 2.0V 330µF (7.3×4.3×2.8)
Reliability at 105°C

Change of Capacitance

Change of Tangent of Loss Angle

Change of Leakage Current

Change of Equivalent Series Resistance

Technical Guide

NICHICON CORPORATION / FPCAP ELECTRONICS (SUZHOU) CO., LTD.
Estimating of Lifetime

**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.

\[ L_X = L_0 \times 10^{\left(\frac{T_0 - T_X}{20}\right)} \]

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

There are two methods to calculate the heat rise (\( \Delta T \)) of a capacitor by ripple current.

a) Measure the temperature of a capacitor in operation by means of fixing a thermocouple on the case of a capacitor or other suitable methods.
   The temperature difference between the temperature measured of the capacitor and the ambient temperature is considered as the heat rise by ripple current.

b) The heat rise by ripple current is calculated by the following formula.

\[ \Delta T = \left( \frac{I}{I_0} \right)^2 \times \Delta T_0 \]

- \( I \) (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

[Aluminum Can Type: About 20°C, Molded Chip Type: About 10°C]

Remark: It is recommended to use the method of formula calculation during the design phase, and use the method of actual measurement when checking as a set.
**DC/DC Converter Primary, Secondary Side Smoothing**

**Input side**
- For Primary Side Smoothing

**Output side**
- For Secondary Side Smoothing

**Back-up Capacitor for Variable Load (1)**

- **12V**
  - FPCAP 16V
  - IC

- **3.3~5V**
  - FPCAP 6.3V
  - IC

- **1.6~1.8V**
  - FPCAP 2.5~4V
  - CPU

**Back-up Capacitor for Variable Load (2)**

- **3.3~5V**
  - FPCAP 6.3V
  - IC

- **1.6~1.8V**
  - FPCAP 2.5~4V
  - CPU

**Noise Filters**

- FPCAP 6.3V
- IC
- IC

**Functional Polymer Aluminum Solid Electrolytic Capacitors**
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 (φ6.3×11L)
ΔV=156mV

Low ESR Tantalum Capacitor
16V100uF (7.3×4.3×2.9) × 4 pcs.
ΔV=59mV

Low ESR Tantalum Capacitor
16V100uF (7.3×4.3×2.9)
ΔV=76mV

Low Impedance Aluminum Capacitor
16V3300uF (φ16×25L)
ΔV=60mV

Low ESR Tantalum Capacitor
16V100uF (7.3×4.3×2.9)
ΔV=58mV
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>
</tr>
</thead>
<tbody>
<tr>
<td>RL80E821MDN1</td>
<td>820</td>
<td>4.2</td>
<td>2.9</td>
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<td>25</td>
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<tr>
<td>RL80G561MDN1</td>
<td>560</td>
<td>4.2</td>
<td>2.9</td>
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<td>RL80J561MDN1</td>
<td>560</td>
<td>5.0</td>
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<td>100</td>
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<td>RS80E331MDN1</td>
<td>330</td>
<td>5.3</td>
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<td>RS80E471MDN1</td>
<td>470</td>
<td>5.3</td>
<td>2.0</td>
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<td>50</td>
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<tr>
<td>RS80E561MDN1</td>
<td>560</td>
<td>5.3</td>
<td>2.0</td>
<td>100</td>
<td>25</td>
</tr>
</tbody>
</table>

Typical ESL by Case Size

<table>
<thead>
<tr>
<th>Classification</th>
<th>Case Size (mm)</th>
<th>ESL (nH, 40MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial Lead Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>φ6.3×8L (S8)</td>
<td></td>
<td>1.8 to 2.2</td>
</tr>
<tr>
<td>φ6.3×10L</td>
<td></td>
<td>2.8 to 3.0</td>
</tr>
<tr>
<td>φ8×8L (L8)</td>
<td></td>
<td>2.7 to 3.1</td>
</tr>
<tr>
<td>φ8×11.5L</td>
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<td>3.9 to 4.1</td>
</tr>
<tr>
<td>φ8×11.5L (R7)</td>
<td></td>
<td>4.6 to 4.9</td>
</tr>
<tr>
<td>φ10×12.5L</td>
<td></td>
<td>5.4 to 5.6</td>
</tr>
<tr>
<td>SMD Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>φ4×5.2L</td>
<td></td>
<td>1.0 to 1.2</td>
</tr>
<tr>
<td>φ6.3×5.7L</td>
<td></td>
<td>2.5 to 2.7</td>
</tr>
<tr>
<td>φ8×11.7L</td>
<td></td>
<td>3.1 to 3.3</td>
</tr>
<tr>
<td>φ10×12.4L</td>
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<td>4.5 to 4.7</td>
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<tr>
<td>7.3×4.3×1.9</td>
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<td>1.3 to 1.5</td>
</tr>
<tr>
<td>7.3×4.3×2.8</td>
<td></td>
<td>1.6 to 1.8</td>
</tr>
</tbody>
</table>

Equivalent Circuit of Capacitor

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

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