Capacitor Committee –
Capacitor Fundamentals 401:
Choosing a Capacitor From Start To Finish
Fred Weber

President
Future Technology Worldwide, LLC

President + Co-Chair Transportation & Capacitor Committees
PSMA

Background:

- 37 years of work experience in the Automotive and Electronics industry
- Background in Manufacturing, Design, Program Management, and Sales Engineering
- FTWLLC, LLC formed in 2001 a Sales Representative firm focused on Power Electronics and Services in the Great Lakes States.

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The principal activities of PSMA include:

- Co-Sponsors of the Applied Power Electronics Conference (APEC)
- Provides and maintains a Web Site with relevant industry and member information
- Conducts regular member surveys to identify areas of importance or concern
- Develops standard industry terminology
- Generates and publishes technology and market reports
- Provides regulatory agency interface
- Organizes technical workshops and seminars
- Coordinates with other power related organizations
- Facilitates benchmarking studies with member companies
- Promotes liaison with users, academia and government

PSMA Benefits:

- **Networking:** Opportunity to meet and interact with your counterparts in other companies on an ongoing basis
- **Valuable Information:** Members enjoy access to information in the Members Only area of the Web site
- **Involvement:** Opportunity to be involved with the planning and managing of APEC -- Applied Power Electronics Conference -- sessions that focus on the specific interest of members
- **Participation:** Participate in committees, workgroups and studies to derive a better understanding of market trends, industry trends and better operational procedures to improve performance
- **Discounts:** Receive discounts on registration fees for attending APEC and other PSMA sponsored events
- **PSMA/APEC Passport Program:** All PSMA members exhibiting at APEC can be included in the Passport to increase booth traffic.
- **Finding Trends:** Increase awareness and knowledge of trends and factors that can impact your company
- **Company Profile:** Listing of your company’s profile on the PSMA Web Site with a hyperlink directly to your company Web Site
- **Resources:** Opportunity to post job openings and view resumes
- **PSMA Publications:** Regular members receive a copy of all new PSMA publications and reports with discounts for additional copies. Affiliate members may purchase the publications and reports at a discount
- **Power Technology Roadmap Report:** Regular members receive a copy with discounts for additional copies. Affiliate members may purchase the report at a discount
- **Benchmarking:** Improve the operation of your company by participating in benchmarking studies with other companies in your industry
- **PSMA Newsletter:** Receive “Update” the quarterly newsletter of the PSMA, with information on activities in the industry and upcoming events. You may contribute articles for publication in the “Update”
- **Member Company Spotlight Banner:** Feature your company’s products on the PSMA Home Page
Capacitor Committee

- Meets once per month for 1 hour
- Creating a new sub-committee for “Energy Storage & Their Applications”
- Members are both from Industry & Universities
- Organizes Workshops, Webinars, and Industry Sessions
  - **Workshops** – Chaired by Pierre Lohrber / Wurth
    Full day event typically held the Saturday before APEC in the same venue
  - **Industry Session** – Chaired by Wilmer Companioni / KEMET
    6 or 7 subject event held during APEC
  - **Webinars** – Chaired by Fred Weber / FTW
    Several different formats – Capacitor Fundamentals Series
    Roadmap Submissions
    Automotive Capacitor Fundamentals
Capacitor Committee Workshops
Mission Statement

The PSMA Capacitor Committee Annual Workshop aligned with APEC has a mission to educate the attendees on capacitor trends, technologies, and innovations. Wherever and whenever applications need energy, Capacitors are at the spotlight, and as energy moves the world it is incumbent for everyone to keep their finger on the pulse of capacitor issues. PSMA’s Capacitor Committee is committed to present the best material available to meet the industry’s needs.
Capacitor Committee Webinars
Automotive Capacitor Fundamentals
3 Webinar Series

Abstract

PSMA Capacitor Committee will be offering a series of 3 educational webinars presented by design leaders in the industry explaining a best practices approach to choosing the capacitor that will be best for your application. The Webinars will be separated by their voltage levels:
1) 12 Volt System – John Rice, Maxim
2) 48 Volt System - TBD
3) High Voltage System (400V to 800V) – Eric Schneider, Independent
Introduction of the Presenter

Eric Schneider
Independent Electrical Engineer

Background:

- More than 35 years of engineering and management experience in industry
- Background in Power Electronics, Energy Conversion, and Energy Storage Development
- Application capability includes consumer products, automotive components and systems, and aerospace systems

Message me on LinkedIn:
www.linkedin.com

Eric Schneider
Technical Specialist - Development and Application of Power Electronics, Energy Storage, and Rotating Machines
In this webinar:

- We explore the use and placement of capacitors in a widely used power supply type – a charger/supply for a laptop computer.
- We will look at a schematic and discuss the roles of the capacitors within the circuit.
- We will then focus our attention on the input and output bulk filter capacitors, and what types of capacitors could be used in those spots in the circuit.
- We will look at data sheets for capacitors with specific traits based on values from a design example, and compare advantages and disadvantages from a technical point of view.
Basic Schematic and Capacitor Roles

- Ref.: AN-6094 from ON Semiconductor
- Flyback type converter – typical output switching frequency around 100kHz.
- Different roles of capacitors in the circuit:
  - Capacitors for the control circuit, like $C_{FB}$
  - Capacitors for voltage spike cancellation, like $C_{SNB}$
  - Capacitors for DC bus smoothing, like $C_{DL1}$ and $C_{O1}$ – also referred to as "bulk" filtering capacitors
DC Bus Capacitors

For this presentation, we will concentrate on choosing the DC bus smoothing (bulk) capacitors.
Capacitor Technology Slide from Webinar 301

Most Common Capacitor Technologies

- Ceramic (MLCC)
- Film (Metalized Film)
- Aluminum (Electrolytic)
Capacitor Technology Slide from Webinar 301

OTHER CAPACITOR TECHNOLOGIES

Tantalum

Supercapacitors
Operating Areas of Capacitor Technologies

Area of interest – Capacitor Tech. Overlap
In this specific example, the input bulk capacitor, C2, is shown as 120uF, 400V.

The output bulk capacitance is shown as 2 capacitors, C13 and C14, and listed as 470uF, 25V.

Capacitor C1, which wasn’t shown in the first circuit example, is for electromagnetic interference (EMI) filtering.

This role could be the subject of another presentation.
Design Considerations and Calculations

• Considerations:
  • The power supply spends the vast majority of operational time at an ambient between 20 and 30 deg. C;
  • The temperature rise is somewhat moderate by design;
  • The device can be handled without discomfort;
  • Therefore, the highest ambient temperature inside for the capacitor under continuous full load condition is 60 deg. C;
  • The device life expectancy is less than 5 years, with about 1/3 of the time at full load conditions;
  • The full load ripple current for the input capacitor is about 1.2a rms; (see next page)
  • The full load ripple current for each output capacitor is about 3.4a rms; (see next page)
Design Considerations and Calculations

- **Input Capacitor Ripple Current Estimate**
  - Capacitor DC voltage approx.:
    - \( V_c \text{ (DC)} \approx \text{VAC} \times \text{Sqrt.2} = 90 \times 1.414 \approx 125 \text{VDC} \)
  - Input power \( \approx \) Output power/efficiency = 65/.9 \approx 72 \text{W} 
  - Input side DC current = Input Power/Capacitor DC voltage = 72/125 \approx 0.6 \text{ A} 
  - Ripple current is approx. 2 \times \text{Input side DC current (rule of thumb)} = 1.2 \text{a rms} 

- **Output Capacitor ESR requirements and Ripple Current Estimate**
  - Assume peak-peak ripple voltage (Vop-p) of 200mV
  - Total peak capacitor current (Icpk) is 4 \times \text{the rated output} = 4 \times 3.42= 13.7 \text{a} 
  - Total ESR = \( \frac{\text{Vop-p}}{\text{Icpk}} = 0.014 \text{ ohm} \)
  - Total Ripple current is approx. 2 \times \text{output side DC current (rule of thumb)} = 6.8 \text{a rms} 
  - Since we are split between 2 capacitors, each cap has an ESR of 0.028 ohm, and a ripple current of 3.4a rms
Input Capacitor – Electrolytic Type

Our application

Important for portable equipment

Our application: Electrolytic Type

<table>
<thead>
<tr>
<th>Snap-in capacitors</th>
<th>B43647</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra compact – 105 °C</td>
<td></td>
</tr>
</tbody>
</table>

Long-life grade capacitors

Applications
- Power supplies
- Frequency converters
- Uninterruptible power supplies
- Medical appliances
- Solar inverters
- Not for automotive applications unless otherwise specified

Features
- Extremely high CV product, ultra compact
- High reliability
- High ripple current capability
- Capacitors pass the needle flame test according to IEC 60695-11-5 for all flame exposure times up to 120 s
- RoHS-compatible

Construction
- Charge/discharge-proof, polar
- Aluminium case, insulated with PET sleeve without insulation sheet at the can bottom
- Snap-in solder pins to hold component in place on PC-board
- Minus pole marking on case surface
- Minus pole not insulated from case
- Overload protection by safety vent on the base

Terminals
- Standard version with 2 terminals,
  2 lengths available: 6.3 and 4.5 mm
- 3 terminals to ensure correct insertion: length 4.5 mm
**Input Capacitor – Electrolytic Type**

Understanding useful life and how it is calculated is the key to choosing an electrolytic capacitor.

<table>
<thead>
<tr>
<th>Specifications and characteristics in brief</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage $V_R$</td>
</tr>
<tr>
<td>Surge voltage $V_S$</td>
</tr>
<tr>
<td>Rated capacitance $C_R$</td>
</tr>
<tr>
<td>Capacitance tolerance</td>
</tr>
<tr>
<td>Dissipation factor $\tan \delta$ (20 °C, 120 Hz)</td>
</tr>
<tr>
<td>Leakage current $I_{\text{leak}}$ (5 min, 20 °C)</td>
</tr>
<tr>
<td>Self-inductance ESL</td>
</tr>
<tr>
<td>Useful life $^{(1)}$</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Requirements:

- $| \Delta C/C | \leq 20\%$ of initial value
- $\tan \delta \leq 2$ times initial specified limit
- $I_{\text{leak}} \leq$ initial specified limit

Voltage endurance test $105 ^\circ C; V_R$

- Post test requirements:
  - $| \Delta C/C | \leq 10\%$ of initial value
  - $\tan \delta \leq 1.3$ times initial specified limit
  - $I_{\text{leak}} \leq$ initial specified limit

Vibration resistance test

- To IEC 60068-2-6, test Fc:
  - Frequency range 10 Hz ... 55 Hz, displacement amplitude 0.35 mm, acceleration max. 5 g, duration 3 x 2 h.
  - Capacitor mounted by its body which is rigidly clamped to the work surface.

Characteristics at low temperature

<table>
<thead>
<tr>
<th>Max. impedance ratio at 100 Hz</th>
<th>$V_R$</th>
<th>450 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z_{25^\circ C}/Z_{20^\circ C}$</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>$Z_{-40^\circ C}/Z_{20^\circ C}$</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

IEC climatic category

- To IEC 60068-1: 25/105/56 (−25 °C/+105 °C/56 days damp heat test)
- The capacitors can be operated in the temperature range of −40 °C to +105 °C but the impedance at −40 °C must be taken into consideration.

Sectional specification

- IEC 60384-4
Input Capacitor – Electrolytic Type

- $I_{AC,R}$ is the ripple current rating.
- We said before that it needs to be 1.2 A.
- Is this a good candidate?
- ESR, which generates heat, changes with temperature and frequency.
- So will the ripple current capability.
- The useful life tool predicts 32000 hours if the supply was always at max.

### Technical data and ordering codes

<table>
<thead>
<tr>
<th>$C_R$ (µF)</th>
<th>Case dimensions</th>
<th>$ESR_{100}$ (100 Hz)</th>
<th>$ESR_{300}$ (300 Hz)</th>
<th>$Z_{max}$ (10 kHz)</th>
<th>$I_{AC,max}$ (100 Hz)</th>
<th>$I_{AC,max}$ (100 Hz)</th>
<th>$I_{AC,R}$ (100 Hz)</th>
<th>Ordering code (composition see below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>22 × 25</td>
<td>880</td>
<td>230</td>
<td>1320</td>
<td>1.70</td>
<td>1.28</td>
<td>0.76</td>
<td>B43647A5127M05#</td>
</tr>
<tr>
<td>150</td>
<td>22 × 30</td>
<td>700</td>
<td>180</td>
<td>1060</td>
<td>2.03</td>
<td>1.53</td>
<td>0.90</td>
<td>B43647A5157M05#</td>
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<tr>
<td>150</td>
<td>25 × 25</td>
<td>710</td>
<td>190</td>
<td>1070</td>
<td>1.94</td>
<td>1.46</td>
<td>0.86</td>
<td>B43647B5157M05#</td>
</tr>
</tbody>
</table>

### Useful life

For useful life calculations, please use our web-based tool "AlCap Useful Life Calculation Tool", which can be found on the Internet under the following link: www.tdk-electronics.tdk.com/alcap

The AlCap Useful Life Calculation Tool provides calculations of useful life as well as additional data for selected capacitor types under operating conditions defined by the user.

In addition, it is possible to calculate useful life expectancies based on temperatures measured by the user in the application.
**Input Capacitor – Electrolytic Type**

**Aluminum Electrolytic Capacitors**

<table>
<thead>
<tr>
<th>B43647A5127M05#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful life calculation</td>
</tr>
</tbody>
</table>

Here is the capacitor and the load condition table.

The temperature input and voltage levels and frequency were set higher than expected.

<table>
<thead>
<tr>
<th>Selected capacitor Ordering code:</th>
<th>B43647A5127M05#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacitance</td>
<td>CR</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>VR</td>
</tr>
<tr>
<td>Diameter x Length</td>
<td>d x l</td>
</tr>
<tr>
<td>Rated temperature</td>
<td>TR</td>
</tr>
<tr>
<td>Rated ripple current</td>
<td>IAC,R</td>
</tr>
<tr>
<td>Rated useful life</td>
<td>LR</td>
</tr>
</tbody>
</table>

Please refer to the data sheet for further product specifications.

**Load condition Calculation method:** Ripple current spectrum

<table>
<thead>
<tr>
<th>Operating voltage</th>
<th>Vo</th>
<th>150 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>TA</td>
<td>70 °C</td>
</tr>
<tr>
<td>Air speed</td>
<td>va</td>
<td>0.0 m/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>f (Hz)</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripple current</td>
<td>IAC,f (A)</td>
<td>1.2</td>
</tr>
</tbody>
</table>
# Input Capacitor – Electrolytic Type

Calculation results
Values at chosen load condition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating useful life</td>
<td>$L_{op}$</td>
</tr>
<tr>
<td>Max. current in percent</td>
<td>74 %</td>
</tr>
<tr>
<td>Power loss</td>
<td>$P$</td>
</tr>
<tr>
<td>Thermal resistance</td>
<td>$R_{th}$</td>
</tr>
<tr>
<td>Inner thermal resistance</td>
<td>$R_{th,i}$</td>
</tr>
<tr>
<td>Hot spot temperature</td>
<td>$T_H$</td>
</tr>
<tr>
<td>Base temperature</td>
<td>$T_B$</td>
</tr>
<tr>
<td></td>
<td>18000 h</td>
</tr>
<tr>
<td></td>
<td>0.44 W</td>
</tr>
<tr>
<td></td>
<td>33.8 K/W</td>
</tr>
<tr>
<td></td>
<td>10.1 K/W</td>
</tr>
<tr>
<td></td>
<td>84.8 °C</td>
</tr>
<tr>
<td></td>
<td>80.4 °C</td>
</tr>
</tbody>
</table>

The calculation results obtained are typical values and are intended for guidance purposes only. The useful life does not constitute a warranty of any kind or a prolongation of the agreed warranty period.

The calculation shows 18000 hours of operation. The temperature rise had the largest effect.
Input Capacitor Alternative - Film Type

- Film capacitors have a very long life compared to electrolytics.
- Want to show what is available if long life is required.
- Package sizes and current ratings comparable to our application do not seem available.

Printed Circuit Board Mount Power Film Capacitors
C4AE, Radial, 2 or 4 Leads, 450 – 1,100 VDC for DC Link

**Overview**

The C4AE capacitor is a polypropylene metallized film capacitor with a rectangular, plastic box-type design (white or grey in color) filled with resin, and uses 2 or 4 tinned copper wires.

**Applications**

Typical applications include DC filtering and energy storage.

**Benefits**

- Self-healing
- Low loss
- High ripple current
- High capacitance density
- High contact reliability
- Suitable for high frequency applications
## Input Capacitor Alternative - Film Type

### Life Expectancy

<table>
<thead>
<tr>
<th>Life expectancy</th>
<th>100,000 hours at $V_{NDC}$ at Hot spot temperature $T_{HS} = +85^\circ C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance drop at end of life</td>
<td>-5% (typical)</td>
</tr>
<tr>
<td>Failure rate IEC 61709</td>
<td>$\leq 300$ FIT at $V_{NDC}$ at Hot spot temperature $T_{HS} = +85^\circ C$</td>
</tr>
</tbody>
</table>

### Table 1 - Ratings & Part Number Reference

<table>
<thead>
<tr>
<th>Cap Value ($\mu F$)</th>
<th>VDC</th>
<th>Dimensions (mm)</th>
<th>$dV/dt$ (V/µs)</th>
<th>Ipkpr</th>
<th>ESL</th>
<th>ESR</th>
<th>$I_{rms}^*$</th>
<th>Rth</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>H</td>
<td>L</td>
<td>P</td>
<td>PI</td>
<td>Apk</td>
<td>nH</td>
<td>mΩ</td>
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<tr>
<td>5.6</td>
<td>450</td>
<td>11</td>
<td>20</td>
<td>31.5</td>
<td>27.5</td>
<td>\</td>
<td>10</td>
<td>54</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>450</td>
<td>13</td>
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<td>31.5</td>
<td>27.5</td>
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<td>27.5</td>
<td>\</td>
<td>10</td>
<td>54</td>
<td>25</td>
</tr>
</tbody>
</table>

- **Long life** indicates high life expectancy.
- **High Current** indicates high current capability.
The dissipation factor is a fraction of the electrolytic example.
### Input Capacitor Alternative - Film Type

#### WIMA DC-LINK MKP4

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**General Data**

<table>
<thead>
<tr>
<th>Capacitance (μF)</th>
<th>W</th>
<th>H</th>
<th>L</th>
<th>PIN</th>
<th>( I_s ) (A)</th>
<th>( I_{(rms)} ) (A)</th>
<th>ESR (mΩ)</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>19</td>
<td>31.5</td>
<td>27.5</td>
<td>2</td>
<td>11</td>
<td>1</td>
<td>238.7</td>
</tr>
<tr>
<td>2</td>
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---

Similar to other example in a smaller package.

---

**DCR4G041006A**
**DCR4G042006A**
**DCR4G043006A**
**DCR4G044006A**
**DCR4G045006A**
**DCR4G047006A**
**DCR4G051006B**
**DCR4G051506D**
**DCR4G052006F**
**DCR4G052506G**
**DCR4G053006L**
**DCR4G054006J**
**DCR4G055007G**
**DCR4G056007G**
**DCR4G057007H**
**DCR4G058007H**
**DCR4G059007H**
**DCR4G061007L**
**DCR4G061207J**
**DCR4G061407J**
Input Capacitor Type Summary

- Aluminum electrolytic capacitors are suitable for this application because of:
  - Low temperature operation;
  - No need for long life.
- If you remove the top off the supply to look inside, you will see an electrolytic input capacitor.
- Film capacitors could be used if long life were a concern.
  - For instance, if you needed a similar supply installed inside a remote piece of test equipment that needs to last 10 – 15 years.
  - Instead of packaging 2 or 3 of the electrolytics, you could replace them with one of the film caps.
Output Capacitor - Electrolytic Type

For a flyback power supply, or any other converter with a high frequency output, low impedance and ESR are the most important trait.

### Long-life grade capacitors

#### Applications
- Automotive electronics

#### Features
- Very low impedance at high frequency
- Very low ESR
- High ripple current capability
- RoHS-compatible

#### Construction
- Radial leads
- Charge-discharge proof, polar
- Aluminum case with PET insulating sleeve
- Minus pole marking on the insulating sleeve
- Case with safety vent
Output Capacitor - Electrolytic Type

- The schematic showed two 470 µF capacitors in parallel. Ripple current is 3.4 amps each.

- Taking into account comparable life and operating temperatures versus the input capacitor, this is a good candidate.

### Technical data and ordering codes

<table>
<thead>
<tr>
<th>VR</th>
<th>Case dimensions</th>
<th>Zmax, 100 kHz</th>
<th>Zmax, 100 kHz</th>
<th>Iac, 100 kHz</th>
<th>Ordering code</th>
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<tbody>
<tr>
<td>120 Hz</td>
<td>d x L (mm)</td>
<td>-10 °C</td>
<td>20 °C</td>
<td>105 °C</td>
<td>mA</td>
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<tr>
<td>20 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 µF</td>
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<td></td>
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<td></td>
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<tr>
<td>100 V DC</td>
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</tr>
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<td>0.007</td>
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### Ordering codes (composition see below)

- B41859C4277M***
- B41859C4337M***
- B41859C4477M***
- B41859C4667M***
- B41859C4188M***
- B41859C4228M***
- B41859C4278M***
- B41859C4338M***
TDK has a solution guide that shows how you could replace electrolytics with multi-layer ceramic capacitors.

There are caveats, though, in that the control circuit and other components may need adjusting or enhancing, so it is not necessarily just a simple swap.
Output Capacitor Alternative - MLCC Type

This is a small component
Output Capacitor Alternative - MLCC Type

- For our application current (6.8 a rms), 4 of these in parallel would generate a modest temperature rise.
- Careful attention will need to be made to board layout so that only minimal inductance is introduced.
Overview

The KEMET Organic Capacitor (KO-CAP) is a solid electrolytic capacitor with a conductive polymer cathode capable of delivering very low ESR and improved capacitance retention at high frequencies. KO-CAP combines the low ESR of multilayer ceramic, the high capacitance of aluminum electrolytic, and the volumetric efficiency of tantalum into a single surface mount package. Unlike liquid electrolyte-based capacitors, KO-CAP has a very long operational life and high ripple current capabilities.

The T52X/T530 provides the widest range of voltages, capacitance and case size options in the KO-CAP family and is suitable for general purpose DC applications for up to 48 volt DC voltage rails.

Benefits

- ESR values down to 5 mQ
- Stable capacitance across temperature and voltage
- No aging effects
- High ripple handling
- Volumetrically efficient
- High frequency capacitance retention
- 100% accelerated steady state aging
- 100% surge current tested
- Halogen-free epoxy and RoHS compliant
Output Capacitor Alternative - Tantalum Type

KEMET Organic Capacitor (KO-CAP®)
T52x/T530 Polymer Electrolytic Capacitors

Table 1 – Ratings & Part Number Reference cont.

<table>
<thead>
<tr>
<th>Rated Voltage VDC at 105°C</th>
<th>Rated Capacitance</th>
<th>Case Code/Case Size</th>
<th>KEMET Part Number</th>
<th>DC Leakage</th>
<th>DF</th>
<th>ESR</th>
<th>Maximum Allowable Ripple Current</th>
<th>MSL</th>
<th>Maximum Operating Temperature</th>
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<tr>
<td></td>
<td>µF</td>
<td>KEMET/EIA</td>
<td>(See below for part options)</td>
<td>µA at 25°C</td>
<td>% at 25°C</td>
<td>mA at 25°C</td>
<td>(rms)</td>
<td>mA at 45°C</td>
<td>°C</td>
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<td>26</td>
<td>25</td>
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<td>T521D07M025A(1)E549</td>
<td>250</td>
<td>10</td>
<td>40</td>
<td>2,400</td>
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<td>T521D07M025A(1)E549</td>
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<td>3</td>
<td>105</td>
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</table>

4 of these will suffice.

Larger than the MLCC, but a lot shorter than the Al electrolytic.
Output Capacitor Type Summary

• Similar to the input side, Aluminum electrolytic capacitors are suitable for this application because of:
  • Low temperature operation;
  • No need for long life.

• If you remove the top off the supply to look inside, you will see 2 electrolytic output capacitors.

• MLCCs or tantalum capacitors could be used to save on packaging volume and board space.
Wrap Up

• In this presentation, we looked at:
  • A common device as an application;
  • The differing roles for capacitors in the application;
  • The most common capacitor types and their operating regions;
  • Types and data sheets for input and output bulk filter capacitors.
Final Questions & Thank You

Please take the survey

We appreciate any ideas or suggestions for improvement.
Thank You and hope you have enjoyed the webinar

“Wisdom is not a product of schooling but of the lifelong attempt to acquire it.” – Albert Einstein

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