High Power Inverters

Applications
## Power Converter Capacitors

### Industries

<table>
<thead>
<tr>
<th>Green Energy</th>
<th>Automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Solar Panels" /></td>
<td><img src="image2.png" alt="Car" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Industrial Equipment" /></td>
</tr>
</tbody>
</table>
Power Converter Components

System Overview

Components

0 Common Mode Choke Coil
3 EMI Core
4 Boost Reactor
7 Current Sensor

Capacitors

1 EMI / RFI Filter 1Φ
2 AC Harmonic Filter 3Φ
5 Snubber
6 DC Link
0 Common Mode Choke
Noise is classified according to the conduction mode into either Common Mode or Differential Mode.

**Common Mode**
- Suppressed by Inductors & Y-capacitors

**Differential Mode**
- Attenuated with Chokes and X-capacitors

Differential Mode is also known as “Normal” Mode.

AC Line Filters are choke coil products used to suppress both types of noise.
AC Line Filters
How to Tell Between Common and Differential Mode

Common Mode
4 Pins

Differential or Normal Mode
2 Pins

SCR

HHB
New Ferrite Material
High $\mu$ Ferrite Development

Developed the Highest $\mu$ S18H

The size of circle shows CISPR 150kHz attenuation characteristics
High Performance Line Filter SCR-HB (SR18)

Features
- Use of high performance SR18 material
- High current (~50A) and high voltage (500V)

Advantages
- High impedance (greater than any other ferrite common mode choke)
- Same performance in smaller size and less winding
- Custom designs available
Hybrid Choke Coil

Conventional

Existing magnetic circuit causing the interference to outer field by leakage flux

New Design

New magnetic circuit suppresses the leakage flux to inside and it does not cause interference
Hybrid Choke Coil Concept

Conventional Design

- Common Mode Choke
- Differential Mode Choke x 2

New Design

- Hybrid Choke

Reduce Footprint & Save Space

3 in 1
Technology Concept
Hybrid Choke Coil

Development of New Material (Ferrite)

New ferrite core with increased Tc and Bs has developed for Hybrid Line-Filter
1 EMI Filters
EMI Filters

KEMET Capabilities

- Wide range of supported applications
  - Attenuate high frequency noise and reduce radiation of EMI noise in DC applications
  - Available in three-phase (high current and high voltage variations) and standard DC EMI filtering
2 AC Harmonic Filter Capacitors
AC Harmonic Filter Capacitors

Power Converter

Function
Reduce the harmonic components overlapped to the fundamental frequency.

Rated Voltages
- 525 – 640+ Vac - Input
- 330+ Vac - Output  (Star Connection)
- 440+ Vac - Output  (Delta Connection)
- > 690 Vac - Wind Generators

Demanded Life Expectancy
- >10 years (100K Hours) – Currently at 60k (C4AF)
Life Expectancy

• Two derating equations exist:

1. **Life Expectancy vs. Voltage:**
   
   \[ L_E = L_N \times \left( \frac{V_N}{V} \right)^8 \]
   
   - \( L_E \): Life expectancy at operating voltage (hours)
   - \( L_N \): Life expectancy at nominal voltage (hours)
   - \( V_N \): Nominal voltage \( U_n \) (V)
   - \( V \): Operating voltage (V)

   **Note:** The above formula is valid within ± 20% of the nominal voltage.

2. **Life Expectancy vs. Temperature:**

   \[ L_E = L_{To} \times 2 \left( T_o - T_{hs} \right) / 7 \]

   - \( L_E \): Life expectancy at operating temperature (hours)
   - \( L_{To} \): Life expectancy at 70°C (hours)
   - \( T_o \): Reference temperature (70°C)
   - \( T_{hs} \): Hot spot case temperature (≤ 70°C)

   **Note:** These equations can be used together
# AC Harmonic Filter Capacitors

## Single Phase vs. Three Phase

<table>
<thead>
<tr>
<th>Feature</th>
<th>Single Phase</th>
<th>Three-Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C44 &amp; C20</strong></td>
<td></td>
<td><strong>C9T</strong></td>
</tr>
<tr>
<td>Cost</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Compactness</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cable Mounting</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bus Bar Mounting</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Parallel Connection</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>(require a daisy-chain)</td>
<td></td>
</tr>
<tr>
<td>Irms/C Ratio</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>High AC Harmonic Component</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

![Diagram of C44P & C20](image1)

![Diagram of C9T](image2)
## AC Harmonic Filter Capacitors

### Dry vs. Impregnated Film Technology

<table>
<thead>
<tr>
<th>Feature</th>
<th>Dry</th>
<th>Impregnated</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temperature</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Capacitance Density</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Overpressure Protection</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- **Impregnated Film** is the best performing for AC filtering.
- **Dry Film** is best suitable for high temperature AC filtering.
3 EMI Core
HV / EV Inverter

Application

Bus Bar EMI Core
Size Capability: 110 x 50 x 35mm / half piece
-40°C ~ +155°C
Ferrite Permeability: 5000
250Amp 100KW
Common Mode Current: 10Amp
CMC: 10uH
DMC: 0.2uH

ESD series
Ferrite
5HT Material
Bus bar

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4 Reactor
200/600V DC/DC Booster

**Application**

- **Boost Inductor**
  - 70 x 70 x 40mm/50KW inductor
  - For 100KW, two phase with 50KW inductor x 2
  - For 150KW, three phase with 50KW x 3
  - -40°C ~ +155°C
  - 20KHz IGBT, 50KHz SiC
  - Inductance: 200uH, 100uH at 200 Amp
  - Power Loss: 100W
  - Thermal Resistance: 0.18 K/W

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Metal Composite Reactor

Features:
- Integrally molded reactor by inject molding of our original technology
- Superior design flexibility by inject molding method
- Leakage flux is small due to have a distributed gap
- Excellent heat dissipation efficiency by integral molding
- Able to support a high-frequency (50kHz or less)

Applications:
- Inverter for HEV/PHEV
- Power conditioner

Specification example:
- Low height type
- Standard type
- Large size

Characteristics (typ.):
Dust Reactor

Features

• Silent and lightweight with adoption of split powder dust core and minimized metal material structure
• Used for both AC and DC link for boosting, smoothing and noise rejection
• Largely custom design
# Boost Inverter

<table>
<thead>
<tr>
<th>No</th>
<th>Solution</th>
<th>Product series</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boost</td>
<td>MCR (Boost Inductor)</td>
<td>Boosting Circuit</td>
</tr>
<tr>
<td>2</td>
<td>Common Mode Noise</td>
<td>ESD (Ferrite Core)</td>
<td>Inverter/Motor - On Harness - On Bus-Bar</td>
</tr>
</tbody>
</table>

## Boost

### MCR Series
1. Operating Temp. -40~+180deg-C
2. Superior Design Flexibility
3. Small Leakage Flux

## Common Leakage Mode Noise

### ESD-R-SR Series
1. Operating Temp. -40~+105 deg-C
2. Effective for kHz Band (Mn-Zn)
3. High-μ Material (S15H)

### ESD-R-M-H/N-H Series
1. Operating Temp. -40~+120 deg-C
2. Effective for kHz Band (Mn-Zn)
3. Effective for MHz Band (Ni-Zn)
4. UL94 V-0
5 Snubber Capacitor
Snubber Capacitors

Function

Connected in parallel with semiconductor components to damp voltage spikes on semiconductor switches.

IGBT Snubber

\[ C = \frac{L \cdot I^2}{\Delta V^2} \]

Rated Voltage:
- 1200 Vdc
- 1600 Vdc
- 3000 Vdc

Demanded Life Expectancy:
- >10 years (100k hours)
Snubber Capacitor
KEMET Solutions for IGBT

- Voltages: 1.2kVdc, 1.6kVdc, 3kVdc

<table>
<thead>
<tr>
<th>Box Wire Terminals</th>
<th>Box Tag Lug</th>
<th>Aluminum Canister</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire terminals total capacitance with parallel</td>
<td>Direct IGBT installation</td>
<td>Bank configuration Internal protection</td>
</tr>
</tbody>
</table>

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Surface Mount High Voltage C0G MLCCs
(500 – 3,000 VDC)

- Patented C0G Dielectric Technology
- Voltage and Temperature Stable
- Capacitance up to 150nF
- EIA 0603 – 4540 Case Sizes
- DC Voltage Ratings of 500 – 3,000V
- DC Voltage Rating of 10,000V Under Development
- Commercial & Automotive Grades

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KONNEKT U2J for High-Efficiency, High-Density Power Applications

- Operating temperature range of −55°C to +125°C
- Extremely high-power density and ripple current capability
- Extremely low equivalent series resistance (ESR)
- No capacitance shift with voltage
- Surface mountable using standard MLCC reflow profiles
- Low-loss orientation option for higher current handling capability

Pb-Free RoHS
6 DC Link Capacitors
DC Link Capacitors

Power Converter

Function
To support a DC network by supplying periodically high currents.

Rated Voltages:
- 700 Vdc - Welders
- 1100 Vdc - Wind Converters
- 1300 Vdc - Wind Converters
- 1500 Vdc - Solar Converters

Demanded Life Expectancy
- >10 years (100k hours)
## DC Link Capacitors

**KEMET Aluminum Electrolytic Technology**

<table>
<thead>
<tr>
<th>Snap-Ins</th>
<th>Screw Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Low power drives</td>
<td>• Medium to high power</td>
</tr>
</tbody>
</table>

*For Snap-Ins:*
- ALC10, ALC40
- PEH526, PEH536

*For Screw Terminals:*
- ALS70/1, ALS80/1, ALS30/31, ALS40/41, PHE205
- PEH200/169, ALS32/33, ALS42/43
## DC Link Capacitors

**KEMET Film Technology**

<table>
<thead>
<tr>
<th>Box</th>
<th>Aluminum &amp; Plastic Can</th>
<th>Bricks</th>
</tr>
</thead>
</table>
| - Layout and performance optimization  
  - PCB mounting | - Modular configuration  
  - Lower volume efficiency  
  - Form factor flexibility | - Best dimensional efficiency  
  - Higher power & temperature |

### Large Form Factor Options

- **C4AQ**
- **C4U**
- **C4DE**
- **C4E**

- 700 Vdc welders
- 900 Vdc solar converters
- 1.1kVdc, 1.3kVdc wind converters
For DC-Link Capacitors:

- Lower capacitance required promotes miniaturization due to:
  - Increasing switching frequency
  - Higher voltages

- Lower capacitance is within the range of MLCC.
  - But these needs must be:
    - Extremely reliable
    - Over-temperature capable
    - Over-voltage capable
    - High current capable
    - Mechanically robust
DC-Link Design Example

Film and Electrolytic Trade Offs

### 3 Phase AC Generator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output V</td>
<td>690 Vac</td>
</tr>
<tr>
<td>Vdc Link</td>
<td>1,000 Vdc</td>
</tr>
<tr>
<td>V Ripple Max</td>
<td>100 V</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Capacitance</td>
<td>500 μF</td>
</tr>
<tr>
<td>Ripple Current</td>
<td>26 A</td>
</tr>
<tr>
<td>Frequency DC-Link</td>
<td>300 Hz</td>
</tr>
<tr>
<td>Temperature</td>
<td>75 °C</td>
</tr>
</tbody>
</table>

### Electrolytic ALS70

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C μF</td>
<td>5,100</td>
</tr>
<tr>
<td>Vdc</td>
<td>500</td>
</tr>
<tr>
<td>D x L mm</td>
<td>77x115</td>
</tr>
<tr>
<td>Volume cm³</td>
<td>535.5</td>
</tr>
<tr>
<td>I Ripple (A)</td>
<td>26.5</td>
</tr>
<tr>
<td>Total Volume</td>
<td>1,071</td>
</tr>
<tr>
<td>Total C μF</td>
<td>2550</td>
</tr>
</tbody>
</table>

### Film C44U

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C μF</td>
<td>500</td>
</tr>
<tr>
<td>Vdc</td>
<td>1,100</td>
</tr>
<tr>
<td>D x L mm</td>
<td>85x174</td>
</tr>
<tr>
<td>Volume cm³</td>
<td>1,257.2</td>
</tr>
<tr>
<td>I Ripple (A)</td>
<td>30</td>
</tr>
<tr>
<td>Total Volume</td>
<td>1,257.2</td>
</tr>
<tr>
<td>Total C μF</td>
<td>500</td>
</tr>
</tbody>
</table>

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DC-Link Capacitors
Film vs. Electrolytic (High Voltage Application)

Electrolytic (ALS70)
- 26 A
- 2,550 μF
- 2,550 Vdc
- Total Volume 1,071

Film (C44U)
- 26 A
- 1,100 μF
- Stable over years
- Total Volume 1,257.2

How long will they last?

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DC-Link Capacitors
Lifetime Calculation

Electrolytic (ALS30)

Parametric Failure:
- Capacitance change > ±10%
- ESR > 2 x initial value
- Impedance > 3 x initial value
- Leakage current > specified limit
- Maximum core temperature exceeded

61,317 Hours (7 Years)

Film (C44U)

LE = Life expectancy at operating V
LN = Life expectancy at nominal voltage
VN = Nominal voltage Un (V)
V = Operating Voltage (V)
** Note, only valid if hot spot < 85°C

\[ L_E = L_N \times \left(\frac{V_N}{V}\right)^8 \]

214,360 Hours (24 Years)
### Electrolytic Life Calculator

**ALS30**
- **23,405.8 Hours (2.67 Years)**

**C44U**
- **214,360 Hours (24 Years)**

**LE = Life expectancy at operating V**

**LN = Life expectancy at nominal voltage**

**VN = Nominal voltage Un (V)**

**V = Operating Voltage (V)**

**Note,** only valid if hot spot < 85°C

### DC-Link Capacitors

**Lifetime Calculation**

<table>
<thead>
<tr>
<th>ALS70ANJ500</th>
<th>Cap</th>
<th>5100 μF</th>
<th>-20% +20%</th>
<th>AS No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>R</td>
<td>ALS70A</td>
<td>U</td>
<td>sjankulosa</td>
</tr>
</tbody>
</table>

| **Ambient Ta** | 75.0 |
| **Average Th**  | 82   |
| **Tr (core rise)** | 4.7  |
| **Max core Tm**  | 105  |
| **Tr for calc**   | 7.0  |

| **Life Factor Le** | 41.50 |
| **RHa °C/Watt**    | 2.444 |
| **Arhenius T2**    | 10   |
| **Arc Tr @ EOL Tm** | 2   |
| **Max ESR (x0)**   | 2    |
| **Act est temp**    | 0    |
| **Use actual esr**  | 1    |

| **Op. Vop**      | 500  |
| **Std. V/s**     | 680  |
| **V Factor Ks**  | 1.284 |

**Life Lop:** 61317

### Design Notes:

- **Max cap @ 95% Fit:** 52.56 μF
- **Physical case fill:** 92.26% Store

---

**Parametric Failure:**
- Capacitance change > ±10%
- ESR > 2 x initial value
- Impedance > 3 x initial value
- Leakage current > specified limit
- Maximum core temperature exceeded
<table>
<thead>
<tr>
<th>Description</th>
<th>360 μF</th>
<th>350 μF</th>
<th>330 μF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capacitance</td>
<td>360 μF</td>
<td>350 μF</td>
<td>330 μF</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>900 Vdc</td>
<td>900 Vdc</td>
<td>900 Vdc</td>
</tr>
<tr>
<td>Individual Capacitor</td>
<td>40μF / 900V</td>
<td>350uF / 900Vdc</td>
<td>110uF / 900Vdc</td>
</tr>
<tr>
<td>Capacitors in Parallel</td>
<td>9</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Assembly Dimensions</td>
<td>115 x 50 x 182</td>
<td>90 x 70 x 180</td>
<td>76 x 76 x 238 (*)</td>
</tr>
<tr>
<td>Assembly Volume ( dm³ )</td>
<td>1,0</td>
<td>1,1</td>
<td>1,4</td>
</tr>
<tr>
<td>Irms @ 10 KHz Tcase=70°C</td>
<td>180 A</td>
<td>90 A</td>
<td>100 A</td>
</tr>
<tr>
<td>Theoretical Stray Inductance</td>
<td>4 nH</td>
<td>10 nH</td>
<td>13 nH</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Cost Factor</td>
<td>100</td>
<td>280</td>
<td>170</td>
</tr>
<tr>
<td>Max. Temperature</td>
<td>(85 °C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Description</th>
<th>360 µF</th>
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<td></td>
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<td>90 A</td>
<td>100 A</td>
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<td>13 nH</td>
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<td>Power Dissipation</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Cost Factor</td>
<td>100</td>
<td>280</td>
<td>170</td>
</tr>
</tbody>
</table>

Max. Temperature (85 C) - Developments: PP 100 °C Snubber and 105 °C DC-Link Box MLCC C0G Ceramic (up 200 °C) Snubber and DC-Link

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## New Design Opportunities

**ALS31**

<table>
<thead>
<tr>
<th>VDC</th>
<th>Rated Capacitance 100Hz 20°C (µF)</th>
<th>Size Code</th>
<th>Case Size D x L (mm)</th>
<th>LOP</th>
<th>Ripple Current 100Hz 85°C (A)</th>
<th>Ripple Current 10kHz 85°C (A)</th>
<th>ESR Maximum 100Hz 20°C (mΩ)</th>
<th>Impedance Maximum 10kHz 20°C (mΩ)</th>
<th>Part Number</th>
<th>Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>2200</td>
<td>MF</td>
<td>66 x 105</td>
<td>19kh</td>
<td>11.1</td>
<td>19.3</td>
<td>67</td>
<td>47</td>
<td>ALS31A222MF450</td>
<td>100%</td>
</tr>
</tbody>
</table>

Increase capacitance and performance in same case size.

**ALS71**

<table>
<thead>
<tr>
<th>VDC</th>
<th>Rated Capacitance 100Hz 20°C (µF)</th>
<th>Size Code</th>
<th>Case Size D x L (mm)</th>
<th>LOP</th>
<th>Ripple Current 100Hz 85°C (A)</th>
<th>Ripple Current 10kHz 85°C (A)</th>
<th>ESR Maximum 100Hz 20°C (mΩ)</th>
<th>Impedance Maximum 10kHz 20°C (mΩ)</th>
<th>Part Number</th>
<th>Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>4300</td>
<td>MF</td>
<td>66 x 105</td>
<td>19kh</td>
<td>13.28</td>
<td>21.45</td>
<td>46.35</td>
<td>30.35</td>
<td>ALS71A432MF450</td>
<td>93%</td>
</tr>
</tbody>
</table>

Reduce case size and cost by keeping CV value.

**ALS31**

<table>
<thead>
<tr>
<th>VDC</th>
<th>Rated Capacitance 100Hz 20°C (µF)</th>
<th>Size Code</th>
<th>Case Size D x L (mm)</th>
<th>LOP</th>
<th>Ripple Current 100Hz 85°C (A)</th>
<th>Ripple Current 10kHz 85°C (A)</th>
<th>ESR Maximum 100Hz 20°C (mΩ)</th>
<th>Impedance Maximum 10kHz 20°C (mΩ)</th>
<th>Part Number</th>
<th>Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>2400</td>
<td>KF</td>
<td>41 x 105</td>
<td>18kh</td>
<td>8.8</td>
<td>15.16</td>
<td>79.77</td>
<td>51.76</td>
<td>ALS71A242KF450</td>
<td>57%</td>
</tr>
</tbody>
</table>
Calculating Current Through Parallel Caps
1. Calculate the impedance of each capacitor. 
   a) Use the ESR at the application frequency.

\[
Z_{C1} = \frac{1}{2\pi \times \text{Freq} \times C_{C1}} + \text{ESR}
\]
Capacitor Impedance
Example: 1Arms at 100kHz

1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.

\[ Z_{PEG1} = \frac{1}{2\pi \times 100Hz \times 47uF} + 1.5\Omega = 35.36\Omega \]

\[ Z_{PEG2} = \frac{1}{2\pi \times 100Hz \times 47uF} + 1.5\Omega = 35.36\Omega \]

\[ Z_{C4AE1} = \frac{1}{2\pi \times 100Hz \times 10uF} + 8.1m\Omega = 159.16\Omega \]

\[ Z_{C4AE2} = \frac{1}{2\pi \times 100Hz \times 10uF} + 8.1m\Omega = 159.16\Omega \]

Note: Obtaining / Using the correct ESR at the application frequency is crucial to the design. Please consult Sales / FAEs / PMs if this data is not in the datasheet.
Total Impedance

1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.

2. Calculate the total impedance in the bank.

\[ Z_{Total} = \left[ \left( \frac{1}{Z_{C1}} \right) + \left( \frac{1}{Z_{C2}} \right) + \cdots + \left( \frac{1}{Z_{C_{\ldots}}} \right) + \left( \frac{1}{Z_{CN}} \right) \right]^{-1} \]
Total Impedance

Example: 1Arms at 100kHz

1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.
2. Calculate the total impedance in the bank.

\[
Z_{\text{Total}} = \left[ \left( \frac{1}{35.36\Omega} \right) + \left( \frac{1}{35.36\Omega} \right) + \cdots + \left( \frac{1}{159.16\Omega} \right) + \left( \frac{1}{159.16\Omega} \right) \right]^{-1} = 14.47\Omega
\]
1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.
2. Calculate the total impedance in the bank.
3. Calculate the current through each capacitor.
   a) Compare the calculated current with the rated current for that part at the application frequency.
   b) If the calculated current is higher than the rated current, look into another solution or discuss lifetime of the part with a PM.

\[ I_{C1} = I_{Total} \left( \frac{Z_{Total}}{Z_{C1}} \right) \]
Capacitor Current
Example: 1Arms at 100kHz

1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.
2. Calculate the total impedance in the bank.
3. Calculate the current into each capacitor.
   a) Compare the calculated current with the rated current for the part at the application frequency.
   b) If the calculated current is higher than the rated current, look into another solution or discuss lifetime of the part with a PM.

\[
I_{PEG1} = 1Arms \left( \frac{14.47\Omega}{35.36\Omega} \right) = 0.4091A
\]

\[
I_{PEG2} = 1Arms \left( \frac{14.47\Omega}{35.36\Omega} \right) = 0.4091A
\]

\[
I_{C4AE1} = 1Arms \left( \frac{14.47\Omega}{159.16\Omega} \right) = 0.0909A
\]

\[
I_{C4AE2} = 1Arms \left( \frac{14.47\Omega}{159.16\Omega} \right) = 0.0909A
\]

\[
I_{RATED} = 6.5A
\]

\[
I_{RATED} = 6.5A
\]
1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.

   \[ Z_{C1} = \frac{1}{2\pi \times \text{Freq} \times C_{C1}} + \text{ESR} \]

   \[ Z_{\text{ALC40}} = \frac{1}{2\pi \times 100\text{Hz} \times 100\mu\text{F}} + 990m\Omega = 16.91\Omega \]

   \[ Z_{\text{C4AE1}} = \frac{1}{2\pi \times 100\text{Hz} \times 10\mu\text{F}} + 8.1m\Omega = 159.16\Omega \]

   \[ Z_{\text{C4AE2}} = \frac{1}{2\pi \times 100\text{Hz} \times 10\mu\text{F}} + 8.1m\Omega = 159.16\Omega \]
1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.

2. Calculate the total impedance in the bank.

\[
Z_{Total} = \left( \frac{1}{Z_C1} + \frac{1}{Z_C2} + \cdots + \frac{1}{Z_Cn} \right)^{-1}
\]

\[
Z_{Total} = \left( \frac{1}{16.91\Omega} + \frac{1}{159.16\Omega} + \frac{1}{159.16\Omega} \right)^{-1} = 13.94\Omega
\]

\[Z_{ALC40} = 16.91\Omega\]
\[Z_{C4AE1} = 159.16\Omega\]
\[Z_{C4AE2} = 159.16\Omega\]
Capacitor Current
Example: 1Arms at 100kHz Recommended Solution

1. Calculate the impedance of each capacitor.
   a) Use the ESR at the application frequency.

2. Calculate the total impedance in the bank.

3. Calculate the current through each capacitor.
   a) Compare the calculated current with the rated current for that part at the application frequency.
   b) If the calculated current is higher than the rated current, look into another solution or discuss lifetime of the part with a PM.

\[ I_{C1} = I_{Total} \left( \frac{Z_{Total}}{Z_{C1}} \right) \]

\[ I_{ALC40} = 1\text{Arms} \left( \frac{13.94\Omega}{16.91\Omega} \right) = 0.8248A \]

\[ I_{C4AE1} = 1\text{Arms} \left( \frac{13.94\Omega}{159.16\Omega} \right) = 0.0876A \]

\[ I_{C4AE2} = 1\text{Arms} \left( \frac{13.94\Omega}{159.16\Omega} \right) = 0.0876A \]

\[ I_{RATED} = 0.85A \]

\[ I_{RATED} = 6.5A \]

\[ I_{RATED} = 6.5A \]
Thank You!