Capacitors for Power Electronics
VARIABLE FREQUENCY DRIVE - VFD

INVERTER CONTROL CIRCUIT
SPEED CONTROL CIRCUIT

LINE

INPUT FILTER

AC TO DC RECTIFIER

DC LINK

DC TO AC CONVERSION

L/C OUTPUT HARMONIC FILTER

MOTOR

SF, PC, PFCH, & ACF

SCREW TERMINAL, POWER FILM, & PLUG IN

SNUBBER

SF, PC, PFCH, & ACF
Schematic diagram, Inverter
VFD (Variable Frequency Drive)
## DC LINK CAPACITORS: Film Versus Aluminum

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>ALUMINUM</th>
<th>FILM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>High (3X Film)</td>
<td>Medium</td>
</tr>
<tr>
<td>ESR</td>
<td>30 mΩ Typical</td>
<td>2.0 mΩ Typical</td>
</tr>
<tr>
<td>Operating Temp Rating (with full ripple)</td>
<td>105°C Max</td>
<td>85°C Max</td>
</tr>
<tr>
<td>Ripple Current (1000 µF, 500 Vdc) @ 85°C</td>
<td>6.3 A</td>
<td>3X-4X aluminum</td>
</tr>
<tr>
<td>Voltage</td>
<td>550 Vdc</td>
<td></td>
</tr>
<tr>
<td>Resistance to Overvoltage</td>
<td>50 V surge</td>
<td>1.5 X rated for 10 s</td>
</tr>
<tr>
<td>Failure Mode</td>
<td>rupture</td>
<td>fail open mode</td>
</tr>
<tr>
<td>Construction</td>
<td>Liquid Electrolyte</td>
<td>Dry, no liquid electrolyte</td>
</tr>
<tr>
<td>Polarity</td>
<td>Must observe polarity</td>
<td>Non Polar</td>
</tr>
</tbody>
</table>
ALUMINUM ELECTROLYTIC CAPACITORS
More Capacitance for the Buck
ALUMINUM ELECTROLYTIC ADVANTAGE

- The high value capacitor choice
- Typically last more than 10 years
- Lowest cost dielectric for high capacitance and energy storage
- 4 to 10 times the capacitance per dollar of film capacitors
- Great for power electronics bus capacitors to 600 V
ALUMINUM ELECTROLYTIC PRINCIPAL APPLICATIONS

- Power-supply
  - input capacitors
  - output capacitors
- Bus capacitors for inverters
  - UPS systems
  - Motor-drives
  - Renewables
- Photoflash and Strobe Flash
- Welders
SCREW TERMINAL
CAPACITOR TYPES
TYPE 550C, THE 105 °C INVERTER CAPACITOR

- Longest life, highest ripple current type
- 200 V to 450 V, inverter voltage range
- Compares with UCC LXR Series
High value, high ripple current type
The next step below Type 550C
200 V to 500 V, inverter voltage range
> 80% of Type 550C ripple capability
Compared with UCC RWF Series Rifa PEH 105 °C
TYPE 500C, LONG-LIFE CAPACITOR

- Twice the life of Type DCMC
- 6.3 V to 500 V, wide range
- > 60% of Type 550C ripple capability
- Compares with CDE Type 3188
  Aerovox Type CG
  Rifa PEH 169 85 °C
TYPE DCMC, BEST VALUE CAPACITOR

- General purpose, first-choice, low cost
- 6.3 V to 550 V, widest range
- 150% of Type 550C capacitance
- > 40% of Type 550C ripple capability
- Compares with
  - CDE Type 3186
  - Aerovox Type CGS
  - UCC U36D Series
TYPICAL HI-RIPPLE LIFETIMES
4700 µF 450 V Comparison
60 °C, 12 A @ 120 Hz, 400 V

<table>
<thead>
<tr>
<th>Type</th>
<th>Case Size (in)</th>
<th>Life (years)</th>
<th>Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCMC</td>
<td>3x5⅛</td>
<td>4.6</td>
<td>100</td>
</tr>
<tr>
<td>500C</td>
<td>3x5⅝</td>
<td>9.5</td>
<td>110</td>
</tr>
<tr>
<td>520C</td>
<td>3x5⅝</td>
<td>23.7</td>
<td>130</td>
</tr>
<tr>
<td>550C</td>
<td>3½x5⅝</td>
<td>48.8</td>
<td>142</td>
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</tbody>
</table>
Industry’s widest selection including:
- Type SLPX 85°C, 3000 h, low cost
- Type SLP 105°C, 3000 h, low cost
- 25% smaller Types 380LQ & 381LQ
- 25% more ripple Type 381LR, 105°C
- 4 & 5 pin Types 382LX and 383LX
POWER FILM CAPACITORS

More Ripple Current for the Buck
The high ripple current capacitor choice.

Higher voltage than aluminum. Up to 1500Vdc. No need to place capacitors in series

- Eliminates need for balancing resistors.

Dry Construction – No Electrolyte

Non Polar

Self healing – open circuit failure mode
POWER FILM
PRINCIPAL APPLICATIONS

- Bus capacitors for inverters in
  - Renewable Energy
    - Solar
    - Wind
    - Fuel Cell
  - Traction
    - Hybrid Electric Buses
    - Off Road vehicles
FILM CAPACITORS FOR INVERTER DC LINK

- Type 947D – Bus Mount DC Link, High Capacitance, High Current, Cylindrical
- Type 944U – Bus Mount DC Link, Very High Current, Low Profile “Hockey Puck” style
- Type UNL – Board Mount DC Link
- Type BLC – Board Mount DC Link
FILM CAPACITORS FOR DC LINK

Metalized Polypropylene, Low Loss, Self Healing.

- Types 947C, 944U and UNL all use low ESR metallized polypropylene technology.

- Types 947D and 944U utilize segmented metallized pattern offering high voltage stress capability and a controlled fusing / clearing mechanism.
Highlights

- Alternative to screw terminal aluminum electrolytic capacitors (higher voltage, higher current)
- 800-1300 Vdc
- Dry, resin filled
- High reliability and life expectancy
- High current to 100 Amps
- Low ESR
FILM CAPACITORS
FOR DC LINK, TYPE 944U
“Hockey Puck” Style

Highlights
- Low Profile, High Current
- 800-1400 Vdc
- Dry, resin filled
- High current to 100 Amps
- Low ESR
- Low Inductance
FILM CAPACITORS
FOR DC LINK, TYPE UNL

Board Mount DC Link

Highlights
- Alternative to aluminum electrolytic snap-in capacitors (higher voltage, higher current)
- 600-1500 Vdc
- Dry, resin filled
- High reliability and life expectancy
- High current to 100 Amps
- Low ESR
- Low Inductance
IGBT Snubbers
What’s an IGBT

- IGBT – Insulated Gate Bipolar Transistor
- Power switch of choice for most inverter applications

Discrete Module
What’s an IGBT Snubber

– The word **snub** means to rebuff, spurn, repulse, give someone the cold shoulder, shortened at the end.
– IGBT Snubber: A device used to protect IGBT switches from overvoltage during turnoff.
– During turn off, a voltage transient appears across the IGBT that may exceed its voltage rating. The voltage transient is proportional to the amount of stray inductance (L) and the rate in change in current with time.

\[ V_{\text{transient}} = -L\frac{di}{dt} \]
IGBT snubbers are designed to protect IGBTs by reducing the voltage spike across the IGBT during turn-off.

A conservative rule of thumb is to use 1µF of capacitance for every 100A of IGBT.
IGBT SNUBBERS

- Discrete IGBT Snubber Capacitors:
  - Axial & Radial board mount types. Series 940C – 943C & DPPM, DPFF

- Direct Mount IGBT Snubbers:
  - SCD, SCC and SCM Series that mount directly to the IGBT module.