Film Capacitor Primer
Film Capacitors, Basic Construction

Film Capacitors

Most AC rated and DC rated film capacitors used in power conversion applications utilize **polypropylene** dielectric because of its low-loss properties.

**Film Dielectrics Used**
- Polyester (PET, PEN)
- Polypropylene
- PPS
- Polycarbonate
- PTFE
- Acrylies
Film Capacitors, Basic Construction

Many AC rated and DC rated film capacitors use **metalized electrodes** for smaller size. The metalized layer is typically zinc, aluminum deposited onto the film in an extremely thin layer. Very high current film capacitor types generally use thicker aluminum foil electrodes.

“Self Healing”, Metalized Electrodes

Aluminum Foil Electrodes

“Film / Foil Capacitor”
Film Capacitors, Basic Construction

- Film capacitors are generally wound in a stagger, with opposing electrodes extended out at each end.

- Ends of the windings are typically sprayed with a fine zinc spray to connect the turns at each end. Leads are attached at both ends prior to being assembled into the desired package. DC film capacitors are typically encapsulated with epoxy or other “dry” system. AC film capacitors are typically oil filled or vacuum impregnated with oil.
AC & DC Film Capacitor Applications

Direct Current (DC)
Is one-directional flow of electric charge:
- Batteries
- DC Power Supplies

Most DC rated applications have a DC bias with ripple or pulsating current present while in service

Alternating Current (AC)
Is two-directional flow of electric charge. Charge reversal occurs at a given frequency (cycles per second)
- AC generator for utilities (60 Hz)
- Resonant Tank Circuits (High frequency)
DC Film Capacitor Applications

Direct Current (DC) Applications
- Filtering/Smoothing
- Energy Discharge
- Snubber

Filtering/Smoothing

Energy Discharge
Energy stored in the capacitor is discharged into a load, e.g., flashlamp

Snubber
An RC snubber is placed across a switching device to reduce voltage transient during turn off
AC Film Capacitor
Applications

Capacitors in an AC Circuit

In AC circuits, the voltage varies sinusoidally over time. The time it takes to complete 1 cycle is its period. The number of cycles per second in known as the frequency.

When AC voltage is applied to a capacitor, the current through the capacitor is at its maximum value when the voltage is passing through 0. The current through the capacitor is said to lead the voltage by 90°.
AC Film Capacitor
Applications

Capacitors in an AC Circuit

Capacitors are not perfect components. They behave primarily as a capacitor, but also exhibit characteristics of resistance and inductance.

The measure of the capacitor’s resistance in an ac circuit is typically referred to as it’s ESR (Equivalent Series Resistance)

In ac circuits ESR causes internal heating in the capacitor. The higher the ESR, frequency, and current, the greater the heating.

\[ P = I^2 \times ESR \]
AC Film Capacitor Applications

Alternating Current (AC) Application
- Filtering/Smoothing
- Harmonic Filters
- Resonant Tank
- PFC

Resonant Circuit

In AC circuits, capacitor current leads voltage by 90° while an inductor’s current lags voltage by 90°. When applied together the phase shifts of a capacitor and inductor will cancel each other out at their resonant frequency.
Can AC Film Capacitors be Used for DC Applications? Vise versa?

Generally-speaking film capacitors will function when either AC or DC is applied. Some are dual-rated. However, to achieve long life, film capacitors designs are typically optimized for either AC or DC applications.

Dielectric, electrodes and encapsulation systems are selected to achieve the best performance based on the voltage waveform, current and other environmental parameters.

AC film capacitors are typically packaged in metal cans, filled or vacuum impregnated with oil to reduce the occurrence of corona discharge.

DC applications do not typically produce corona. Most DC film capacitors are encapsulated with epoxy in a “dry” construction.
End of Section
AC Film Capacitors: Markets and Applications
AC Film Capacitors, Construction

- Most use metalized polypropylene windings for its self-healing properties, low loss and efficient size.

- High current types often use plain (non-metallized) polypropylene film dielectric with aluminum foil electrodes to handle the high current.
AC film capacitors are generally wound in a stagger, with opposing electrodes extended out at each end.

Ends of the windings are typically sprayed with a fine zinc spray to connect the turns at each end. Leads are attached at both ends prior to being assembled into the desired package. AC capacitors oil-filled or vacuum impregnated with oil (canola).
AC Capacitors, Major Types & Markets

- Motor run
- HID lighting
- Microwave Ovens
- Power electronics & Utility
  - Line conditioning
  - Harmonic filtering
    - Single phase
    - Three phase
  - Power factor correction
- Resonant Tank, Induction Heating
Motor-run Capacitor Markets

• Used with split phase, fractional horsepower motors to start rotation and improve torque performance.
  • HVAC, Fan and compressor
    • Rooftop
    • Unitary, residential & commercial
    • Room
  • Air compressors
  • Oxygen generators
  • Specialty applications
    • Swimming pool pumps
    • Petroleum pumps
Motor-run Characteristics

- Capacitance to 100µF
- Voltages up to 660 Vac
  - 370 & 440 common
- Single and dual ratings
  - Compressor and fan all in one
- Round or oval
- Aluminum cases
- Temperature to 70 °C (85 °C specials)
- Frequency 60 Hz
- UL recognized – protected
- CSA certified
- Reliable 60,000 h life
Motor-run Competitors

- Various Asian Manufacturers
- Nueva Generacion (NGM)
  - Regal Beloit
  - Genteq
Microwave Oven Capacitors

• Markets
  • Commercial, restaurant-grade microwave ovens

• Characteristics
  • Capacitance 0.5 to 2.0 µF
  • Voltage up to 3,000 Vac

• Competitors
  • Various Asian manufacturers
HID lighting type (High intensity discharge)

• Markets
  • HID Fixture / Ballast Mfg.
    • Metal Halide, HPS, MV

• Characteristics
  • Capacitance to 60 μF
  • Voltage up to 660 Vac
  • Temperature 90°C /100°C
  • UL recognized – protected
    • 10,000 AMPS AFC tested
  • CSA certified
  • External discharge resistor
  • Extremely reliable 60,000 h life

• Competition
  • Various Asian manufacturers
Power Electronics
Line Harmonic Filters

• Markets
  • Solar / Wind inverter output harmonic filtering
  • Uninterruptable power supply (UPS)
    • Tuned filter (harmonic reduction), input filter
  • Line conditioner / power supply
  • VSD (Variable Speed Drives) input / output filter
  • AFE (Active Front End) filters

• Characteristics
  • Single-phase or three-phase
  • Voltages to 8500 vac
  • Frequency 60 Hz + high harmonic content
  • High current
  • Extruded aluminum, or custom welded case
  • Dry or Gel filled type

• Competitors
  – TDK/Epcos, Vishay, AVX, Electronicon, ASC, ECI, NGM, ICAR, Kemet, Ducati
Power Factor Correction

• Markets
  • Industrial power factor correction for unity power factory

• Characteristics
  • Single-phase or three-phase
  • Up to 325 KVAR
  • Delta or wye internal connections
  • Voltages up to 4800 Vac
  • Frequency 50 or 60 Hz
  • Extruded aluminum, or custom welded case
  • Dry or oil impregnated available

• Competitors
  – Epcos, Vishay, AVX, Electronicon, ASC, ECI, NGM, ICAR, Kemet, Ducati
AC Resonant Tank

• Markets
  • Induction Heating
    • Forging, Melting, Hardening (Automotive, Aerospace, Industrial, Coating)

• Characteristics
  • KVAR up to 15,000
  • Vrms up to 8,500
  • Irms up to 5,000
  • Frequency up to 500 KHz
  • Available in drawn, custom metal case and conduction cooled construction
  • Water-cooled construction available

• Competitors
  – Epcos, Vishay, AVX, Electronicon, ASC, ECI, NGM, ICAR, Kemet, Ducati
# AC Applications Markets

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<tr>
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<td></td>
<td>• Ferro resonant power supplies</td>
</tr>
<tr>
<td>Oxygen generators</td>
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<td></td>
<td>• Induction Heating</td>
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</tbody>
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AC Capacitors
Where to Focus

Motor-run, HID Lighting, Microwave
- Customers needing high quality capacitors
- Made in USA, NA

Power Electronics and Power Quality
- Inverters
- Solar
- UPS
- Variable speed drives
- Power conditioning
- Induction Heating
AC Capacitors
Product Support

Motor-run, HID Lighting, Microwave and Power Electronics (Small extruded can types)
Jack Chmura, Product Marketing Manager
Rui Batista, Product Manager
CDE, New Bedford

Large Welded Metal or Plastic Case
Chris Brewster, Business Unit Director
CD, Snow Hill
End of Section
DC Film Capacitors
DC Film Capacitors, Construction

• Most use metalized polypropylene windings for its self-healing properties, low loss and efficient size. Some are made with polyester film.

• High current types often use plain (non-metallized) polypropylene film dielectric with aluminum foil electrodes to handle the high current.
DC Film Capacitors, Construction

• DC film capacitors are generally wound in a stagger, with opposing electrodes extended out at each end.

• Ends of the windings are typically sprayed with a fine zinc spray to connect the turns at each end. Leads are attached at both ends prior to being assembled into the desired package. DC capacitors are typically encapsulated with epoxy or other “dry” system.
DC Film Capacitors, Form Factors

- Surface Mount
- Radial-Leaded Dipped
- Axial lead Wrap & Fill
- Radial-Leaded Box
- Direct Mount Snubber
- Cylindrical Plastic Case
- Cylindrical Metal Case
DC Film Capacitors, Form Factors

Metal Can Oil-Filled

Molded or Custom Box

Custom Plastic or Metal Case

Large Plastic Case

Welded case
DC Film Capacitors, Major Applications

- General Purpose DC Filter
- Inverter
  - DC Link (Bulk Storage, Filtering)
  - Snubber
- Pulse Power (Energy Storage/Discharge)
  - Laser
  - Flash Lamp
  - Pulse forming networks
General Purpose
DC Film Capacitors

Filtering Applications
(Industrial, Medical, Military)

- Electronic Controls
- Power Supplies
- Motor Controls
Inverter DC Link & Snubber Film Capacitors

- Motor Drive
- Traction Drive
- UPS
- Flywheel Backup
- Battery Charger
- Solar
- Wind
- Medical Imaging
Pulse DC Film Capacitors

Segmented Metalized Film
Pulse DC Film, Defibrillator Capacitors

- Aluminum, steel or plastic case options
- Mono-phasic or bi-phasic designs
- 32 to 500 µF
- 800 to 6,000 VDC
- Energy Density up to 2J/cc
- Custom designs available. including specialty form factors
- Market Trend: Pocket Defibs
Pulse DC Film Capacitors, High Energy Discharge

Applications
Electromagnetic launchers, radiotherapy, defibrillator, pulse forming networks, particle accelerators

Custom Capabilities
- Capacitance: up to 50,000 µF
- Voltage (DC): up to 450,000 VDC
- Current (Peak): up to 250,000 kA
- Inductance (nH): As low as 25nH
- Energy Density: Up to 3 J/cc
- Designs optimized for high or low rep discharge rates
- Metal cases or isolated plastic cases available
- Wide variety of terminations available

https://www.cde.com/custom-solutions/high-energy-storage-pulse-discharge
Custom DC Film Applications

- Specialty Strobe (Pulse)
  - Tasers
  - Airport Runway Lighting
  - Aircraft Lighting
  - Flashing Beacons
- Motion Control (Bus Filter and Snubbers)
  - Motor Drives
  - Elevators
  - Aircraft actuators to control flap movement
  - Computer Numerical Control Equipment
- HVAC (Filters and Snubbers)
- Electric Vehicles (Filters and Snubbers)
  - Electric Trains
  - Electric Cars & Trucks
- Welding and Induction Heating (Filters, DC Link and Snubbers)
Custom DC Film Applications

- Battery Chargers (Filters, DC Link, and Snubbers)
  - Electric vehicles
- Power Supplies (Filters, DC Link, and Snubbers)
  - UPS
  - Cable Backup
  - Linear Power Supplies SMPS
- Alternative backup (Filters, DC Link, and Snubbers)
  - Flywheel Energy Storage
- Medical (Filters, Snubbers and Energy Discharge)
  - X-Ray and MRI imaging
  - Defibrillation, Energy Discharge
  - Radiotherapy
- Emergency Vehicle Strobe Lighting (Pulse)
  - Ambulance, Police, Fire, Strobe Lighting
Custom DC Film Applications

- Generators (Filters and Snubbers)
  - Gasoline or Diesel to Electric
- Commercial / Residential Power Backup (Filters and Snubbers)
  - Fuel Cell Technology
- Military
  - Radar
  - Electric Vehicles
  - Aircraft
  - Power Supplies
  - Motion Control
  - Railguns
- Research (Pulse Discharge)
  - Fusion reactors
  - Particle accelerators
DC Film Capacitors, Competitors

- Custom Pulse
- DC Link
- Snubber
  - Wrap&fill Axial
  - Radial Box Type
  - Radial Dipped
- Surface Mount

Competitors:
- General Atomics
- Vishay
- AVX
- TDK
- KEMET
- Electronicon
- ASC Capacitors
- Electronic Concepts
- Panasonic
- Dearborn Electronics, Inc.
- AVX
- EPCOS
- WIMA
- NIC Components Corp.
Standard Form Factors and Small Custom (DC Link, Snubber, General Purpose, Defibrillator)

**Larry Bromley, Product Manager,**
CDE New Bedford

**Chris Kelly, Product Manager,**
CDE New Bedford, MA

Large Welded Metal or Plastic Case

**Chris Brewster, Business Unit Director,**
CD Snow Hill, SC
End of Section