High Voltage Ceramic Capacitors
(HV MLCCs)

Design and Characteristics
What is MLCC Surface Arcing?

Influences
- Humidity
- Surface Contamination
- Creepage Distance

Electrical breakdown between the two MLCC terminations or between one of the terminations and the internal electrodes of the capacitor within the ceramic body.
The Phenomenon of Surface Arcing

First Counter Electrode

Ionization of Air

Opposing Electrodes

Electric Field

Opposing Terminations
The Phenomenon of Surface Arcing
Surface Arcing Between MLCC Termination and the
Internal Electrode Structure
Surface Arcing Failure Modes

Terminal-to-Terminal Arcing

Terminal-to-Active Arcing

Carbon Traces

Voltage Breakdown Failures
Solutions for MLCC Surface Arcing

Surface Coatings

- MLCC Coating
  - Added by MLCC supplier
  - Additional process step
  - Critical that there is no damage to or air gap under the coating

- PCB Coating
  - Added after PCB assembly
  - Additional process step
  - Added cost
  - Cannot rework

Serial Electrode Designs

- Reduce electric field strength
  - Available capacitance in a MLCC package size is lowered
  - Allows for higher voltage capability
  - Reduces the probability of MLCC failure due to flex crack

ArcShield Designs

- Reduce electric field strength
- Reduce ionization of air at MLCC surface
- Maximizes available capacitance in a MLCC package size
The Benefits of Coating Technology

- Low K Coating
- Creepage Distance
- Ionization of Air
Issues With Coating Technologies

Electric Arc

Damaged Coating
Serial Electrode Design
Reduction of Electric Field

Single MLCC

1000V

1μF 1000V

Five Series MLCCs

1000V 1000V 1000V 1000V 1000V

Electric Field Distributed Across Individual MLCCs

Single Monolithic Structure (Serial Design)

1000V 1000V 1000V 1000V 1000V

Electric Field Distributed Across Each Serial Design

\[
\frac{1}{C_{eff}} = \sum \frac{1}{C_N}
\]
Serial Electrode Design

High-Voltage Ceramic

Also known as “Floating Electrode” or “Cascade Electrode” designs

Capacitive Area

Capacitive Area

Separation Between Series Elements
“Serial” to “Shield” Design Comparison

“Serial” Design
• With capacitors (N) in series, the acting voltage on each capacitor is reduced by the reciprocal of the number of capacitors (1/N).
• Effective Capacitance is reduced:
\[
\frac{1}{C_{eff}} = \sum \frac{1}{C_N}
\]

“Shield” Design
• Larger electrode area overlap A so higher capacitance while retaining high voltage breakdown.
• Thickness d between opposing electrodes increased:
\[
C = \frac{\epsilon_0 K N A}{d}
\]
Explanation of Shield Design

Reduction of Electric Field

Terminal-to-Terminal Arcing

Standard Design

• Opposite Field extends close to terminal of opposed polarity so low energy barrier

Terminal-to-Terminal Arcing

ArcShield Design

• Opposite Field is longer distance from terminal of opposed polarity increasing size of energy barrier
Consider a Standard Design

- In a standard overlap X7R MLCC there are 3 ways of failing high voltage:
  1. Arcing between terminal and 1\textsuperscript{st} electrode of opposite polarity
  2. Arcing between terminals
  3. Internal breakdown

Shield designs solve these voltage breakdown issues by:

- Adding a shield to prevent 1.
- The shield also creates a barrier to 2.
- Thicker actives for higher breakdown 3.
KEMET ArcShield Technology

Summary

• Permanent Protection

• No protective coating necessary

• Higher breakdown voltage capability than similarly rated devices using coating technology.

• Downsizing and board space saving opportunities.
ArcShield Key Features and Benefits

- **Patented Electrode Design**
  - Suppresses an arc-over event while increasing available capacitance

- **Permanent protection**
  - Competitive versions often use a non-permanent surface coating

- **BME X7R Dielectric**
  - 500, 630 and 1,000Vdc

- **0603 - 2225 Case Sizes**

- **1.0nF – 560nF**

- **Flexible Termination Available**

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“*The World’s Smallest High Voltage MLCC’s*”

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Thank You!