KEMET MIL-PRF-32535 Series for Defense and Aerospace Applications
Outline

- Defense and Aerospace Background
- MIL-PRF-55681 and MIL-PRF-123 Overview
- MLCC Advances in Commercial and Automotive Applications
  - Any why Defense and Aerospace have not followed
- Introduce MIL-PRF-32535 Specification
- KEMET Product Offering for MIL-PRF-32535
- Ordering Information
Defense and Aerospace
MLCCs for D&A Applications

- Conservative designs
- Constructed and screened per military standard
- Design and change control
- Full material traceability
- Verified electrical and environmental performance
- Periodic maintenance testing
- Strict oversight on materials and processes
## Military vs Space Grade
### What’s the difference?

<table>
<thead>
<tr>
<th></th>
<th><strong>Military Grade</strong></th>
<th><strong>Space Grade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Also Known As</strong></td>
<td>Standard and Established Reliability</td>
<td>High Reliability</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Non-critical military applications such as communications devices, ground weapons, military equipment not used for navigation and Safety</td>
<td>Space, missiles, avionic safety and navigation equipment</td>
</tr>
<tr>
<td><strong>Special Requirements</strong></td>
<td>Periodic inspection for electrical, environmental, and mechanical inspection.</td>
<td>Every lot receives electrical, environmental, and mechanical inspection.</td>
</tr>
</tbody>
</table>
Group Testing Overview

MIL-PRF Group Inspection

- Group A
  - Thermal Shock
  - DPA
  - CSAM
  - UVBD
- Group B
  - Voltage Conditioning
  - Solderability
  - Life Testing
- Group C
  - Visual Mechanical
  - Flex
MIL-PRF-55681 (CDR)
Military Grade - Established Reliability

Overview

- Military Grade - Established Reliability
- Military & Avionics applications
- >25 year field history
- Legacy PME
- 50 & 100V rating available
- NP0/BP and BR/BX Dielectrics
- 0805 – 2225 Case Sizes
- Group A and C Testing

<table>
<thead>
<tr>
<th>CDR01</th>
<th>B</th>
<th>P</th>
<th>101</th>
<th>B</th>
<th>K</th>
<th>Z</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Style &amp; Size Code</td>
<td>Rated Temperature</td>
<td>Dielectric</td>
<td>Capacitance</td>
<td>Rated Voltage</td>
<td>Tolerance</td>
<td>Termination Finish</td>
<td>Failure Rate</td>
</tr>
</tbody>
</table>
MIL-PRF-123 (CKS)
Space Grade (High Reliability)

Overview
- Space Grade (High Reliability)
- Space, Missile, and other Hi Rel Applications
- >25 year field history
- Prevents Nickel electrode system (No BME)
- 50 & 100V rating available
- NP0/BP and BR/BX Dielectrics
- 0805 – 2225 Case Sizes, Leaded
- Group A, B, and C Testing

<table>
<thead>
<tr>
<th>M123</th>
<th>A</th>
<th>10</th>
<th>BX</th>
<th>B</th>
<th>472</th>
<th>K</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military Spec Number</td>
<td>Modification Number</td>
<td>Slash Sheet</td>
<td>Temperature Characteristic</td>
<td>Rated Voltage</td>
<td>Capacitance</td>
<td>Tolerance</td>
<td>Termination Finish</td>
</tr>
</tbody>
</table>
Electronics Industry Trends
Commercial and Automotive

- Active and Passive Component Size
- Functionality and Density

Time

- IoT
- Autonomous Vehicles
- HEV
- Smart Phones
- Tablets
- Mobile Phones
- Laptops
- PCs
MLCC Miniaturization

1206 → 0805
MLCC Miniaturization

Termination

Electrodes

Ceramic

\[ C = \text{Design Capacitance} \]
\[ K = \text{Dielectric Constant} \]
\[ A = \text{Overlap Area} \]
\[ d = \text{Ceramic Thickness} \]
\[ n = \text{Number of Electrodes} \]

Capacitances in parallel are additive

\[ C_T = C_1 + C_2 + C_3 + \ldots + C_n \]

\[ C = \frac{\varepsilon_0 KA(n-1)}{d} \]
MLCC Trends
Movement towards BME

**PME**
- Most suppliers reducing development efforts in PME
- Thicker layers
- Reduced layout count
- Low-medium volumetric efficiency

**BME**
- Majority of capacitor technology development is in BME since early 2000’s
- Thinner layers
- High layer count
- High volumetric efficiency

**MLCC Trend**
- Thinner layers
- Reduced layout count
- Low-medium volumetric efficiency

**Miniaturization**

**Time**

**PME→BME Transition**
MLCC Trends
Movement towards BME

10x cap increase in BME over PME
BME Reliability

BME MLCC’s are used in many applications where reliability is critical
• Automotive (>15 years)
• Medical instrumentation and implantable (10+ years)
MIL-PRF-55681 and MIL-PRF-123 Restrictions

**MIL-PRF-55681**
- Legacy PME
  - Customers will not use BME versions of 55681
  - Limited to PME only

**MIL-PRF-123**
- Prevents use of nickel electrodes
  - Most BME MLCCs have nickel electrodes
  - Limited to PME only

**MIL-PRF-32535**
- Need for new military standard allowing for thinner dielectrics and higher CV ceramic capacitors
- Cannot capitalize on industry trends
- Prevents miniaturization
- Limits technological advancements
MIL-PRF-32535
Joint Effort

Leading Capacitor Manufacturers

Defense Logistics Agency (DLA)

MIL-PRF-32535

Benefits

• Increased capacitance
• Increased volumetric efficiency (HiCV)
• Broader case size offering (down to 0201)
• Promotes miniaturization

Defense and Aerospace Customers

• Thinner Dielectrics
• Allows for BME (PME is still allowed)
• Standard Reliability (M level)
• High Reliability (T level)
• Flexible termination option
MIL-PRF-32535
Does Not Replace MIL-PRF-55681 and MIL-PRF-123

- MIL-PRF-123 (PME)
- MIL-PRF-55681 (PME)
- MIL-PRF-32535 (BME or PME)
Industry’s First Military Qualified BME Ceramic Capacitors
QPL listed per MIL-PRF-32535

- Defense & Aerospace Applications
- High Reliability
- High Capacitance
- Broad Case Size & Voltage Range
High CV Military/Space Grade MLCCs
MIL-PRF-32535 C0G/BP

NEW HiCV Military / Space Grade

Standard reliability ("M" Level)
High reliability ("T" Level)

Up to a 18-fold increase in capacitance

Standard and Flexible Terminations

C0G/BP Dielectrics

0402 - 2220 Case Sizes

4 – 200 Vdc Ratings

<table>
<thead>
<tr>
<th>Dielectric</th>
<th>TCC @0V</th>
<th>TCC @ Rated V</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0G</td>
<td>0 ±30 ppm/°C</td>
<td>Not Required</td>
</tr>
<tr>
<td>BP</td>
<td>0 ±30 ppm/°C</td>
<td>0 ±30 ppm/°C</td>
</tr>
</tbody>
</table>

Base Metal Electrode Technology
NEW HiCV Military / Space Grade

Standard reliability ("M" Level)
High reliability ("T" Level)

Up to a 55-fold increase in capacitance

Standard and Flexible Terminations

X7R Dielectric

0402 - 2220 Case Sizes

4 – 100 Vdc Ratings

BME Base Metal Electrode Technology
MIL-PRF-32535

Construction

Standard Termination

- Dielectric (CaZrO$_3$ or BaTi$_3$)
- Inner Electrodes (Ni)
- End Termination (Cu)
- Epoxy Layer (Ag)
- Barrier Layer (Ni)
- Termination Finish

Flexible Termination

Termination Finishes
- Solder Plated SnPb - 3% Pb Minimum
- Solder Dipped SnPb - 3% Pb Minimum
- Gold (Au)
MIL-PRF-32535
What Advantages?

Capacitance

**C0G/BP**
- 330pF 100V
- 3.3nF 50V
- 8.2nF 50V

**X7R**
- 56nF 100V
- 27nF 100V
- 18nF 100V

**PME**
(MIL-PRF123 or MIL-PRF-55681)
- 1206
- 1210
- 2225

**BME**
(MIL-PRF-32535)
- 0402
- 0603
- 0805
MIL-PRF-32535
What Advantages?

**Desired Capacitor:**
C0G/BP 330pF 100V

**Desired Capacitor:**
C0G/BP 18nF 100V
### MIL-PRF-32535
What Advantages – C0G/BP Offering

<table>
<thead>
<tr>
<th>Case Size (Inches)</th>
<th>Case Size (mm)</th>
<th>Rated Voltage (Vdc)</th>
<th>Maximum Available Capacitance (nF)</th>
<th>CAP Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MIL-PRF-55681</td>
<td>MIL-PRF-123</td>
</tr>
<tr>
<td>0402 1005</td>
<td>0402</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>- 1.0</td>
<td>0.68</td>
</tr>
<tr>
<td>0603 1608</td>
<td>0603</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>- 5.6</td>
<td>3.9</td>
</tr>
<tr>
<td>0805 2012</td>
<td>0805</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>0.68 10</td>
<td>0.68 8.2</td>
</tr>
<tr>
<td>1206 3216</td>
<td>1206</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>2.2 27</td>
<td>2.2 18</td>
</tr>
<tr>
<td>1210 3216</td>
<td>1210</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>3.3 47</td>
<td>3.3 33</td>
</tr>
<tr>
<td>1812 4532</td>
<td>1812</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>10.0 100</td>
<td>10.0 68</td>
</tr>
<tr>
<td>2220 5650</td>
<td>2220</td>
<td>4 / 6.3 / 10 / 16 / 25</td>
<td>- 180</td>
<td>- 150</td>
</tr>
</tbody>
</table>
MIL-PRF-32535
Component Edge

M3253502E1B101JZMB
(C0402K101J1EML)
Request Samples for this part

Specs Sheet | SMD MIL C0G PRF32535 Datasheet | STEP

Capacitance
100 pF

Temperature Coefficient
C0G

Approvals
MIL-PRF-32535 M-Level

Capacitance Tolerance
5%

RoHS
No

Chip Size
0402

Voltage DC
100 V

Termination
Solder Plated

Packaging
Waffle Pack

No Inventory Available

Temperature Range
-55/125°C

Failure Rate
N/A

Packaging Quantity
368
# MIL-PRF-32535

## How to Order

### MIL-PRF-32535 Ordering Information

<table>
<thead>
<tr>
<th>M32535</th>
<th>04</th>
<th>E1</th>
<th>Z</th>
<th>104</th>
<th>J</th>
<th>R</th>
<th>M</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL Prefix</td>
<td>Slash Sheet</td>
<td>Characteristic/Dielectric</td>
<td>Rated Voltage (VDC)</td>
<td>Capacitance Code (pF)</td>
<td>Capacitance Tolerance</td>
<td>Termination</td>
<td>Product Level</td>
<td>Electrode</td>
</tr>
<tr>
<td>02 = 0402</td>
<td>03 = 0603</td>
<td>04 = 0805</td>
<td>05 = 1206</td>
<td>06 = 1210</td>
<td>07 = 1812</td>
<td>08 = 2220</td>
<td>E1 = CDG BP = BP</td>
<td>V = 4</td>
</tr>
<tr>
<td>B = +0.1 pF</td>
<td>C = +0.25 pF</td>
<td>D = +0.5 pF</td>
<td>F = ±1%</td>
<td>G = ±2%</td>
<td>J = ±5%</td>
<td>K = ±10%</td>
<td>D = Sn/Pb solder dipped</td>
<td>G = Nickel gold plating</td>
</tr>
<tr>
<td>B = BME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Termination options D, R, V, and L are not available in EIA 0402 case size.
2. Termination option D is not available in EIA 0603 case size.

### Packaging C-Spec Ordering Options Table

<table>
<thead>
<tr>
<th>Packaging Type</th>
<th>Packaging/Grade Ordering Code (C-Spec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Packaging (Waffle Tray)</td>
<td>Not required (Blank)</td>
</tr>
<tr>
<td>7” Tape &amp; Reel</td>
<td>Contact Sales</td>
</tr>
</tbody>
</table>

### KEMET Part Number Equivalent (For Reference Only)

<table>
<thead>
<tr>
<th>C</th>
<th>D1206</th>
<th>K</th>
<th>104</th>
<th>J</th>
<th>3</th>
<th>G</th>
<th>M</th>
<th>L</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic</td>
<td>Specification/Series</td>
<td>Capacitance Code (pF)</td>
<td>Capacitance Tolerance</td>
<td>Rated Voltage (VDC)</td>
<td>Dielectric</td>
<td>Failure Rate/Design</td>
<td>Termination Finish</td>
<td>Packaging/Grade (C-Spec)</td>
<td></td>
</tr>
<tr>
<td>0402</td>
<td>MIL-PRF-32535</td>
<td>Two significant digits and number of zeros. Use 9 for 1.0 - 9.9 pF. Use 8 for 0.5 - 9.99 pF. Ex. 2.2 pF = 229, 0.5 pF = 500.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0603</td>
<td>0005</td>
<td>1206</td>
<td>1210</td>
<td>1812</td>
<td>2220</td>
<td>E = CDG G = BF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0402</td>
<td>M = M Level</td>
<td>standard termination</td>
<td>N = M Level</td>
<td>flexible termination</td>
<td>T = T Level, standard termination</td>
<td>V = V Level, flexible termination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0603</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1206</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1210</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1812</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2220</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See "Packaging C-Spec Ordering Options Table" below