Welcome to the KEMET Ceramic Capacitor Flex Crack Mitigation product training module. This module will review sources of stress in surface mount multilayer ceramic capacitors, provide board layout recommendations, and discuss benefits of KEMET’s flex crack mitigation product portfolio.
Cracking of ceramic capacitors has been a concern in PCB manufacturing for quite some time. It is often a result of board stress due to thermal cycling, board flexure or pick-and-place assembly. As the ceramic capacitor is inherently rigid, non-elastic, any bending of the board or excessive force applied to the capacitor will create stress which can be transmitted through the solder joint and directly to the ceramic body. It often originates at the edge of the termination band closest the substrate, and subsequently propagates through the body of the capacitor at a high angle or in some cases to the opposing edge of the same termination band.

If the crack crosses internal electrodes originating from both terminated ends of the capacitor, there will be a measureable loss in capacitance and a short circuit can ensue.

The graph on the right illustrates capacitance performance during a board flexure test. As shown, when the capacitor is cracked there is a dramatic drop in measured capacitance.

Flex cracks provide an ingress for both moisture and contaminants, promoting a short circuit within the capacitor. This condition will lead to a catastrophic failure of the device.
Careful circuit board design is needed in order to avoid placing MLCC’s near areas of high flexure stress such as board edges, push connectors and mounting holes. Another source of stress is depanelization, in which several small boards are assembled as one large unit that must then be singulated. Additionally, careful handling of boards during chip population and subsequent SMT processes is necessary in order to avoid board-flexure-related cracking.
KEMET offers a complete portfolio of flex mitigation solutions that address both component flex cracks and the ensuing catastrophic failure mode of a typical MLCC.

KEMET solutions include “fail-open” internal electrode designs, a flexible termination system, a combination of both “fail open” and flexible termination, and mechanical isolation.
Fail open technology reduces the risk of a fail-short condition in a cracked device through the use of unique internal electrode structures.

The first configuration on the left is known as “Open-Mode”. For mid to high capacitance values, this solution works by extending the margin area between the end termination and the effective (active) area, creating a “safe zone” as shown in the image. This design does not prevent the crack but rather mitigates the effect, as the crack does not cross electrodes originating from opposite ends of the device.

For low to mid capacitance values, KEMET offers the Floating Electrode design (or serial cap), which utilizes a cascading internal electrode design configured to form multiple capacitors in series within a single device. This internal design results in a floating electrode structure. Even if a crack was to propagate through one of the active areas, the device may loose capacitance but will not fail-short. Note that a typical crack cannot cross electrodes originating from both ends of the capacitor. It can only cross electrodes that originate from one end of the capacitor and those floating between the active areas of the internal capacitors.
Another technology developed to address cracking of MLCCs is Flexible Termination. This technology does not address the outcome of a flex crack, but rather improves the flex performance of the MLCC.

Flexible termination consists of a four part termination system. The inner layer, or copper undercoat, is covered by a special conductive silver epoxy that provides an essential tear-away feature. This feature acts to steer any potential flex crack away from the ceramic body into this more benign area of the termination system.

Developed for all available capacitance values, the key characteristic of the flexible termination is that it can be applied to any surface mount capacitor, regardless of size, voltage, or application temperature up to 150ºC. Although this technology does not eliminate the potential for mechanical damage that may propagate during extreme environmental and handling conditions, it does provide superior flex performance over standard termination systems.
For applications that require added protection, KEMET offers FE-CAP and FO-CAP which incorporate two existing flex mitigation technologies: Flexible Termination and Open Mode or Floating Electrode designs.

Both electrode designs mitigate the risk of a low IR or short circuit failure, while the flexible termination component improves the capacitor’s mechanical performance; shifting stress away from the ceramic body and into the termination area. The combination of these two technologies provide an enhanced level of protection for low to high capacitance devices.
The most advanced mechanical and thermal stress performance is achieved by mechanically isolating the ceramic component of the capacitor from the printed circuit board. Isolation also addresses concerns for audible, microphonic noise that may occur when voltage is applied. As part of our Flex Mitigation portfolio KEMET offers several Mechanical Isolation solutions in both commercial and automotive grades.

Despite component evolution, many legacy products still exist today that offer superior flex performance over traditional surface mount devices. Thru-hole radial and axial components mechanically isolate the ceramic component of the capacitor through the use of lead wire. These devices are available in a variety of dielectric materials, voltage ratings, and capacitance values and are suitable for applications that are prone to frequent mechanical stress. (such as connectors that are used to interface with external devices that are frequently attached and detached). These devices offer strong mechanical bonds to the PCB and excellent thermal cycling capability when compared to traditional SMD devices.

KEMET Power Solutions (KPS) devices utilize a proprietary lead-frame technology to vertically stack one or two multilayer ceramic chip capacitors into a single compact surface mount package. The attached lead-frame mechanically isolates the capacitors from the printed circuit board while providing a surface mount form factor. A two chip stack offers up to double the capacitance in the same or smaller design footprint.
when compared to traditional surface mount MLCC devices.

Capable of withstanding up to 10mm of board flex capability, all three solutions are environmentally friendly and are in compliance with RoHS legislation.
Seen here is a Weibull chart that illustrates the flex performance of a standard MLCC (illustrated in black data points) as compared to our flexible termination (in red data points) and KPS technologies (in green data points). Both mitigation technologies significantly improve flex performance and offer up to 10 mm of flex performance.

As illustrated, a small portion of the population in the flexible termination category exhibit failures between 3.5mm and 10mm (tail). KPS technology offers far superior flex performance over both standard and flexible termination technologies with a smaller tail and tighter distribution within the 8mm to 10mm range.
In summary KEMET offers a complete portfolio of flex crack mitigation solutions that addresses most footprints, mounting techniques, flex capability and failure modes.

Our Fail Open technology consisting of both “Open Mode” and “Floating Electrode” internal electrode designs, addresses the failure mode of surface mount MLCCs. They are designed to fail open, should the ceramic body be stressed and cracked.

Flexible Termination Technology improves the flex performance of the capacitor by directing the stress away from the ceramic body and into the termination area.

Hybrid Technology, the combination of fail open and flexible termination technologies, addresses both the failure mode and flex performance of the capacitor. This technology was developed for safety critical applications that require an enhanced level of protection.

The most advanced and effective solution is achieved using Mechanical Isolation Technology. Isolating the ceramic capacitor from the printed circuit board is the most effective way of protecting the ceramic component of the capacitor during mechanical or thermal stress. This technology also reduces the amount of microphonic noise that may occur when voltage is applied to the circuit, and allows for bulk capacitance configurations (capacitor stacking).
All 4 technologies are available in both commercial and automotive grades.
The sixth digit within KEMET’s part numbering system designates the flex crack mitigation style of your choice. Use the letter “F” when selecting the open mode style or “J”, if you choose open mode plus flexible terminations. The floating electrode style is designated by the letter “S”. Use “Y” to include flexible terminations with floating electrodes. If you select standard internal construction with flexible terminations, “X” is the letter used in the sixth digit.

For KEMET’s KPS series with proprietary lead frame technology, the designator can be found in the 13th digit as either a “1” or “2”.

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<table>
<thead>
<tr>
<th>Flexibility Style</th>
<th>Designator</th>
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<tbody>
<tr>
<td>Open Mode</td>
<td>C0805F C1206F C1210F C1812F</td>
</tr>
<tr>
<td>Open Mode + Flexible Termination</td>
<td>use J in the 6th digit</td>
</tr>
<tr>
<td>Floating Electrode</td>
<td>C0402S C0603S C0805S C1206S C1210S C1812S</td>
</tr>
<tr>
<td>Floating Electrode + Flexible Termination</td>
<td>use Y in 6th digit</td>
</tr>
<tr>
<td>Flexible Termination Only</td>
<td>C0603X C0805X C1206X C1210X C1812X C2228X</td>
</tr>
</tbody>
</table>

In the KPS part numbering system, a “1” or “2” in the 13th digit calls out the number of stacks: example: C1812C226M3R2C

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SEM micrographs show the preferred mode of crack propagation along the interface between the copper/glass and silver epoxy termination layers.
The primary failure mode of surface mount MLCC’s is low IR failures due to flex cracks. Since the inception of surface mount processing, this type of failure represents a significant portion of customer complaints and inquiries. To address this failure mode, KEMET has developed a complete line of Flex Crack Mitigation solutions that can be successfully integrated into both existing and new designs. Solutions exist to meet most capacitance, footprint, rated voltage and mounting style needs.

All solutions outlined in this presentation are readily available and new Flexible Termination Engineering Kits are also available. Automotive Grade products meet or exceed the requirements outlined by the Automotive Electronics Council. Details regarding test methods and conditions are referenced in document AEC–Q200, Stress Test Qualification for Passive Components. For additional information regarding KEMET Flex Mitigation Solutions, please visit our flex mitigation solutions microsite at http://www.kemet.com/flex