Frequently asked questions regarding:

TDK's Guide to Flex Cracking in Multilayer Ceramic Capacitors

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Abstract

Multilayer ceramic capacitors are small, volumetrically efficient, and cost effective. However, these advantages come with trade-offs. Ceramics, by nature, are brittle and vulnerable to cracking from many sources. One of the most common sources is the flexure, or flex, crack.

This paper will discuss the mechanics of flex cracking in MLCCs, as well as ways to minimize the occurrences of flex cracks.

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TDK Guide to MLCC Flex Cracking

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Q1. What is meant by the term "flex crack"?

A flex crack refers to a crack formed by excess bending of an MLCC once it has been soldered onto a PCB.

These cracks differ in appearance to cracks created by other means, such as impact or electrical overstress.

Q2. Why do flex cracks occur?

The dielectric material in an MLCC is a ceramic compound. Ceramics, by nature, are brittle materials that are strong under compression, but weak under tension.

The ceramic's brittle nature does not allow for plastic deformation. If the mechanical stress induced on an MLCC is too great, the part will crack as a method of reducing this stress.

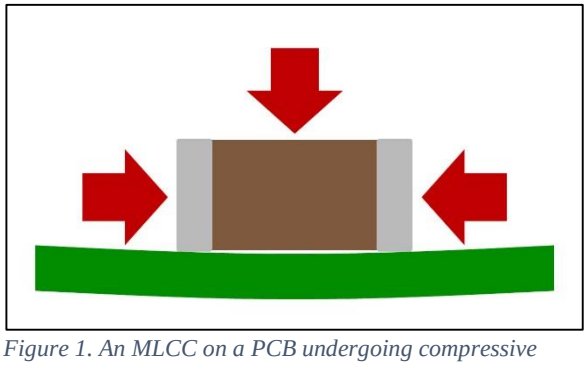

Figure 1. An MLCC on a PCB undergoing compressive forces due to a concave bend

MLCCs will rarely crack during a concave bend of the PCB, because the forces exerted on the part are compressive during these bends.

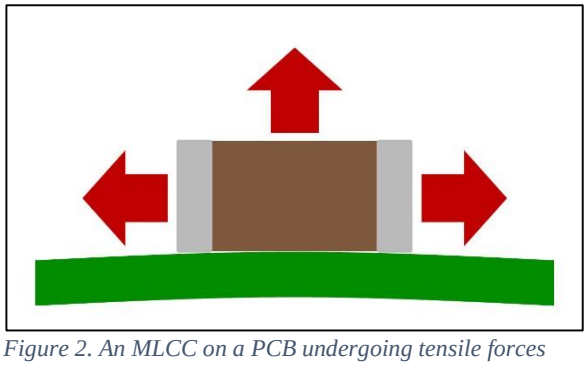

Figure 2. An MLCC on a PCB undergoing tensile forces due to a convex bend

MLCC's are very susceptible to cracking during a convex bend of the PCB, because the part is undergoing tension.

Q3. What does a flex crack look like?

The signature flex crack is sometimes referred to as a "45° crack". These cracks originate near the start of the termination (the origin of stress on the part) on the mounted side of the MLCC and continue upwards at a 45° angle (the direction of bending stress on the part) until it reaches the termination at the outer edge of the MLCC.

The 45° crack is the most commonly seen flex crack, but other flex cracks are possible, particularly if the part underwent especially severe bending.

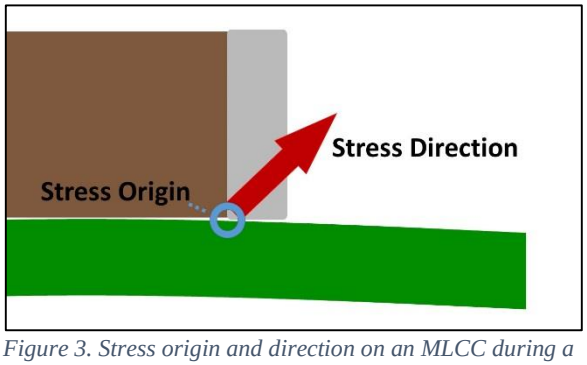

Figure 3. Stress origin and direction on an MLCC during a convex bend

External visual detection of a flex crack is rare, although sometimes a discoloration of the dielectric is visible on the surface. This area will appear lighter in color than the normal dielectric.

Usually, the crack is only found once the part has undergone a destructive physical analysis (DPA), also called a cross-sectioning.

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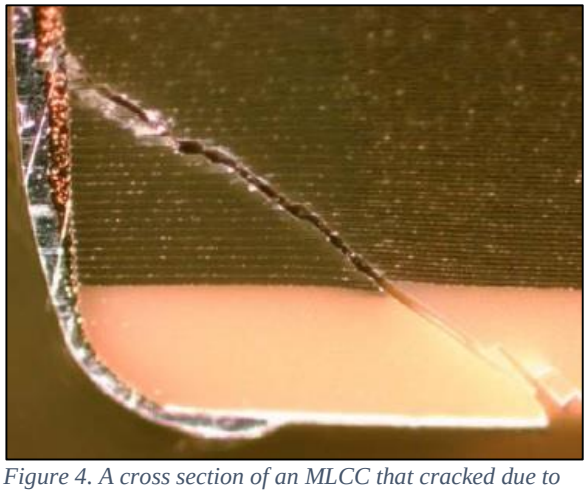

Figure 4. A cross section of an MLCC that cracked due to excess board flexure

Sometimes, if the MLCC's termination is removed, the flex crack can be observed, if the crack has propagated the surface.

These cracks can sometimes be visible on the bottom of the MLCC.

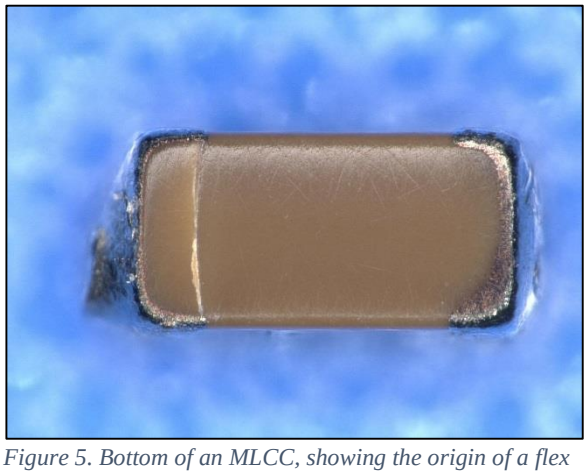

Figure 5. Bottom of an MLCC, showing the origin of a flex crack.

During cases of severe board stress, cracks could form on both ends of the MLCC.

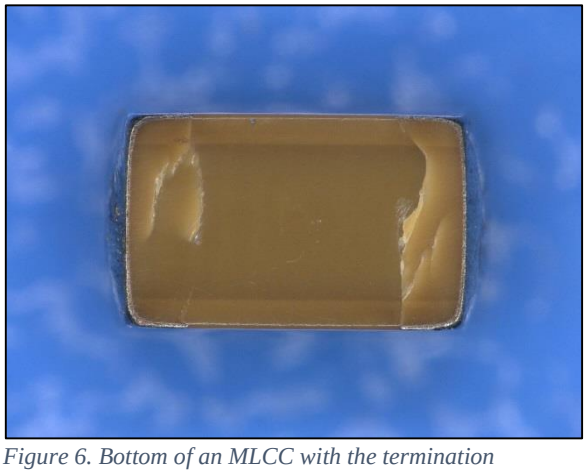

Figure 6. Bottom of an MLCC with the termination removed. Cracks are visible at both ends.

Q4. What happens to the MLCC once it is cracked?

Once a crack forms, this can allow moisture and contaminants to penetrate inside the component. If the crack crosses the active stack (the overlapping area of the electrodes) this can lead to a low electrical resistance path or "leaky short" developing over time. Once this low resistance path forms, this can cause further breakdown of the dielectric due to overheating. This overheating can lead to a true short circuit developing.

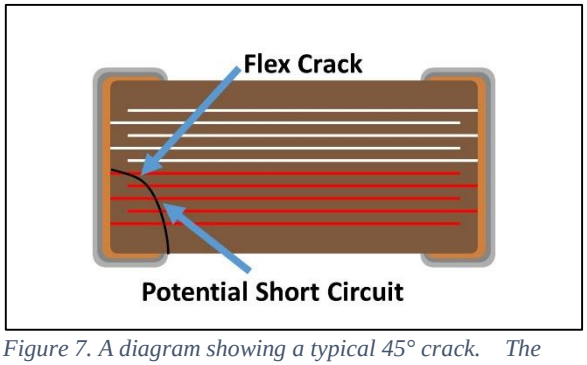

Figure 7. A diagram showing a typical 45° crack. The red electrodes are where the crack has passed through the active stack. This represents a risk for a short circuit.

Q5. What are some common ways that flex cracking occurs?

Any activity that subjects the PCB to significant bending after the MLCCs have been soldered on the board risks cracking.

There are many ways in which a board could experience flexure, both during and after manufacturing.

PCBs frequently undergo a great amount of stress during depaneling. A few additional

examples of ways in which a board could bend during the manufacturing process are: attaching connectors and wiring harnesses to connector sockets, sliding the boards into housings (without supporting the board), and screwing down the boards onto screw mounts.

Q6. How can I detect a flex crack?

A flex crack is most frequently detected by electrical measurement as a decrease in insulation resistance. The MLCCs IR will decrease because the crack creates a weak point in the dielectric. Decreases in IR are usually detected by increases in leakage current.

A loss of capacitance or an increase in dissipation factor are also electrical indicators that a crack has occurred.

Q7. How can I help prevent flex cracking?

The best way to prevent cracks is to ensure the board is not subjected to unnecessary external forces. Installing board stiffeners or supports can help prevent a board from bending. Board flexure during manufacturing can often be overlooked. Examining the manufacturing process can lead to finding ways reduce the stresses induced on the boards.

Additionally, part placement on the boards plays a large role in the amount of stress induced on the part during a bend. Placing parts farther away from depaneling planes and screw mounts can help prevent exposing MLCCs to unnecessary stress during manufacturing. Parts placed parallel to the depaneling planes will experience less stress.

Excess solder can lead to increased stress on MLCCs during bending. Care should be taken to use the soldering specifications provided by the manufacturer.

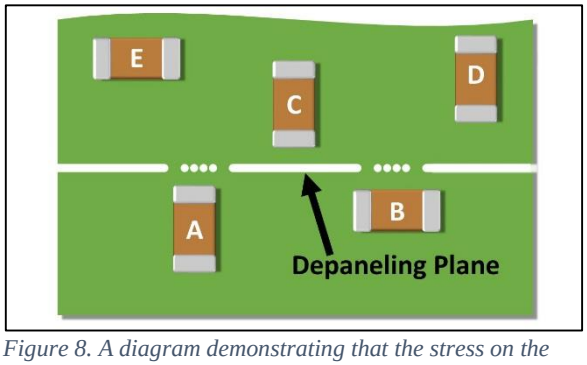

Figure 8. A diagram demonstrating that the stress on the capacitor during depaneling is greatest to least in the following order A > B = C > D > E.

Q8. Does TDK offer any solutions for flex cracking?

TDK has many flex cracking solutions including, Open Mode, Soft Termination, Serial Design, and Mega Cap.

Open Mode caps have an extended “L” gap (the distance between the termination and the electrode). This means that when the common 45° crack occurs, it will not travel through the active stack, and therefore will create an open circuit instead of a short circuit.

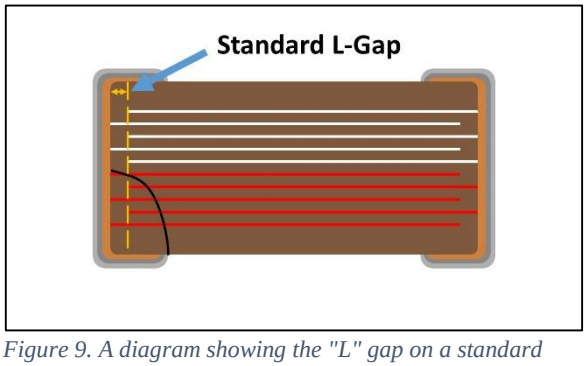

Figure 9. A diagram showing the "L" gap on a standard MLCC.

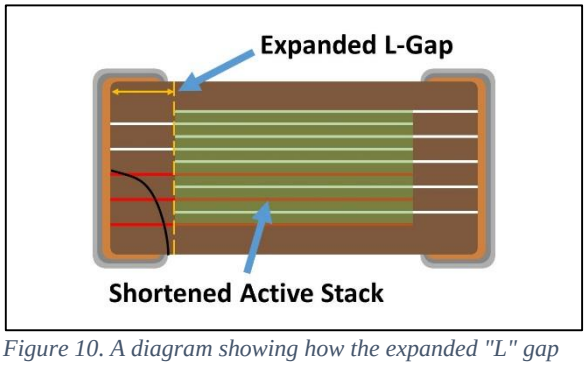

Figure 10. A diagram showing how the expanded "L" gap helps prevent a short circuit from flex cracking.

TDK’s Soft Termination MLCC’s have a layer of conductive resin built into the termination. This layer of resin, located between the Cu and Ni

layers, helps absorb mechanical stresses from bending and vibration to prevent a crack from occurring. When the part undergoes extreme bending, the termination is designed to separate from the resin before a crack develops.

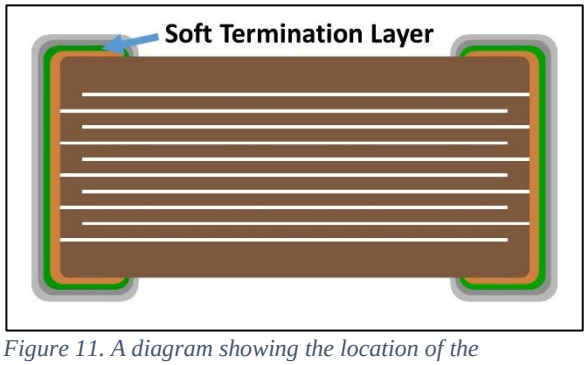

Figure 11. A diagram showing the location of the conductive resin layer (shown in green for emphasis).

TDK's Serial Design capacitors are effectively two capacitors in series, in a single ceramic body. These caps are designed to satisfy certain specifications for series caps on battery lines.

The two capacitors ensure that if one cracks, there still exists a second capacitor. This helps prevent a short circuit in the event of a crack. However, TDK's serial design is also equipped with Soft Termination. This helps prevent a crack in the first place.

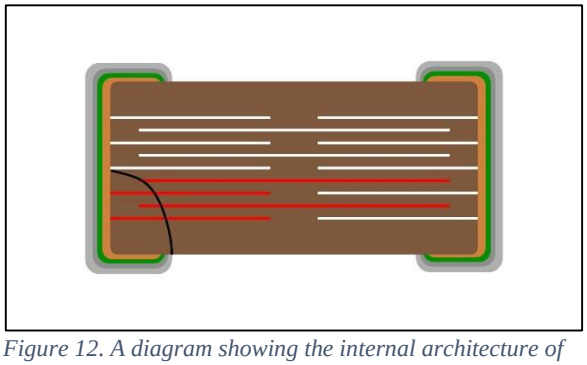

Figure 12. A diagram showing the internal architecture of a serial design capacitor. A short has not occurred, even though the part has cracked.

TDK's Mega Cap is a leaded, stacked MLCC. The metal leads absorb much of the stress from bending and vibrations.

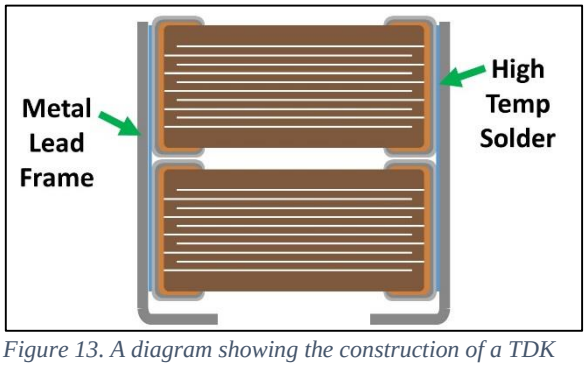

Figure 13. A diagram showing the construction of a TDK Mega Cap.

Conclusion

Flex cracking remains the biggest issues with MLCCs. Many of these risks can be mitigated during design. In order to combat the instances where these risks cannot be mitigated, TDK has developed many flex cracking solutions. For more information, please visit our website, or contact your local sales representative.

End of Report

Contact TDK for further information or visit our website at www.tdk.com.

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