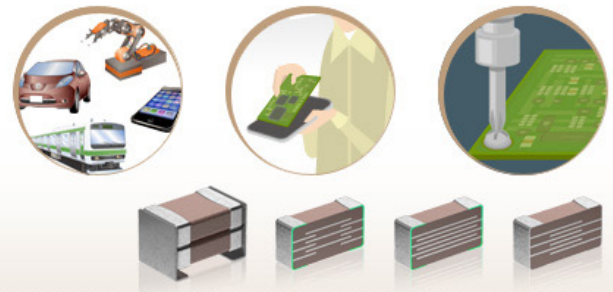


Reliability improvement

Life elongation



Flex Crack Countermeasures

in MLCCs (Multilayer Ceramic Chip Capacitors)

Flex Crack Countermeasures in MLCCs Outline

When a crack occurs on the element of an MLCC (Multilayer Ceramic Chip Capacitor) due to depaneling of the print circuit board, screw fastening, or shock from a vibration or a drop, it may lead to a short circuit failure. Among failure modes, there are open circuit failures and short circuit failures. Short circuit failures can even cause problems such as abnormal heat generation, smoking, or ignition of the MLCC, and therefore it is indispensable to take measures against them, particularly for equipment for which reliability is required.

TDK offers special types of MLCC products with redundancy design, in order to avoid short circuit failures and improve the reliability of equipment. Please select products that suit your purposes and use them to improve the reliability of your products.

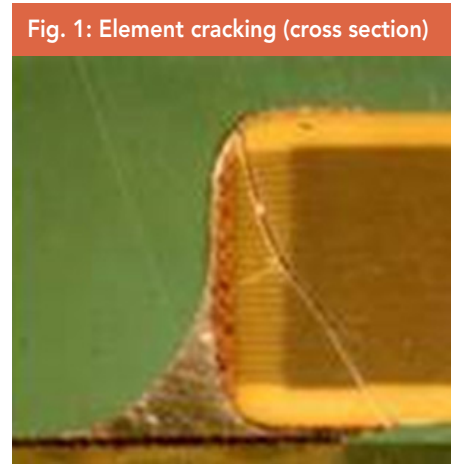






Fig. 1: Element cracking (cross section)

Major causes and process of flex cracks that occur in MLCCs
 Flexure damage often causes cracks. The cracks are generated inside the capacitor element and electrical conduction occurs between opposing electrodes.

Applications and boards that require special caution against flex crack countermeasures
 A fine crack that occurs during the process from SMD mounting to set assembly might progress to cracking of the capacitor element when the product is sent to the market and used.

TDK offers following MLCC products as flex crack countermeasures.

- | | |
|---|---|
|  <p>1) Metal caps disperse flex stress and reduce load applied to the capacitor:
 MEGACAP</p> |  <p>2) Soft terminations absorb flex stress and reduce load applied to the capacitor:
 Soft termination</p> |
|  <p>3) Dual fail-safe function that absorbs flex stress and prevents short circuit failures in the case of crack occurrences:
 Serial design (the CEU series)</p> |  <p>4) Less prone to short circuit failures even if cracks occur on the element:
 Open mode</p> |

Comparison of the 4 solutions: Summary of "Flex Crack Countermeasures in MLCCs"

Major causes of short circuit failures that occur in MLCCs

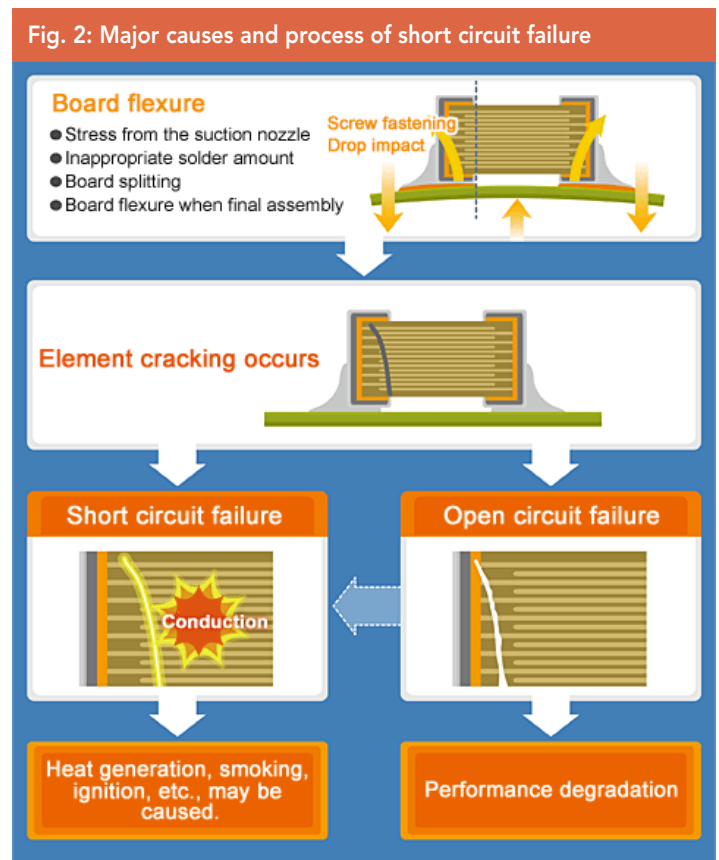
Flexure damage often causes cracks. The cracks are generated inside the capacitor element and electrical conduction occurs between opposing electrodes.

Flex cracking is due to excessive circuit board flexure. As for the causes of board flexure, there are various causes including problems during the manufacturing process, such as solder stress due to an inappropriate amount of solder, stress applied at the time of depaneling or screw fastening, or board flexure at the time of final assembly, in addition to drops, vibration, or thermal expansion during use.

Ceramics are strong in compression but weak in tension. Thus, when a soldered MLCC experiences excessive board flex, a crack is easily generated in the element.

A flex crack can cause an electrical conduction between opposing internal electrodes. It is also possible that an fail open can progress to a fail short with continue product usage.

If a crack on a capacitor element progresses to a short circuit failure, it may cause problems such as heat generation, smoking, or ignition; therefore, it is indispensable to take measures against them, particularly in equipment where reliability is essential.



Applications and boards that require precaution to avoid flex cracks in the element and countermeasures against short circuit failures.

A fine crack that occurs during the process from SMD mounting to set assembly might progress to cracking of the capacitor element when the product is sent to the market and used. Such a risk is higher in equipment exposed to vibration or shock, such as automotive electronics, railway equipment, or industrial equipment. In addition, the probability of the occurrence of a crack is higher in equipment that can experience frequent shock due to drops, such as keyless entry or smart entry equipment.

In equipment used in a humid environment, condensation is generated from water vapor and may enter into an element crack, causing ionization of the metal of the internal electrodes and ion migration. This will cause an open circuit failure to progress to a short circuit failure.

Fig. 3: Applications that require flex crack countermeasures (1/2)



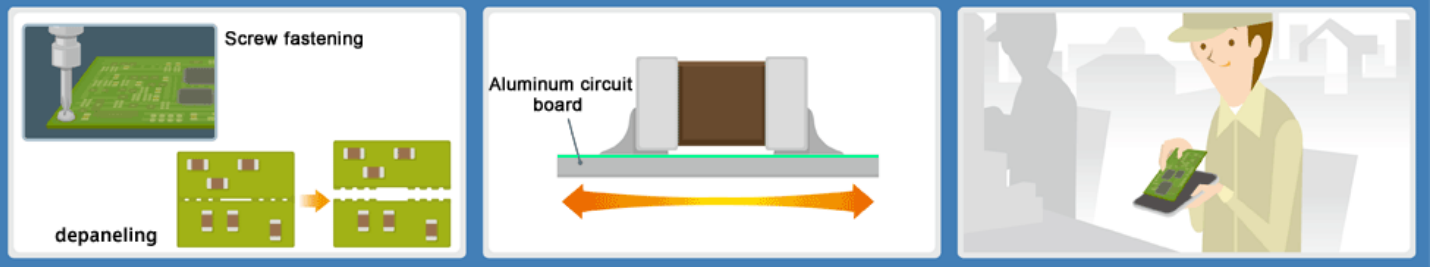
Products exposed to vibration or shock

Equipment expected to experience shock due to drops

Equipment used in a humid environment

Manufacturing can cause cracks to occur in the capacitor element due to expansion and contracting of the board when an MLCC is directly attached to an aluminum circuit board, etc., having large thermal expansion, not to mention at areas near screws or depaneling. In addition, it is common that boards are bent excessively during board manufacturing or final assembly, and fragile ceramic components tend to get damaged when they are soldered to boards.

Fig. 4: Applications that require flex crack countermeasures (2/2)



MLCCs near screws or depaneling

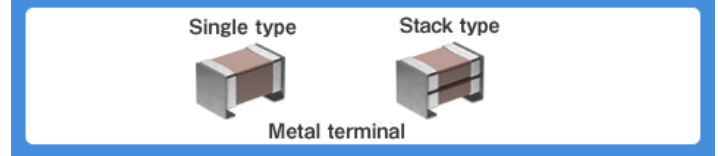
Board having large thermal expansion

Design that requires the board to be bent excessively during board manufacturing or final assembly

1 Metal caps disperse flex stress and reduce load applied to the capacitor MEGACAP

MEGACAP is a type of MLCC in which metal caps are attached to the terminal electrodes, and is available in single and double stacked configuration (Fig. 5).

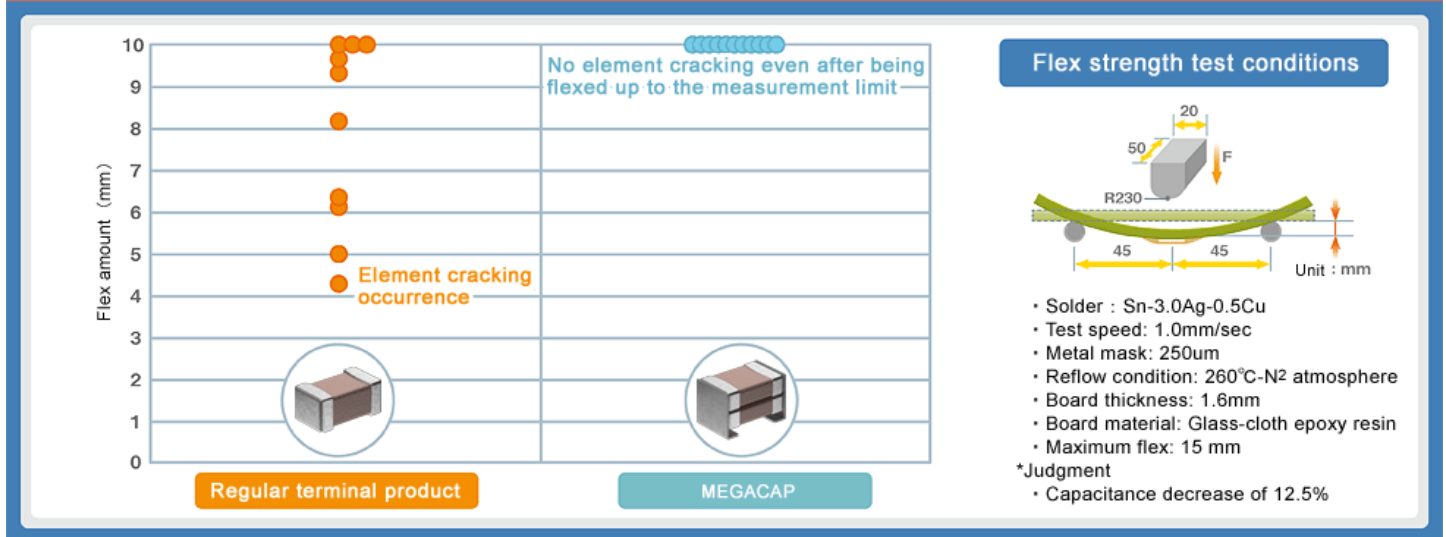
Fig. 5: MEGACAP structure



No element cracks occur with board flexure up to 10mm

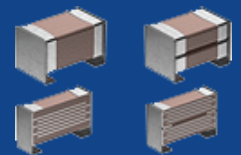
Fig. 6 is a comparison of the flex strengths of a regular terminal product and MEGACAP. Element cracks occurred in the regular product after it was flexed up to several millimeters. On the contrary, no cracking occurred when MEGACAP even after it was flexed 10 millimeters or more.

Fig. 6: Flex strength comparison with the 5750 size (Comparison between a regular terminal product and MEGACAP)



[MEGACAP features]

- Absorbs stress of board flexure by its unique metal frames, and can be mounted on aluminum circuit boards.
- Provided with metal caps over the external electrodes that absorb stress caused by mechanical shocks. Also features improved vibration resistance.
- Realizes twice the capacitance of regular products without changing capacitor footprint.
- Features lower ESR and ESL compared to those of aluminum electrolytic capacitors.



[Major applications]

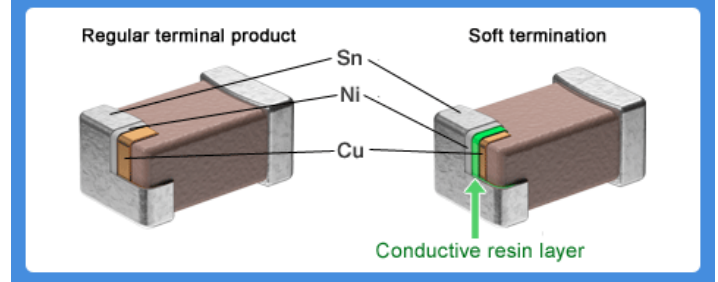
- Automotive applications (EPS, ABS, EV, HEV, LED lamps, etc.)
- Smoothing circuits, DC-DC converters, LED, HID
- Application in environments with severe temperature changes, singing capacitor countermeasures
- Smoothing, decoupling, X capacitors, Y capacitors, or snubber circuits of xEV (DC-DC converters, inverters, chargers), EPS, ABS, LED/HID lamps, etc.
- Areas of aluminum electrolytic capacitors where high-frequency noise cannot be reduced due to large parasitic inductance or where there is a risk of thermal runaway due to large ESR
- Areas where electrolytic capacitors or film capacitors cannot be placed because there is a high-temperature device (e.g. IGBT)

2 Soft terminations absorb flex stress and reduce load applied to the capacitor Soft termination

In the terminal electrode of a regular MLCC, the Cu under layer is plated with Ni and Sn. Soft termination is a type of MLCC in which a conductive resin layer is provided between the Cu and Ni plating layer (Fig. 7).

The resin layer absorbs stress accompanying expansion or shrinkage of the solder joints due to thermal shock or flex stress on the board and prevents cracking of the capacitor element.

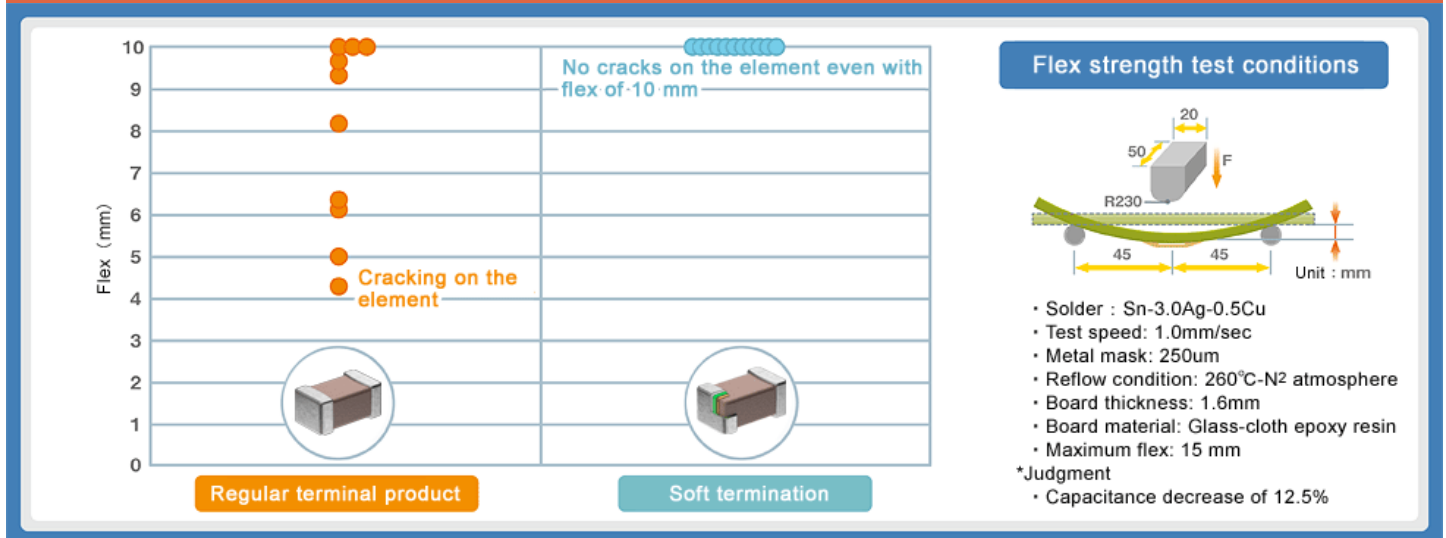
Fig. 7: Difference between a regular terminal product and Soft termination



No cracks developed after the board was flexed up to 10 mm

Fig. 8 shows the data of a board flex resistance (critical bending) test. In a conventional product, cracks developed on the ceramics element even with a flex of about 4 mm. On the contrary, Soft termination can safely withstand twice as much flex.

Fig. 8: Comparison of flex strength in 3216 size products (comparison between a regular electrode product and Soft termination)



Capacitor element does not develop cracks, but the terminal electrodes peel off owing to the fail-safe function, even under excessive stress

When excessive stress was continuously applied, cracks developed on the ceramics element in a conventional product. On the contrary, in Soft termination, no cracks developed on the element, even though there was peeling of the nickel plating layer and the conductive resin layer. This shows that the conductive resin layer has an excellent effect to prevent element cracks.

However, it has been confirmed that no resin peeling occurs even at 6 mm, which exceeds the 5 mm of the flexure guarantee condition.

Fig. 9: When pressure is applied excessively, the terminal electrodes peel off and prevents the occurrence of element cracks

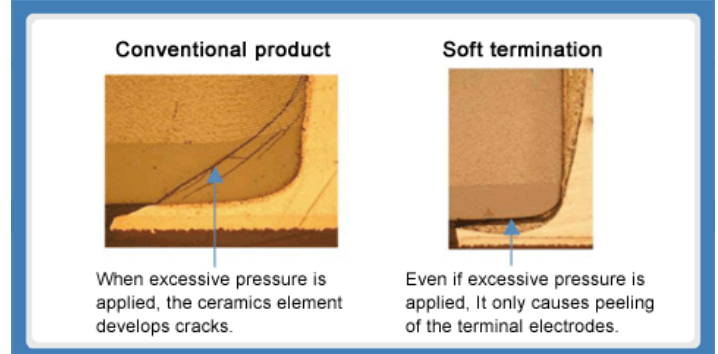
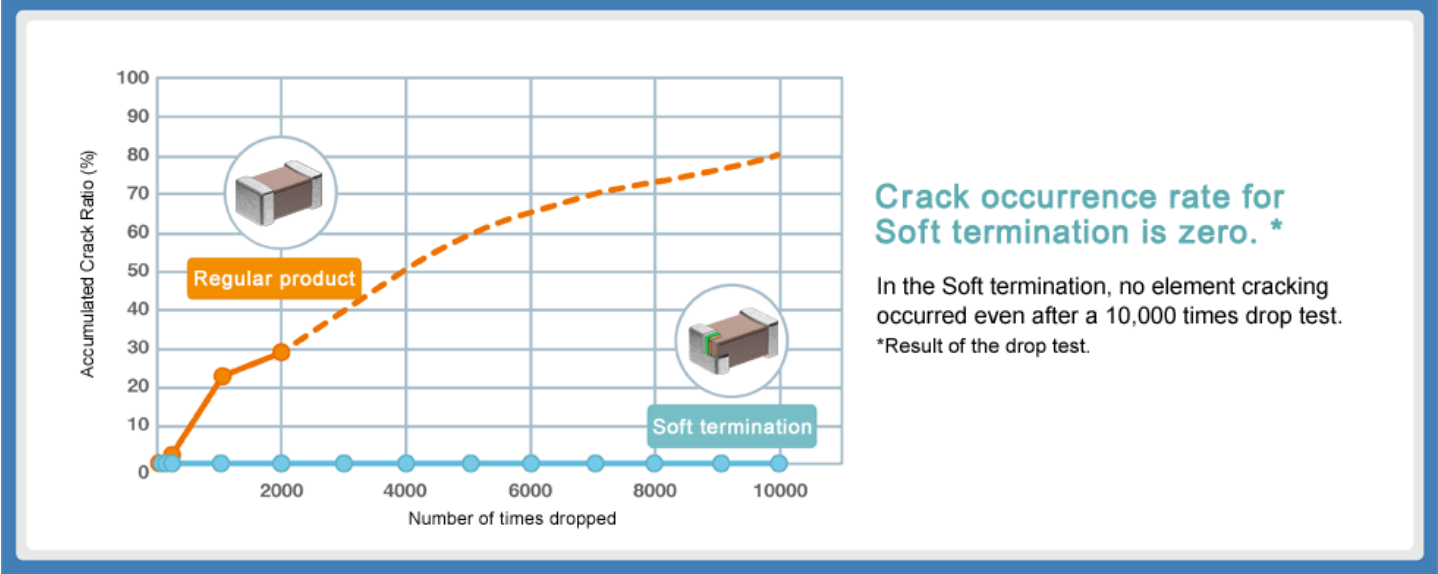


Fig. 10: Tumbling test result (comparison between a regular product and Soft termination)



The test condition was set to satisfy the requirements for mobile phone applications. No cracks developed after a drop test with 10,000 cycles, while passing a 85/85 humidity test.

This shows that the resin electrode parts absorbed shock.

Tumbling test condition

- Dropping height: 1 m
 - Dropping frequency 16 times/min
 - Times of dropping: 10,000 times
- ➔
- No abnormalities in properties and appearances
 - Humidity load test (85°C/85%RH/WV/1,000 hrs)

Test machine: YOSHIDA SEIKI rotating drum test machine (MODEL RDT-1000)

Applications: used to repeatedly drop products such as cellular phones or other small and light products, connectors, and remote controllers, to investigate the impact on the products.

Standard: JIS C 60068-2-32, IEC 60068-2-32

[Features of Soft termination]

- Improves resistance to bending, flex, and drop impacts of the board.
- Conductive resin absorbs external stress including thermal shock or mechanical stress and protects components.



[Major applications]

- Countermeasure against or prevention of "flex-cracking" of units that require handling of boards to which multilayer ceramic capacitors have been soldered
- Electric circuits mounted to aluminum circuit boards, SMT applications requiring strong resistance to bending, in which reliability of solder joints can become an issue
- Smart phones, PCs, smart keys, wearable devices, car multimedia, switching power supplies, base stations, automotive applications (EPS, ABS, EV, HEV, LED lamps, etc.)

3 Dual fail-safe function that absorbs flex stress and prevents short circuit failures in the case of crack occurrences Serial design (the CEU series)

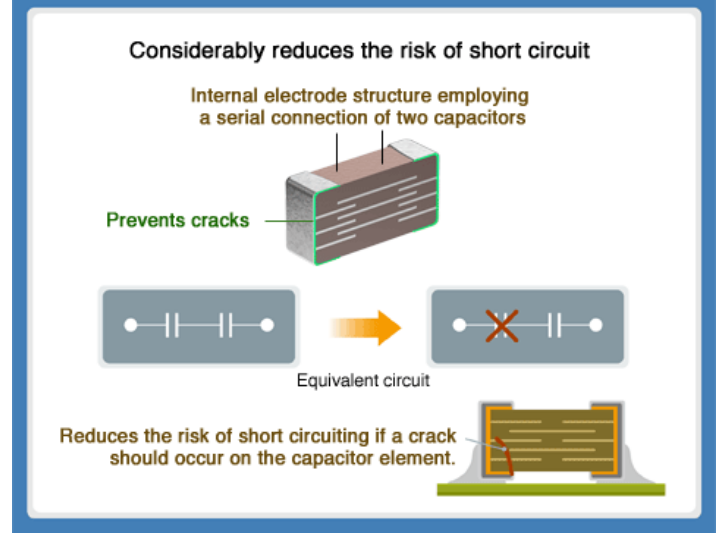
Serial design (the CEU series) is a type of MLCC with the highest safety adopting dual safety designs for crack occurrence prevention and short circuit occurrence prevention.

Firstly, the conductive resin layers are inserted in the terminal electrodes, and the resin electrode layers absorb stress applied by flex or thermal expansion of the board, preventing crack occurrences.

Secondly, the internal electrodes adopt a special structure, which is equivalent to a serial connection of two capacitors. This structure will reduce the risk of short-circuiting if a crack should occur on the capacitor element.

Moreover, the CEU series is compliant with AEC-Q200 and can be used for automotive applications.

Fig. 11: Two short circuit countermeasures of Serial design



Safety can be easily achieved due to the internal structure connecting 2 capacitors in series

When regular products are replaced with Serial design (the CEU series) in power lines carrying a large current, safety can be easily enhanced due to their dual fail-safe function. Since just one Serial design (the CEU series) product can realize safety design which usually employs a serial connection of two regular products, mounting areas or mounting costs can also be reduced (Fig. 12).

Fig. 12: Image of replacement of regular products with Serial design (the CEU series)



[Features of Serial design (the CEU series)]

- Fail-safe function employing a serial connection of two capacitors inside one product prevents unexpected short circuit accidents.
- Improves resistance to bending, drop impacts, thermal shock, and heat cycle of the board.
- The conductive resin absorbs external stress, protecting solder joints and components.



[Major applications]

- Automotive applications (EPS, ABS, EV, HEV, LED lamps, etc.)
- Smoothing circuits, DC-DC converters, LED/HID lamps
- Application in environments with severe temperature changes, countermeasure against piezoelectric effect
- Circuits directly connected to 12 V or 24 V battery lines or circuits requiring enhanced safety
- Countermeasure against high-frequency noise (radio noise), surges, or electrostatic discharges (ESD)

[Related information]

Serial design also have thermal shock resistance.

For information on thermal shock resistance, please refer to [»Solder Crack Countermeasures in MLCCs..](#)

4 Less prone to short circuit failures even if cracks occur on the element Open mode

Open mode is a type of MLCC in which the gap between the terminal electrode and the internal electrode on the opposing terminal electrode side (called L-Gap) is longer than that of regular products.

By making the overlapping portion of the opposing internal electrodes shorter, it is ensured that the opposing electrodes do not overlap at places where cracks may occur.

Due to this, the risk of short-circuit can be reduced even if cracks should occur.

* The design concept of the Open mode is for the reduction of the risk of short-circuit mode breaking, and it does not mean that the products will always have an open-circuit when it is damaged.

Fig. 13: Open mode structure

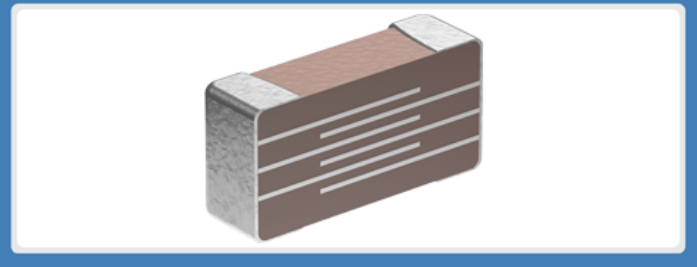
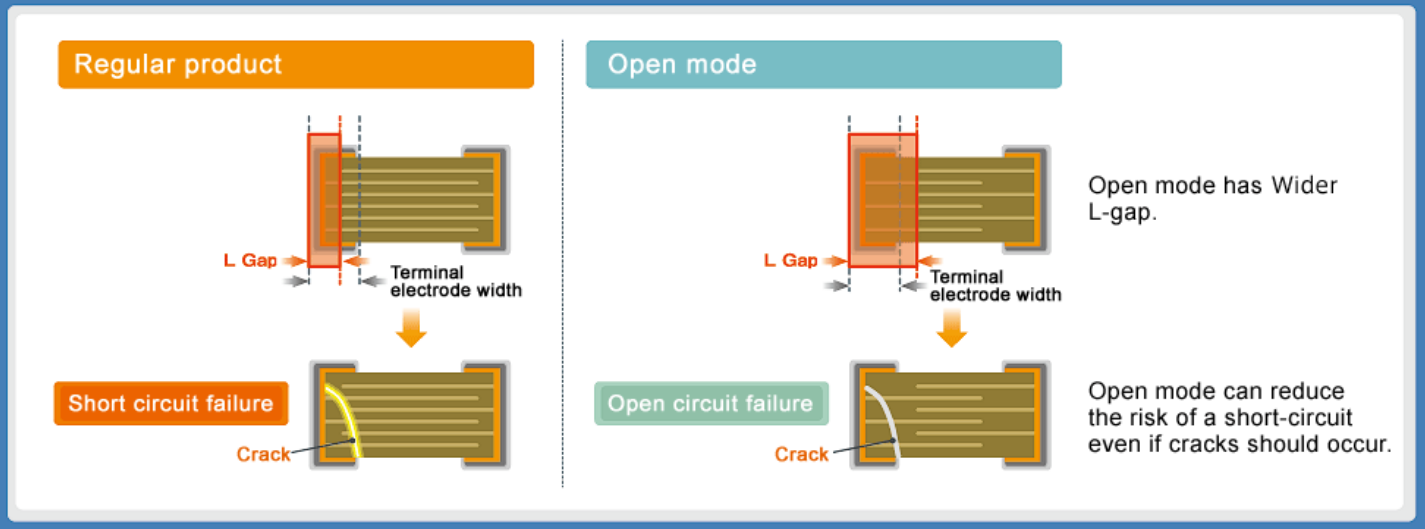


Fig. 14: Failure simulations (comparison between a regular product and Open mode)



[Features of Open mode]

- The gap between the terminal electrode and internal electrode is made Wider so as to reduce the risk of short circuit even if cracks should occur.



[Major applications]

- Areas where board flex has occurred repeatedly, areas with high risk, or problematic areas
- Applications in which high reliability is required and mechanical stress is high
- Battery line circuits that are susceptible to bending stress of the board
- Circuits over 20 A
- DC-DC converters, etc.
- Parts where a safety design is particularly required, including power circuits. Decoupling, smoothing, surge countermeasures, ESD

[Related material]

»FAQ: What is the "1210 Rule" of MLCCs (Multilayer Ceramic Capacitors)?

Summary of "Flex Crack Countermeasures in MLCCs"

- A flex crack occurs when a crack develops on the capacitor element and conduction occurs between opposing internal electrodes.
- Special caution is required in applications in equipment exposed to vibrations or shock, equipment that can experience frequent shocks, equipment used in a moist environment, areas near screws and board splitting, in aluminum circuit boards having large thermal expansion, and in designs in which boards are excessively bent during final assembly.

TDK offers MLCC products for redundant designs such as the following, for the purpose of avoiding short circuit failures.



1) Metal caps disperse flex stress and reduce load applied to the capacitor:

MEGACAP



2) Soft terminations absorb flex stress and reduce load applied to the capacitor:

Soft termination



3) Dual fail-safe function that absorbs flex stress and prevents short circuit failures in the case of crack occurrences:

Serial design (the CEU series)




4) Less prone to short circuit failures even if cracks occur on the element:

Open mode

The features of each product are summarized in the table 15 below.

Table 15: Comparison of flex crack countermeasures for MLCCs

	image	Flex stress	Large capacity	Cost	Applications
1) MEGACAP		★★★	★★★	★	Circuits requiring especially high reliability and large capacitance
2) Soft termination		★★	★★	★★	Circuits in which flex stress or thermal shock can become an issue
3) Serial design, the CEU series (resin electrode + safety structure)		★★	★	★★	Circuits in which flex stress or thermal shock can become an issue and a serial connection of capacitors is considered
4) Open mode		★★	★	★★★★	Circuits that do not require very big capacitance but flex stress can be an issue