



Be Safe
Wherever You Go



High Reliability Automotive Use

Multilayer Ceramic Chip Capacitors



Core Technologies Create High Reliability

Extreme cold to searing heat, incessant exposure to strong vibrations and shocks, and many other adverse factors—electronic components in cars are subject to extremely harsh conditions and therefore need to provide much higher reliability than general use products. Making full use of its rich store of advanced core technologies such as materials technology, layering technology, and sintering technology, TDK is offering a wide range of highly reliable multilayer ceramic chip capacitors for automotive use. These are grouped into various product series, such as high temperature resistance types suitable for use near the engine (X8R), COG characteristics types, mid voltage types with high capacitance, Mega Cap types with excellent thermal stress resistance etc. All of these products are designed to make a significant contribution to safe and pleasant driving.

Multilayer Ceramic Capacitors Provide a Great Balance of Characteristics

A capacitor has the function of condensing and storing an electrical charge, which is why it used to be called a condenser. The measure of how much charge it stores is called capacitance, from which the current name is derived. The magnitude of the capacitance is determined by the surface area (S) of the opposing electrode plates, the narrowness (d) of the gap between the electrodes, and the relative dielectric constant (ϵ_r) of the dielectric (insulator) between the electrodes.

Multilayer ceramic chip capacitors used frequently in modern electronic devices have multiple layers of electrodes and dielectric sandwiched within the capacitor housing to enlarge the electrode area. This type of capacitor was developed for practical use in the middle of the 20th century, but the concept of a simple condenser with layered electrodes and dielectric existed already in the middle of the 19th century. Because thinly sliced mica was used as dielectric, the condenser was called a mica condenser. While the relative dielectric constant of air is about 1, mica has a rating of between 6 and 8, which means that high capacitance can be achieved with this material.

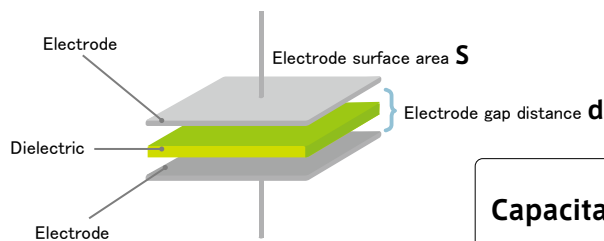
The relative dielectric constant of the various types of plastic film used for film capacitors is 2 to 3, while that of aluminum oxide film used as dielectric in aluminum electrolytic capacitors

is on the order of 8 to 10. The relative dielectric constant of ceramic dielectric is about 10 to 100 at the lower end, and as much as 1000 to 20000 at the higher end. Consequently, multilayer ceramic chip capacitors can provide very high capacitance even in products with small dimensions, which is the major reason for their great popularity.

The capacitance is only one of the many characteristics of a capacitor. Other aspects that are of importance include temperature characteristics, rated voltage, frequency response and many more. Depending on the application, different types of capacitors are required, and each type has its advantages and disadvantages. For example, aluminum electrolytic capacitors provide very high capacitance values, but their high frequency response characteristics are not very good and they also have a relatively short service life.

The capacitor type with the best overall balance of rated voltage, frequency response, service life etc. is the multilayer ceramic chip capacitor. Because it can be manufactured as a chip component, it offers excellent performance at reasonable cost, and the progress of thin layer and multi layer technology has brought its capacitance within the realm of electrolytic capacitors.

Basic capacitor construction and capacitance



- Larger electrode surface area = larger capacitance
- Higher relative dielectric constant = larger capacitance
- Smaller electrode gap distance = larger capacitance

$$\text{Capacitance } C = \epsilon_0 \epsilon_r \frac{S}{d}$$

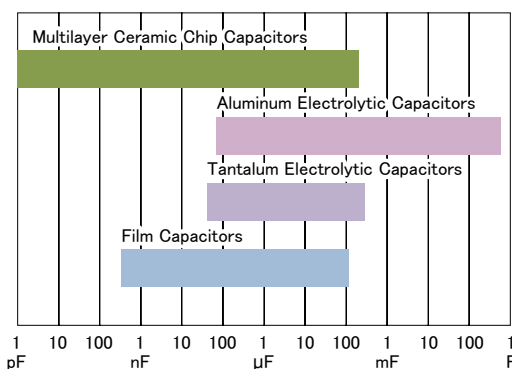
ϵ_0 : Dielectric constant in vacuum
($8.854 \times 10^{-12} \text{F/m}$)

ϵ_r : Relative dielectric constant in a material

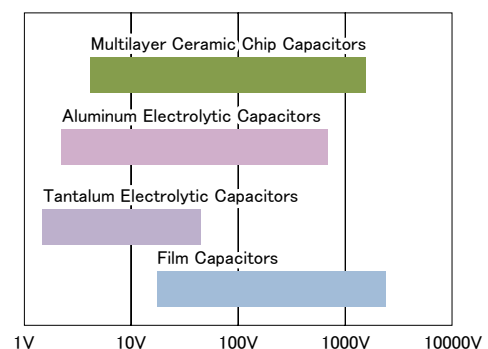
Various dielectrics and their relative dielectric constant

Dielectric	Relative dielectric constant
Air	1
Various plastic films	2~3
Mica	6~8
Aluminum oxide	8~10
Ceramics (low relative dielectric constant type)	10~100
Ceramics (high relative dielectric constant type)	1000~20000

Capacitance ranges of various capacitor types



Rated voltage range of various capacitors



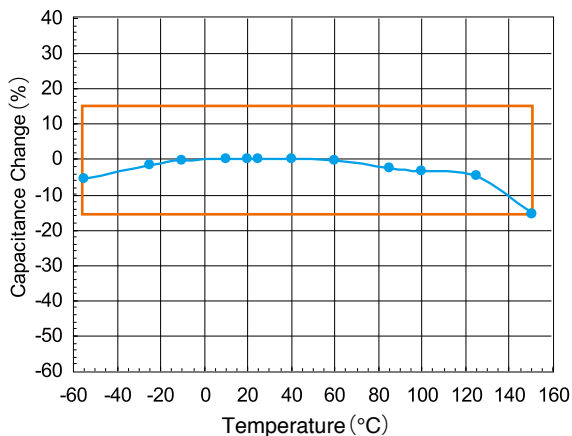
X8R Characteristics Can Withstand Even Engine Surface Temperatures of 150 °C

Multilayer ceramic chip capacitors can be largely divided into two categories, namely low relative dielectric constant types using CaZrO₃ (calcium zirconate) or similar as dielectric (Class I), and high relative dielectric constant types using barium titanate (BaTiO₃) or similar as dielectric (Class II). To obtain high capacitance, the high relative dielectric constant type is best, but this type has an important drawback, namely the fact that capacitance changes depending on the temperature. By contrast, the low relative dielectric constant type shows little capacitance variation depending on temperature. It is therefore used extensively in applications such as filter circuits and oscillators, where stable characteristics are important. These products are therefore also referred to as temperature compensating capacitors. The fact that electronic devices for use in automobiles are subject to extreme environment conditions is a major difference to general electronic devices. As automobiles get more and more electronic, the number of ECU (Electronic Control Unit) devices in a single car can be between 10 and 100, resulting in a large number of wire harnesses criss-crossing the vehicle. Because the weight of these harnesses can reach several dozen kilograms, there is a tendency to position the ECUs in the engine room, thereby reducing the length of the harnesses and the related weight. However, the temperature in the engine room reaches about 125 °C, and as much as 150 °C on the engine surface.

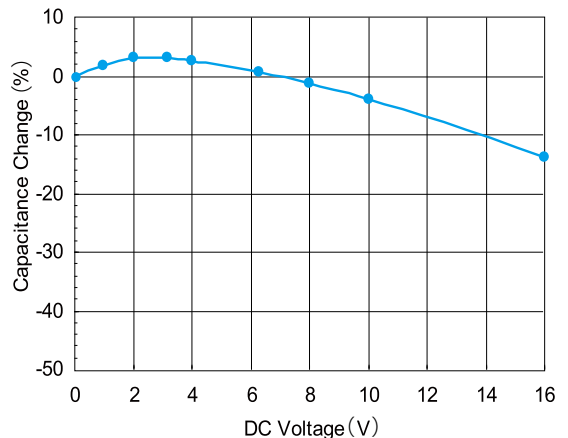
Electronic components for automotive use therefore must be able to withstand very high temperatures and be able to maintain stable operation over a wide temperature range. X7R and X8R type multilayer ceramic chip capacitors (high relative dielectric constant) fulfill these requirements.

X7R specifications prescribe a temperature range of -55 to +125 °C with a capacitance tolerance of maximum ±15%. For X8R, the temperature range is -55 to +150 °C and the tolerance also ±15% (EIA standard). With high relative dielectric constant type capacitors described above, meeting these requirements is difficult, but to realize X8R specifications is an important challenge with a view to the further progress of car electronics. By improving material composition and manufacturing conditions, TDK was able to optimize the particle structure of the dielectric ceramics and achieve a more uniform particle size. Following in the footsteps of 125 °C rated X7R compliant products, the company succeeded in bringing 150 °C X8R compliant multilayer ceramic chip capacitors to the market. The availability of X8R products meets the advanced needs of the market and means that temperature-related limitations to ECU placement are eliminated. Performance and reliability of the engine control unit, sensor modules, HID, ABS and other automotive devices will benefit from this development.

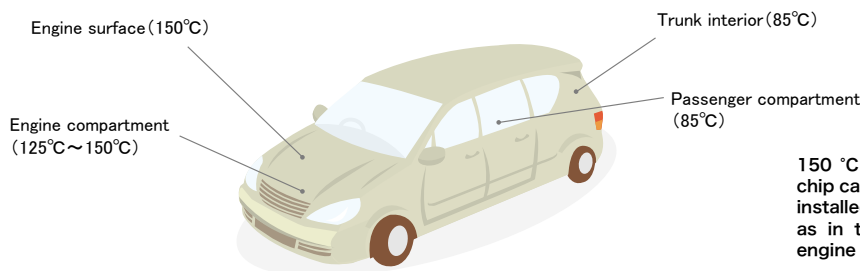
Temperature characteristics



DC bias characteristics



Ambient temperatures in a car



150 °C rated X8R compliant multilayer ceramic chip capacitors can be used in electronic devices installed in high-temperature environments such as in the vicinity of the engine and near the engine surface.

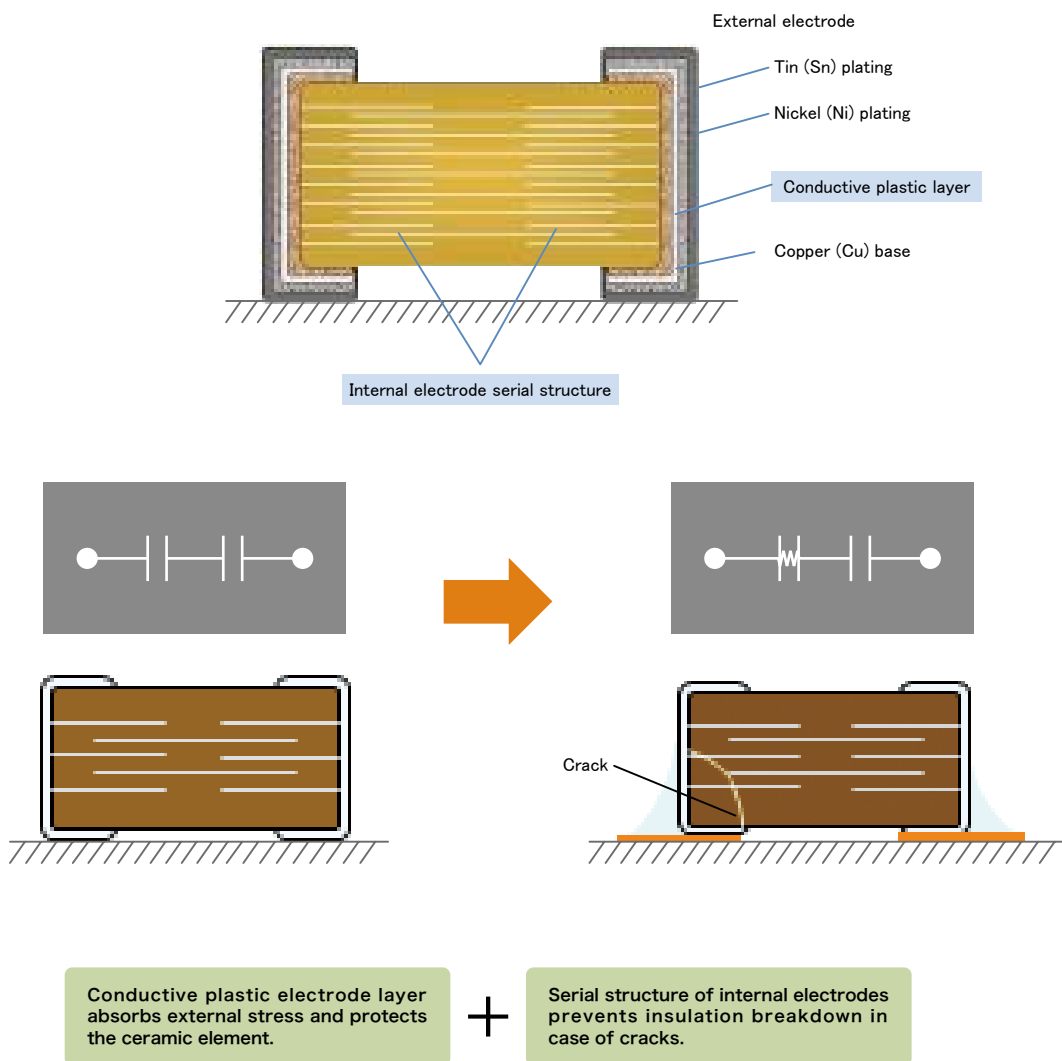
Dual Fail-Safe Design Ensures High Reliability: CEU Series

A multilayer ceramic chip capacitor incorporates multiple dielectric and internal electrode layers in a sandwiched configuration. Because this is an equivalent circuit to a parallel connection of multiple capacitors, insulation breakdown in even just one capacitor will result in short-circuiting. But if two multilayer ceramic chip capacitors are connected in series, insulation breakdown in one capacitor will not cause a short-circuit of the entire arrangement. The CEU series is based on this principle. It features an internal electrode structure that is the equivalent of a serial connection of two capacitors. An important feature of the CEU series is dual fail-safe design. The external electrodes use a conductive plastic layer to absorb

and soften bending stress of the PCB, thereby preventing the occurrence of cracks. In addition, the internal electrode structure employs a serial connection of two capacitors. If a crack should develop in one capacitor element and cause breakdown short-circuiting, insulation breakdown is avoided by the second capacitor.

This dual fail-safe design of the CEU series is optimal for the power supply lines of automotive equipment, where safety is a foremost concern. The design also helps to save space on the circuit board because two capacitors are located in the space of one.

Internal construction of CEU series multilayer ceramic chip capacitors



Mega Cap Type Provides Outstanding Resistance to Thermal Stress and Board Flexing

The power supplies of automotive equipment frequently use metal circuit boards made of aluminum or similar, in order to enhance heat dissipation. However, due to the drastic temperature changes in an automobile, the aluminum board tends to shrink and expand, which causes large stresses on the multilayer ceramic chip capacitors and can lead to cracks in the solder joints and the capacitor element.

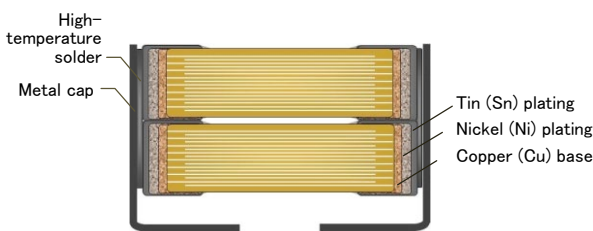
For example, a temperature change from -55 °C to +125 °C will cause an expansion of 7 µm in the mounting surface of a size 1608 (1.6 x 0.8 mm) multilayer ceramic chip capacitor. For a size 4532 (4.5 x 3.2 mm) product, the expansion amounts to 20 µm. In addition to the changes in temperature, vibrations and mechanical shocks also exert a bending stress on the board, thereby increasing the risk of cracks still further. A solution to this problem is presented by a multilayer ceramic chip

capacitor type with metal caps on the external electrodes. TDK markets such a product under the name "Mega Cap."

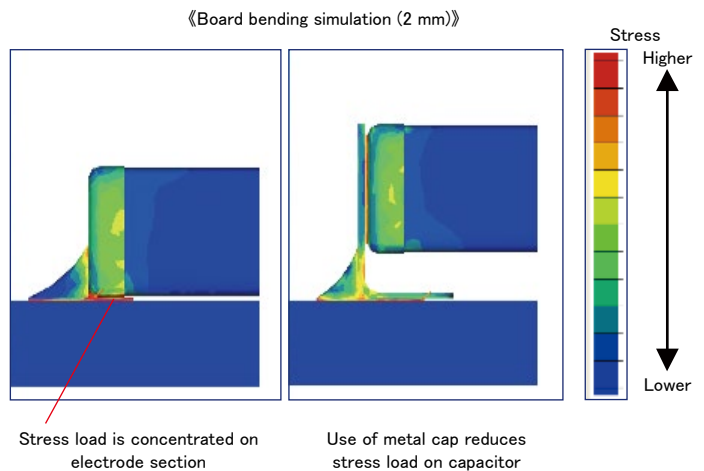
The Mega Cap has proven to be highly reliable, developing no cracks even in a thermal stress test with 3000 cycles. The Mega Cap is also available in a stacked type with two capacitors and a metal cap. This allows a reduction in footprint requirements for circuits where two capacitors of the same rating are used in parallel.

When an AC current is applied to a conventional multilayer ceramic chip capacitor soldered to a board, the ceramic element will expand and contract due to the electrostrictive effect, which can cause the board to vibrate and be heard as a sound. This problem of sound emission which is also known as "singing capacitors" is another area where use of Mega Cap product can be highly effective.

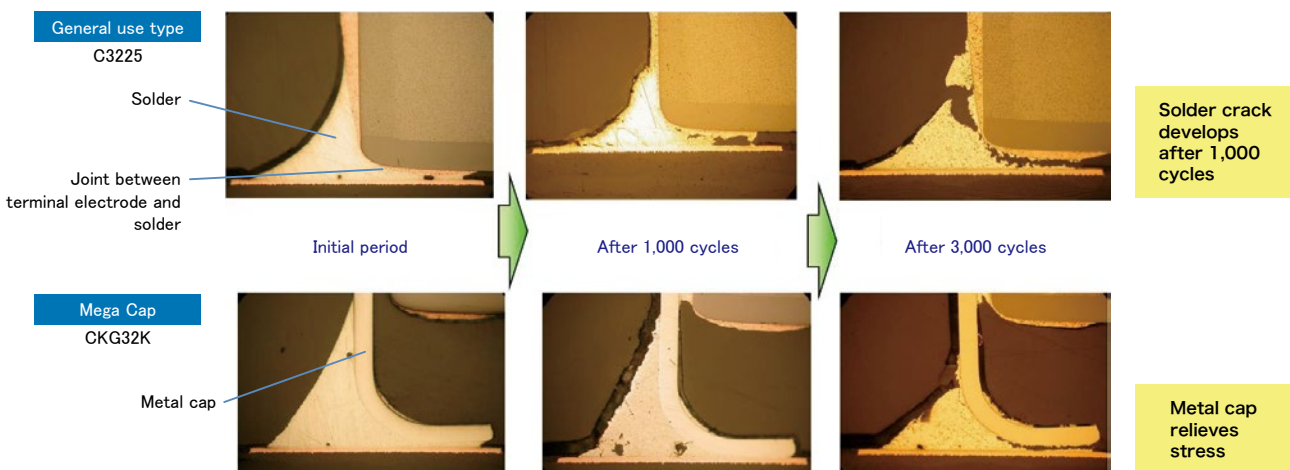
Construction principle of a Mega Cap (dual stacked type)



Reduction of stress caused by thermal expansion of aluminum board



Thermal stress test comparison



TDK Multilayer Ceramic Chip Capacitors for Automotive Use

Modern cars are so reliant on electronics that they sometimes are described as rolling electronic devices. The number of electronic components used in them increases year by year. Looking at multilayer ceramic chip capacitors alone, there are about a thousand or more, in ECUs and other equipment. TDK is putting its core technologies to optimum use in this regard. Materials technology, process technology, evaluation and simulation technology, production technology, device & module technology

combine to create multilayer ceramic chip capacitors that are tailor-made for automotive applications. All products are completely free of RoHS regulated substances such as lead, mercury, cadmium etc. in order to reduce the burden on the environment. With a view towards the more widespread acceptance of hybrid electric vehicles (HEV) and electric vehicles (EV), TDK is further bolstering its lineup of electronic components for automotive use, to contribute to safe, reliable, and enjoyable driving.

TDK capacitors for automotive use

General use type

High relative dielectric constant and low relative dielectric constant (temperature compensating) products

Mid voltage type

Rated voltage 100 to 630 V
X7R, X7T, X7S characteristics products etc.



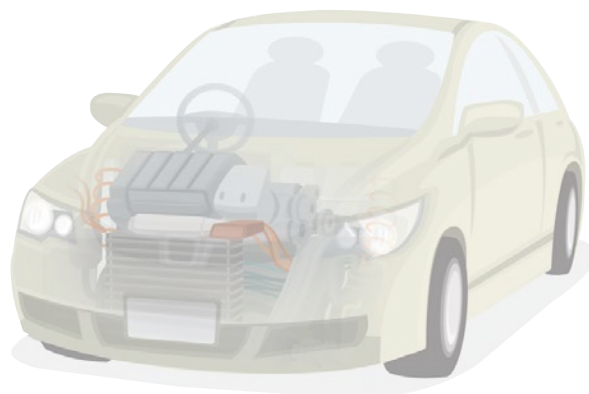
High temperature type

150 °C guaranteed X8R characteristics product

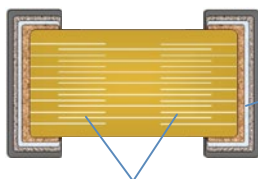


Mega cap type

Metal cap provides protection from thermal and mechanical stress



CEU series

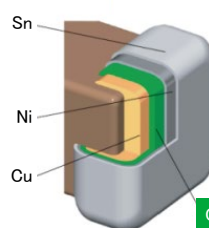


Internal electrode serial connection + plastic electrode ensures high reliability

Conductive plastic layer

Internal electrode serial structure

Conductive plastic electrode type



Developed for lead-free solder use. Conductive plastic layer inserted in external electrode.

Conductive plastic electrode

CER series

ESR control type



Conductive adhesive mounting compliant electrode type

Product using ternary compound AgPdCu terminal compliant with conductive adhesive mounting, etc.

