Switching Regulator Series

# The Important Points of Multi-layer Ceramic Capacitor Used in Buck Converter circuit

Multi-layer Ceramic Capacitor (MLCC) with large-capacitance can be used as smoothing-capacitor in power supply circuits. Compared to other capacitor types such as an electrolytic capacitor, MLCC differs in frequency characteristics, temperature characteristics, and DC voltage characteristics. Using unmatched MLCC may not obtain required target characteristics for power supply circuit and may cause abnormal operation. This application note explains the important points while using MLCC.

## Types of Multi-layer ceramic capacitor (MLCC)

MLCC can be broadly classified into two types; for temperature compensation and for high-dielectric constant. MLCC for temperature compensation uses Titanium oxide (TiO2) and Calcium zirconate (CaZrO3) as material for its paraelectric. Therefore, it cannot suit for capacitor with large-capacitance as relative permittivity is small, about 20 to 300. Moreover, since relative permittivity changes linearly with temperature, the temperature coefficient can be restricted between +100 to -4700ppm/°C by adjusting composition of the dielectric material. The capacitor for temperature compensation in power circuit is used in time-constant circuits such as Snubber-circuit and for SOFT-START.

MLCC for high-dielectric constant uses Barium titanate (BaTiO3) as main material for its paraelectic. With its big relative permittivity of 1,000 to 20,000, it can be capacitor with small in size and high-capacitance. But, this material changes tremendously with temperature, so using it for time-constant circuits needs caution.

In later part, the explanation will focus on high-dielectric constant MLCC used as input/output capacitor in a power circuit.

## Frequency Characteristics

MLCC has extremely small ESR (Equivalent Series Resistance) compared to other capacitor types such as electrolytic capacitor. Figure1 shows frequency characteristics of all major types of capacitors. Ripple voltage of output is expected to become smaller by using MLCC in a power circuit. However in earlier power-IC designs, usage of MLCC with ultra-low ESR was not considered. Therefore, phase of feedback circuit rotates too much at high-frequency area, causing power circuit to operate unstably and may cause oscillation in worst case. When MLCC has to be used at any cost, connecting a low-ohmic resistor more than 10mΩ in series is recommended, and may deteriorate the frequency characteristics.

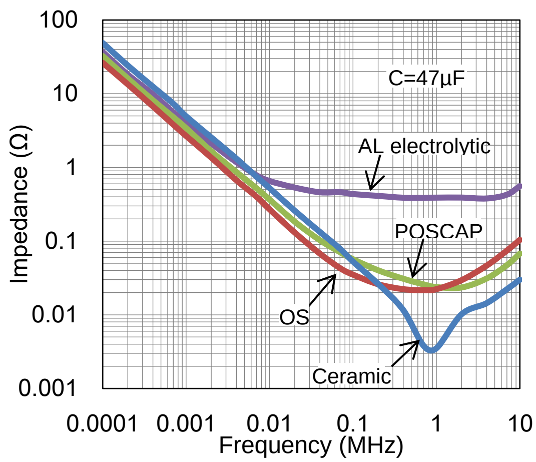


Figure 1. Frequency Characteristics of Capacitors

| Parameter | Temperature compensation MLCC | High-dielectric constant MLCC |
|---|---|---|
| Paraelectric material | Titanium oxide ($TiO_2$)<br>Calcium zirconate ($CaZrO_3$) | Barium titanate ($BaTiO_3$) |
| Relative permittivity | 20 to 300 | 1,000 to 20,000 |
| Temperature characteristics | +100 to -4700ppm/°C | +30 to -82% |
| Capacity | ≤ 0.1µF | ≥ 68pF |
| Capacitance-change when voltage input | Almost no change | Changes |
| Capacitance-change over time | Almost no change | Changes |
| Application circuits | Snubber, Time-constant<br>High-frequency circuit, Audio | Smoothing power, Decoupling circuit |

Table 1. Characteristics of Laminated Ceramic Capacitor



No. 62AN089E Rev.002
JANUARY 2020

## Temperature Characteristics

High-dielectric series MLCC with high-capacitance has products with various temperature characteristics. Table 2 and Figure 2 show typical temperature characteristics. The characteristic curve changes in various ways within the tolerance range of the each product. Since the Temperature characteristics are standardized, it's easy to judge by the capacitor's type name.

Products with smaller capacitance tolerance（±15%）, such as B, X5R, R, X7R, X8R are recommended for temperature characteristics used in the power circuits. The characteristics of X7U, F, Y5V, Z5U, Z5V are inexpensive, but capacitance tolerance (-82%) is large, making it to operate stable only at room temperature. Do not use capacitors with such characteristics in power circuit as it may cause trouble.

Judging from the operating temperature range of application equipment used, and choosing from B, X5R, R, and X7R characteristics are recommended.

| Standard | Characteristics | Basic temperature | Temperature range | Capacitance tolerance |
|---|---|---|---|---|
| JIS | B | 20°C | -25～+85°C | ±10% |
| EIA | X5R | 25°C | -55～+85°C | ±15% |
| | X5S | | | ±22% |
| | X5T | | | +22%, -33% |
| | X6S | | -55～+105°C | ±22% |
| | X6T | | | +22%, -33% |
| JIS | R | 20°C | -55～+125°C | ±15% |
| EIA | X7R | 25°C | -55～+125°C | ±15% |
| | X7S | | | ±22% |
| | X7T | | | +22%, -33% |
| | X7U | | | +22%, -56% |
| | X8R | | -55～+150°C | ±15% |
| JIS | F | 20°C | -25～+85°C | +30%, -80% |
| EIA | Y5V | 25°C | -30～+85°C | +22%, -82% |
| | Z5U | | +10～+85°C | +22%, -56% |
| | Z5V | | | +22%, -82% |

Table 2. Major Temperature Characteristics of High-dielectric constant type MLCC

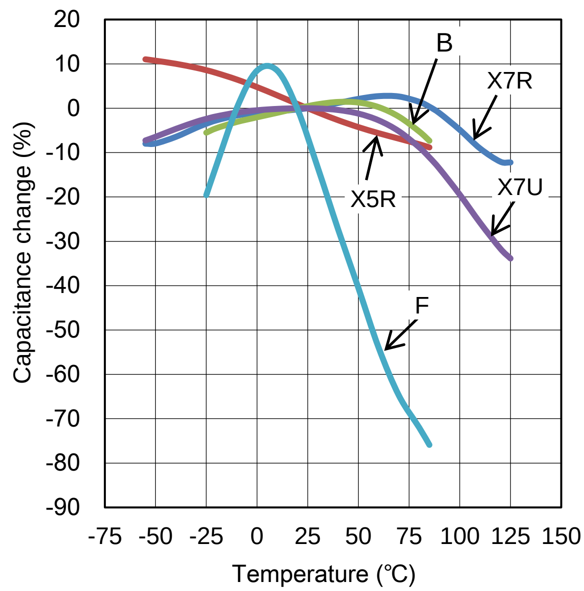


Figure 2. Major Temperature Characteristics of High-dielectric constant type MLCC

## DC Voltage Characteristics

The capacitance value changes by applying DC voltage to high-dielectric series type MLCC. This is peculiar only to this capacitor type and does not happen in other types, such as electrolytic capacitor and temperature-compensation type MLCC.

Let's take a look at MLCC of Murata Manufacturing Co., Ltd. as an example of DC voltage characteristics. Figure 3 shows characteristics of a capacitor with 10µF/10V (B) that differs in size (L×W). Both of these products are of same 0.95mm thickness. Tendency of bigger capacitance reduction, with smaller size part can be observed, when DC voltage is applied. 1608 size capacitor can only be used for 1V even though it is rated for 10V. Caution is required in confirming the changing characteristics, when switching to smaller-size capacitors to reduce PCB mounting area.

Figure 4 shows characteristics of 10µF/10V (B) capacitor with different thickness (T), and same size (L×W). Tendency of lesser capacitance reduction, with larger thickness part (bigger volume) can be observed, when DC voltage is applied. Caution is required in confirming the changing characteristics, when smaller-thickness of capacitors are used due to PCB height-restriction in slimmer designs.

Figure 5 shows DC voltage characteristics with capacitors of different rated-voltages. Both capacitors are of 10µF (B), size 3216(1216), thickness 1.80mm. Product with 50V reduces capacitance more than product with 16V rated-voltage, on applying DC voltage.

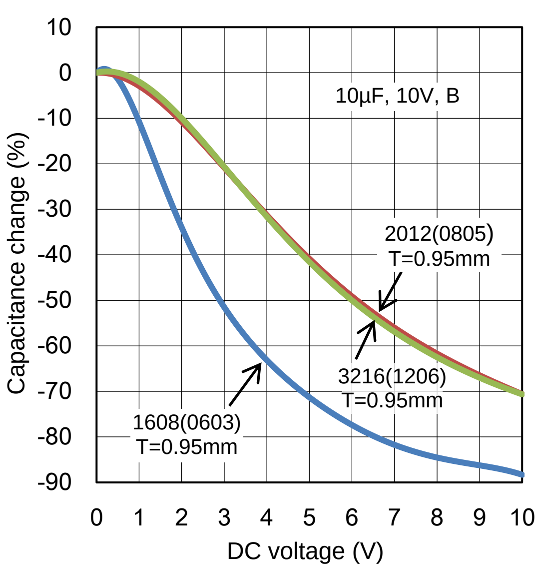


Figure 3. DC voltage characteristics
Difference in size (L×W)

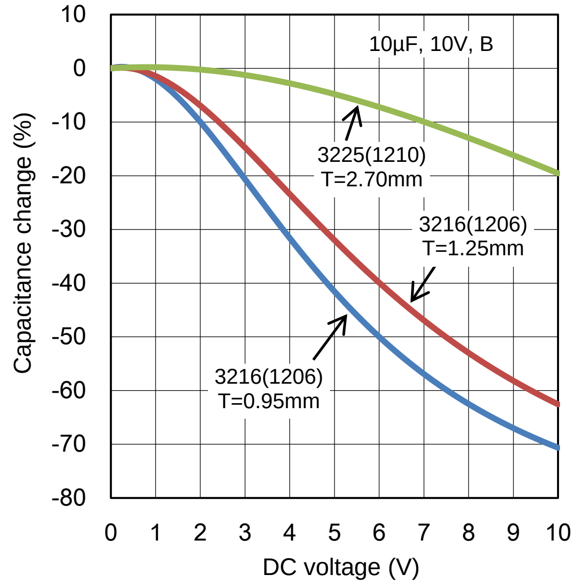


Figure 4. DC voltage characteristics
Difference in thickness (T)

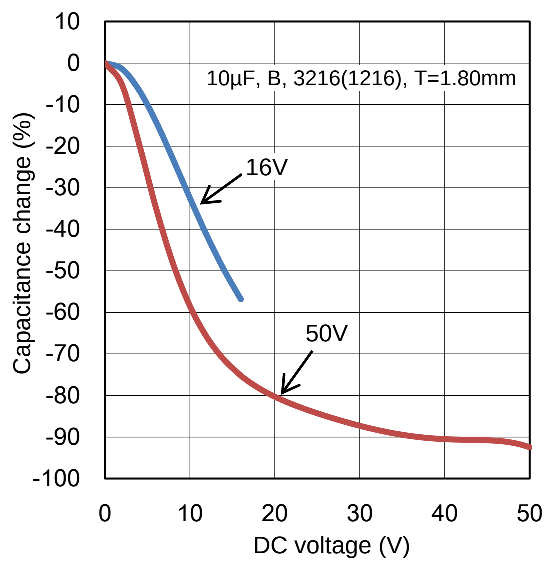


Figure 5. DC voltage characteristics
Difference in Rated-voltage

As to choosing the capacitor with higher rated-voltage, does not always guarantee higher performance. Selecting a MLCC simply by checking only the specification of capacitance and rated-voltage can deteriorate the characteristics of a power circuit. Always request the manufacturer for detailed characteristics data.

MLCC of Murata Manufacturing Co., Ltd can be easily confirmed by 'SimSurfing', a design support system on their website which shares various characteristics. (as of 2020/ January)

## Chronological change

High-dielectric series type MLCC has a characteristic that deteriorates capacitance-value with time. Figure 6 shoes the example of chronological change. “0” represents the point where 24-hours have passed after mounting. Capacitance value decreases linearly when time axis is shown in logarithmic. MLCC for temperature-compensation type does not have this kind of chronological changes.

Capacitor with reduced capacitance by chronological change recovers its capacitance by being heated to more than Curie temperature (about 125°C) by solder, etc. Also that same capacitor starts chronological change when it cools down to below Curie temperature.

Capacitance calculation for the chronological change is necessary while designing for long-term active equipment such as in industrial application.

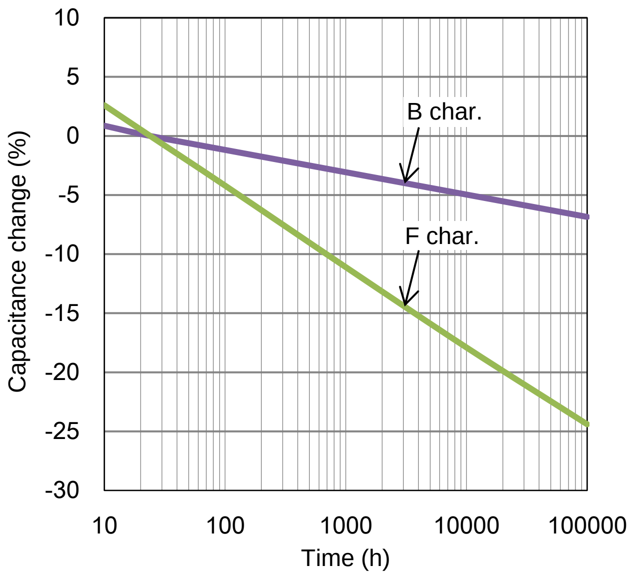


Figure 6. Example of Chronological change in High-dielectric series MLCC

## Heat generation characteristics

When ripple current (AC, alternating current) flows through a capacitor, the resistor element generates heat and temperature of capacitor itself rises. But since MLCC has extremely small ESR (equivalent series resistance), amount of heat is less and ripple resistance capability is excellent. Many MLCC manufacturers recommend surface temperature to be below 20°C while usage.

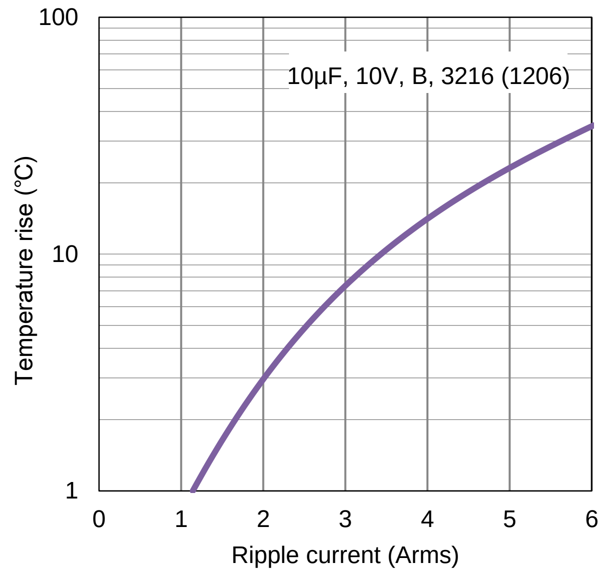


Figure 7. Example of self-heating of high-dielectric series MLCC

## Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

10) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

11) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

12) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

13) This document, in part or in whole, may not be reprinted or reproduced without prior consent of ROHM.

ROHM SEMICONDUCTOR

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

### ROHM Customer Support System

http://www.rohm.com/contact/