# ESR Control Multilayer Ceramic Capacitors

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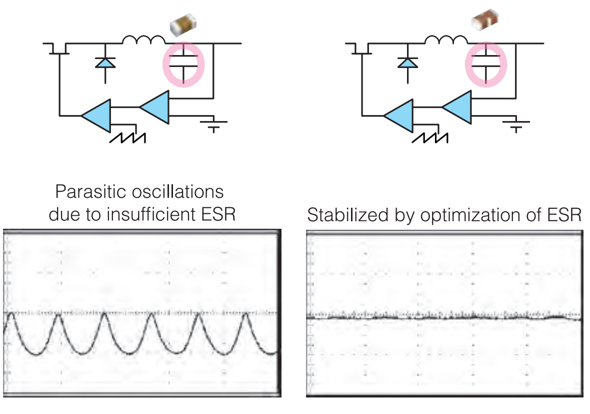
## 1 Product Overview

Conventional multilayer ceramic chip capacitors (MLCCs) possess some negative effects, due to their small ESR (equivalent series resistance) (Figure 1).

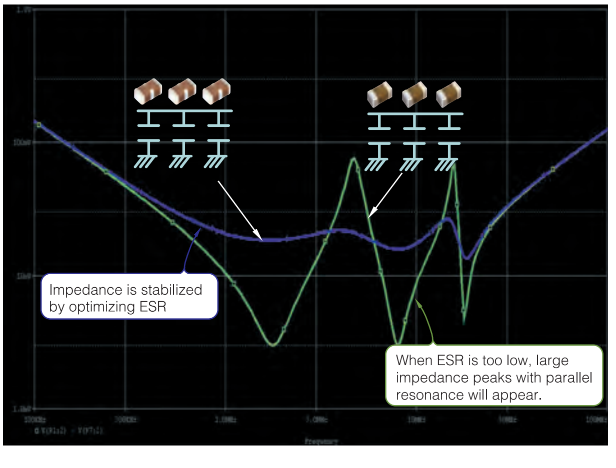
For instance, when MLCCs are used for output decoupling of switching power sources, deterioration of responsiveness or parasitic oscillations will easily occur due to phase delay of the feedback circuit, although they exert a good ripple rejection effect. For this reason, there is a need to perform phase compensation using complicated circuit networks, which in turn requires more components.

**Figure 1 Negative Effects of Insufficient ESR**

Decoupling of a switching power source




Decoupling of a circuit with large current / low voltage




In addition, insufficient ESR has a negative effect on decoupling capacitors of CPUs, which operate at low voltages and large currents. Multiple capacitors with different self-resonant frequencies (SFRs) are used for CPU decoupling circuits to achieve low impedance over a wide frequency band and to control voltage variations in response to high frequency currents. When the ESR of a capacitor is extremely low, a strong impedance peak occurs due to parallel resonance between capacitors. When a high-frequency current flows that is equivalent to that of the frequency, the power supply voltage can change suddenly, causing malfunctions.

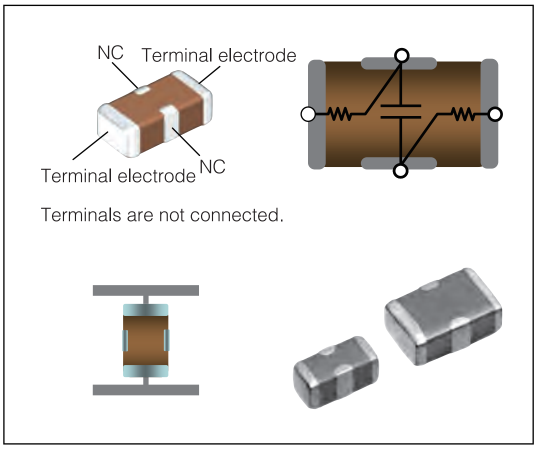
In order to resolve problems such as the above, these products have adopted a newly-developed electrode structure that allows for arbitrary ESR design while maintaining long life and high integrity, which are characteristics of ceramic capacitors. These products allow for the selection of ESR values that are suitable for each application.

In a switching power source, the compensation circuit can be simplified and operations can be stabilized without increasing ripple voltage by moderately increasing the ESR of the MLCC. In a decoupling capacitor for a CPU, flatter impedance characteristics, which suppress voltage fluctuations of the CPU, can be realized by optimizing the ESR.

## 2 Electrical Characteristics

The equivalent circuits and electrical characteristics of the products are shown in Figure 2 and Figure 3. At present, the 1608 and 2012 type products are commercially available. The capacitance of the 1608 type product is a maximum of 1 $\mu$F, and the capacitance of the 2012 type product is 10 $\mu$F. A dielectric material with X5R temperature characteristics (±15% at –25 to +85°C) is used for both of them.

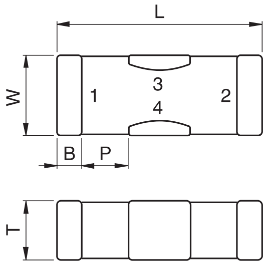
## Figure 2 Structure and Equivalent Circuit




The impedance frequency characteristics are shown in Figure 4 and Figure 5. The CERD1CX5R0G106M, CERD1JX5R0G106M and CERD2AX5R0G106M are 2012 type products with a capacitance of 10 $\mu$F and ESR values of 20 mΩ, 50 mΩ and 100 mΩ respectively. The CERB2CX5R0G105M, CERB2MX5R0G105M and CERB3UX5R0G105M are 1608 type products, with a capacitance of 1 $\mu$F and ESR values of 200 mΩ, 650 mΩ and 1200 mΩ respectively.

These products make it possible to design ESR values at predetermined values, since their ESL (equivalent series inductance) has a smaller increase than existing MLCCs. By selecting optimum ESR values according to application, it will be possible to improve electrical characteristics, reduce mounting space, and increase reliability.

## Figure 3 External Appearance, Dimensions, and Electrical Characteristics




| Type | CERB (1608) | CERD (2012) |
|---|---|---|
| L | 1.60±0.20 mm | 2.00±0.20 mm |
| W | 0.80±0.10 mm | 1.25±0.20 mm |
| T | 0.80±0.10 mm | 0.85±0.15 mm |
| B | 0.10 mm min. | 0.30±0.20 mm |
| P | 0.20 mm min. | 0.20 mm min. |

CERB = 1608
CERD = 2012

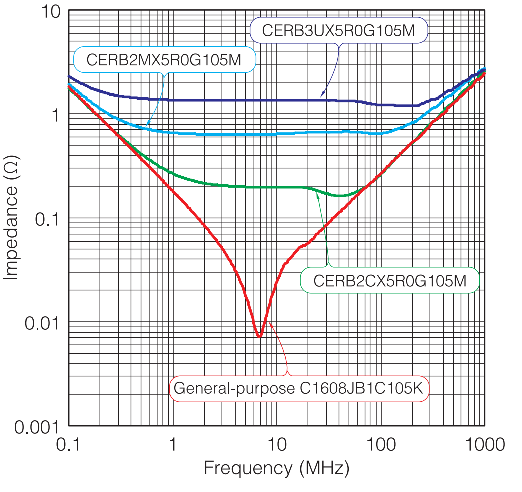
**Electrical characteristics**

| Part No. | CERB□□*X5R0G105M | CERD□□ *X5R0G106M |
|---|---|---|
| Capacitance | 1μF | 10 μF |
| Capacitance tolerance | ±20% | ±20 % |
| D.F. | 10% max. | 10 % max. |
| Insulation resistance | 100 MΩ min. | 10 MΩ min. |
| Rated voltage | DC 4.0 V (0G) | DC 4.0V (0G) |
| Temperature characteristics | X5R (±15%) | X5R (±15%) |
| Temperature ranges | –55 to +85 °C | –55 to +85 °C |
| ESR | 10 to 1200 mΩ | 10 to 500 mΩ |

*□□ in the product names are the ESR codes.

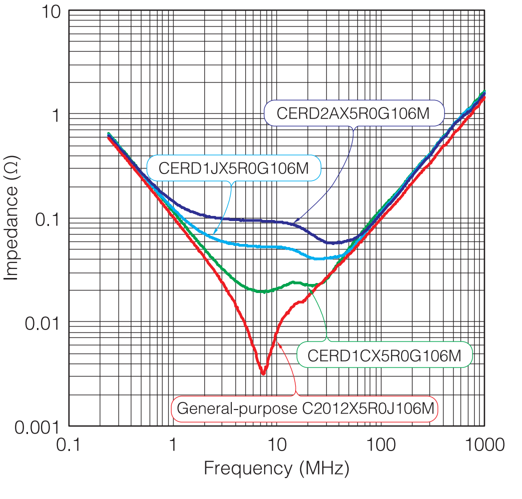
## Figure 4 Impedance Frequency Characteristics

CERB series




## Figure 5 Impedance Frequency Characteristics

CERD series



## 3 Example of Effects of the Products

As an example of the effects of the products, the power circuit and decoupling capacitors of a CPU were converted into equivalent circuits, and the source impedance and voltage fluctuation were simulated. Two conditions were provided for the decoupling capacitors; condition 1, under which the existing 2012 type MLCCs with a 10 $\mu$F capacitance and 1608 type MLCCs with a 1 $\mu$F capacitance (30 pieces of each) were used, and condition 2, under which CERD1FX5R0G106M ESL control MLCCs (2012 type/10 $\mu$F/ESR=35 m$\Omega$) (30 pieces) were used , as is shown in Figure 6.

The results of the frequency analysis are shown in Figure 7. Under condition 1, a large impedance with anti-resonance appeared due to the small ESR. Under condition 2, no significant impedance peak was observed, and impedance characteristics were flatter, compared to those noticed under condition 1. Furthermore, a current variation of 30 A to 90 A at 370 kHz was provided under both conditions 1 and 2, and then the time axis of the power source voltage was analyzed. The simulation results are shown in Figure 8. The voltage fluctuation was smaller under condition 2, compared to that noticed under condition 1, showing that selecting ESR values optimum for the decoupling capacitors is effective for ensuring power integrity and reducing the number of parts.

**Figure 6 Decoupling Capacitors Used in Simulations**

Condition 1

| | Capacitance / piece ($\mu$F) | ESR / piece (m$\Omega$) | ESL / piece (pH) | Quantity (pieces) |
|---|---|---|---|---|
| Polymeric aluminum electrolytic capacitor | 820 | 7 | 4000 | 8 |
| 2012 type / 10 μF | 8 | 4.5 | 218 | 30 |
| 1608 type / 1 μF | 0.8 | 9 | 258 | 30 |

Condition 2

| | Capacitance / piece ($\mu$F) | ESR / piece (m$\Omega$) | ESL / piece (pH) | Quantity (pieces) |
|---|---|---|---|---|
| Polymeric aluminum electrolytic capacitor | 820 | 7 | 4000 | 8 |
| CER1FX5R0G106M | 8 | 35 | 210 | 30 |

**Figure 7 Results of Frequency Characteristics Analysis**

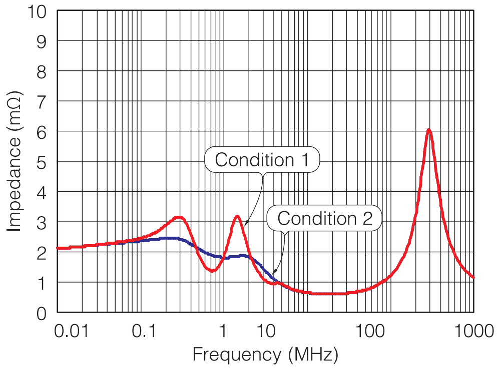



**Figure 8 Results of Power Supply Voltage**