ESR Control
Multilayer Ceramic Capacitors

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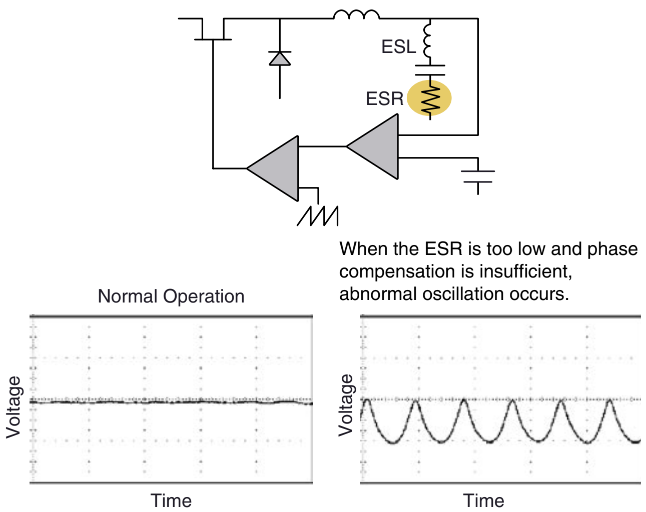
1. Introduction

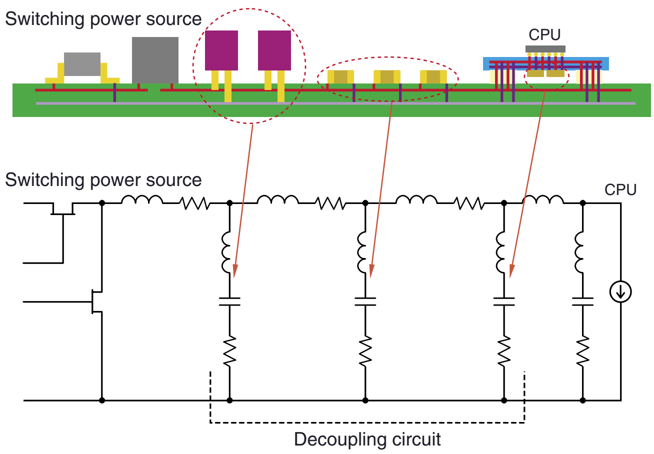
With conventional multilayer ceramic capacitors, low ESR (Equivalent Series Resistance) and a high Q factor are considered better. However, depending on the application, a low ESR can be disadvantageous and may cause problems with the electrical characteristics, or may cause problems with the design. For example, when a multilayer ceramic capacitor is used for switching power source output decoupling as shown in Figure 1, it is better to remove switching noise such as ripples and spikes, but phase lag often occurs with the feedback circuit of the switching power source when the ESR is low. This can cause deterioration of the load responsiveness or abnormal oscillation. In this case, in order to use multilayer ceramic capacitors, it is necessary to execute phase compensation using complicated circuit networks, which in turn requires more components.

Figure 1 Switching power source parasitic oscillation due to low ESR



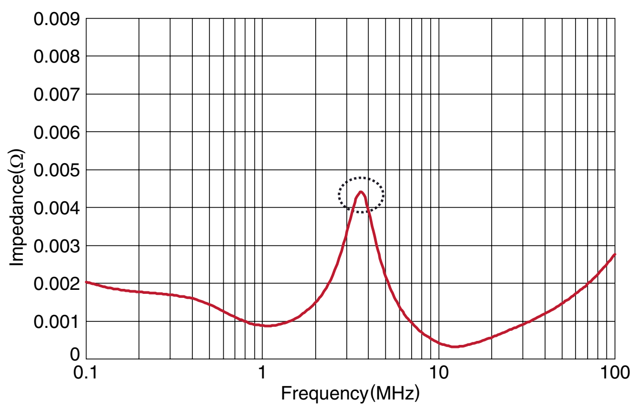
Low ESR may have a negative effect on the CPU decoupling circuit, which operates at a low voltage and large current. Figure 2 shows a model of a decoupling circuit. Multiple capacitors with different Self-Resonant Frequencies (SRF) are used for CPU decoupling circuits to achieve low impedance over a wide band and control voltage variation of high-frequency currents that flow to the CPU.

Figure 2 CPU decoupling circuit



When the capacitor's ESR is extremely low, a strong impedance peak occurs due to parallel resonance between capacitors as shown in Figure 3. When a high-frequency current equivalent to that frequency flows, the power source voltage can change suddenly causing jitters and lags over the transmission signal. As a result, logic errors can occur, and excess voltage over the semiconductor's withstand voltage might be triggered by the power source.

Figure 3 Decoupling circuit anti-resonance



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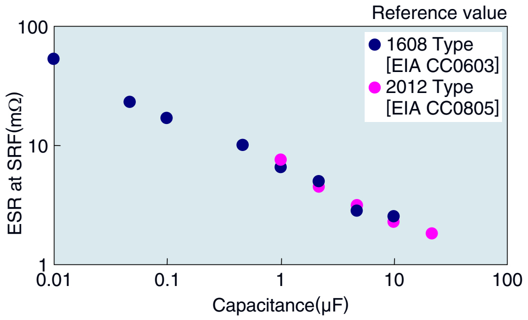
Generally, the ESR of multilayer ceramic capacitors at high frequencies is equivalent to the conductor resistance of the internal electrode. Therefore, the more layers the internal electrode has, the smaller the ESR. Figure 4 shows the relationship between the capacitance and ESR for multilayer ceramic capacitors. The higher the capacitance, the smaller the ESR, so it is very difficult to select the optimal multilayer ceramic capacitor with both the desire capacitance and desired ESR from among existing products.

Figure 4 Relationship between capacitance and ESR



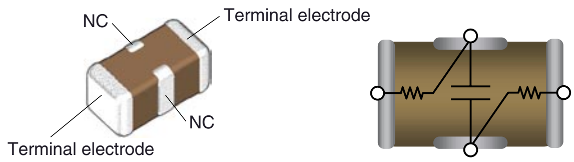
In order to resolve problems related to the low ESR of multilayer ceramic capacitors, TDK has developed “ESR Control Multilayer Ceramic Capacitors” that allow for arbitrary ESR design while maintaining high integrity of the ceramic capacitor characteristics. The following will explain more details.

2. Product overview

This product allows arbitrary setting of the ESR value by changing the conductor resistance of the layers based on a combination of multiple internal electrode patterns developed by TDK. Figure 5 shows the structure and equivalent circuits of the product. By using this structure, it is possible to manufacture products with different ESR values while maintaining the same chip size, capacitance, and withstand voltage.

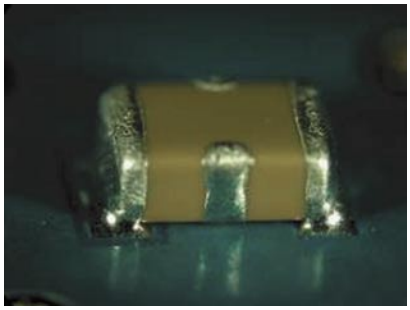
This product also contains internal electrodes that use dielectric ceramics and nickel, which are also used for existing multilayer ceramic capacitors, and contain terminal electrodes that use copper and metallic plated layers. These products are manufactured using TDK's accumulated material technologies and thin multi-layering process.

Figure 5 Structure and equivalent circuit



NC terminals are not connected.

Installation example of a printed substrate



Therefore, these products can be used in high-temperature environments while maintaining the same small size as existing products. The mounting land pattern is compatible with existing multilayer ceramic capacitors and there are no special restrictions related to the wiring and layout of printed substrates.

3. Electrical characteristics

The 1608 type and 2012 type are the current commercial products. The capacitance of the 1608 type is a maximum of 1μF, and the capacitance of the 2012 type is 10μF, and the temperature characteristics are X5R (+/−15%[−25 to +85°C]).

Figure 6 shows the electrical characteristics. Figures 7 and 8 show the impedance frequency characteristics. The CERD**X5R0G106M is a 2012 type with a capacitance of 10μF and an adjustable ESR value, and the CERB** X5R0G105M is a 1608 type with a capacitance of 1μF and an adjustable ESR value.

Figure 6 Electrical characteristics

Part No.	CERD**X5R0G106M	CERB**X5R0G105M
Capacitance	10μF	1μF
Capacitance tolerance	±20%	±20%
D.F.	10% max.	10% max.
IR	10MΩ min.	100MΩ min.
Rated voltage	DC.4V(0G)	DC.4V(0G)
Temperature characteristics	X5R −55 to +85°C/±15%	X5R −55 to +85°C/±15%
ESR	500mΩ	1200mΩ

Figure 7 Impedance characteristics 1

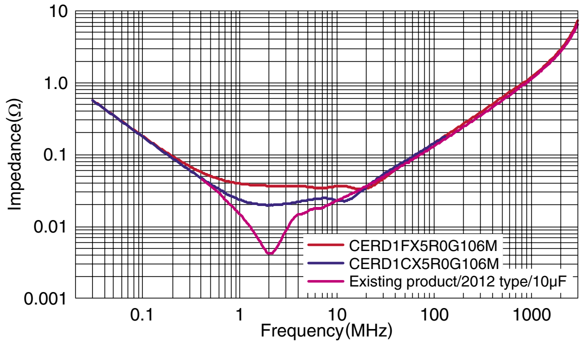
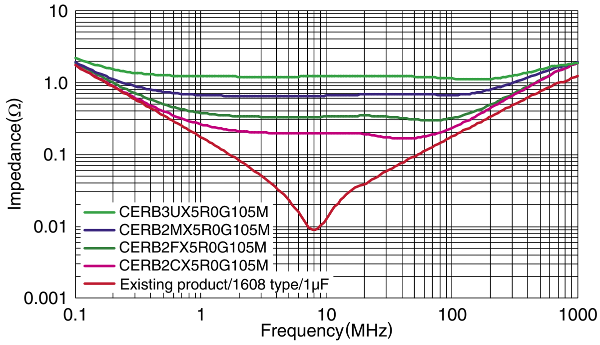


Figure 8 Impedance characteristics 2



Only the ERS values are different from existing products, and the capacitance and ESL (equivalent series inductance) are not so different. In addition to selecting the application, it is also possible to select the optimal ESR value to improve electrical characteristics, reduce installation space, and improve reliability.

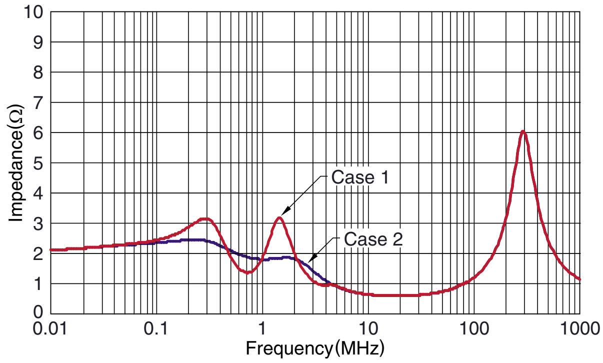
4. Application examples

We conducted simulations for CPU decoupling circuits using equivalent circuit models in order to verify product efficiency.

The decoupling circuit in Case 1 used 30 multipurpose 2012 type products with a capacitance of 10μF and 30 1608 type products with a capacitance of 1μF, and the decoupling circuit for Case 2 used 30 CERD1FX5R0G106M ESR control multilayer capacitors (2012 type/10μF/ESR = 35mΩ).

Figure 9 shows the results of the frequency analysis. Case 1 showed an impedance peak with anti-resonance, but Case 2 did not show much impedance fluctuation and was flatter than in Case 1. A load variation of 30A-90A at 370kHz was given to both Case 1 and Case 2, and then the time axis of the power source voltage was analyzed.

Figure 9 Frequency analysis using equivalent circuit models



Case 1

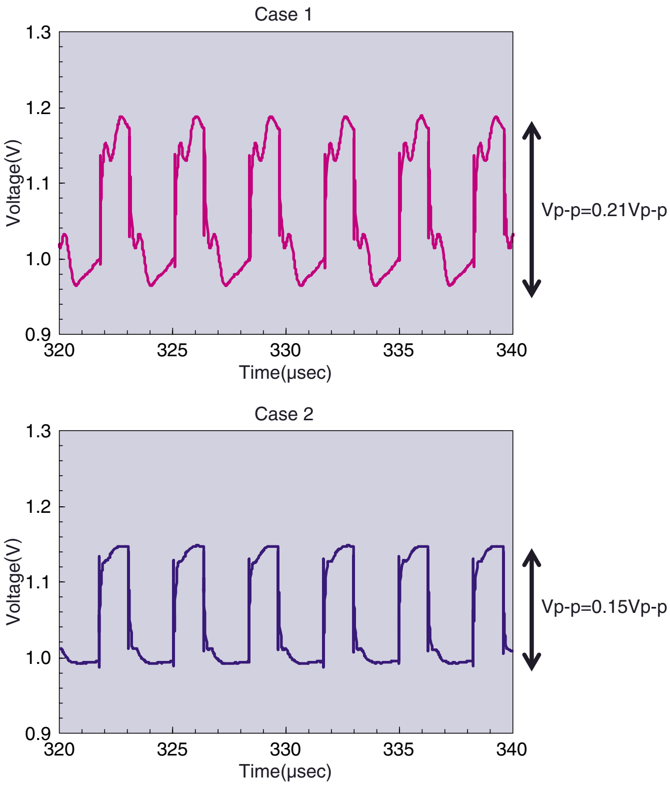
Item	Cap/pc (μF)	ESR/pc (mΩ)	ESL/pc (pH)	Qty (pcs)
Polymeric aluminum electrolytic capacitor	820	7	4000	8
2012 Type/10μF	8	4.5	218	30
1608 Type/1μF	0.8	9	258	30

Case 2

Item	Cap/pc (μF)	ESR/pc (mΩ)	ESL/pc (pH)	Qty (pcs)
Polymeric aluminum electrolytic capacitor	820	7	4000	8
CER1FX5R0G106M	8	35	210	30

Figure 10 shows the load voltage waveform. The voltage variation for Case 2 was smaller than that of Case 1. The result of the simulation showed that these products are effective at ensuring power integrity and reducing the number of components.

Figure 10 Time axis analysis using equivalent circuit models



5. Conclusion

Semiconductors have become smaller and more integrated requiring lower voltages and larger currents. Therefore, the influence of power source noise on the signal wave has become greater, and power integrity and signal integrity have become more closely related. When this product is used for decoupling capacitors, it is possible to design smaller power source impedances and thus improve power integrity. TDK will continue to develop products that are smaller and have larger capacity while maintaining accurate ESR.

• Please note that the articles from the June 12, 2008 Edition of the Dempa Shimbun contained in this chapter have been edited by our company.