5.4. Resonant Capacitors in High-Power Resonant Circuits

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Abstract

In high-power applications such as automotive onboard chargers (OBCs), server power supplies, and large-scale wireless power transfer (WPT) systems, resonant circuits (LLC and LC) are now the norm. This paper presents the advantages of using multilayer ceramic capacitors (MLCCs) as resonant capacitors, replacing traditional film capacitors. We review the technical requirements—high voltage handling, high-frequency performance, low loss, and long-term reliability, and robustness in harsh environments — and introduce Murata's 630 Vdc/1000 Vdc MLCC product lines. Finally, we describe the "Simsurfing" selection tool that streamlines part choice for designers.

Summary

LLC resonant converters in EV and PHV OBCs typically operate at 60 kHz–400 kHz with peak-to-peak voltages up to ~ few kV. To handle this voltage range and provide the required capacitance value, series–parallel capacitor networks are required, driving demand for compact, low-ESR/ESL components. MLCCs offer a 3× smaller footprint, lower heat generation, and superior temperature tolerance compared to film types. Voltage-derating curves guide designers to maintain capacitor surface temperatures below 125 °C over a 10-year lifespan. Murata's "Simsurfing" tool automates optimal MLCC selection and sizing.

1. Introduction

Recent advances in electric vehicle charging and wireless power transfer have driven resonant circuit adoption above 90%. LLC topologies maximize efficiency and reduce filter demands, while LC circuits support large-power WPT for industrial robots and EVs. Designers increasingly require capacitors that combine stable capacitance (>10 nF), minimal dielectric loss, and compact package sizes. This paper examines MLCCs' suitability for high-power resonant applications and outlines practical selection guidance.

2. Technical Requirements for Resonant Capacitors

a) High-Voltage Operation

WPT and OBC resonant circuits see p-p voltages from a few hundred volts to few kV. This usually implies that MLCCs are to be arranged in series strings to meet voltage ratings. Series strings reduce total capacitance; parallel branches restore capacitance, thereby necessitating small individual MLCC footprints for multi-element networks.

b) High-Frequency Operation

Automotive WPT standards fix resonance at 85 kHz in international regulations from the perspectives of enabling efficient power transfer, ensuring safety, achieving electromagnetic compatibility (EMC) compliance, and maintaining interoperability across different systems., while OBCs vary 60–400 kHz. High-frequency excitation increases capacitor self-heating; low-loss MLCC materials are essential to limit temperature rise ($\Delta T < 20$ °C) under continuous operation.

3. Comparison with Film Capacitors

MLCC advantages are following.

a) High Power Density

MLCCs achieve large capacitance values in compact and thin form factors, enabling the provision of required capacitance while minimizing installation space in high-power circuits.

b) Low Dielectric Loss

MLCCs exhibit very low dielectric losses, characterized by minimal equivalent series resistance (ESR) and equivalent series inductance (ESL), which suppress heat generation and power losses in high-frequency resonant circuits, thereby enabling efficient operation.

c) Excellent Thermal Characteristics and Long-Term Reliability

MLCCs maintain stable performance under high-temperature environments (-55 to +125deg.C) and possess the reliability necessary for prolonged use, making them well suited for demanding industrial and automotive high-load applications.

Murata’s MLCCs maintain stable capacitance and minimal loss, making them ideal for high-power resonant service.

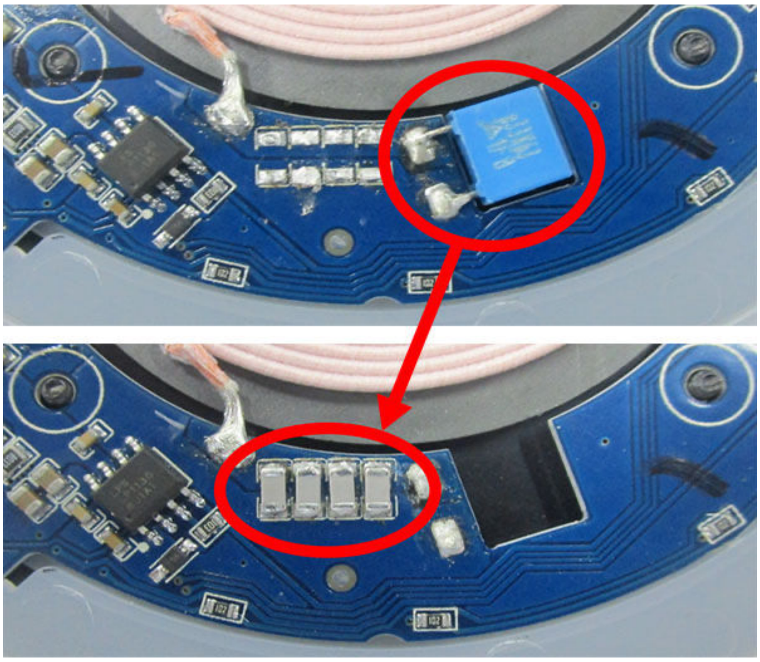

Figure 1: Photos of Replacement MLCC from Film Capacitors

4. Murata Resonant MLCC Lineup

Murata offers two package families: standard chip (sizes 3216M–3225M; 5.6–33 nF) and metal-terminal chip (up to 54 nF stacking 5750M). Both support C0G dielectric (0±30 ppm/°C) and 10-year reliability targets. Metal-terminal types also mitigate solder-crack risks in automotive service.

	Chip type MLCC	Metal Terminal Type MLCC
Appearance		
Operating Temp. Range	−55 to +125°C	−55 to +125°C
Vdc	630 V / 1000 V	630 V / 1000 V
Temp. Range	C0G (EIA): 0±30ppm/°C (25 to 125°C)	C0G (EIA): 0±30ppm/°C (25 to 125°C)
Cap. Range	5.6 to 10nF / 10 to 33nF	15 to 54nF

Figure 2: Murata Resonant MLCC Lineup

5. Selection Guidelines

a) Self-Heating Limitations

Capacitor operating voltage must ensure surface temperature remains below 125 °C over lifetime. Murata defines allowable DC and p-p voltage curves by frequency.

b) Voltage Derating Curves

Frequency is divided into three regions:
1) <10 kHz: rated voltage governs.
2) 10–100 kHz: continuous thermal rise limits voltage.
3) 100 kHz: initial heating limits voltage.
Designers must consult product-specific derating charts.

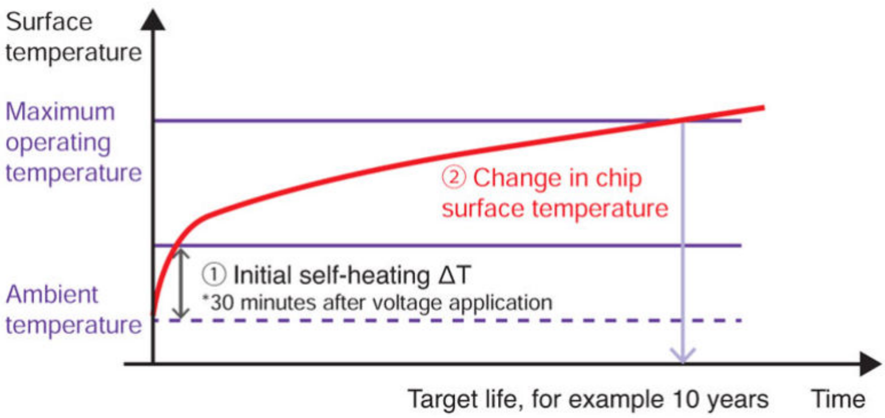

Figure 3: Change in surface temperature of capacitor

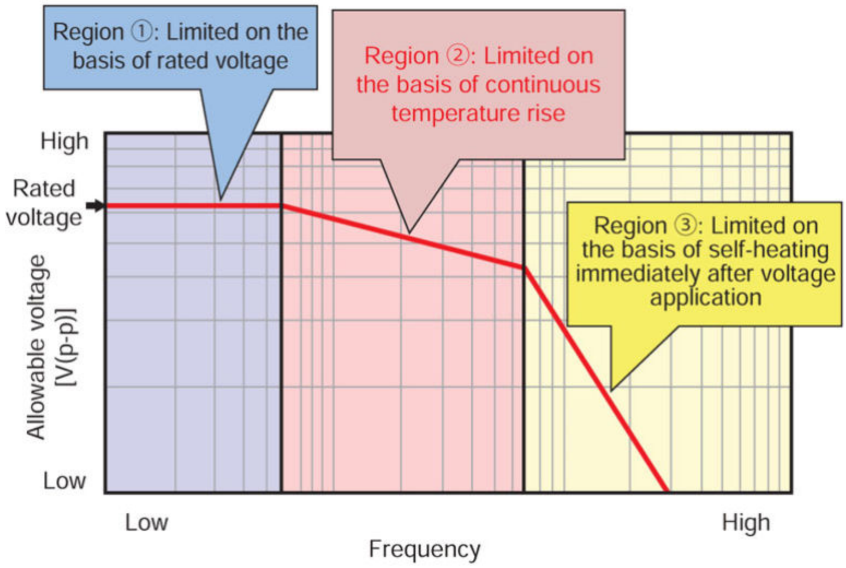

Figure 4: Allowable voltage curve set on the basis of self-heating evaluation

6. Selection Tool: Simsurfing

Murata's "Simsurfing" web tool enables users to enter operating voltage, frequency, temperature, and required capacitance. The tool outputs recommended MLCCs and series/parallel configurations, dramatically simplifying design.

Conclusion

MLCCs deliver compact size, low loss, high-temperature stability, and long-term reliability essential for modern high-power resonant circuits. Proper series–parallel design, guided by voltage derating curves and aided by "Simsurfing," allows engineers to confidently replace film capacitors and optimize system efficiency.

References

- Murata MLCC Datasheets, C0G Low-Loss Series.
- "Simsurfing" Selection Tool User Guide, Murata Electronics.
- ISO 21780:2019, Road vehicles—Low voltage power supply systems.