Murata's Ceramic Capacitor Serves Next Series of Power Electronics

There is growing concern about environmental issues these days. In the automotive industry, for example, there has been a focused effort towards developing the hybrid electric vehicle (HEV) and electric vehicle (EV). In the meantime, more functions are being operated by electronics while the technology trend for in-vehicle electronics has changed significantly. Specifically, the development of advanced power electronics technology, starting with HEV and EV drive motor control inverters, is set to become an important driving force in the evolution of automotives.

To keep up with this market trend, Murata Manufacturing Co., Ltd. developed the EVC series multilayer monolithic ceramic capacitor (MLCC) specialized for power electronic applications. This development is aimed at facilitating advances in downscaling as well as increasing the efficiency of inverter equipment.

Various Capacitors in Comparison

Today, film capacitors and aluminum electrolytic capacitors are largely used as smoothing capacitors for inverters of drive motors and electric air-conditioners installed in HEVs and EVs. The EVC series capacitors have certain advantages over film capacitors and aluminum electrolytic capacitors. Moreover, they can potentially make large improvements to these applications.

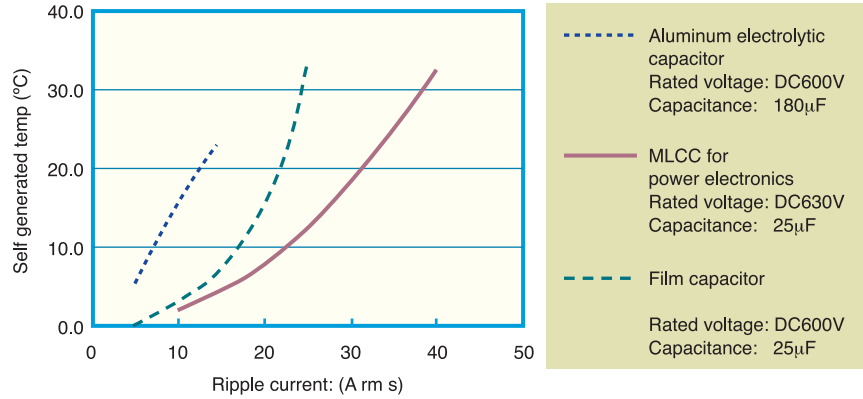

Fig. 2: Heat generation comparison of various capacitors

High allowable ripple current

Figure 1 shows a comparison of the equivalent series resistance (ESR) of various capacitors. The ESR of the EVC series MLCC is lower than that of the film capacitor and aluminum electrolytic capacitor. Most notably, the difference in the ESR ratings among these capacitors becomes apparent in the high-frequency side. When the heat-generation characteristics of these different types of capacitors were actually compared, the EVC series MLCC exhibits the lowest heat generation (See Figure 2). Assuming that the allowable self-heating temperature of these capacitors is the same, it is apparent from Figure 2 that the EVC series capacitors have a larger allowable ripple current capacity than film capacitors and aluminum electrolytic capacitors.

External appearance of MLCC for power electronics

Small size and large capacitance

MLCC uses ceramics with a high relative permittivity for its dielectrics and a dielectric constant that is very much higher than that of other types of capacitors, thus offering small size and large capacitance. For example, the capacitance per unit volume of MLCC is about several times larger than that of a film capacitor with the same specifications. In the case of aluminum electrolytic capacitor, there is not much difference in the capacitance per unit volume compared with the MLCC. The ESR rating of an aluminum electrolytic capacitor, however, becomes extremely high especially in a low-temperature environment because of its structure, and in some cases, its effective capacitance during actual operation becomes equal or less than that of MLCC.

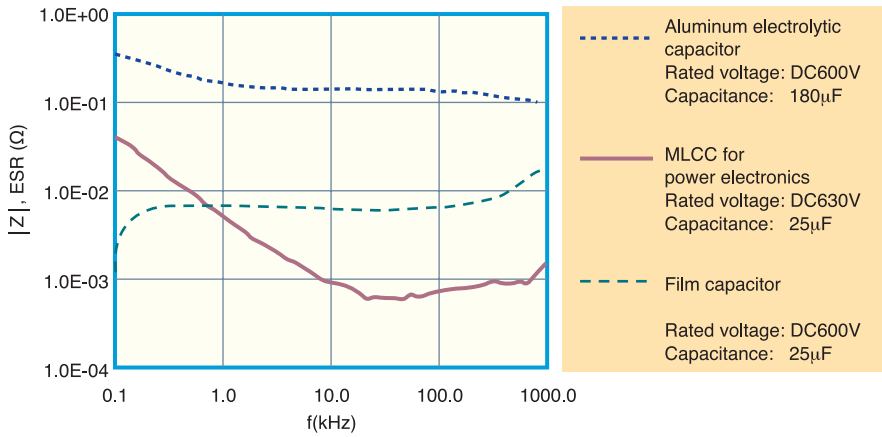

Fig. 1: ESR comparison of various capacitors

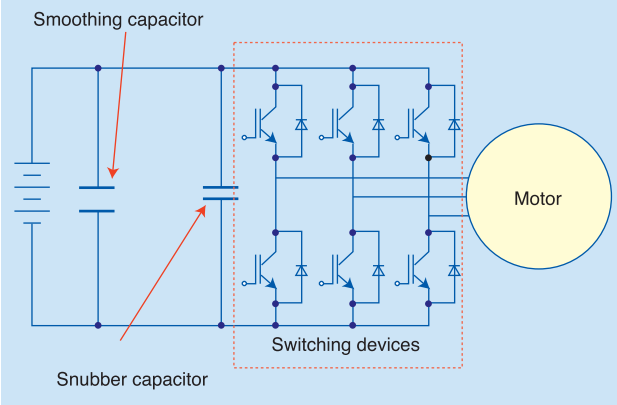

Fig. 3: Vehicle-mounted inverter circuit diagram

High-temperature assurance

MLCC is made up of materials that resist degradation from comparatively high temperatures. The maximum operating temperature of film capacitors and aluminum electrolytic capacitors is about 105°C due to the property of materials they are made of. MLCC, however, can potentially assure operation in temperatures of 150°C or higher.

The EVC Series MLCC

Photo 1 shows the EVC series MLCC. It has an outside dimension of 32 × 40 × 3.7mm with a rated voltage of DC 250V, and an effective capacitance of 38µF when DC 150V is applied. This capacitor is specialized for inverter smoothing application with an allowable ripple current per unit exceeding 20Arms. The company's largest general-purpose capacitor that is being mass-produced measures 5.7 × 5.0mm. The volume of EVC series is about 100 times that of Murata's largest product.

A capacitor used for power electronics must have large capacitance under DC bias and high allowable ripple current. However, it is difficult for the BaTiO3 general-purpose MLCC to implement both characteristics with the right balance. General-purpose products are not always suitable for power electronics in terms of the material characteristics because of very large drop in capacitance under DC bias or very high heat generation caused by ripple current due to a high dielectric loss. Consequently, Murata Manufacturing developed a special ceramic material for the EVC series that assures both high capacitance under bias and low-dielectric loss.

The EVC series has a structure with metal terminal pins in order to absorb mechanical stress from a board. Normally, a solder is used as the attaching medium. Capacitors soldered to a board are vulnerable to stress and often crack with changes in temperature. Therefore, they are not suitable for use in high-temperature environments. The use of conductive resin as an attaching medium can provide high-temperature support. However, there is higher resistance at the attached portions of capacitors that use conductive resin. Therefore, this method is not suitable for large current applications. For this reason, Murata Manufacturing developed a new attaching technology that was put into practical use for high-temperature and large-current applications such as power electronics.

Proposed Applications

The EVC series targets a wide range of large-power applications. At present, it is proposed for use mainly in two applications.

Smoothing application

A typical circuit of a vehicle-mounted inverter is presented in Figure 3. As mentioned earlier, mainly large-capacity aluminum electrolytic capacitors and film capacitors are used for inverter smoothing applications. Under the present circumstances, however, the allowable ripple current determines the capacitance of a capacitor being used. It is assumed that capacitors with more capacitance than what is required are now being used.

Since the EVC series has a high allowable ripple current, it could be possible to get a sufficient smoothing function from an EVC capacitor with a capacitance smaller than aluminum electrolytic capacitors and film capacitors. Combining the EVC series with the small-size and large-capacity features of MLCC could significantly contribute to downsizing the entire system. The EVC series is already being installed in some electric vehicles.

Snubber application

MLCC is especially suited for the snubber application of inverter circuits. For the snubber application, either a smoothing capacitor performs the snubber function or a film capacitor is added for use as a snubber in the current system.

The primary advantage of MLCC for snubber application is its low equivalent series inductance (ESL). Figure 4 shows the frequency characteristics of various capacitors. Since MLCC has a low ESL, the impedance specifically at the high-frequency side is low. Even though MLCC has a smaller capacitance than the film capacitor used for comparison in this graph, the surge reduction effect of MLCC is favorable based on the voltage across the capacitor for actual surge reduction (See Figure 5).

The second advantage of MLCC is that

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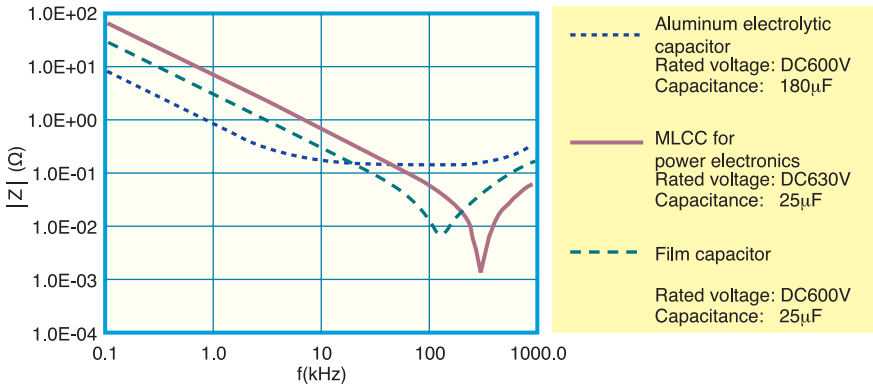

Fig. 4: Frequency characteristic comparison of various capacitors

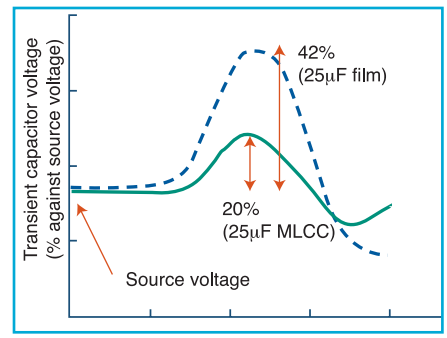

Fig. 5: Noise reduction comparison between MLCC and film capacitor

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it can be placed near a source of surge generation. Normally, because of their volume and heat-resistance performance, aluminum electrolytic capacitors and film capacitors cannot be installed near a switching device, which is a source of surge generation, thus the wiring inductance becomes high. Therefore, unnecessary large-capacitance capacitors are required to get the proper surge reduction effect. MLCC, on the other hand, offers superior heat-resistance performance, small size, and large capacitance and can be installed near a switching device. With even a smaller capacitance, it can provide the required surge reduction effect. In this manner, the EVC series can provide solutions for downsizing the entire system and cutting down cost.

Product Development, Expansion

Murata Manufacturing is planning to expand the EVC series rated voltage and capacitance lineup. Moreover, it intends to provide wide-range solutions that take full advantage of the EVC series capacitors, and contribute to the progress of power electronics technology and protection of the global environment.

About This Article:

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