MLC Capacitors in Automotive Power Electronics

The demand for better economy and lower CO2 emissions is driving automotive electronics in directions not previously experienced in this field. Electrical loads in automotive systems over the last few decades have evolved from simple lighting and battery-charging to engine management and control, sensors and safety and of course 'infotainment' making the car smarter and more sophisticated. All of which is driving Multilayer Ceramic Capacitors (MLCCs) into higher voltage and higher temperature applications.

Peter Scutt, Knowles Capacitors Syfer Technology facility, UK

While this trend continues increased use of electronics in high intensity lighting, safety systems, transmission & controls and power train systems for better propulsion can be observed. Incorporating electrical loads and replacing the conventional mechanical and hydraulic loads in the powertrain improves efficiency leading to more focus on electric vehicle concepts – hybrid (HEV) and pure (EV).

However, this increasing need and demand makes the conventional 12 V power system more challenging. As such, it is critical to have higher voltages in order to handle power train loads more efficiently – and with flexibility. Switched-mode power supplies (SMPS) provide the basis to do so. This is made possible due to advances in power electronics brought about by higher specified components such as MLCC's.

Implementation of power electronic circuits makes the system smaller and lighter and therefore provides the basis to improve the fuel efficiency as well. Advances in dielectric materials used on Multilayer Ceramic Capacitors, such as the X8R family, have resulted in increasing capacitance values along with increased voltage ratings (up to 3 kV). Increased MLC chip sizes and the inclusion of Syfer's patented StackiCap™ product has also given further increases in available capacitance values and added benefits of volumetric efficiency.

In response to changing market demands, Syfer have recently improved and expanded their range of AEC-Q200 automotive qualified capacitors (Figure 1) to include voltage ratings to 3 kV; safety rated class X&Y capacitors for AC charging circuits; X8R dielectrics to 150ºC; chip sizes to 3640; StackiCap capacitors with high volumetric efficiency and open-mode and tandem-cap options for improved

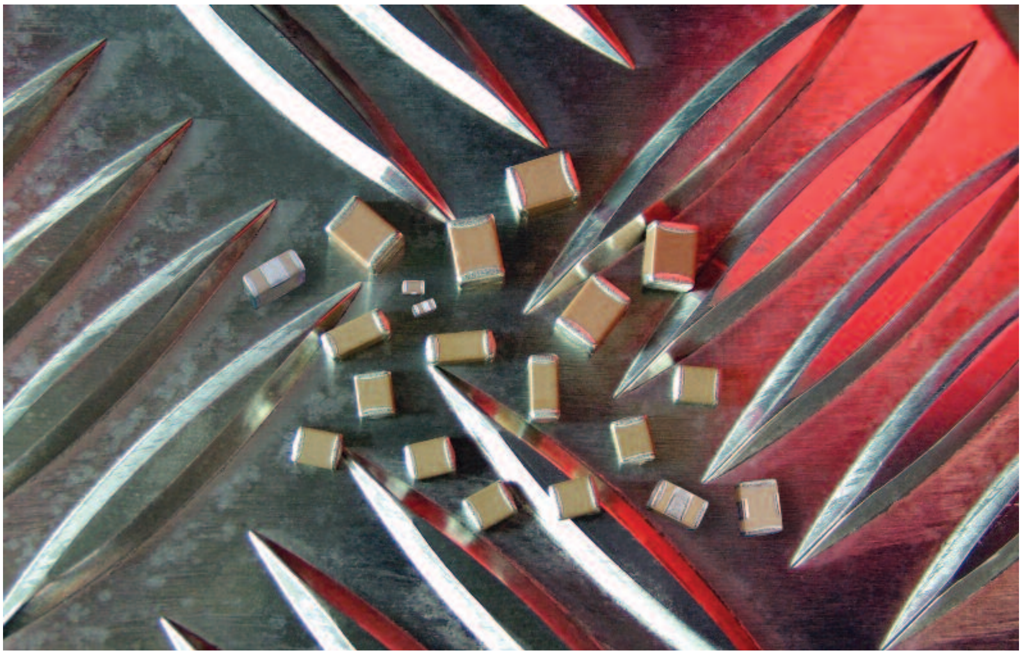

Figure 1: Multilayer Ceramic Capacitors, such as the X8R family, offer increased capacitance values along with higher voltage ratings (up to 3 kV)

Dielectric Classification	Lower Temperature (°C)	Upper Temperature (°C)	Maximum Cap Change
C0G	-55	+125	±30ppm/K
X5R	-55	+85	±15%
X7R	-55	+125	±15%
X8R	-55	+150	±15%

Table 1: Syfer products are normally rated over the temperature range of -55 to +150ºC

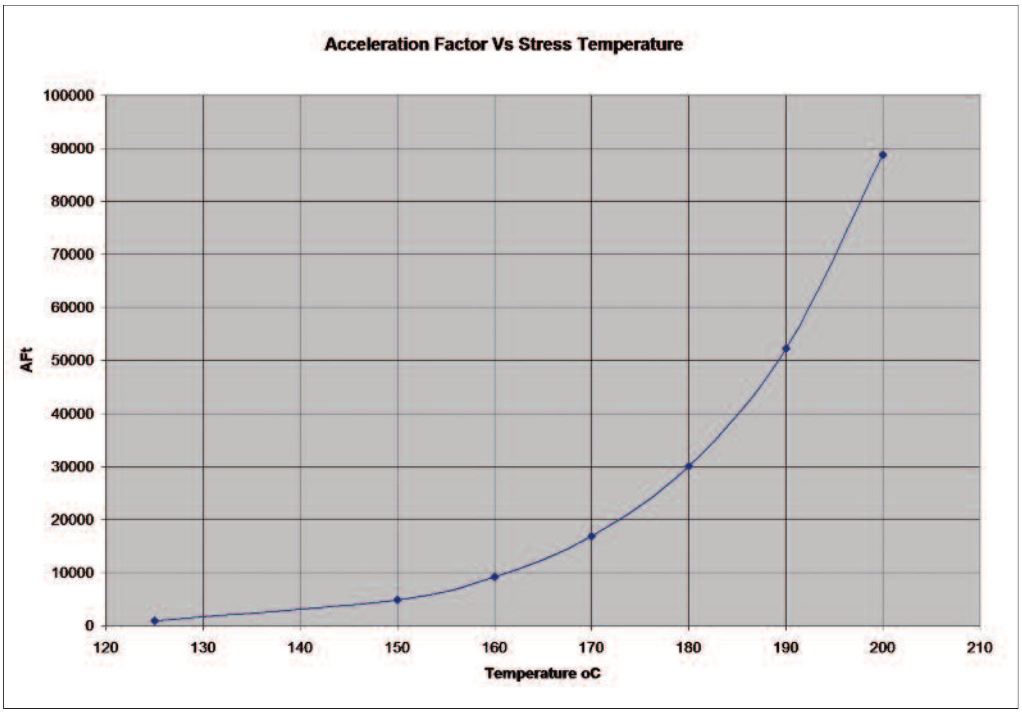

Figure 2: Temperature has a disproportionate affect and the reliability factor increases significantly as temperature rises

reliability. However the limiting factor is often the temperature performance of standard dielectric materials. In the case of Syfer products, they are normally rated over the temperature range of -55°C to +150°C (as shown in Table 1).

Use at extended temperatures

Beyond the expanded AEC-Q200 qualified ranges, Syfer have developed products with extended temperature capabilities. These parts are suitable for certain automotive and industrial applications where a wider temperature range is often requested, particularly for temperatures up to 200°C. After extensive testing performed at our manufacturing facility it is possible to make recommendations on part suitability for use at higher temperatures. Whilst not qualified to AEC-Q200, these meet Syfer's quality and reliability requirements. It should be noted however, that although parts will function at temperatures up to 200°C the electrical properties will not meet the normal C0G, X5R, X7R or X8R specifications.

The reliability of multilayer ceramic capacitors is directly related to the voltage applied and the operating temperature. Both voltage and temperature have an influence on the reliability acceleration factor, but temperature has a disproportionate affect and the reliability factor increases significantly as temperature rises (see Table 2 and Figure 2).

Thermal stress alone is sufficient to cause electrical failure. Thermal breakdown takes place when heat is generated in the dielectric at a higher rate than it can be conducted away. This leads to increased conductivity, more heat generation and eventually to instability in the form of an uncontrolled, often very rapid temperature rise. The temperatures attained when a capacitor discharges through a region of localized thermal runaway can be high enough to melt the dielectric material. When determining whether a particular component is suitable for use at high temperatures, customers must consider the thermal stress, and the effect of the elevated temperature on basic electrical properties such as capacitance, dissipation factor and insulation resistance.

Recommendations

Reliability testing of components at temperatures of up to 200°C has also been carried out. As component reliability is detrimentally affected due to thermal stresses it is not recommended that standard components are used at temperatures >125°C however:

For temperatures up to 160°C, most standard components will give reliable performance, but the Syfer recommendation is for the component user to select components with a voltage rating ≥30 % higher than the component that would normally be selected.

For example, if a 0805 50V 10 nF component would normally be used, the recommendation would be to use an 0805 100 V 10 nF part – NB the 0805 63V 10nF would not meet the recommendation as the voltage increase is only 26 %.

For temperatures >160°C, Syfer test data shows that the reliability is affected exponentially in a similar way to that shown on the thermal stress graph above. This makes it very difficult to provide a simple set of rules for component users to apply for use between >160°C and 200°C.

Consequently, for component use >160°C, Syfer recommends the user contacts our technical team with details of the exact application and they will recommend the most suitable component. This will ensure they will always get the most reliable and cost effective solution to their needs.

As an example, the recommended component size for a particular application may be a 1206 size chip for use at 170°C, but for the same capacitance value and working voltage an 1812 chip may be needed for use at 200°C.

Stress Temperature (°C)	125	150	160	170	180	190	200
Acceleration Factor	871	4884	9203	16854	30051	52258	88776

Table 2: Both voltage and temperature have an influence on the reliability acceleration factor