MLCCs for Automotive Electronics: Focusing on Interference Suppression and High Operating Temperatures

By Martin Leupold

Electronic components in vehicles must function properly, not only for the safety of passengers, but also for their comfort. However, the more cars incorporate communication and connectivity technology, the higher the risk of signal interference and its effects. To guarantee undisturbed functionality, the emission and transmission of electromagnetic interference must be reduced to a regulated value. A popular option is ceramic capacitors, which effectively filter out voltage spikes.

Due to their importance in automotive applications, Vishay makes sure that these components not only meet but exceed the highest quality standards according to AEC-Q200. During qualification tests, the capacitors are exposed to extreme temperature changes, high humidity, strong vibrations, and the highest operating temperatures - all of which reflect the harsh operating environments found in cars.

With the latest extension of ceramic capacitor lines, the HOTcap® series, we tested the devices unpowered for 2000 hours at 175 °C, which is much longer than the 1000 hours that the AEC-Q200 standard requires. We also specified the high temperature operating life test for 2000 hours at 175 °C and twice the rated voltage, which is again much higher than the AEC-Q200 standard requires (the AEC-Q200 standard is 1000 hours at 125 °C and rated voltage). Furthermore, temperature cycling is tested from -55 °C to +175 °C (the AEC-Q200 standard specifies a max. of +125 °C) and the 85 / 85 test (85 °C, 85 % relative humidity) for 1000 hours at rated voltage. The AEC-Q200 criteria are used as the basis for extended test specifications we perform in our internal approval process, ensuring our components perform above the AEC-Q200 level (1).

With the HOTcap devices (K…H series), Vishay has set the benchmark in terms of quality and performance to strengthen our competitive edge. In fact, the capacitors are the world's first Class 1 and 2 ceramics to feature extremely high operating temperatures of 175 °C and 200 °C, respectively, making them unique among automotive electronic components. The series features multi-layer ceramic capacitors (MLCCs), which are manufactured with high tech ceramic and precious metal electrodes in a special wet-cast process. This procedure strengthens the bonding of individual layers to each other and contributes a tremendous share to the increased reliability, lifetime, and performance of the components. This is because under extreme conditions, a delamination of single layers is effectively suppressed. Radial lead-wires are soldered onto the terminations of the chips, which are finally covered with high temperature resistant epoxy resin.

This technology enables high capacitance along with small body sizes at a competitive price. The products are available with capacitances starting from 100 pF to 1 µF at rated voltages up to 200 V_{DC}. The devices feature a very stable C0G ceramic dielectric (± 30 ppm/K) and a new X0U ceramic dielectric with a permissible change in capacitance of +22 % / -56 % within the operating temperature range of -55 °C to +175 °C. All capacitors are lead (Pb)-free according to RoHS and REACH regulations.

Through-hole capacitors show two major benefits versus surface-mount devices: a higher temperature resistance and a higher resistance against mechanical stress. Due to the use of lead-wires, twists and / or vibrations of the PCB cause less harm to the chip capacitor, which prevents breakage and other defects. Hence, the lead-wires take over a shock-absorbing function. To save space, it is also possible to assemble the leaded MLCCs without having a PCB. For instance, they may be welded onto lead frames and overmolded with plastics. This could be beneficial for sensors used in automobiles, DC motors, or cable harnesses.

Along with the introduction of HOTcap (K…H series) devices, Vishay has defined a new quality and performance standard for interference signal suppression in automotive applications, while meeting the requirements for higher operating temperatures. This means added value for customers in terms of performance and temperature resistance, resulting in higher reliability and longer lifetimes.

Note

(1) The usage of HOTcap capacitors at 175 °C is unlimited in duration.
Furthermore, temperatures of 200 °C are permissible for a limited cumulated lifetime of 500 hours

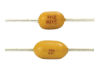
THE VISHAY ADVANTAGE AND WHY IT MATTERS...

AUTOMOTIVE APPLICATIONS

Leaded Multilayer Ceramic Capacitors (MLCCs) for Improved Performance Against Mechanical Stress

AUTOMOTIVE GRADE

Harsh environmental conditions → Mechanical stress to the PCB → Mechanical stress on the MLCC → MLCC has to absorb or withstand → Proper function of the device

Product Family		Advantage	Why it Matters (Benefit to the Engineer)	Where Should it Be Considered	Best Parameter / Example
	A...R series	Robust against mechanical stress	Leaded MLCCs effectively absorb stress caused by deflection or vibration of the PCB and prevent cracking	In applications in which the PCB is affected by mechanical stress	Available with axial and radial leads and several lead designs
	K...R series				
	K...H series	Lower buzzing noise	AC voltage applied to MLCCs causes vibration along with an audible buzzing noise. Leaded MLCCs reduce the effect of vibration	When AC voltage is applied to the MLCC	

Other Customer Benefits	How is This Achieved?	Example Device / Details	Comments
High operating temperature	Due to the use of a special epoxy coating and superior Vitramon chips	Operating temperature range of K...H series from –55 °C to +175 °C	It has been approved for 200 °C for a maximum of 500 hours
May be welded directly onto lead frames or cable harnesses	There are lead wires soldered onto the terminations of the MLCC	Available with straight or flat bend leads and lead spaces of 2.5 mm or 5.0 mm	May be overmolded with plastic
AEC-Q200 qualified	Using superior Vitramon chips exceeding AEC-Q200 requirements	Vishay's high temperature operating life test conditions are approx. 500 times more demanding than those of AEC-Q200 standard	K...H series had been tested at a rated temperature of 175 °C instead of specified at 125 °C

DID YOU KNOW?

TCC VERSUS OPERATING TEMPERATURE

To start with, let's recall some definitions:

- The temperature characteristic of capacitance (TCC) expresses the capacitance drift over a certain temperature range
- The operating temperature provides the lower and upper limits in which you may run the component

You might think that the operating temperature range should be within the same limits as the TCC, but in fact that is not necessaryly true. Below, we explain why there is no connection between operating temperature and TCC.

Ceramic materials are classified into different ceramic classes (Class 1, 2, and 3). The TCC definition based on the Electronic Industry Association (EIA) provides a three-character code, which describes the low and high temperature limit and the range of the capacitance change. This change is important in many applications because the component must have a well-defined capacitance value at every temperature occuring in operation.

Let's have a look at the most prominent TCC in Class 2 ceramics: X7R. It is usually assumed to have an upward operation temperature limit of +125 °C, but what if we were to tell you that it is much higher when it comes to Vishay devices?

As Table 1 illustrates, the temperature range for X7R is from –55 °C (X) to +125 °C (7). In this temperature range, the maximum permitted capacitance change is ± 15 % (R). Driven by the automotive industry, which is looking for higher temperatures, the X8R TCC has been getting more attention, and many suppliers have launched new X8R devices. The difference between X7R and X8R is the upper temperature range. If you use an X8R ceramic, the capacitance will be within ± 15 %, even up to +150 °C. However, this has nothing to do with the maximum operating temperature, which may be higher (or lower) than the TCC. That's why many customers stay with the more cost-effective X7R even if they operate beyond +125 °C.

Vishay's X7R devices in our Automotive Grade leaded MLCC families operate at up to +160 °C. The capacitance is within ± 15 % up to +125 °C. Beyond that point, it will drop down further. Although the EIA code has no provision for this, Vishay specifies this drift in the datasheet (see Chart 1). We feel our customers should not miss out on this very important detail. If you know this capacitance drift, you just need to use a higher capacitance value. We have released all our TCCs (C0G, X7R, and X8R) for our axial- and radial-leaded automotive MLCC series for operating temperatures up to an industry-high +160 °C, meeting and exceeding the AEC-Q200 standard.

Our HOTcap® devices are tested and released according to the AEC-Q200 standard for operating temperatures, all the way up to +175 °C. There is no EIA letter equivalent for +175 °C, hence we created a new TCC code: the X0U. This means that from –55 °C (X) to +175 °C (0), the capacitance may drift within +22 % and –56 % (U). Simulatanuously, HOTcap® devices are specified as X7R and X9V, i.e. up to 125 °C the capacitance drift is limited to ± 15 % and up to 200 °C it may drop down to –82 %. Refer to Chart 1 to check out the typical capacitance drift of our C0G and X7R ceramics up to 200 °C. Note that the X7R material fulfills all three TCC criteria: X7R, X0U, and X9V.

Latest news: HOTcap® devices of both ceramic types, C0G and X7R, have been released to an industry-record temperature level of +200 °C (for a limited lifetime of maximum 500 hours).

Table 1: TCC system for Class 2 ceramics acc. to EIA198

Minimum Temperature	
X	-55 °C
Y	-30 °C
Z	+10 °C

Maximum Temperature	
4	+65 °C
5	+85 °C
6	+105 °C
7	+125 °C
8	+150 °C
9	+200 °C

Capacitance Change Permitted	
A	± 1.0 %
B	± 1.5 %
C	± 2.2 %
D	± 3.3 %
E	± 4.7 %
F	± 7.5 %
P	± 10 %
R	± 15 %
S	± 22 %
T	+22 % / -33 %
U	+22 % / -56 %
V	+22 % / -82 %

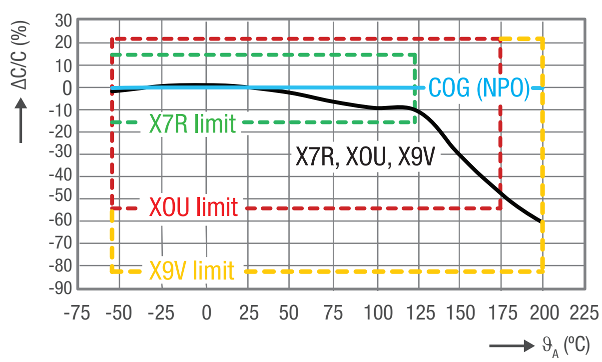
Table 2: TCC system for Class 1 ceramics acc. to EIA198

Significant Digits of Temperature Coefficient	
C	0.0
M	1.0
P	1.5
R	2.2
S	3.3
T	4.7
U	7.5

Multiplier of Temperature Coefficient	
0	–1
1	–10
2	–100
3	–1000
5	+1
6	+10
7	+100
8	+1000

Tolerance in ppm/°C	
G	± 30
H	± 60
J	± 120
K	± 250
L	± 500
M	± 1000
N	± 2500

Chart 1: Typical capacitance change versus temperature of Vishay's HOTcap® devices



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