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 %

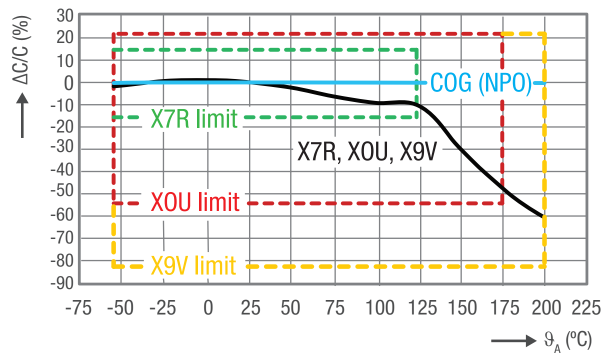
Table 2: TCC system for Class 1 ceramics acc. to EIA198

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



cmll@vishay.com
VMN-MS7407-1709