Ceramic transient voltage suppressors

Reliability

Date: November 2010

1 Overview

Reliability is defined as the ability of a component to perform its intended (specified) function without failure in a given period of time (the lifetime of the component) under stated conditions.
In mathematically terms, reliability is also expressed as the probability that a component will fail to function after a specified time interval.

The reliability of ceramic transient voltage suppressors is dependent on their design, material properties, manufacturing process and life cycle environment.

Failure rate

Information on component failure rates provide the manufacturer with a basis for reliability forecasts and allow them to estimate future service requirements.

If the fraction ΔN of a large number N of identical components fails during the time Δt, the failure rate (averaged over Δt) is indicated by $\lambda = \Delta N / (N \cdot \Delta t)$. The failure rate depends on the failure criteria, the load and the operating time.

The dimension of the failure rate is the reciprocal of time and the unit used is 10^{-9} / h = 1 fit (failure in time).

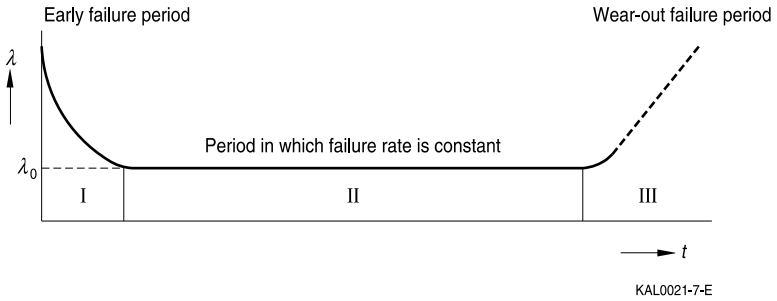

Figure 1

Region II is assumed to be the "service period" of components. It is thus considered to be sufficient to state the (virtually) constant failure rate λ_0.

1.1 Lifetime

The mean life of CTVS devices as a function of

- voltage class
- ambient temperature
- applied voltage ratio (AVR)

can be derived from figure 2 and 3.

There is a marked difference for CU series between “low-voltage ceramics” (≤K40) and “high-voltage ceramics” (≥K50).

The applied voltage ratio AVR is defined as the ratio between intended operating voltage and maximum permissible operating voltage

$$AVR = \frac{V^*}{V_{max}} \qquad \text{(equ. 1)}$$

Reaching the maximum average power dissipation is defined as the end of useful life. But the CTVS is still functional.

The increase in leakage current is, to a good approximation

$$i_L = A + k \cdot \sqrt{t} \qquad \text{(equ. 2)}$$

i_L leakage current at constant voltage

A factor, dependent on temperature, AVR, geometry, encapsulating material

k slope coefficient of leakage current over $\sqrt{t}$

Investigations at different temperatures and AVRs show that the logarithm of lifetime is in a linear relation to reciprocal ambient temperature.The slope of this curve is virtually constant for zinc oxide. It can be attributed to activation energy.

The theoretical background of these relations is known as the Arrhenius model. Figures 2 and 3 show evaluation for CTVS components.

EPCOS lifetime tests extend over a period of several 10^3 hours. The higher lifetime figures are determined by extrapolation on the Arrhenius model.

1.2 Failure rate

The failure rate λ is the reciprocal of mean life in hours, the unit being fit (failures in time) = 10^{-9}/h.

$$\lambda = \frac{10^9}{ML\,[h]}\ [fit] \qquad \text{(equ. 3)}$$

Accordingly, typical failure rates can be derived from mean life figures dependent on applied voltage and temperature or schematically shown in figures 2 and 3.

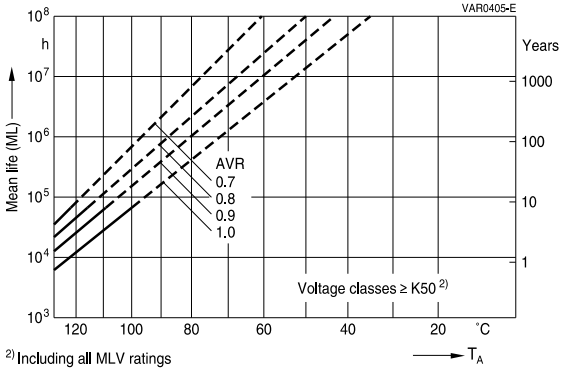

Figure 2
Mean life on Arrhenius model for CTVS (except CU ≤ K40). Applied voltage ratio (AVR) referred to maximum permissible operating voltage

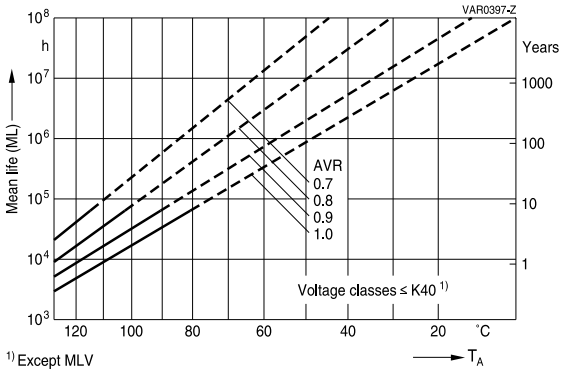

Figure 3
Mean life on Arrhenius model for CU series with voltage classes ≤ K40

Failure rate figures refer to the average production status and are therefore to be understood as mean values (statistical expectations) for a large number of delivery lots of identical CTVS devices. These figures are based on application experience and on data obtained from preceding tests under normal conditions, or – for purposes of accelerated aging – more severe conditions.

2 Reliability tests

A variety of endurance tests and environmental tests are conducted to assure the reliability of ceramic transient voltage suppressors. These tests are derived from the extremes of expected application conditions, with test conditions intensified to obtain authoritative results within a reasonable period.

The reliability testing programs of EPCOS are based on the test plans of international standards and customer requirements.

EPCOS performs reliability tests to qualify new component families and for periodic requalification.

2.1 Tests of multilayer varistors (MLVs) and CeraDiodes

The following tests for MLVs and CeraDiodes are performed according to IEC 60068.
Preconditioning: reflow soldering on PCB.
After testing a visual check is performed. Criteria: no visible damage of component.

Pulse strength tests

Test	Standard	Test method/conditions	Criteria
Surge current derating, 8/20 µs	IEC 61000-4-5	Surge current (8/20 µs), unipolar, amplitude corresponding to derating curve for 20 µs Number of pulses: 1	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$ (measured in direction of surge current)
ESD contact discharge	IEC 61000-4-2	Test voltage: up to 8 kV Number of test pulses: 20 Polarity: +/– Discharge network: 150 pF, 330 Ω	$\lvert\Delta V/V$ (1 mA)$\rvert$ depending on type
ESD air discharge	IEC 61000-4-2	Test voltage: up to 15 kV Number of test pulses: 20 Polarity: +/– Discharge network: 150 pF, 330 Ω	$\lvert\Delta V/V$ (1 mA)$\rvert$ depending on type
Load dump (only for specific automotive types)	ISO 7637-2	Number of pulses: 10 Pulse interval: 60 s Pulse duration: 500 ms	$\lvert\Delta V/V$ (1 mA)$\rvert < 15\%$ (measured in direction of load)

Environmental tests

Test	Standard	Test method/conditions	Criteria
High-temperature life test	MIL-STD-202F, method 108A, condition D	Temperature: $T_{op,max}$ Duration: 1000 h Applied voltage: $V_{DC,max}$	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$
Fast temperature cycling (thermal shock)	IEC 60068-2-14, test N_a	Minimum temperature: LCT Maximum temperature: UCT Dwell time: 15 min Transfer time: < 30 s Number of cycles: depending on type	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$
Damp heat, steady state	IEC 60068-2-3	Temperature: 40 °C Humidity: 93 % r.h. Duration: 56 days Applied voltage: $0.1 \cdot V_{DC,max}$	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$
Biased humidity (only for specific automotive types)	IEC 60068-2-67 Cy	Temperature: 85 °C Humidity: 85 % r.h. Duration: 1000 h Applied voltage: $V_{DC,max}$	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$
High-temperature exposure	IEC 60068-2-2 Ba	Temperature: UCT Duration: 1000 h Applied voltage: unpowered	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$

Mechanical strength tests

Test	Standard	Test method/conditions	Criteria
Bump/mechanical shock	IEC 60068-2-29 Eb	Pulse duration: 6 ms Max. acceleration: 400 m/s^2 Number of bumps: 4000 Pulse: half sine	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 5\%$
Vibration	IEC 60068-2-6 Fc	Frequency range: 10 ... 55 Hz Amplitude: 0.75 mm or 98 m/s^2 Duration: 6 hrs (3 x 2 h) Pulse: sinewave	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 5\%$
Board flex		Deflection: 2 mm Duration: 60 s	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$
Terminal strength	IEC 60068-2-21 U_{e3}	Shear force applied to component soldered on PCB	Shear force: depending on case size ≥ 5 N for chip 0402 ≥ 10 N for chip 0603 ... 2220 ≥ 10 N for array components

Note for automotive application:
Especially for automotive applications EPCOS performs qualification based on AEC-Q200, Rev. C. In term of PPAP request test data of representatives of product family will be delivered.

2.2 Tests of ESD/EMI filters

The following tests for ESD/EMI filters are performed according to IEC 60068.
Preconditioning: reflow soldering on PCB.
After testing a visual check is performed. Criteria: no visible damage of component.

Pulse strength tests

Test	Standard	Test method/conditions	Criteria
ESD contact discharge	IEC 61000-4-2	Test voltage: up to 8 kV Number of test pulses: 20 Polarity: +/- Discharge network: 150 pF, 330 Ω	$\lvert\Delta V/V$ (1 mA)$\rvert$ depending on type
ESD air discharge	IEC 61000-4-2	Test voltage: up to 15 kV Number of test pulses: 20 Polarity: +/- Discharge network: 150 pF, 330 Ω	$\lvert\Delta V/V$ (1 mA)$\rvert$ depending on type

Environmental tests

Test	Standard	Test method/conditions	Criteria
High-temperature life test	MIL-STD-202F, method 108A, condition D	Temperature: $T_{op,max}$ Duration: 1000 h Applied voltage: $V_{DC,max}$	$\|\Delta V/V$ (1 mA)$\| \leq 10\%$
Fast temperature cycling (thermal shock)	IEC 60068-2-14, test N_a	Minimum temperature: LCT Maximum temperature: UCT Dwell time: 15 min Transfer time: < 30 s Number of cycles: depending on type	$\|\Delta V/V$ (1 mA)$\| \leq 10\%$
Damp heat, steady state	IEC 60068-2-3	Temperature: 40 °C Humidity: 93 % r.h. Duration: 56 days Applied voltage: $0.1 \cdot V_{DC,max}$	$\|\Delta V/V$ (1 mA)$\| \leq 10\%$

Mechanical strength tests

Test	Standard	Test method/conditions	Criteria
Bord flex		Deflection: 2 mm Duration: 60 s	$\|\Delta V/V$ (1 mA)$\| \leq 10\%$ $\|\Delta C/C_0\| \leq 10\%$
Terminal strength	IEC 60068-2-21 U_{e3}	Shear force applied to component soldered on PCB	Shear force: ≥ 10 N

2.3 Tests of SMD disk varistors (CU)

The following tests for SMD varistors, monolithic (CU) varistors are performed according to IEC 60068.
Preconditioning: reflow soldering on PCB.
After testing a visual check is performed. Criteria: no visible damage of component.

Pulse strength tests

Test	Standard	Test method/conditions	Criteria
Surge current derating, 8/20 µs	IEC 61000-4-5	Surge current (8/20 µs), unipolar, amplitude corresponding to derating curve for 20 µs Number of pulses: 1	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$ (measured in direction of surge current)
Load dump	ISO 7637-2	Number of pulses: 10 Pulse interval: 60 s Pulse duration: 500 ms	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 15\%$ (measured in direction of load)

Environmental tests

Test	Standard	Test method/conditions	Criteria
High-temperature life test	MIL-STD-202F, method 108A, condition D	Temperature: $T_{op,max}$ Duration: 1000 h Applied voltage: $V_{DC,max}$	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$
Fast temperature cycling (thermal shock)	IEC 60068-2-14, test N_a	Minimum temperature: LCT Maximum temperature: UCT Dwell time: 15 min Transfer time: < 30 s Number of cycles: depending on type	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$
Damp heat, steady state	IEC 60068-2-3	Temperature: 40 °C Humidity: 93 % r.h. Duration: 56 days Applied voltage: $0.1 \cdot V_{DC,max}$	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$
High-temperature exposure	IEC 60068-2-2 Ba	Temperature: UCT Duration: 1000 h Applied voltage: unpowered	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$

Mechanical strength tests

Test	Standard	Test method/conditions	Criteria
Bump/mechanical shock	IEC 60068-2-29 Eb	Pulse duration: 6 ms Max. acceleration: 400 m/s^2 Number of bumps: 4000 Pulse: half sine	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 5\%$
Vibration	IEC 60068-2-6 Fc	Frequency range: 10 ... 55 Hz Amplitude: 0.75 mm or 98 m/s^2 Duration: 6 h (3 x 2 h) Pulse: sinewave	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 5\%$
Board flex		Deflection: 2 mm Duration: 60 s	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$

2.4 Tests of leaded transient voltage/RFI suppressors

The following tests for leaded varistors (SHCV) are performed according to IEC 60068.
After testing a visual check is performed. Criteria: no visible damage of component.

Pulse strength tests

Test	Standard	Test method/conditions	Criteria
Surge current derating, 8/20 µs	IEC 61000-4-5	Surge current (8/20 µs), unipolar, amplitude corresponding to derating curve for 20 µs Number of pulses: 1	$\lvert\Delta V/V$ (1 mA)$\rvert \leq 10\%$ (measured in direction of surge current)
Load dump (only for specific automotive types)	ISO 7637-2	Number of pulses: 10 Pulse interval: 60 s Pulse duration: 500 ms	$\lvert\Delta V/V$ (1 mA)$\rvert < 15\%$ (measured in direction of load)

Reliability

Environmental tests

Test	Standard	Test method/conditions	Criteria
High-temperature life test	MIL-STD-202F, method 108A, condition D	Temperature: $T_{op,max}$ Duration: 1000 h Applied voltage: $V_{DC,max}$	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$
Fast temperature cycling (thermal shock)	IEC 60068-2-14, test N_a	Minimum temperature: LCT Maximum temperature: UCT Dwell time: 15 min Transfer time: < 30 s Number of cycles: depending on type	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$
Damp heat, steady state	IEC 60068-2-3	Temperature: 40 °C Humidity: 93 % r.h. Duration: 56 days Applied voltage: $0.1 \cdot V_{DC,max}$	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$
High-temperature exposure	IEC 60068-2-2 Ba	Temperature: UCT Duration: 1000 h Applied voltage: unpowered	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 10\%$ $\lvert\Delta C/C_0\rvert \leq 10\%$

Mechanical strength tests

Test	Standard	Test method/conditions	Criteria
Bump/mechanical shock	IEC 60068-2-29 Eb	Pulse duration: 6 ms Max. acceleration: 400 m/s^2 Number of bumps: 4000 Pulse: half sine	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 5\%$ $\lvert\Delta C/C_0\rvert \leq 5\%$
Vibration	IEC 60068-2-6 Fc	Frequency range: 10 ... 55 Hz Amplitude: 0.75 mm or 98 m/s^2 Duration: 6 h (3 x 2 h) Pulse: sinewave	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 5\%$ $\lvert\Delta C/C_0\rvert \leq 5\%$
Terminal strength	IEC 60068-2-21 U_{e3}	Force applied to the terminal in direction of its axis	$\lvert\Delta V/V\ (1\ mA)\rvert \leq 5\%$ $\lvert\Delta C/C_0\rvert \leq 5\%$ No break of solder joint, no wire break

Note for automotive application:
Especially for automotive applications EPCOS performs qualification based on AEC−Q200, Rev. C. In term of PPAP request test data of representatives of product family will be delivered.

3 Approvals

EPCOS varistors have received the following certifications:

Underwriters Laboratories, Inc.

UL 1449 Transient voltage surge suppressors: File E97877
SMD types CU series

Canadian Standards Association (CSA)

Class 2221 01 Accessories and Parts for Electronic Products
Metal oxide varistors, for use as across-the-line transient protectors: Master contract No. 175 282
SMD types CU series, voltage classes ≥ K130