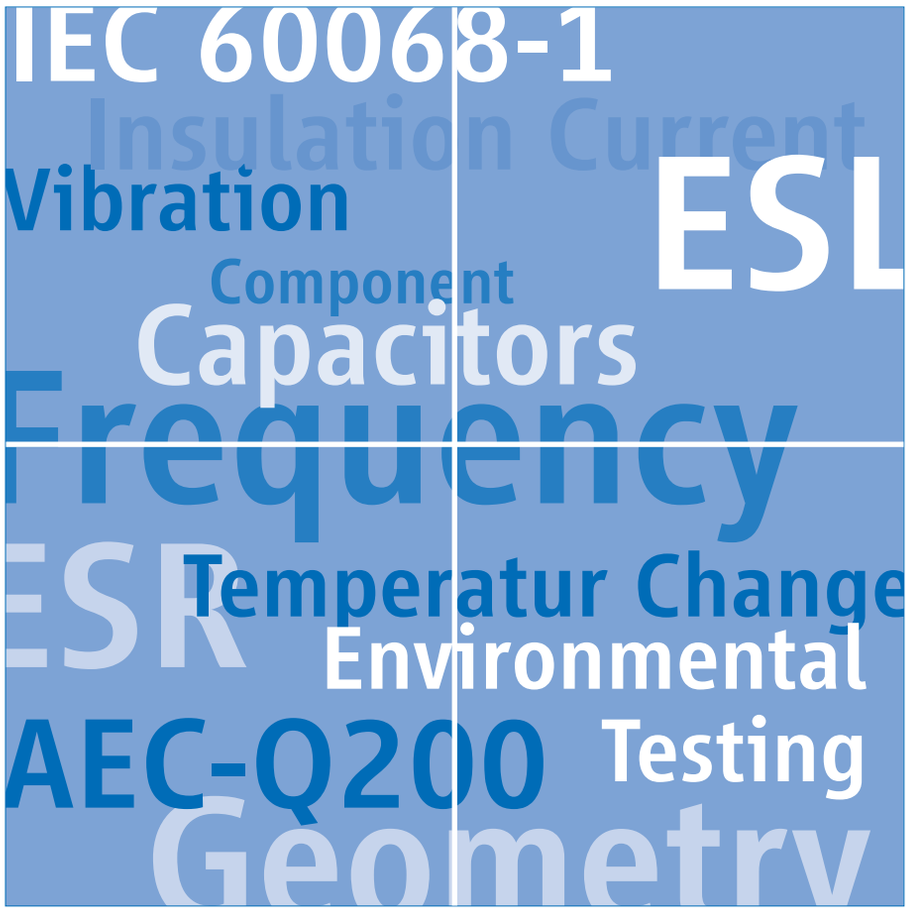
ZVEI:
Die Elektroindustrie

Basic Qualification of DC-Link Capacitors for Automotive Use

General Requirements, Test Conditions and Tests



German Electrical and Electronic Manufacturers' Association

ZVEI:
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Imprint

Basic Qualification of DC-Link Capacitors for Automotive Use

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Preface

This requirements document was created by the "ZVEI/ECPE Film Capacitors Core Group" working group with representatives from the automotive, the device and the capacitor manufacturers.

This requirements document makes no claim to completeness. Automotive manufacturers and device manufacturers are free to request additional state-of-the-art tests at any time.

As the individual manufacturers may make changes, only the company standards of the respective manufacturers created on the basis of this requirements document shall apply.

Any deviations from this requirements document are listed on the cover sheet of the company standards (in justified exceptional cases, deviations may be represented in the body of the standard in italics). If, in individual cases, modifications to individual test sections are required, such modifications shall be agreed upon separately between the departments responsible of the manufacturer and the supplier.

Table of Content

1. Scope of Application

This document specifies requirements, test conditions and tests to validate characteristics including the service life of application-specific film capacitors for use in motor vehicle components.

The requirements, test conditions and tests listed in this document largely relate to application-specific film capacitors developed for use in motor vehicle power electronics for the application as a DC-link capacitor in the intermediate circuit of the 48 V on-board electrical system or of HV applications.

Power electronics in the motor vehicle shall be tested in accordance with the environmental qualification standards of the vehicle manufacturers. Because the AEC-Q200 is not applicable for the capacitors considered here, this requirements document defines a set of tests to ensure the basic suitability of the capacitor for this use.

A vehicle with an electric power train is typically described with the following design service life parameters.

The tests in this document do not replace the tests specified in the Component Requirement Specifications for complete vehicle components or additional or deviating further requirements, test conditions and tests described therein.

This document contains no tests to validate the thermal interface between capacitors, power electronics and the cooling system on the component level.

The qualification requirements shall be expanded or adapted for the application of technologically innovative designs if necessary. The content and scope of supplements shall therefore be specified and documented in coordination between the responsible parties prior to sourcing.

Service life	15 years
Mileage	300000 km
Operating hours, driving	8000 h
Operating hours, charging/ pre-conditioning	30000 h (22000 h charging + 8000 h vehicle pre-conditioning)

Table 1: Example for a design service life

2. Overview

The tests described in the following are intended to validate the characteristics and service life of capacitors for use in the vehicle.

The basis of the specified tests are the currently-known failure mechanisms and the motor vehicle-specific application profiles of power electronics.

The validation includes:

Electrical characterisation (frequency-dependent)

- E-01 Capacitance
- E-02 Insulation resistance
- E-03 ESR
- E-04 ESL
- E-05 Insulation strength to surrounding area (e.g. housing)

Mechanical characterisation

- M-01 Geometry
- M-02 Visual inspection

Environmental tests / exposure tests

- B -01 Thermal shock
- B-02 Damp heat, steady state
- B-03 High temperature
- B-04 Vibration
- B-05 Charge/discharge test
- B-06 Short-circuit test

The characterisation measurements are intended to determine the basic functional characteristics and mechanical data of component elements. They shall be performed before, during and after the test.

The environmental tests simulate the exposure of components in the vehicle, and thereby, of the component element.

3. References to Standards

The documents cited in the following are required for the application of this document. Only the issue referred to applies in the case of dated references. The last issue of the document (including all changes) to which reference is made applies.

Standard	Abstract
ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories
IEC 60068-1	Environmental influences; Part 1: General and guidance
IEC 60068-2-2	Environmental testing; Part 2: Tests; Test B: Dry heat
IEC 60068-2-14	Environmental testing; Part 2: Tests; Test N: Change of temperature
IEC 60068-2-47	Environmental testing; Part 2-47: Tests; Mounting of specimens for vibration, impact and similar dynamic tests
IEC 60068-2-64	Environmental testing; Part 2-64: Tests; Test Fh: Vibration, broadband random and guidance
IEC 60068-2-78	Environmental testing; Part 2: Tests; Test Cab: Damp heat, steady state
IEC 60384-1	Fixed capacitors for use in electronic equipment – Part 1: Generic specification
IEC 61071	Capacitors for power electronics

Table 2: References to standards

4. Terms and Definitions

4.1 Terms

Component element	A capacitor in the sense of section 1.
Component	Complete device, control unit or mechatronic (with housing)
System	Functionally linked components, e.g. power train consisting of electric machine, power electronics, control unit and sensors.
Device under test	The component element to be tested, system or the component to be tested.
Vehicle preconditioning	Vehicle climate control prior to departure using energy from the mains supply

Table 3: Terms

4.2 Abbreviations

C	Capacitance
$C_{initial}$	Initial capacitance on the new part
C_{rated}	Rated capacitance
ΔC	Measured change in capacitance after exposure
ΔT	Rise or change in temperature in general
ESL	Equivalent series inductance
ESR	Equivalent series resistance
f	Frequency
HV	High voltage
I	Current
I_{iso}	Insulation current
R_{iso}	Insulation resistance
RH	Relative humidity
T_{RT}	Room temperature
T_{amb}	Ambient temperature capacitor
T_{max}	Maximum specified operating temperature when de-energised, thermal equilibrium, (upper category temperature; data sheet information for the component element)
T_{min}	Minimum ambient temperature (lower category temperature, typically -40 °C)
tanδ	Loss factor
U	Voltage

U_{rated}	Rated voltage of a capacitor (labeling, data sheet)
U_{test}	Test voltage
$(dU/dt)_{pulse}$	Set value for charge/discharge test
$(dU/dt)_{short}$	Set value for the short-circuit test
U_{TC}	Isolation voltage of the connections (T – Terminal) to the housing (C – Case)

Table 4: Abbreviations

4.3 Standard Tolerances

Tolerances refer to the set value and the measured value. Ensure that the specified tolerances are complied with independent of the tolerances of the test system. If no other tolerances are specified in the individual tests, use the tolerances from Table 5 or Table 6.

If two tolerance values are specified, the first value listed specifies the upper tolerance and the second value listed specifies the lower tolerance of the value range.

Frequencies	± 1 %
Temperatures	± 2 °C
Indirectly determined temperatures	± 5 °C
Humidity	± 5 %
Times	+ 5 %; – 0 %
Voltage	± 2 %
Currents	± 2 %

Table 5: Definitions of standard tolerances for set values

Insulation resistance	- 5 %
Capacitance	± 0,5 %
Voltage	± 0,5 %
Currents	± 0,5 %

Table 6: Definitions of accuracy for measured values

4.4 Standard Values

Unless otherwise specified, the standard values for measurement in accordance with Table 7 shall apply.

Room Temperature	T_{RT} defined as 23 °C ± 5 °C
Humidity	RH = 25 % to 75 % relative humidity (in accordance with IEC 60068-1)
Test temperature	T_{RT}

Table 7: Definitions of standard values

4.5 Thermal Equilibrium

A component exposed to a constant ambient temperature under defined operating conditions is regarded as continuous-temperature controlled when the temperature of any part of the component has not deviated from the target temperature by more than 5 K at any point in time.

The time until this thermal equilibrium is complete shall be defined experimentally by the manufactures and specified in the testing documentation. In case of temperature cycling tests, after reaching the specified temperature benchmark value for continuous-temperature control, the units under test shall additionally be held for a defined time to allow mechanical stress to place strains on the components. This additional holding time is specified for the respective test.

4.6 Sampling Rates and Measured Value Resolutions

The sampling rate and bandwidth of the measuring system shall be adapted to the respective test. All measured values with all maximum values (peaks) shall be recorded.

The resolution of the measured values shall be adapted to the respective test. It shall be guaranteed that voltage peaks that occur do not lead to overflow or are not measurable if the resolution is too low. Data reduction/abstraction (e.g. limit value monitoring) must not suppress anomalies.

When the measured values for the lifetime tests are defined, it shall be ensured that the measured values are recorded with sufficient granularity with respect to the expected lifetime to ensure that the End-of-Life can be determined reliably and precisely.

4.7 Parameter Test

The parameter test is intended for the characterisation of the electrical and mechanical characteristics of the units under test before (to ensure that only faultless units under test are entered into qualification tests) and after the individual test sequences. It should yield information about the characteristic parameters of the capacitors, which may vary due to variations in production and the stress they are exposed to during the individual tests. Unless otherwise stated, the individual test steps of the parameter tests shall be conducted, documented and the deviations from the specified tolerances evidenced before and after the individual test respectively.

The objective of the measurements and tests is to:

- ensure the absence of defects of all units under test
- ensure the fulfillment of all the requirements
- prove the functional behavior and the accuracy of all functions
- characterise the units under test

4.8 Physical Analysis

The physical analysis is a detailed analysis of failed parts.

The physical analysis of successfully tested parts is performed according to individulal agreement between parties.

Proceed as follows:

- perform and document the non-destructive tests/ analyses
- identify/coordinate further tests/analyses with the specialist client department responsible on the basis of the results of the non-destructive tests/ analyses
- perform and document the destructive tests/ analyses
- archive the specimens and damaged parts

The change in the unit under test comparable with initial conditions shall be evaluated.
The results shall be documented in the test report.

4.9 Restriction on Performance

The test lab shall be organised and operated in accordance with DIN EN ISO/IEC 17025. All test equipment used for measuring shall be calibrated in accordance with DIN EN ISO/IEC 17025 (or as is specified or recommended by the manufacturer), and based on the National Institute of Standards (e.g. in Germany PTB; National Metrology Institute of Germany) or another equivalent national test lab. The test devices, workshop equipment, installations and testing procedures used must not distort the behavior of the unit under test. These shall be documented in the test report together with the precisions and the calibration expiration date.

5. Electrical Characterisation

The objective of the electrical characterisation is to determine changes in the electrical parameters due to the tests carried out. The measurements shall therefore be performed in the identical manner before and after the tests.

5.1 E-01 Capacitance

5.1.1 Purpose

The measurement is intended to determine the capacitance of the unit under test.

5.1.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}
Test voltage	Small signal measurement
Frequency	100 Hz or 120 Hz

5.2 E-02 Insulation Resistance Measurement

5.2.1 Purpose

The measurement is intended to determine the insulation resistance of the unit under test.

5.2.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT} and T_{max}
Test voltage	Rated voltage of the capacitor
Frequency	0 Hz (direct current)
Measurement time	60 s after the test voltage is reached

5.3 E-03 ESR

5.3.1 Purpose

The measurement is intended to determine the equivalent series resistance of the unit under test at the electrical connections in accordance with the measuring point in the data sheet.

5.3.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}
Test voltage	Small signal measurement
Frequency	1, 10, 20 kHz or in accordance with the data sheet

5.4 E-04 ESL

5.4.1 Purpose

The measurement is intended to determine the equivalent series inductance of the unit under test at the electrical connections in accordance with the measuring point in the data sheet.

5.4.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}
Test voltage	Small signal measurement
Frequency	1 MHz

5.5 E-05 Insulation Strength against the Environment

5.5.1 Purpose

The measurement is intended to test the insulation strength of the unit under test against the environment. If the unit under test has a metal housing, the test shall be performed between this housing and the electrically interconnected connections. If no metal housing is present, the external surfaces shall be covered with a metallic housing replica and tested. The electrical connections of the unit under test shall have cutouts in the housing replica in compliance with the required creapage distance and clearance.

5.5.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}
Test voltage U_{TC}	$U_{rated} \leq 60$ V: 750 V $U_{rated} \leq 500$ V: 2820 V $U_{rated} > 500$ V: $\sqrt{2}$ x (2 x rated voltage of the capacitor + 1 kV)
Frequency	0 Hz (direct current)
Duration of test	60 s in each polarity

6. Mechanical Characterisation

6.1 M-01 Geometry

6.1.1 Purpose

The measurement is intended to determine the geometric data of the unit under test related to the drawing. All measured values must be within the specified tolerances.

At least length, width, height as well as the position of the electrical and mechanical connections shall be measured for the mechanical characterisation.

6.1.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}

6.2 M-02 Visual Inspection

6.2.1 Purpose

This test is intended to evaluate the appearance of the unit under test.

The visual inspection should detect anomalies such as cracking in the potting and housing, corrosion of the connections, etc. A photograph shall be included in the test report in a resolution corresponding to the current state-of-the-art.

6.2.2 Test

The measurement shall be carried out with the following parameters:

Test temperature	T_{RT}

7. Environmental and Exposure Tests

7.1 B-01 Thermal Shock

7.1.1 Purpose

This test simulates the component element's thermal exposure to shock-like temperature changes during vehicle operation. It is intended to validate the component element in terms of fault profiles, such as cracking, delamination and short circuits due to thermal changes.

7.1.2 Test

The test shall be performed in accordance with DIN EN 60068-2-14 with the two-chamber method with the following parameters:

Lower test temperature	-40 °C
Upper test temperature	T_{max}
Number of cycles	1000
Holding time	At least 5 min after thermal equilibrium
Voltage	None

7.2 B-02 Damp Heat, Steady State

7.2.1 Purpose

This accelerated test simulates the exposure of the component element to damp heat during the vehicle service life. The test is intended to validate the quality and reliability of the component element to faults caused by damp heat such as corrosion, migration/ dendrite growth, swelling and degradation of plastics.

7.2.2 Test

The test shall be performed in accordance with DIN EN 60068-2-78 with the following parameters:

Test temperature	65 °C
Test humidity	93 % RH, no condensation
Duration of test	1750 h
Test voltage	1700 h without U_{rated} 50 h of the test time with U_{rated} at the end of the test time

7.3 B-03 High Temperature

7.3.1 Purpose

This accelerated test simulates the thermal exposure of the component elements during the vehicle service life. It is intended to validate the quality and reliability of the component element with respect to faults that occur due to thermal exposure such as diffusion, migration and oxidation.

7.3.2 Test

The test shall be performed in accordance with DIN EN 60068-2-2 with the following parameters:

Test temperature	T_{max}
Duration of test	2500 h
Test voltage	U_{rated}

7.4 B-04 Vibration

7.4.1 Purpose

This test simulates the exposure of the component element to vibrations during automotive operation. It is intended to validate the component element's durability with regards to fault profiles such as component detachment and material fatigue.

7.4.2 Test

The units under test shall be fixed to the designated areas and the electrical connections shall be connected close to reality. See DIN EN 60068-2-47 for guidance. The test shall be performed in accordance with DIN EN 60068-2-64 with the following parameters:

Test temperatur	T_{RT}	
Exitation	Broadband random vibration	
Test duration for each spatial axis	8 h	
RMS value of acceleration	30,8 m/s²	
Test voltage	no voltage	
Vibration profile see figure below	Frequency in Hz	Power density spectrum in $(m/s^2)^2/Hz$
	5	0.884
	10	20
	55	6.5
	180	0.25
	300	0.25
	360	0.14
	1000	0.14
	2000	0.14

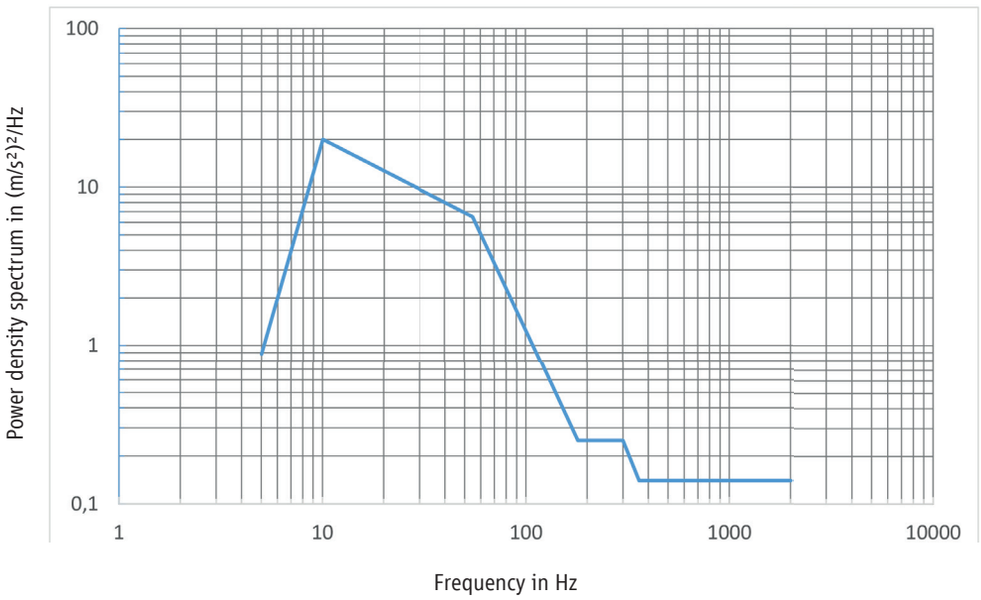


Figure 1: Vibration profile

7.5 B-05 Charge/ Discharge Test

7.5.1 Purpose

These tests simulate the charging and discharging behavior of the capacitor. This test shall detect possible damages to the contacts inside the capacitor. $(dU/dt)_{pulse}$ shall be set in accordance with the data sheet using external circuitry.

7.5.2 Test

The test shall be carried out in accordance with IEC 60384-1 with the following parameters:

Charging voltage	Rated voltage
Number of cycles	10000 (charge/discharge)
$(dU/dt)_{pulse}$	in accordance with the data sheet
Test temperature	T_{RT}

7.6 B-06 Short-Circuit Test

7.6.1 Purpose

These tests simulate the short circuit behavior of the capacitor. $(dU/dt)_{short}$ shall be set in accordance with the data sheet using charging voltage.

7.6.2 Test

The test shall be carried out in accordance with IEC 61071 with the following parameters:

Charging voltage	Rated voltage to reach $(dU/dt)_{short}$ while discharging
Number of cycles	5
Condition	2 minutes pause between charges
Test temperature	T_{RT}
$(dU/dt)_{short}$	in accordance with the data sheet

7.7 Acceptance Criteria:

The following parameters and their drift must be determined before and after each environmental or exposure test

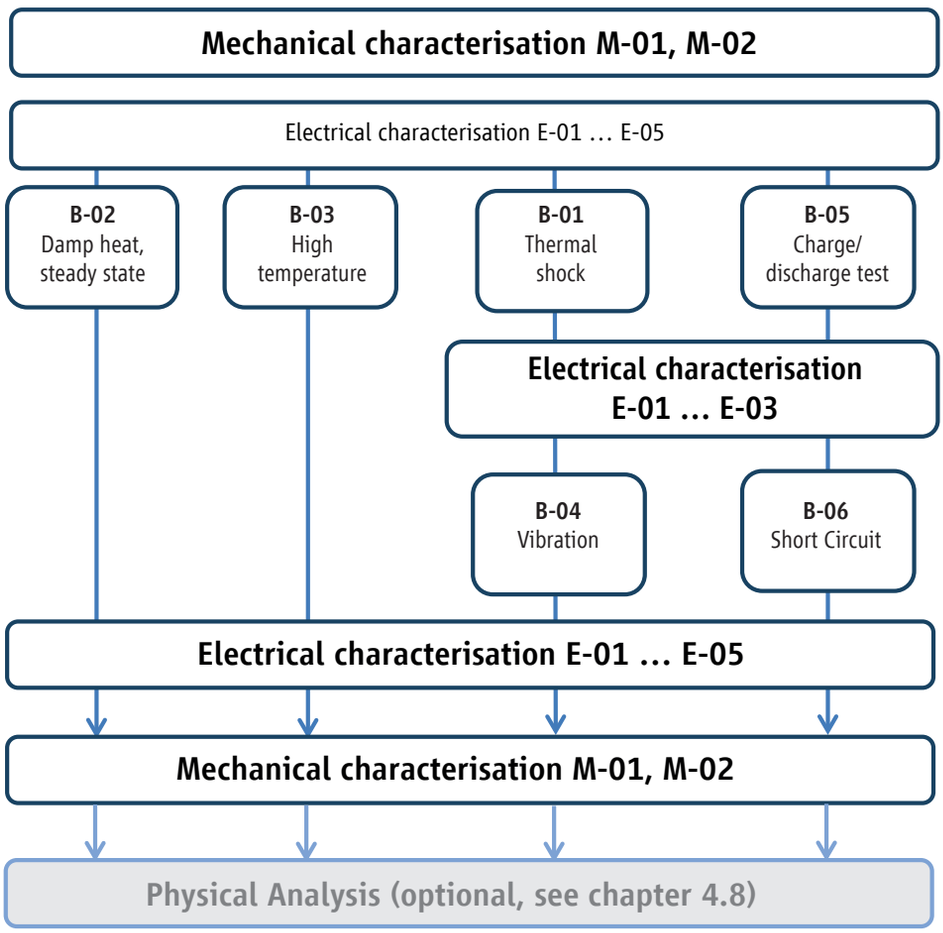
1. Capacitance
2. ESR
3. Insulation resistance

All values must lie within the specifications in the data sheet. The data sheet should contain: rated values and their limits for the delivery condition and regarding the service life (the limits for the delivery condition and service life may be different).

The parameters shall be determined in accordance with Chapter 5, Electrical Characterisation.

8. Test Sequence Diagram

The test sequence is run through 6 parts per path.



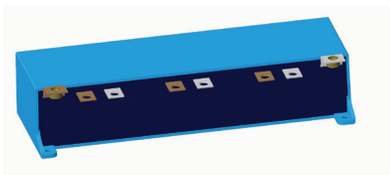
Appendix A

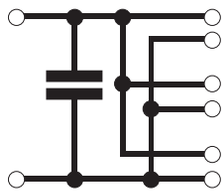
Example Data Sheet

Data sheet

Capacitor: ABCDEF 05507a000

Customer: _____





Characteristic values:

Parameters	Condition[1)]	Min.	Type	Max.	Unit
Rated capacitance C_{rated}			500		µF
C_{rated} tolerance		-5		10	%
Rated voltage U_{rated}	$T_{min} \leq T_{amb} \leq T_{max}$			500	VDC
Insulation resistance R_{iso} between the connections	$U = U_{rated}$; 60 s	100			MΩ
Isolation voltage U_{TC} connections to the housing	no breakdown; 60 s per polarity	3,000			VDC
ESR 1 kHz				0,4	mΩ
ESR 10 kHz				1,0	mΩ
ESR 20 kHz				1,4	mΩ
ESL 1 MHz				15	nH
T_{max} (C charged)	0A; U_{rated}			110	°C
I_{rated} (endurance test)	Convection cooling; $T_{amb.}$ = 80 °C; 20 kHz sinusoidal; no additional heat input via thermal conduction or radiation			150	Arms
dU/dt_{pulse} (x 1,000)				20	V/µs
dU/dt_{short} (x 5)				100	V/µs
Length			250		mm
Width			70		mm
Height			50		mm
Weight			1,250		g

[1)] $T_{amb} = T_{RT}$, unless otherwise specified

Data sheet

Capacitor: ABCDEF 05507a000

Customer: _____

Performance in the ZVEI environmental/exposure tests:

B-01 Thermal shock + B-04 Vibration

Performance

$\lvert\Delta C/C_{initial}\rvert$ 120 Hz	ESR 1 kHz	ESR 10 kHz	ESR 20 kHz	ESL 1 MHz	R_{ISO} DC
< 5 %	< 2 mΩ	< 4 mΩ	< 6 mΩ	< 30 nH	> 50 MΩ

B-02 high damp heat, steady state

Performance

$\lvert\Delta C/C_{initial}\rvert$ 120 Hz	ESR 1 kHz	ESR 10 kHz	ESR 20 kHz	ESL 1 MHz	R_{ISO} DC
< 4 %	< 1 mΩ	< 2 mΩ	< 3 mΩ	< 25 nH	> 50 MΩ

B-03 High temperature

Performance

$\lvert\Delta C/C_{initial}\rvert$ 120 Hz	ESR 1 kHz	ESR 10 kHz	ESR 20 kHz	ESL 1 MHz	R_{ISO} DC
< 3 %	< 1,5 mΩ	< 3 mΩ	< 4,5 mΩ	< 25 nH	> 50 MΩ

B-05 Charge/discharge test + B-06 Short-circuit test

Performance

$\lvert\Delta C/C_{initial}\rvert$ 120 Hz	ESR 1 kHz	ESR 10 kHz	ESR 20 kHz	ESL 1 MHz	R_{ISO} DC
< 5 %	< 1 mΩ	< 2 mΩ	< 3 mΩ	< 15 nH	> 50 MΩ

Additional manufacturer specifications

Appendix B

General

Short product and technology cycles as well as new environmental regulations ("Pb-free", flame retardants, ….) frequently result in process and material changes of components, printed circuit boards, assembly techniques and circuit layout which have to be evaluated.

The ZVEI "Guideline for Customer Notifications of Product and /or Process Changes (PCN) of Electronic Components specified for Automotive Applications" describes an appropriate methodology for dealing with changed electronic components. The table below in this guideline presents recommendations for how to assess typical changes of electronic components. These recommendations promote an open risk-based discussion between supplier and customer regarding qualifications.

This document adapts the structure of the DeltaQualificationMatrices developed by the ZVEI Working Group "PCN-Methodology", but it is not a part of the official documentation (Link to the official PCN-Documents of the ZVEI: https://www.zvei.org/PCN). Actual contents represents state-of-the-art technology and does not claim to be comprehensive. Deviation from proposed guideline shall be mutually agreed as customer specific requirements have to be considered.

Basic Qualification-Table Application (completion by component manufacturer)

a) This table has to be used for changes only. The table is not applicable for new product or special qualifications (for instance for encapsulation of module).

b) If a change is not listed in this table, the qualification plan has to be defined and agreed between customer and supplier.

c) In case of deviations from tests, which should be considered this should be notified and commented by the component manufacturer in the area "Reason for exception of tests". Test results in form of generic data (G) are allowed when notified and justified.

Evaluation Levels are categorized as follows

- "C: Component level": The evaluation of a change at component level by the component manufacturer is sufficient. Generic data from other relevant evaluations can be used.
- "A: Application level": The intended change described in the PCN may influence the properties of the application (e.g. Electronic Control Unit). In addition to the evaluation under C the influence of the change in the application is evaluated by suitable investigations by the customer. The scope of the evaluation has to be aligned with the OEM. It has to be considered whether the application / assembly requirements are already sufficiently safeguarded by other qualifications (application specific risk assessment).
- "*: will become A/C after decision": is subject to a case by case evaluation.
- "**: Not relevant for qualification matrix": Changes which fulfill neither A nor C definitions.

Important Notes

- Tests identified by the table have to be considered and checked if they are necessary to assess the specific change. Test modifications or generic data have to be justified in detail.
- Categories, comments and notes need attention, as they provide important hints and limitations.

Disclaimer:
This document adapts the structure of the DeltaQualificationMatrices developed by the ZVEI Working Group "PCN-Methodology", BUT IT IS NOT PART OF THE OFFICIAL DOCUMENTATION (Link to the official PCN-Documents of the ZVEI: https://www.zvei.org/PCN).

I = Information Note required
P = PCN required
-- = Not required

	Assessment of impact regarding following aspects - contractual agreements - technical interface of processability/manufacturability of customer - form, fit, function, quality performance, reliability	Remaining risks on Supply Chain?		Understanding of component experts	Examples to explain	Evaluation level A / C A: Application level C: Component level *: will become A/C after decision **: Not relevant for qualification matrix	Further applicable conditions	Line evaluation (can be evaluated by data or audit/on site check)	Check of specification (for raw material only)	Thermal Shock (linked with B-04 Vibration)	Damp Heat, Steady State	High Temperature	Vibration (linked with B-01 Thermal Shock)	Charge/Discharge Test (linked with B-06 Short-Circuit Test)	Short-Circuit Test (linked with B-05 Charge/Discharge Test)	Geometry	Visual Inspection	Electrical Characterization	Remarks
	Type of change	No	Yes							B-01	B-02	B-03	B-04	B-05	B-06	M-01	M02	E-01 bis E-05	
	DC-Link film capacitors																		
	Any																		
DCL-FLM-AN-01	Any change with impact on special customer characteristics/contractual agreements	P	P		Not relevant for technical evaluation.	**		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-AN-02	Any change with impact on technical interface or processability/manufacturabiliy of customer	P	P		Technical interface means component terminals.	A		-	-	-	-	-	-	-	-	-	-	-	
	DATASHEET / SPECIFICATION																		
DCL-FLM-DS-01	Change of electrical/mechanical parameters or drawing	P	P	Change of application relevant information **Not included:** Editorial changes.	e.g. tighten of electrical parameter distribution	A	Risk assessment depending on change for each application.	-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-DS-02	Correction of data sheet / specification	I	P	No technical change of the product, only correction in description (wording, drawing, …) **(I):** In case of editorial changes. **(P):** In case of impact on product integrity.	e.g. data sheet correction because of new information about component behavior	**		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-DS-03	Specification of additional parameters	I	P	Description of a new not previously covered parameter. No technical change of the product. **(I):** no influence **(P):** Risk assessment depending on change for each application to provide evidence of additional parameters (stat. evaluation)	e.g. adding new (tested) parameter.	C		-	-	-	-	-	-	-	-	-	-	-	
	MATERIAL OR SUPPLIER																		
DCL-FLM-MA-01	Change of material composition or change of supplier - Sealing Compound	P	P	Typicaly change within epoxy **or** PU sealing without effect to mechanical properties. **Note:** Change from epoxy sealing into PU sealing (both direction) will lead to generate a new product.	e.g. change of epoxy or PU composition	C	**A: in combination with DCL-FLM-DS-01 or if change of sealing compound with effect to mechanical properties.**	-	●	●	●	●	●	●	●	●	●	●	
DCL-FLM-MA-02	Change of material composition or change of supplier - Package	P	P	Change material of package	Change material of package, e.g. change from PBT to PPS e.g. change of glas fiber ratio	C		-	●	●	●	●	●	-	-	●	●	●	
DCL-FLM-MA-03	Change of material composition or change of supplier - Terminals	P	P	Change of Terminals (e.g. Busbar) **Note:** If change of lead frame material leads to an ESR change, than change of data sheet **(DCL-FLM-DS-01**) has to be respected.	e.g. change of basis material from Cu to Fe e.g. change of finishing from SnPb to Sn	A	**A: in combination with DCL-FLM-DS-01**	-	●	●	●	-	●	●	●	●	●	●	
DCL-FLM-MA-04	Change of material composition or change of supplier - Raw Material for Metal Spray (Schoop)	P	P	Change of Raw Material for Metal Spray (Schoop): Use different material for metal spray process for boxed and naked types	e.g. change of spray metal wire	C		-	●	●	●	●	●	●	-	-	-	●	
DCL-FLM-MA-05	Change of material composition or change of supplier - Base film / dielectric material	P	P		e.g. change of additives (<1%) of film composition (same raw material)	C		-	●	●	●	●	-	●	●	-	-	●	
DCL-FLM-MA-06	Change of material composition or change of supplier - Metallization	P	P		e.g. change from Al to Zn or Al-Zn ratio	C		-	●	●	●	●	-	●	●	-	-	●	
DCL-FLM-MA-07	Any changes of further materials or change of supplier	I	P			C	***2: test to be mutually agreed**		●	*2	*2	*2	*2	*2	*2	*2	*2	*2	
	DESIGN																		
DCL-FLM-DE-01	Changes of terminal (surface finish, shape, color, appearance or dimension structure - Busbar Dimensions / Thickness / Terminal Area)	P	P	Change of busbar dimension	e.g. change of drill holes, e.g. change of thickness of terminal	A	Visual inspection only on outside surface	-	-	●	-	-	●	●	●	●	●	●	
DCL-FLM-DE-02	Change of mechanical dimensions	P	P	Change of fix points of terminations or housing	e.g. measures, drill holes	A		-	-	-	-	-	●	-	-	●	●	-	
DCL-FLM-DE-03	Changes of inner construction - Inner Connection	P	P	Change of inner connection	e.g. change from soldered connection to welded connection e.g. changed connection to schoop layer e.g. change of inner construction of housing	C		-	-	●	●	-	●	●	●	-	-	●	
DCL-FLM-DE-04	Changes of appearance	I	P	Change of appearance. **(I):** Change in appaerance *without* impact on product integrity. **(P):** Change in appearance *with* impact on product integrity. **Note**: Marking on device is defined as seperate change (**DCL-FLM-PV-02**).	e.g. change or adding of colour on component	C	Check if MATERIAL is affected.	-	-	-	-	-	●	-	-	●	●	●	
DCL-FLM-DE-05	Changes of inner construction - Film	I	P	Change of film design	e.g. change to a different film supplier/metallization profile	C	**A: in combination with DCL-FLM-DS-01**	-	●	●	●	●	-	●	●	-	-	B	
DCL-FLM-DE-06	Changes of inner construction - Insulation System	I	P	Change of inner insulation to protect winding element against housing.	e.g. change of potting material e.g. change of number of inner insulation layers (depending of insulation material thickness)	C		-	●	●	●	●	●	-	-	-	-	B	
DCL-FLM-DE-07	Changes of housing (surface finish, color, appearance)	I	P	Change of housing	e.g. change of surface	C		-	-	●	●	-	●	-	-	●	●	-	
	PROCESS																		
DCL-FLM-PR-01	Changes in process technology or manufacturing methods - Assembly	I	P	Change of resin filling or hardening process	e.g. change in resin filling process (mixing, sequences, potting, …) e.g. change in hardening process (temperature, time, …)	C		●	-	●	●	●	●	-	-	-	●	-	
DCL-FLM-PR-02	Changes in process technology or manufacturing methods - Terminal Attach	I	P	Change Terminal Attach Process to winding element	e.g. spraying e.g. welding / soldering	C		●	-	●	-	●	●	●	●	-	-	B	
DCL-FLM-PR-03	Changes in process technology or manufacturing methods - Winding	I	P	Change of winding, flattening or tempering process	e.g. change of tempering temperature	C		●	-	●	●	●	-	●	●	-	-	B	
DCL-FLM-PR-04	Tuning of process parameter within specification	-	P	Variation within process specification.	e.g. process optimization	C		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PR-05	Any further changes of process technology or manufacturing methods	I	P	change of process	e.g. change of machinery or tools	C	***2: test to be mutually agreed**		●	*2	*2	*2	*2	*2	*2	*2	*2	*2	
	PACKING / SHIPPING - NEW MATERIAL, CRITICAL DIMENSIONS																		
DCL-FLM-PN-01	Packing / shipping specification change (loosening of tolerances), carrier change, labelling, product marking	P	P	Change of packing specification.		**	customer specific agreement	-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PN-02	Dry pack requirements change	P	P	Change of drypack requirements.	e.g. change of MSL e.g. change in dry pack assurance (HIC, MBB)	**		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PN-03	Change of carrier (tray)	P	P	Change of carrier	e.g. change by material e.g. change by geometry.	**		-	-	-	-	-	-	-	-	-	-	-	
	PACKING / SHIPPING - VISUAL INSPECTION																		
DCL-FLM-PV-01	Change of labelling	I	P	Change of labelling	**(I)** e.g. additional information (RoHS stamp) **(P)** e.g. change of customer specific information	**		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PV-02	Change of product marking	I	P	Marking on device.	e.g. change of content of marking e.g. change of method of marking e.g. change of appearance of marking	**		-	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PV-03	Change of packing/shipping specification	P	P	Change in packing specification which does not described a change of dimensions or material of the packing.	e.g. change of documentation in packing specification	**		-	-	-	-	-	-	-	-	-	-	-	
	LOGISTICS / CAPACITY / TESTING - EQUIPMENT																		
DCL-FLM-EQ-01	Production from a new equipment/tool which uses a different technology or which due to its unique form or function can be expected to influence the integrity of the final product	P	P	Change in process technique which is not already covered above. **Note:** Significant changes affecting the product not covered by the table require also a PCN.	e.g. implementation of new machines	C	Perform reliability tests (*1) according to affected processes as per DCL-FLM-PR-01 to DCL-FLM-PR-04 (e.g. New winding machine requires DCL-FLM-PR-03)	●	-	*1	*1	*1	*1	*1	*1	-	*1	*1	
DCL-FLM-EQ-02	Production from a new equipment/tool which uses the same basic technology (replacement equipment or extension of existing equipment pool)	-	P	PCN required for dedicated equipment for sensitive component production.	e.g. extension of existing machine capacity	C	Perform reliability tests (*1) according to affected processes as per DCL-FLM-PR-01 to DCL-FLM-PR-04 (e.g. New winding machine requires DCL-FLM-PR-03)	●	-	*1	*1	*1	*1	*1	*1	-	*1	*1	
DCL-FLM-EQ-03	Change in final test equipment type that uses a different technology	P	P	Change of final test equipment which use different technology. PCN required for dedicated equipment for sensitive parameters.	e.g. change of tester platform	C		●	-	-	-	-	-	-	-	-	-	B	
	LOGISTICS / CAPACITY / TESTING - PROCESS FLOW																		
DCL-FLM-PF-01	Manufacturing site transfer or movement of a part of production process to a different location/site	P	P	Change of manufacturing site. **Note:** Reorganization inside one plant/site is not affected!	Movement or transfer of manufacturing site or process step(s) to a different location/site.	C		●	-	●	●	●	●	●	●	●	●	B	
DCL-FLM-PF-02	Elimination or addition of a manufacturing process step	I	P	Change of manufacturing process sequence.	e.g. washing / cleaning process e.g. change of order of processes	C		●	-	-	-	-	-	-	-	-	-	-	
DCL-FLM-PF-03	Elimination of final electrical measurement / test flow block	I	P	Reduction of final testing. PCN required for dedicated final test reductions for sensitive parameters.	e.g. elemination of a frequency within frequency dependent test.	C		-	-	-	-	-	-	-	-	-	-	-	
	LOGISTICS / CAPACITY / TESTING - Q-GATE																		
DCL-FLM-QG-01	Change of test coverage used by the supplier to ensure data sheet compliance (e.g., elimination/addition of electrical measurement/test flow block, relaxation/enhancement of monitoring procedure or sampling)	I	P	Change of test coverage.	e.g. change from 100% to sample inspection e.g. test flow block, reduction from three to two temperature measurements	C		-	-	-	-	-	-	-	-	-	-	-	
Tests, which should be considered for the appropriate process change.								-	-	-	-	-	-	-	-	-	-	-	
Tests, which should be considered for the appropriate process change after selection of condition table.								-	-	-	-	-	-	-	-	-	-	-	
Suppliers performed tests (mark with an 'X' for done or 'G' for generic)																			
Reason for exception of tests:																			

B = Comparative data (unchanged vs. changed) required

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