IEC 60384-22

Edition 4.0 2024-06
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

Fixed capacitors for use in electronic equipment – Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

IEC 60384-22:2024-06 CMV(en)

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CONTENTS

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This commented version (CMV) of the official standard IEC 60384-22:2024 edition 4.0 allows the user to identify the changes made to the previous IEC 60384-22:2019 edition 3.0. Furthermore, comments from IEC TC 40 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60384-22 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the document has been completely restructured to comply with the ISO/IEC Directives, Part 2 and to make it more useable; tables, figures and references have been revised accordingly; Annex X contains all cross-references of changes in clause/subclause numbers;
b) the requirements of reference temperature 25 °C has been added in Table 5, Table 9, Table 10, Table 12, Table 14 and Table 17;
c) the table of temperature characteristics of capacitance for the reference temperature 25 °C have been added in Table C.1, Table C.2 and Table C.3;
d) the requirement in 5.5.2 (visual examination) has been repeated in 5.9.3, 5.10.6, 5.11.4, 5.12.6, 5.13.8, 5.14.6 and 5.15.6;
e) the deflection D in the very robust designs has been added in 5.9.1;
f) Annex C has been changed informative into normative;
g) Clause D.5 (Test schedule for quality conformance inspection) has been newly added to withdraw the blank detail specification: IEC 60384-22-1.

The text of this International Standard is based on the following documents:

Draft	Report on voting
40/3120/FDIS	40/3139/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60384 series, published under the general title *Fixed capacitors for use in electronic equipment*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

1 Scope

This part of IEC 60384 is applicable to fixed unencapsulated surface mount multilayer capacitors of ceramic dielectric, Class 2, for use in electronic equipment. These capacitors have metallized connecting pads or soldering strips and are intended to be mounted on printed boards, or directly onto substrates for hybrid circuits.

Capacitors for electromagnetic interference suppression are not included but are covered by IEC 60384-14.

The object of this document is to ~~prescribe~~ specify preferred ratings and characteristics and to select from IEC 60384-1:2021 the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of capacitor. ~~Test severities and requirements prescribed in detail specifications referring to this sectional specification are of equal or higher performance levels; lower performance levels are not permitted.~~ Test severities and requirements specified in detail specifications referring to this document provide specific test severities and requirements of an equal or higher performance level. Further information on the conception of generic, sectional and detail specifications can be found in the Introduction of IEC 60384-1:2021. 1

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60063, *Preferred number series for resistors and capacitors*~~

~~IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*~~

IEC 60068-2-58~~:2015~~, *Environmental testing – Part 2-58: Tests – Test Td – Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*
~~IEC 60068-2-58:2015/AMD1:2017~~

IEC 60384-1:~~2016~~2021, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 61193-2:2007, *Quality assessment system – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

~~ISO 3:1973, *Preferred numbers – Series of preferred numbers*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60384-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
surface mount multilayer capacitor
multilayer capacitor whose small dimensions and nature or shape of terminations make it suitable for surface mounting in hybrid circuits and on printed boards

3.2
capacitor of ceramic dielectric, Class 2
capacitor that has a dielectric with a high permittivity and is suitable for by-pass and coupling applications or for frequency-discriminating circuits where low losses and high stability of capacitance are not of major importance

Note 1 to entry: The ceramic dielectric is characterized by a non-linear change of capacitance over the category temperature range (see Table 3).

3.3
subclass
<Class 2> maximum percentage change of capacitance within the category temperature range with respect to the capacitance at the reference temperature 20 °C or 25 °C

Note 1 to entry: The subclass may be expressed in code form (see Table 3 and Annex C).

3.4
category temperature range
ambient temperature range for which the capacitor has been designed to operate continuously

Note 1 to entry: This is given by the lower and upper category temperature (see Table 3 and Annex C).

3.5
rated temperature
T_R
maximum ambient temperature at which the rated voltage ~~may~~ can be continuously applied

3.6
rated voltage
U_R
maximum DC voltage that ~~may~~ can be applied continuously to a capacitor at any temperature between the lower category temperature and the rated temperature

Note 1 to entry: The maximum DC voltage is the sum of the DC voltage and peak AC voltage or peak pulse voltage applied to the capacitor.

3.7
category voltage
U_C
maximum voltage that can be applied continuously to a capacitor at its upper category temperature

4 Preferred ratings and characteristics

4.1 Preferred characteristics

Preferred climatic categories only shall be given in the preferred characteristics.

The capacitors covered by this document are classified into climatic categories in accordance with the general rules given in IEC 60068-1:2013, Annex A.

For reference temperature 20 °C, the lower and upper category temperatures and the duration of the damp heat, steady state test shall be chosen from the following:

- lower category temperature: −55 °C, −40 °C, −25 °C, −10 °C and +10 °C;
- upper category temperature: +70 °C, +85 °C, +100 °C, +125 °C and +150 °C;
- duration of the damp heat, steady state test (40 °C, 93 % RH): 4, 10, 21 and 56 days.

For reference temperature 25 °C, the lower and upper category temperatures shall be chosen from Table C.1 in Annex C. **2**

The severities of the cold and dry heat tests are the lower and upper category temperatures respectively.

NOTE The resistance to humidity resulting from the above climatic category is for the capacitors in their unmounted state. The climatic performance of the capacitors after mounting is greatly influenced by the mounting substrate, the mounting method (see 5.4) and the final coating.

4.2 Preferred values of ratings

4.2.1 Rated temperature (T_R)

The rated temperature is equal to the upper category temperature for capacitors with the upper category temperature not exceeding 125 °C, unless otherwise stated in the detail specification.

4.2.2 Rated voltage (U_R)

The preferred values of the rated voltage are the values of the R5 series of ISO 3. If other values are needed, they shall be chosen from the R10 series.

The sum of the DC voltage and the peak AC voltage or the peak-to-peak AC voltage, whichever is the greater, applied to the capacitor shall not exceed the rated voltage.

4.2.3 Category voltage (U_C)

The category voltage is equal to the rated voltage for capacitors with the upper category temperature not exceeding 125 °C. Any category voltages which are different from the rated voltage, for capacitors with the upper category temperature exceeding 125 °C or for high-voltage capacitors with rated voltages about 500 V, shall be given in the detail specification.

The preferred values of the category voltage at 125 °C upper category temperature for high volumetric capacitors with a rated voltage of 16 V and less and a rated temperature of 85 °C are given in Table 1.

Table 1 – Preferred values of category voltages

U_R	V	2,5	4	6,3	10	16
U_C	V	1,6	2,5	4	6,3	10

NOTE The numeric values of U_C are calculated by the following:

$$U_C = 0{,}63 \times U_R$$

4.2.4 Preferred values of nominal capacitance and associated tolerance values

4.2.4.1 Preferred values of nominal capacitance

Nominal capacitance values ~~shall~~ should be taken from ~~the number series of IEC 60063;~~ the E3, E6 and E12 series ~~are preferred~~ given in IEC 60063.

4.2.4.2 Preferred tolerances on nominal capacitance

See Table 2.

Table 2 – Preferred tolerances

Preferred series	Tolerance %	Letter code
E3 and E6	−20/+80	Z
	−20/+50	S
E6	± 20	M
E6 and E12	± 10	K

4.2.5 Temperature characteristic of capacitance

Table 3 ~~denotes with a cross the preferred values of~~ shows the temperature characteristic with and without DC voltage applied for the reference temperature 20 °C. The method of coding the subclass is also given; for example a dielectric with a percentage change of ±20 % without DC voltage applied over the temperature range from −55 °C to +125 °C will be defined as a dielectric of subclass 2C1.The temperature characteristics, category temperatures and corresponding codes for the reference temperature 25 °C are given in Annex C. The temperature range for which the temperature characteristic of the dielectric is defined is the same as the category temperature range.

Table 3 – Temperature characteristic of capacitance

Sub-class letter code	Maximum capacitance change within the category temperature range with respect to the capacitance at 20 °C measured with and without a DC voltage applied %		Category temperature range and corresponding number code					
			−55/+150 °C	−55/+125 °C	−55/+85 °C	−40/+85 °C	−25/+85 °C	+10/+85 °C
	without DC voltage applied	with DC voltage applied[a]	0	1	2	3	4	6
2B	±10	Requirements specified in the detail specification			~~×~~	~~×~~	~~×~~	
2C	±20			~~×~~	~~×~~	~~×~~		
2D	+20/−30			~~×~~			~~×~~	
2E	+22/−56				~~×~~	~~×~~	~~×~~	~~×~~
2F	+30/−80				~~×~~	~~×~~	~~×~~	~~×~~
2R	±15		~~×~~	~~×~~	~~×~~		~~×~~	

When the upper category temperature is above 125 °C, the limits of capacitance change, both with and without DC voltage applied, should be given in the detail specification.

NOTE Annex C can be referred to for preferred values of the temperature characteristic for the reference temperature of 25 °C.

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

~~NOTE 2 "×" indicates preferred.~~

~~NOTE See Annex C for the reference temperature of 25 °C as an informative guidance.~~

4.2.6 Dimensions

Suggested rules for the specification and coding of dimensions are given in Annex A.

Specific dimensions shall be given in the detail specification.

5 Test and measurement procedures

5.1 General

This Clause 5 supplements the information given in IEC 60384-1:~~2016~~2021, Clause 5 to Clause 10.

5.2 Special preconditioning

Unless otherwise specified in the detail specification, the special preconditioning, when specified in this document before a test or a sequence of test, shall be carried out under the following conditions.

Exposure at upper category temperature or at such higher temperature as may be specified in the detail specification during 1 h, followed by recovery during (24 ± 1) h under standard atmospheric conditions for testing.

NOTE Capacitors lose capacitance continuously with time in accordance with a logarithmic law (this is called ageing). However, if the capacitor is heated to a temperature above the Curie point of its dielectric, then "de-ageing" takes place, i.e. the capacitance lost through "ageing" is regained, and "ageing" recommences from the time when the capacitor recools. The purpose of special preconditioning is to bring the capacitor to a defined state regardless of its previous history (see Clause B.4 for further information).

5.3 Measuring conditions

See IEC 60384-1:~~2016~~2021, 5.2.1.

5.4 Mounting

See IEC 60384-1:~~2016~~2021, 5.5.

5.5 Visual examination and check of dimensions

5.5.1 General

See IEC 60384-1:~~2016~~2021, 7.1, with the details of 5.5.2 and 5.5.3.

5.5.2 Visual examination

A visual examination shall be carried out with suitable equipment with approximately 10× magnification and lighting appropriate to the specimen under test and the quality level required. In case the specimen are very small components, the visual examination may be carried out with higher magnification.

The operator should have available facilities for incident or transmitted illumination as well as an appropriate measuring facility.

5.5.3 Requirements

5.5.3.1 General

Quantitative values for the requirements below may be given in the detail or in the manufacturer's specification.

5.5.3.2 Requirements for the ceramic

Requirements for the ceramic are as follows:

a) Be free of cracks or fissures, except small damages on the surface, that do not deteriorate the performance of the capacitor (examples: see Figure 1 and Figure 2).

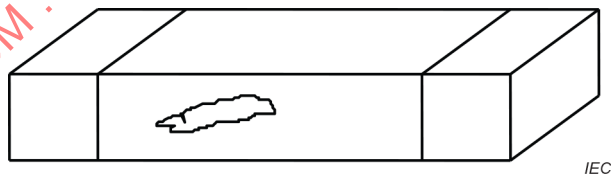
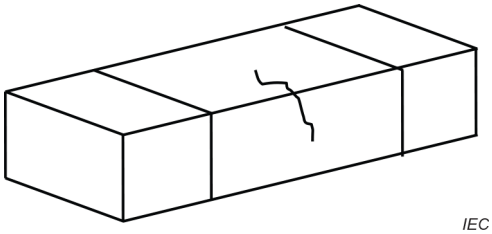


Figure 1 – Fault: crack or fissure



NOTE Crack or fissure on one side or extending from one face to another over a corner.

Figure 2 – Fault: crack or fissure

b) Not exhibit visible separation or delamination between the layers of the capacitor (see Figure 3).

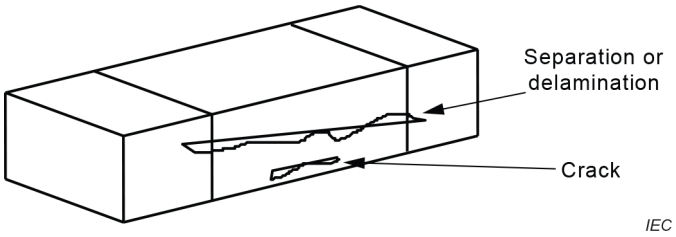


Figure 3 – Separation or delamination

c) Not exhibit exposed electrodes between the two terminations (see Figure 4).

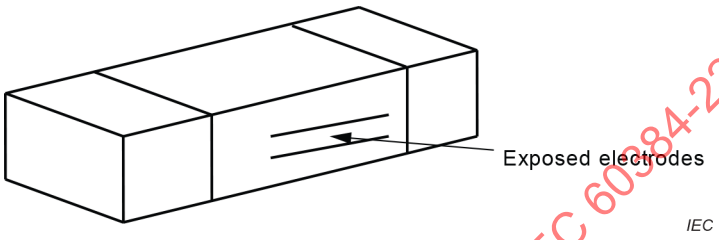


Figure 4 – Exposed electrodes

d) The ceramic body shall be free of any conducting smears (metallization, tinning, etc.) on a central zone between two adjacent terminations which is equal to the minimum distance between those (Annex A, dimension L_4).

5.5.3.3 Requirements for the metallization

Requirements for the metallization are as follows:

a) Not exhibit any visible detachment of the metallized terminations and not exhibit any exposed electrodes (see Figure 4).

b) The principal faces (see Figure 5) are those noted A, B and C.

In the case of capacitors of square section, the faces D and E are also considered principal.

The maximum area of gaps in metallization on each principal face shall not be greater than 15 % of the area of that face; these gaps shall not be concentrated in the same area. The gaps in metallization shall not affect the two principal edges of each extremity of the block (or four edges for square section capacitors). Dissolution of the end face plating (leaching) shall not exceed 25 % of the length of the edge concerned.

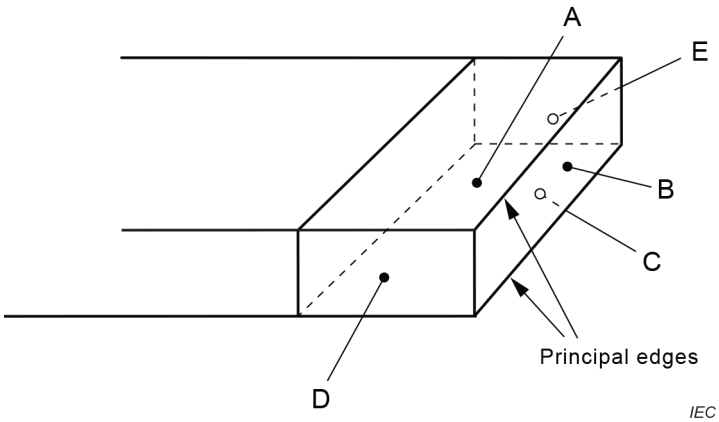


Figure 5 – Principal faces

5.6 Electrical tests

5.6.1 Capacitance

5.6.1.1 General

See IEC 60384-1:~~2016~~2021, 6.3, with the details of 5.6.1.2 and 5.6.1.3.

5.6.1.2 Measuring conditions

See Table 4, unless otherwise specified in the detail specification.

Table 4 – Measuring conditions

Nominal capacitance	Rated voltage U_R	Frequency	Measuring voltage V RMS	Referee voltage V RMS
CN < 100 pF	[a]	1 MHz	1,0 ± 0,2	1,0 ± 0,02
100 pF ≤ CN ≤ 10 µF	U_R > 6,3 V	1 kHz	1,0 ± 0,2	1,0 ± 0,02
	U_R ≤ 6,3 V	1 kHz	0,5 ± 0,2	0,5 ± 0,02
CN > 10 µF	[a]	100 Hz or 120 Hz	0,5 ± 0,2	0,5 ± 0,02

[a] All-rated voltages (U_R).

5.6.1.3 Requirements

The capacitance value as measured in the unmounted state, shall correspond with the rated value taking into account the specified tolerance.

The capacitance as measured in the mounted state in accordance with Group 3 is for reference purposes only in further tests.

For referee measurements, the capacitance value shall be the value extrapolated to an ageing time of 1 000 h, unless otherwise specified in the detail specification (see Annex B for explanations). ~~If applying the ageing time other than 1 000 h, that may be specified in the detail specification.~~

5.6.2 Tangent of loss angle (tan δ)

5.6.2.1 General

See IEC 60384-1:~~2016~~2021, 6.4, with the details of 5.6.2.2 and 5.6.2.3.

5.6.2.2 Measuring conditions

The measuring conditions are the same as those of 5.6.1. The inaccuracy of the measuring equipment shall not exceed 1×10^{-3}.

5.6.2.3 Requirements

The tangent of loss angle as measured in the unmounted state shall not exceed the limit given in Table 5.

Table 5 – Tangent of loss angle limits

Reference temperature	Rated voltage U_R	Subclass	Tangent of loss angle
20°C	$U_R \geq 10$ V	All subclass codes	Not exceed 0,035 or value as may be given in the detail specification
	$U_R < 10$ V	2B, 2C, 2R	0,1
		2D, 2E	0,15
		2F	0,2
25°C	$U_R \geq 10$ V	All subclass codes	Not exceed 0,035 or value as may be given in the detail specification
	$U_R < 10$ V	R	0,1
		S	0,1
		T	0,15
		U	0,15
NOTE See 4.2.5 and Annex C for an explanation of the subclass codes.			

The tangent of loss angle as measured in the mounted state in accordance with Group 3 is for reference purposes only in further tests.

5.6.3 Insulation resistance

5.6.3.1 General

See IEC 60384-1:~~2016~~2021, 6.1, with the details of 5.6.3.2 to 5.6.3.4.

5.6.3.2 Preparation for test

Prior to the test, capacitors shall be carefully cleaned to remove any contamination.

Care shall be taken to maintain cleanliness in the test chambers and during post-test measurements. Before the measurement, the capacitors shall be fully discharged. The insulation resistance shall be measured between the terminations.

5.6.3.3 Measuring conditions

See IEC 60384-1:~~2016~~2021, 6.1.2, with the following details.

The measuring voltage may be of any value not greater than U_R, the referee voltage being U_R, for a capacitor with a rated voltage below or equal to 1 kV. For U_R > 1 kV the referee voltage shall be 1 kV.

The insulation resistance (R_i) shall be measured after the voltage has been applied for (60 ± 5) s.

For lot-by-lot testing (Group A), the test may be terminated in a shorter time, if the required value of insulation resistance is reached.

The product of the internal resistance of the voltage source and the nominal capacitance of the capacitor shall not exceed 1 s, unless otherwise ~~prescribed~~ specified in the detail specification.

The charge current shall not exceed 0,05 A. For capacitors with rated voltages of 1 kV and above, a lower limit (value) may be given in the detail specification.

5.6.3.4 Requirements

The insulation resistance shall meet the following requirements.

C_N ≤ 25 nF	R_i ≥ 4 000 MΩ
C_N > 25 nF	$R_i \times C_N$ ≥ 100 s

5.6.4 Voltage proof

5.6.4.1 General

See IEC 60384-1:~~2016~~2021, 6.2, with the details of 5.6.4.2 to 5.6.4.4.

5.6.4.2 Test conditions

The product of R_1 and the nominal capacitance C_X shall be smaller than or equal to 1 s.

NOTE R_1 is a charging resistor that includes the internal resistance of the voltage source. More information can be found in IEC 60384-1:~~2016~~2021, 6.2.2.

The charge current shall not exceed 0,05 A.

For capacitors with rated voltages of 1 kV and above, a lower charge current limit value may be given in the detail specification. To protect the capacitors against flashover, the test may be performed in a suitable insulating medium.

5.6.4.3 Test voltages

The test voltages in accordance with Table 6 shall be applied between the measuring points of 6.1.3 and Table 3 in IEC 60384-1:~~2016~~2021, for a period of 1 min for qualification approval testing and for a period of 1 s for the lot-by-lot quality conformance testing.

Table 6 – Test voltages

Rated voltage V	Test voltage V
U_R ≤ 100	2,5 U_R
100 < U_R ≤ 200	1,5 U_R + 100
200 < U_R ≤ 500	1,3 U_R + 100
500 < U_R < 1 000	1,3 U_R
U_R ≥ 1 000	1,2 U_R

5.6.4.4 Requirement

There shall be no breakdown or flashover during the test.

5.6.5 Impedance (if required by the detail specification)

5.6.5.1 General

See IEC 60384-1:~~2016~~2021, 6.6, with the details of 5.6.5.2 and 5.6.5.3.

5.6.5.2 Measuring conditions

The frequency of measurement: 100 kHz, with a relative tolerance of ±10 %.

5.6.5.3 Requirements

Impedance shall be specified in the detail specification.

5.6.6 Equivalent series resistance [ESR] (if required by the detail specification)

5.6.6.1 General

See IEC 60384-1:~~2016~~2021, 6.4.2, with the details of 5.6.6.2 and 5.6.6.3.

5.6.6.2 Measuring conditions

The frequency of measurement: 100 kHz, with a relative tolerance of ±10 %.

5.6.6.3 Requirements

The ESR shall be specified in the detail specification.

5.7 Temperature characteristic of capacitance (reference temperature 20 °C)

5.7.1 Special preconditioning

See 6.2.

5.7.2 Measuring conditions

See IEC 60384-1:~~2016~~2021, 6.8.1, with the following details.

The capacitors shall be measured in unmounted ~~state as well as the conditions of Table 11~~ stage following the steps and conditions given in Table 7.

The measuring steps and conditions for a reference temperature 25 °C are given in Annex C.

Table 7 – Details of measuring conditions

Measuring step	Temperature °C	DC voltage applied
1	20 ± 2	–
2	T_A [a] ± 3	–
3	20 ± 2	–
4	T_B [b] ± 2	–
5	T_B ± 2	×
6	20 ± 2	×
7	T_A ± 3	×
8	20 ± 2	–

Measurements may be made at such intermediate temperatures as to ensure that the requirements of 4.2.5 are met.

~~NOTE~~ Reference capacitance is the capacitance measured at Step 3.

~~NOTE~~ Because of the effects described in the Note in 5.2, the capacitance values measured at temperature reference, Steps 5 to 7, with DC voltage applied, are time dependent. This time dependency is included in the given limits for capacitance change. The capacitance changes between the first and the last measurements at temperature reference, Steps 1 and 8, indicates the amount of ageing involved. In the case of a dispute about the results of measurements with DC voltage applied, it is advisable to agree upon a fixed time interval between measurements at temperature reference, Steps 5 and 7 with DC voltage applied (see IEC 60384-1:~~2016~~2021, 6.8.1.3).

NOTE "–" indicates: no DC voltage applied

"×" indicates: DC voltage applied (if specified in the detail specification)

[a] T_A = Lower category temperature.

[b] T_B = Upper category temperature.

5.7.3 Requirements

Temperature characteristic with and without DC voltage applied shall not exceed the values given in Table 3. The variation of capacitance shall be calculated in accordance with IEC 60384-1:~~2016~~2021, 6.8.3.1.

5.8 Shear test

See IEC 60384-1:~~2016~~2021, 7.7.

A force shall be selected from 1 N, 2 N, 5 N or 10 N and specified in the detail specification.

5.9 Substrate bending test

5.9.1 General

See IEC 60384-1:~~2016~~2021, 7.8.

Unless otherwise specified in the detail specification,

– the deflection D shall be selected from 1 mm, 2 mm or 3 mm, higher deflection values may be given in the detail specification in case of very robust designs.

– the number of bends shall be 1 time,

– the radius of the bending tool shall be 5 mm.
– When the deflection D is 2 mm or less, the radius may be 230 mm.
– the duration in the bent state shall be 5 s.

For 1005M or smaller size, the thickness of substrate should be 0,8 mm.

5.9.2 Initial measurement

The capacitance shall be measured as specified in 5.6.1 and in the detail specification.

5.9.3 Final inspection

The capacitors shall be visually examined and there shall be no visible damage. See 5.5.2.

The change of capacitance with board in bent position shall not exceed 10 %.

5.10 Resistance to soldering heat

5.10.1 General

See IEC 60068-2-58 with the details of 5.10.2 to 5.10.6.

5.10.2 Special preconditioning

See 5.2.

5.10.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.10.4 Test conditions

5.10.4.1 Solder bath method (applicable to 1608M, 2012M and 3216M)

NOTE See Table A.1 for explanation of the size code.

See IEC 60068-2-58, Test Td_2, Method 1, with the following details, if not otherwise specified in the detail specification.

The specimen shall be preheated to a temperature of 110 °C to 140 °C and maintained for 30 s to 60 s.

Solder alloy:	Sn-Pb or Sn-Ag-Cu
Temperature:	260 °C ± 5 °C
Duration of immersion:	10 s ± 1 s
Depth of immersion:	10 mm
Number of immersions:	1

5.10.4.2 Infrared and forced gas convection soldering system

See IEC 60068-2-58, Test Td_2, Method 2, with the following details:

a) the solder paste shall be applied to the test substrate;
b) the thickness of solder deposit shall be specified in the detail specification;
c) the terminations of the specimen shall be placed on the solder paste;

d) solder alloy: Sn-Pb;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 5) °C and maintained at this temperature for (10 ± 1) s;

e) solder alloy: Sn-Ag-Cu;

unless otherwise specified in the detail specification, the reflow temperature profile shall be selected from Table 8 and Figure 6.

Table 8 – Reflow temperature profiles for Sn-Ag-Cu alloy

Alloy composition		T_1 °C	T_2 °C	t_1 s	T_3 °C	t_2 s	T_4 °C	t_3 s
Lead-free solder (Sn-Ag-Cu)	Test 1	150 ± 5	180 ± 5	120 ± 5	220	60 to 90	250	20 to 40 at T_4 – ~~5 K~~ 5 °C
	~~Test 2~~	~~150 ± 5~~	~~180 ± 5~~	~~120 ± 5~~	~~220~~	~~≤ 60~~	~~255~~	~~≤ 20 at T_4 – 10 K~~

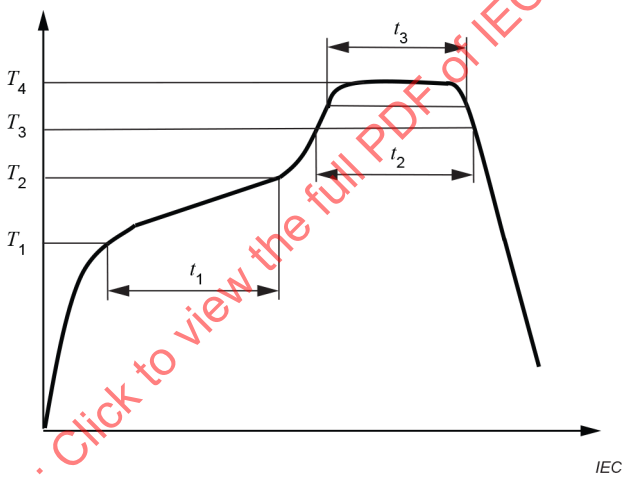


Figure 6 – Reflow temperature profile

f) number of each test: 1, unless otherwise specified in the detail specification.

g) the temperature profile of d) or e) shall be specified in the detail specification.

5.10.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

The flux residues shall be removed with a suitable solvent.

5.10.6 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined and measured and shall meet the following requirements.

Under normal lighting and approximately 10× magnification, there shall be no signs of damage such as cracks. See 5.5.2.

Dissolution of the end face plating (leaching) shall not exceed 25 % of the length of the edge concerned. The detail specification may ~~prescribe~~ specify further details.

The capacitance shall be measured in accordance with 5.6.1 and the change shall not exceed the values in Table 9.

Table 9 – Maximum capacitance change

Reference temperature 20 °C	
Subclass	**Requirements**
2B and 2C	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 4.2.5 for an explanation of the subclass codes.	
Reference temperature 25 °C	
Subclass	**Requirements**
R	±10 %
S	±10 %
T	±15 %
U	±20 %
NOTE See Table C.2 for an explanation of the subclass codes.	

5.11 Solderability

5.11.1 General

See IEC 60068-2-58 with the details of 5.11.2 to 5.11.4.

5.11.2 Test conditions

5.11.2.1 Solder bath method (applicable to 1608M, 2012M and 3216M)

NOTE See Table A.1 for explanation of the size code.

See IEC 60068-2-58, Test Td_1, Method 1, with the following details, if not otherwise specified in the detail specification.

The specimen shall be preheated to a temperature of 80 °C to 140 °C and maintained for 30 s to 60 s.

Solder alloy:	Sn-Pb	Sn-Ag-Cu
Temperature:	(235 ± 5) °C	(245 ± 5) °C
Duration of immersion:	(2 ± 0,2) s	(3 ± 0,3) s
Depth of immersion:	10 mm	10 mm
Number of immersions:	1	1

5.11.2.2 Infrared and forced gas convection soldering system

See IEC 60068-2-58, Test Td_1, Method 2, with the following details:

a) the solder paste shall be applied to the test substrate;
b) the thickness of solder deposit shall be specified in the detail specification;
c) the terminations of the specimen shall be placed on the solder paste;

d) solder alloy: Sn-Pb;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in the infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (215 ± 3) °C and maintained at this temperature for (10 ± 1) s;

e) solder alloy: Sn-Ag-Cu;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 5) °C to (180 ± 5) °C for 60 s to 120 s in the infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 3) °C. The time above 225 °C shall be (20 ± 5) s;

f) the temperature profile of d) or e) shall be specified in the detail specification.

5.11.3 Recovery

The flux residues shall be removed with a suitable solvent.

5.11.4 Final inspection, measurements and requirements

The capacitors shall be visually examined under normal lighting and approximately 10× magnification. There shall be no signs of damage. See 5.5.2.

Both end face and the contact areas shall be covered with a smooth and bright solder coating with no more than a small number of scattered imperfections such as pinholes or unwetted or de-wetted areas. These imperfections shall not be concentrated in one area.

The detail specification may ~~prescribe~~ specify further requirements.

5.12 Rapid change of temperature

5.12.1 General

This test shall be applied only to capacitors for which the category temperature is greater 110 °C.

See IEC 60384-1:~~2016~~2021, 8.1, with the details of 5.12.2 to 5.12.6.

The capacitors shall be mounted in accordance with 5.4.

5.12.2 Special preconditioning

See 5.2.

5.12.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.12.4 Number of cycles

The number of cycles: 5

Duration of exposure at the temperature limits: 30 min.

5.12.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.12.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitance shall be measured in accordance with 5.6.1 and the change shall not exceed the value in Table 10.

Table 10 – Maximum capacitance change

Reference temperature 20 °C	
Subclass	**Requirements**
2B and 2C	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 4.2.5 for an explanation of the subclass codes.	
Reference temperature 25 °C	
Subclass	**Requirements**
R	±10 %
S	±10 %
T	±15 %
U	±20 %
NOTE See Table C.2 for an explanation of the subclass codes.	

5.13 Climatic sequence

5.13.1 General

See IEC 60384-1:~~2016~~2021, 8.2, with the details of 5.13.2 to 5.13.8.

5.13.2 Special preconditioning

See 5.2.

5.13.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.13.4 Dry heat

See IEC 60384-1:~~2016~~2021, 8.2.3.

5.13.5 Damp heat, cyclic, Test Db, first cycle

See IEC 60384-1:~~2016~~2021, 8.2.4.

5.13.6 Cold

See IEC 60384-1:~~2016~~2021, 8.2.5, with the following details.

The capacitors shall be visually examined. There shall be no visible damage.

5.13.7 Damp heat, cyclic, Test Db, remaining cycles

5.13.7.1 General

See IEC 60384-1:~~2016~~2021, 8.2.7, with the details of 5.13.7.2 and 5.13.7.3.

5.13.7.2 Test conditions

No voltage applied.

The remaining cycles shall be tested in accordance with Table 11.

Table 11 – Number of damp heat cycles

Category	No. of cycles of 24 h
- / – / 56	5
- / – / 21	1
- / – / 10	1
- / – / 04	0

5.13.7.3 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.13.8 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 12.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 12 shall be met.

Table 12 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements (reference temperature 20°C)			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclasses 2E	Subclasses 2F
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %	$\Delta C/C$ ≤ ± 30 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					
Measurement	Measuring conditions	Requirements (reference temperature 25°C)			
		Subclasses R	Subclasses S	Subclasses T	Subclasses U
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.14 Damp heat, steady state

5.14.1 General

See IEC 60384-1:~~2016~~2021, 8.3, with the details of 5.14.2 to 5.14.6.

The capacitors shall be mounted in accordance with 5.4.

5.14.2 Special preconditioning

See 5.2.

5.14.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.14.4 Test conditions

No voltage shall be applied, unless otherwise specified in the detail specification.

The severity of the test should be selected from the test conditions as shown in Table 13 and be specified in the detail specification.

The duration time should be selected in accordance with 4.1 and shall be specified in the detail specification.

Table 13 – Test conditions for damp heat, steady state

Severity	Temperature °C	Relative humidity %
1	+85 ± 2	85 ± 3
2	+60 ± 2	93 ± 3
3	+40 ± 2	93 ± 3

When the application of voltage is ~~prescribed~~ specified, U_R shall be applied to one half of the lot and no voltage shall be applied to the other half of the lot.

Within 15 min after removal from the damp heat test, the voltage proof test in accordance with 5.6.4 shall be carried out, but with the rated voltage applied.

For safety reasons, different conditions for the application of voltage to capacitors with rated voltages of 1 kV or above may be given in the detail specification.

5.14.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.14.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 14.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made, the capacitors shall be preconditioned in accordance with 5.2 and then the requirement in Table 14 shall be met.

Table 14 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements (reference temperature 20°C)			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclasses 2E	Subclasses 2F
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %	$\Delta C/C$ ≤ ± 30 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					
Measurement	Measuring conditions	Requirements (reference temperature 25°C)			
		Subclasses R	Subclasses S	Subclasses T	Subclasses U
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.15 Endurance

5.15.1 General

See IEC 60384-1:~~2016~~2021, 8.5, with the details of 5.15.2 to 5.15.6.

The capacitors shall be mounted in accordance with 5.4.

5.15.2 Special preconditioning

See 5.2.

5.15.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.15.4 Test conditions

If the category voltage is equal to the rated voltage, the capacitors shall be tested as in Table 15.

Table 15 – Endurance test conditions ($U_C = U_R$)

U_R	U_R ≤ 200	200 < U_R ≤ 500	U_R > 500
Temperature	Upper category temperature		
Voltage (DC)	1,5 U_R	1,3 U_R	1,2 U_R
Duration	1 000 h	1 500 h	2 000 h

If the category voltage is not equal to the rated voltage, the capacitors shall be tested as in Table 16.

Table 16 – Endurance test conditions ($U_C \neq U_R$)

U_R	$U_R \leq 200$		$200 < U_R \leq 500$		$U_R > 500$	
Temperature	T_R	T_B	T_R	T_B	T_R	T_B
Voltage (DC)	1,5 U_R	1,5 U_C	1,3 U_R	1,3 U_C	1,2 U_R	1,2 U_C
Duration	1 000 h		1 500 h		2 000 h	
Sample	Divided into two parts		Divided into two parts		Divided into two parts	
T_R = Rated temperature. T_B = Upper category temperatures > 85 °C, such as 100 °C.						

5.15.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.15.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 17.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 17 shall be met.

Table 17 – Final inspection, measurements and requirements of endurance test

Measurement	Measuring conditions	Requirements (reference temperature 20 °C)			
		Subclasses 2B and 2C	**Subclasses** 2D and 2R	**Subclasses** 2E	**Subclasses** 2F
Capacitance	5.6.1	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 15$ %	$\Delta C/C \leq \pm 20$ %	$\Delta C/C \leq \pm 30$ %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	$R_i \geq 2\,000$ MΩ or $R_i \times C_N \geq 50$ s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					
Measurement	**Measuring conditions**	**Requirements (reference temperature 25 °C)**			
		Subclasses R	**Subclasses** S	**Subclasses** T	**Subclasses** U
Capacitance	5.6.1	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 15$ %	$\Delta C/C \leq \pm 20$ %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	$R_i \geq 2\,000$ MΩ or $R_i \times C_N \geq 50$ s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.16 Robustness of terminations (only for capacitors with strip termination)

5.16.1 General

See IEC 60384-1:~~2016~~2021, 7.3, with the details of 5.16.2 and 5.16.3.

5.16.2 Test conditions

Unless otherwise specified in the detail specification, the conditions of the tests are as follows:

Test Ua_1: force: 2,5 N;

Test Ub, Method 1: force: 2,5 N;

number of bends: 1.

5.16.3 Final inspection and requirements

The capacitors shall be visually examined. There shall be no visible damage.

5.17 Component solvent resistance (if required)

See IEC 60384-1:~~2016~~2021, 9.4.

5.18 Solvent resistance of the marking (if required)

See IEC 60384-1:~~2016~~2021, 9.5.

5.19 Accelerated damp heat, steady state (if required)

5.19.1 General

See IEC 60384-1:~~2016~~2021, 8.9, with the details of 5.19.2 to 5.19.5.

The capacitors shall be mounted in accordance with 5.4 and IEC 60384-1:~~2016~~2021, 8.9.1.

Half the capacitors shall be connected in series with resistors of 100 kΩ, with a relative tolerance of ±10 % and half in series with resistors of 6,8 kΩ, with a relative tolerance of ±10 %.

5.19.2 Initial measurement

The capacitors shall be measured for insulation resistance with a voltage of 1,5 V ± 0,1 V applied across the capacitor and resistor in series.

The insulation resistance, including the series resistor, shall meet the requirements given in Table 18.

Table 18 – Initial requirements

Measurement	Measuring conditions	Requirements	
Insulation resistance	(1,5 ± 0,1) V	Connected to 100 kΩ resistors	$C_N \leq 25$ nF: $R_i \geq 4\,000$ MΩ $C_N > 25$ nF: $(R_i - 100\ \text{k}\Omega) \times C_N \geq 100$ s
		Connected to 6,8 kΩ resistors	$C_N \leq 25$ nF: $R_i \geq 4\,000$ MΩ $C_N > 25$ nF: $(R_i - 6{,}8\ \text{k}\Omega) \times C_N \geq 100$ s

5.19.3 Conditioning

The capacitors with associated resistors shall be subjected to conditioning at (85 ± 2) °C, (85 ± 3) % relative humidity for the test duration given in Table 19. The voltage given in Table 19 shall be applied to the capacitors connected to 100 kΩ resistors and those connected to 6,8 kΩ resistors. In both cases, the voltage shall be applied across the capacitor/resistor combination.

Care shall be taken to avoid condensation of water on the capacitors or substrates. This ~~may~~ can happen if the door is opened during the test before the humidity is lowered.

Table 19 – Conditioning

Connected resistors kΩ	Applied voltage	Duration
100	(1,5 ± 0,1) V or the voltage specified in the detail specification	168 h, 500 h or 1 000 h; as specified in the detail specification
6,8	(50 ± 0,1) V or U_R, whichever is the lower, or the voltage specified in the detail specification	

5.19.4 Recovery

The applied voltage shall be disconnected, and the capacitors and resistors shall be removed from the test chamber and allowed to recover for 24 ± 2 h in standard atmospheric conditions for testing.

5.19.5 Final measurements

The capacitors shall be measured for insulation resistance, as in 5.19.2.

The insulation resistance, including the series resistor, shall be higher than 0,1 times the values given in 5.19.2.

6 Marking

6.1 General

See IEC 60384-1:~~2016~~2021, 4.3, with the details of 6.2 to 6.6.

6.2 Information for marking

The information given in the marking is normally selected from the following list; the relative importance of each item is indicated by its position in the list:

– nominal capacitance;
– rated voltage (DC voltage may be indicated by the symbol: ⎓ [IEC 60417-5031(2002-10)] or ⎓);
– tolerance on nominal capacitance;
– dielectric subclass as applicable (in accordance with 4.2.5 or Annex C);
– year and month (or week) of manufacture;
– manufacturer's name or trade mark;
– climatic category;
– manufacturer's type designation;
– reference to the detail specification.

6.3 Marking on the body

These capacitors are generally not marked on the body. If some marking can be applied, they shall be clearly marked with as many as possible of the items stated in 6.2 as is considered useful. Any duplication of information in the marking on the capacitor should be avoided.

6.4 Requirements for marking

Any marking shall be legible and not easily smeared or removed by rubbing with fingers.

6.5 Marking of the packaging

The packaging containing the capacitor(s) shall be clearly marked with all the information listed in 6.2.

6.6 Additional marking

Any additional marking shall be so applied that no confusion can arise.

7 Information to be given in a detail specification

7.1 General

The detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic, sectional or blank detail specification. When more severe requirements are included, they shall be ~~listed in 1.9 of the detail specification and~~ indicated in the test schedules, for example by an asterisk.

The information given in 7.2 may be presented in tabular form if more convenient.

The information in 7.2 to 7.5 shall be given in each detail specification and the values quoted should be selected from those given in the appropriate clause of this document.

7.2 Outline drawing and dimensions

There shall be an illustration of the capacitors as an aid to easy recognition and for comparison of the capacitors with others.

Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification. All dimensions shall be stated in millimetres, however, when the original dimensions are given in inches, the converted metric dimensions in millimetres shall be added.

Normally the numerical values shall be given for the length, width and height of the body. When necessary, for example when a number of items (sizes and capacitance/voltage ranges) are covered by a detail specification, the dimensions and their associated tolerances shall be placed in a table below the drawing.

When the configuration is other than described above, the detail specification shall state such dimensional information as will adequately describe the capacitors.

7.3 Mounting

The detail specification shall give guidance on methods of mounting for normal use. Mounting for test and measurement purposes (when required) shall be in accordance with 5.4 of this document.

7.4 Rating and characteristics

7.4.1 General

The ratings and characteristics shall be in accordance with the relevant clauses of this document, together with 7.4.2, 7.4.3 and 7.4.4.

7.4.2 Nominal capacitance range

~~See 6.2.4.1.~~

The nominal capacitance range shall be specified as described in 4.2.4.1.

When products approved to the detail specification have different ranges, the following statement should be added: "The range of capacitance values available in each voltage range is given in the register of approvals, available for example on the IECQ on-line certificate system website www.iecq.org".

7.4.3 Particular characteristics

Additional characteristics may be listed, when they are considered necessary to specify adequately the component for design and application purposes.

7.4.4 Soldering

The detail specification shall ~~prescribe~~ specify the test methods, severities and requirements applicable for the solderability and the resistance to soldering heat tests.

7.5 Marking

The detail specification shall specify the content of the marking on the capacitor and on the packaging. Deviations from Clause 6 shall be specifically stated in the detail specification.

8 Quality assessment procedures

8.1 Primary stage of manufacture

The primary stage of manufacture is the first common firing of the dielectric-electrode assembly.

8.2 Structurally similar components

Capacitors considered as being structurally similar are capacitors produced with similar processes and materials, though they may be of different case sizes and values.

8.3 Certified records of released lots

The information required in IEC 60384-1:~~2016~~2021, Q.1.5, shall be made available when ~~prescribed~~ specified in the detail specification and when requested by a purchaser. After the endurance test, the parameters for which variables information is required are the capacitance change, tan δ and the insulation resistance.

8.4 Qualification approval

8.4.1 General

The procedures for qualification approval testing are given in IEC 60384-1:~~2016~~2021, Clause Q.2.

The schedule to be used for qualification approval testing on the basis of lot-by-lot and periodic tests is given in Annex D. The procedure using a fixed sample size schedule is given in 8.4.2 and 8.4.3.

8.4.2 Qualification approval on the basis of the fixed sample size procedures

The fixed sample size procedure is described in IEC 60384-1:~~2016~~2021, Q.2.4. The sample shall be representative of the range of capacitors for which approval is sought. This range may ~~or may not~~ be different from the complete range covered by the detail specification.

For each temperature characteristic, the sample shall consist of specimens of capacitors of maximum and minimum size and for each of these sizes, the maximum capacitance value for the highest rated voltage and minimum rated voltage of the voltage ranges for which approval is sought. When there are more than four rated voltages, an intermediate voltage shall also be tested. Thus, for the approval of a range, testing is required of either four or six values (capacitance/voltage combinations) for each temperature characteristic. Where the total range consists of fewer than four values, the number of specimens to be tested shall be that required for four values.

In case assessment level EZ is used, spare specimens are permitted as follows:

Two (for six values) or three (for four values) per value may be used as replacements for specimens that are non-conforming because of incidents not attributable to the manufacturer.

The numbers given in Group 0 assume that all groups are applicable. If this is not so, the numbers may be reduced accordingly.

When additional groups are introduced into the qualification approval test schedule, the number of specimens required for Group 0 shall be increased by the same number as that required for the additional groups.

Table 20 gives the number of samples to be tested in each group or subgroup together with the number of permissible non-conformances for the qualification approval test.

8.4.3 Tests

The complete series of tests specified in Table 20 and Table 21 are required for the approval of capacitors covered by one detail specification. The tests of each group shall be carried out in the order given.

The whole sample shall be subjected to the tests of Group 0 and then divided for the other groups.

Non-conforming specimens found during the tests of Group 0 shall not be used for the other groups.

"One non-conforming item" is counted when a capacitor has not satisfied the whole or a part of the tests of a group.

The approval is granted when the number of non-conforming items is zero.

Table 20 and Table 21 together form the fixed sample size test schedule. Table 20 includes the details for the sampling and permissible non-conforming items for the different tests or groups of tests. Table 21 together with the details of the test contained in Clause 5 gives a complete summary of test conditions and performance requirements and indicates where, for example for the test method or conditions of test, a choice shall be made in the detail specification.

The conditions of test and performance requirements for the fixed sample size test schedule shall be identical to those ~~prescribed~~ specified in the detail specification for quality conformance inspection.

Table 20 – Fixed sample size test plan for qualification approval
Assessment level EZ

Group No.	Test	Subclause of this document	Number of specimens n[e]	Permissible number of nonconforming items c
0	Visual examination	5.5	132 + 24[f]	0
	Dimensions	5.5		
	Capacitance	5.6.1		
	Tangent of loss angle	5.6.2		
	Insulation resistance	5.6.3		
	Voltage proof	5.6.4		
	Spare specimens		12	
1A	Robustness of termination[g]	5.16	12	0
	Resistance to soldering heat	5.10		
	Component solvent resistance[b]	5.17		
1B	Impedance[b]	5.6.5	12	0
	Equivalent series resistance [ESR][b]	5.6.6		
	Solderability	5.11		
	Solvent resistance of marking[b]	5.18		
2	Substrate bending test[d]	5.9	12	0
3[a]	Mounting	5.4	84 + 24[f]	0[c]
	Visual examination	5.5		
	Capacitance	5.6.1		
	Tangent of loss angle	5.6.2		
	Insulation resistance	5.6.3		
	Voltage proof	5.6.4		
3.1	Shear test [h]	5.8	24	0
	Rapid change of temperature	5.12		
	Climatic sequence	5.13		
3.2	Damp heat, steady state	5.14	24	0
3.3	Endurance	5.15	36	0
3.4	Accelerated damp heat, steady state [b]	5.19	24[f]	0
4	Temperature characteristic of capacitance	5.7	12	0

[a] The values of these measurements serve as initial measurements for the tests of Group 3.
[b] If required in the detail specification.
[c] The capacitors found non-conforming items after mounting shall not be taken into account when calculating the permissible non-conforming for the following tests. They shall be replaced by spare capacitors.
[d] Not applicable to capacitors, which, in accordance with their detail specification, shall only be mounted on alumina substrates.
[e] Capacitance/voltage combinations, see 8.4.2.
[f] Additional capacitors, if Group 3.4 is tested.
[g] Applicable to capacitors with strip terminations.
[h] Not applicable to capacitors with strip terminations.

Table 21 – Test schedule for qualification approval

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (n) and number of non-conforming items (c)	Performance requirements (see NOTE 1)
GROUP 0	ND		See Table 4	
8.5 Visual examination				As in 8.5.3 Legible marking and as specified in the detail specification
8.5 Dimension (detail)				See the detail specification
8.6.1 Capacitance		Frequency: ... Hz Measuring voltage:...V RMS		Within specified tolerance
8.6.2 Tangent of loss angle (tan δ)		Frequency and Measuring voltage same as in 8.6.1		As in 8.6.2.3
8.6.3 Insulation resistance		See detail specification for the method		As in 8.6.3.4
8.6.4 Voltage proof		See detail specification for the method		No breakdown or flashover
GROUP 1A	D		See Table 4	
8.16 Robustness of termination (if applicable)		Test Ua_1, Force:2,5 N Test Ub, Method 1, Force:2,5 N, Number of bends:1 Visual examination		No visible damage
8.10.3 Initial measurement		Capacitance		
8.10 Resistance to soldering heat		Special preconditioning as in 8.2 See detail specification for the method Recovery: (24 ± 2) h		
8.10.6 Final measurement		Visual examination Capacitance		As in 8.10.6 As in 8.10.6
8.17 Component solvent resistance (if required)		Solvent: ... Solvent temperature:... Method 2 Recovery: ...		See detail specification
GROUP 1B	D		See Table 4	
8.6.5 Impedance (if required)		Frequency: 100 kHz		See detail specification
8.6.6 ESR (if required)		Frequency: 100 kHz		See detail specification
8.11 Solderability		See detail specification for the method		
8.11.4 Final measurements		Visual examination		As in 8.11.4
8.18 Solvent resistance of the marking [a] (if required)		Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...		Legible marking

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (n) and number of non-conforming items (c)	Performance requirements (see NOTE 1)
GROUP 2	D		See Table 4	
8.9 Substrate bending test		Deflection: ...		See detail specification
		Number of bends: ...		
8.9.2 Initial measurement		Capacitance		
8.9.3 Final inspection		Capacitance (with printed board in bent position)		$\lvert\Delta C/C\rvert \leq 10\ \%$
		Visual examination		No visible damage
GROUP 3	D		See Table 4	
8.4 Mounting		Substrate material: ...[b]		
		Visual examination		As in 8.5.3
		Capacitance		Within specified tolerance
		Tangent of loss angle		As in 8.6.2.3
		Insulation resistance		As in 8.6.3.4
		Voltage proof		No breakdown or flashover
GROUP 3.1	D		See Table 4	
8.8 Shear test		Visual examination		No visible damage
8.12.3 Initial measurement		Capacitance		
8.12 Rapid change of temperature		Special preconditioning as in 8.2		
		T_A = Lower category temperature		
		T_B = Upper category temperature		
		Five cycles		
		Duration t_1 = 30 min		
		Recovery: (24 ± 2) h		
8.12.6 Final measurements		Visual examination		No visible damage
		Capacitance		$\Delta C/C$: as in 8.12.6
8.13 Climatic sequence		Special preconditioning as in 8.2		
8.13.3 Initial Measurement		Capacitance		
8.13.4 Dry heat		Temperature: upper category temperature		
		Duration: 16 h		
8.13.5 Damp heat, cyclic, test Db, first cycle				
8.13.6 Cold		Temperature: lower category temperature		
		Duration: 2 h		
		Visual examination		No visible damage
8.13.7 Damp heat, cyclic, test Db, remaining cycles		Recovery: (24 ± 2) h		
8.13.8 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$: as in 8.13.8
		Tangent of loss angle		As in 8.13.8
		Insulation resistance		As in 8.13.8

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (n) and number of non-conforming items (c)	Performance requirements (see NOTE 1)
GROUP 3.2	D		See Table 4	
8.14 Damp heat, steady state		Special preconditioning as in 8.2		
8.14.3 Initial measurement		Capacitance Recovery: (24 ± 2) h		
8.14.6 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$: as in 8.14.6
		Tangent of loss angle		As in 8.14.6
		Insulation resistance		As in 8.14.6
GROUP 3.3	D		See Table 4	
8.15 Endurance		Special preconditioning as in 8.2 Duration: ... h Temperature: ...°C Voltage: ...V		
8.15.3 Initial measurement		Capacitance Recovery: (24 ± 2) h		
8.15.6 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$: as in 8.15.6
		Tangent of loss angle		As in 8.15.6
		Insulation resistance		As in 8.15.6
Group 3.4	D		See Table 4	
8.19 Accelerated damp heat, steady state (if required)		Duration: ... h Temperature: (85 ± 2) °C Humidity: (85 ± 3) % RH		
8.19.2 Initial measurement		Insulation resistance		As in 8.19.2
8.19.5 Final measurement		Recovery: (24 ± 2) h Insulation resistance		As in 8.19.5
Group 4	ND		See Table 4	
8.7 Temperature characteristic of capacitance		Special preconditioning as in 8.2		$\Delta C/C$: as in 8.7.3

NOTE 1 Subclause numbers of test and performance requirements refer to Clause 8.

NOTE 2 In this table: D = destructive, ND= non-destructive.

[a] This test may be carried out on capacitors mounted on a substrate.

[b] When different substrate materials are used for the individual subgroup, the detail specification shall indicate which substrate material is used in each subgroup.

Test[a]		Conditions of test[a]	D or ND[b]	*n* / *c* (see Table 20)	Performance requirements[a]
GROUP 0			ND	See Table 20	
5.5	Visual examination				As in 5.5.3 Legible marking and as specified in the detail specification
5.5	Dimension (detail)				See the detail specification
5.6.1	Capacitance	Frequency: ... Hz Measuring voltage: V RMS			Within specified tolerance
5.6.2	Tangent of loss angle (tan δ)	Frequency and Measuring voltage same as in 5.6.1			As in 5.6.2.3
5.6.3	Insulation resistance	See the detail specification for the method			As in 5.6.3.4
5.6.4	Voltage proof	See detail specification for the method			No breakdown or flashover
GROUP 1A			D	See Table 20	
5.16	Robustness of termination (if applicable)	Test Ua1, Force:2,5 N Test Ub, Method 1, Force:2,5 N Number of bends:1 Visual examination			No visible damage
5.10.3	Initial measurement	Capacitance			
5.10	Resistance to soldering heat	Special preconditioning as in 5.2 See the detail specification for the method Recovery: (24 ± 2) h			
5.10.6	Final inspection, measurement and requirements	Visual examination Capacitance			As in 5.10.6 As in 5.10.6
5.17	Component solvent resistance (if required)	Solvent: ... Solvent temperature: Method 2 Recovery: ...			See the detail specification
GROUP 1B			D	See Table 20	
5.6.5	Impedance (if required)	Frequency: 100 kHz			See the detail specification
5.6.6	ESR (if required)	Frequency: 100 kHz			See the detail specification
5.11	Solderability	See the detail specification for the method			
5.11.4	Final inspection, measurement and requirements	Visual examination			As in 5.11.4
5.18	Solvent resistance of the marking [c] (if required)	Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...			Legible marking
GROUP 2			D	See Table 20	
5.9	Substrate bending test	Deflection: ... Number of bends: ...			See the detail specification

Test[a]		Conditions of test[a]	D or ND[b]	*n* | *c* (see Table 20)	Performance requirements[a]
5.9.2	Initial measurement	Capacitance			
5.9.3	Final inspection	Capacitance (with printed board in bent position)			$\lvert \Delta C/C \rvert$ ≤ 10 %
		Visual examination			No visible damage
GROUP 3			D	See Table 20	
5.4	Mounting	Substrate material: …[d]			
		Visual examination			As in 5.5.3
		Capacitance			Within specified tolerance
		Tangent of loss angle			As in 5.6.2.3
		Insulation resistance			As in 5.6.3.4
		Voltage proof			No breakdown or flashover
GROUP 3.1			D	See Table 20	
5.8	Shear test	Visual examination			No visible damage
5.12.3	Initial measurement	Capacitance			
5.12	Rapid change of temperature	Special preconditioning as in 5.2			
		T_A = Lower category temperature			
		T_B = Upper category temperature			
		Five cycles			
		Duration t_1 = 30 min			
		Recovery: (24 ± 2) h			
5.12.6	Final inspection, measurement and requirements	Visual examination			No visible damage
		Capacitance			$\Delta C/C$: as in 5.12.6
5.13	Climatic sequence	Special preconditioning as in 5.2			
5.13.3	Initial Measurement	Capacitance			
5.13.4	Dry heat	Temperature: upper category temperature			
		Duration: 16 h			
5.13.5	Damp heat, cyclic, test Db, first cycle				
5.13.6	Cold	Temperature: lower category temperature			
		Duration: 2 h			
		Visual examination			No visible damage
5.13.7	Damp heat, cyclic, test Db, remaining cycles	Recovery: (24 ± 2) h			
5.13.8	Final inspection, measurement and requirements	Visual examination			No visible damage
					Legible marking
		Capacitance			$\Delta C/C$: as in 5.13.8
		Tangent of loss angle			As in 5.13.8
		Insulation resistance			As in 5.13.8
GROUP 3.2			D	See Table 20	

Test[a]		Conditions of test[a]	D or ND[b]	*n* | *c* (see Table 20)	Performance requirements[a]
5.14	Damp heat, steady state	Special preconditioning as in 5.2			
5.14.3	Initial measurement	Capacitance			
		Recovery: (24 ± 2) h			
5.14.6	Final inspection, measurement and requirements	Visual examination			No visible damage
					Legible marking
		Capacitance			$\Delta C/C$: as in 5.14.6
		Tangent of loss angle			As in 5.14.6
		Insulation resistance			As in 5.14.6
GROUP 3.3			D	See Table 20	
5.15	Endurance	Special preconditioning as in 5.2			
		Duration: … h			
		Temperature: …°C			
		Voltage: …V			
5.15.3	Initial measurement	Capacitance			
		Recovery: (24 ± 2) h			
5.15.6	Final inspection, measurement and requirements	Visual examination			No visible damage
					Legible marking
		Capacitance			$\Delta C/C$: as in 5.15.6
		Tangent of loss angle			As in 5.15.6
		Insulation resistance			As in 5.15.6
GROUP 3.4			D	See Table 20	
5.19	Accelerated damp heat, steady state (if required)	Duration: … h			
		Temperature: (85 ± 2) °C			
		Humidity: (85 ± 3) % RH			
5.19.2	Initial measurement	Insulation resistance			As in 5.19.2
5.19.5	Final measurements	Recovery: (24 ± 2) h			As in 5.19.5
		Insulation resistance			
GROUP 4			ND	See Table 20	
5.7	Temperature characteristic of capacitance	Special preconditioning as in 5.2			$\Delta C/C$: as in 5.7.3

[a] Subclause numbers of test and performance requirements refer to Clause 5.

[b] In this table: D = destructive, ND= non-destructive.

[c] This test may be carried out on capacitors mounted on a substrate.

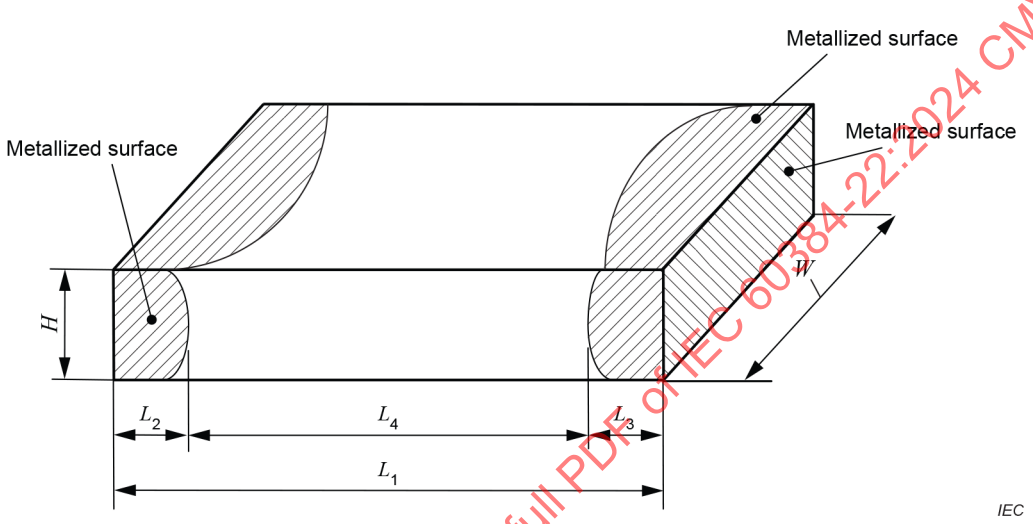
[d] When different substrate materials are used for the individual subgroup, the detail specification shall indicate which substrate material is used in each subgroup.

Annex A
(normative)

Guidance for the specification and coding of dimensions of fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

The principles given in Figure A.1 ~~should~~ shall be considered in the dimensioning of the capacitors.

Dimensions are specified in Table A.1.



Dimension W should not exceed dimension L_1.

Dimension H should not exceed dimension W.

If necessary, the thickness of tinning should be specified.

Figure A.1 – Dimensions

Table A.1 – Dimensions

Code	Length L_1	Width W	L_2; L_3 Minimum	L_4 Minimum
0201M	0,25 ± 0,013	0,125 ± 0,013	0,04	0,06
0402M	0,4 ± 0,02	0,2 ± 0,02	0,05	0,1
0603M	0,6 ± 0,03	0,3 ± 0,03	0,1	0,2
1005M	1,0 ± 0,05	0,5 ± 0,05	0,1	0,3
1608M	1,6 ± 0,1	0,8 ± 0,1	0,2	0,5
2012M	2,0 ± 0,1	1,25 ± 0,1	0,2	0,7
3216M	3,2 ± 0,2	1,6 ± 0,15	0,3	1,4
3225M	3,2 ± 0,2	2,5 ± 0,2	0,3	1,4
4532M	4,5 ± 0,3	3,2 ± 0,2	0,3	2,0
5750M	5,7 ± 0,4	5,0 ± 0,4	0,3	2,5
NOTE Dimension in millimetres.				

Other case sizes and dimensions may be specified in the detail specification.

Annex B
(~~informative~~normative)

Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

B.1 General

Most Class 2 dielectrics used for ceramic capacitors have ferroelectric properties and exhibit a Curie temperature.

Above this temperature, the dielectric has the highly symmetric cubic crystal structure whereas below the Curie temperature the crystal structure is less symmetrical. Although in single crystals this phase transition is very sharp, in practical ceramics, it is often spread over a finite temperature range, but in all cases, it is linked with a peak in the capacitance/temperature curve.

Under the influence of thermal vibration, the ions in the crystal lattice continue to move to positions of lower potential energy for a long time after the dielectric has cooled through the Curie temperature. This gives rise to the phenomenon of capacitance ageing, whereby the capacitor continually decreases its capacitance.

However, if the capacitor is heated to a temperature above the Curie temperature, then de-ageing takes place, i.e. the capacitance lost through ageing is regained, and ageing recommences from the time when the capacitor recools.

B.2 Law of capacitance ageing

During the first hour after cooling through the Curie temperature, the loss of capacitance is not well defined, but after this time, it follows a logarithmic law (see K.W. Plessner, Proc. Phys. Soc., vol. 69B, P1261, 1956) which can be expressed in terms of an ageing constant.

The ageing constant k is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a "decade", i.e. a time in which the capacitor increases its age tenfold for example from 1 h to 10 h.

As the law of decrease of capacitance is logarithmic, the percentage loss of capacitance will be $2 \times k$ between 1 h and 100 h age and $3 \times k$ between 1 h and 1 000 h. This ~~may~~ can be expressed mathematically by the following equation:

$$C_t = C_1 \left(1 - \frac{k}{100} \times \lg t\right) \quad \text{(B.1)}$$

where

C_t is the capacitance t h after the start of the ageing process;

C_1 is the capacitance 1 h after the start of the ageing process;

k is the ageing constant in percent per decade (as defined above);

t is the time in h from the start of the ageing process.

The ageing constant may be declared by the manufacturer for a particular ceramic dielectric, or it may be defined by de-ageing the capacitor and measuring the capacitance at two known times thereafter.

k is then given by the following equation:

$$k = \frac{100 \times \left(C_{t_1} - C_{t_2}\right)}{C_{t_1} \times \lg t_2 - C_{t_2} \times \lg t_1} \tag{B.2}$$

If capacitance measurements are made three or more times, then it is possible to derive k from the slope of a graph where C_t is plotted against lg t.

It is also possible to plot log C against lg t.

During measurements of ageing, the capacitor should be maintained at a constant temperature so that capacitance variations due to the temperature characteristic do not mask those due to ageing.

B.3 Capacitance measurements and capacitance tolerance

Because of ageing, it is necessary to specify a reference age at which the capacitance shall be within the ~~prescribed~~ specified tolerance. This is fixed at 1 000 h, since for practical purposes there is not much further loss of capacitance after this time.

In order to calculate the capacitance $C_{1\,000}$ after 1 000 h, the ageing constant shall be known or determined as in Clause B.2, when the following formula may be used:

$$C_{1000} = C_t \left[1 - \frac{k}{100}(3 - \lg t)\right] \tag{B.3}$$

For factory measurements, the loss of capacitance from the age at time of measurement to 1 000 h age will be known and can be off-set by using asymmetric inspection tolerances.

For example, if it is known that the capacitance loss will be 5 %, then the capacitors may be inspected to limits of +25/−15 % instead of 20 %.

Capacitance is normally declared at 20 °C, and it may be necessary to measure at this temperature or correct the results to this temperature. Errors can also arise from heat from the hands, and capacitors should therefore always be handled with tweezers.

B.4 Special preconditioning (see 5.2)

In many of the tests in this document, it is required to measure the capacitance change which results from a given conditioning (for example climatic sequence). In order to avoid the interfering effect of ageing, the capacitor is specially preconditioned before these tests by maintaining it for 1 h at the upper category temperature followed by 24 h at standard atmospheric conditions for testing.

For those capacitors with a Curie temperature below the upper category temperature, this results in de-ageing and the conditioning is also arranged, if possible, to bring the capacitors to an age of 24 h, so that capacitance changes due to ageing are minimized.

If the Curie temperature of the dielectric is above the upper category temperature, then the special preconditioning will not completely de-age the capacitor, but it will nevertheless bring it into a state where its capacitance is not so dependent on its previous history, and the same effect will be achieved, though completely de-aged. In order to de-age such capacitors completely, temperature up to 160 °C ~~may~~ can be required~~, and this temperature could be deleterious to the encapsulation~~. Therefore, in the few cases where complete de-ageing of such capacitors ~~may~~ can be required, the detail specification shall be consulted for details and any necessary precautions.

Annex C
(informativenormative) 3

Temperature characteristics of capacitance for the reference temperature of 25 °C

The temperature characteristics of capacitance for the reference temperature of 25 °C have often been used due to marketing needs and because of their actual performance. These temperature characteristics and codes are shown in Table C.1 and the exact conditions of temperature characteristics of capacitance are shown in Table C.2.

Table C.1 – Temperature characteristics of capacitance for the reference temperature of 25 °C

Code of temperature characteristics of capacitance	Maximum capacitance change %	Temperature range °C
X5R	± 15	−55 to +85
X7R	± 15	−55 to +125
X8R	± 15	−55 to +150
X6S	± 22	−55 to +105
X7S	± 22	−55 to +125
Y5V	−82 to +22	−30 to +85

Table C.2 – Measuring conditions of temperature characteristic of capacitance for the reference temperature of 25 °C

Measuring step	Temperature °C
1	25 ± 2
2	T_A [a] ± 3
3	25 ± 2
4	T_B [b] ± 2
5	25 ± 2
Measurements may be made at such intermediate temperatures as to ensure that the requirements of Table C.1 are met.	
NOTE Reference capacitance is the capacitance measured at Step 3.	
[a] T_A = Lower category temperature. [b] T_B = Upper category temperature.	

For the temperature characteristics of capacitance for the reference temperature 25 °C (the related EIA-198-1-F), the lower and upper category temperatures shall be chosen from Table C.1.

Table C.2 denotes with a cross the preferred values of the temperature characteristic with and without DC voltage applied. The method of coding the subclass is also given according to Table C.1; for example, a dielectric with a percentage change of ±15 % without DC voltage applied over the temperature range from −55 °C to +125 °C will be defined as dielectric of subclass X7R.

The exact conditions of temperature characteristics of capacitance are shown in Table C.3.

Table C.1 – Temperature characteristics of capacitance 4

Category Temperature characteristic capacitance				Maximum capacitance change within the category temperature range with respect to the capacitance at 25 °C measured with and without a DC voltage applied		
Lower category temperature		Upper category temperature		%		
Alpha symbol	Low temperature °C	Numeric symbol	High temperature	Sub-class letter code	Without DC voltage applied	With DC voltage applied [a] (if required)
Z	+10	2	+45	A	± 1,0	Requirements specified in the detail specification
Y	-30	4	+65	B	± 1,5	
X	-55	5	+85	C	± .2,2	
		6	+105	D	± 3,3	
		7	+125	E	± 4,7	
		8	+150	F	± 7,5	
		9	+200	P	± 10	
		3	+175[b]	R	± 15	
				S	± 22	
				T	+ 22/- 33	
				U	+ 22/- 56	
				V	+ 22/- 82	
				L[c]	+ 15/- 40	
				Q[c]	+ 15/- 70	

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

[b] Upper category temperature of 175 °C is not defined in EIA-198-1-F.

[c] Maximum capacitance change "L" +15/-40, "Q" +15/-70 are not defined in EIA-198-1-F. 5

Table C.2 – Preferred values of the temperature characteristic of capacitance with and without a DC voltage applied

Sub-class letter code	Maximum capacitance change within the category temperature range with respect to the capacitance at 20 °C measured with and without a DC voltage applied %		Category temperature range and corresponding number code			
			−55/+85 °C	−55/+105 °C	−55/+125 °C	−55/+150 °C
	without DC voltage applied	with DC voltage applied (if required) [a]	X5	X6	X7	X8
R	±15	Requirements specified in the detail specification	x	x	x	x
S	±22			x	x	x
T	+22/−33			x	x	x
U	+22/−56			x	x	x

NOTE "×" indicates preferred.

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

Table C.3 – Measuring conditions of temperature characteristic of capacitance for the reference temperature 25 °C

Method	Measuring step	Temperature °C	DC voltage applied
A	1	25 ± 2	–
	2	T_A ± 2	–
	3	25 ± 2	–
	4	T_B ± 2	–
	5	T_B ± 2	×
	6	25 ± 2	×
	7	T_A ± 2	×
B	1 2 3 4	See above	–

Measurements may be made at such intermediate temperatures as to ensure that the requirements of 4.2.5 are met.

NOTE 1 "–" indicates: no DC voltage applied

"×" indicates: rated voltage

NOTE 2 Reference capacitance is the capacitance measured at Step 3.

T_A = Lower category temperature.

T_B = Upper category temperature.

Annex D
(normative)

Quality conformance inspection

D.1 Formation of inspection lots

D.1.1 Groups A and B inspection

These tests shall be carried out on a lot-by-lot basis.

A manufacturer may aggregate the current production into inspection lots subject to the following safeguards:

a) The inspection lot shall consist of structurally similar capacitors (see 8.2).

b) The sample tested shall be representative of the values and the dimensions contained in the inspection lot:
   – in relation to their number;
   – with a minimum of five of any one value.

c) If there are fewer than five of any one value in the sample the basis for the drawing of samples shall be agreed between the manufacturer and the certification body (CB).

D.1.2 Group C inspection

These tests shall be carried out on a periodic basis.

Samples shall be representative of the current production of the specified periods and shall be divided into small, medium and large sizes. In order to cover the range of approvals in any period, one voltage shall be tested from each group of sizes. In subsequent periods, other sizes and/or voltage ratings in production shall be tested with the aim of covering the whole range.

D.2 Test schedule

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in ~~Clause 2 of the blank detail specification~~ Table D.3 and Table D.4.

D.3 Delayed delivery

When, in accordance with the procedures of IEC 60384-1:~~2016~~2021, Q.1.7, re-inspection shall be made, solderability and capacitance shall be checked as specified in Groups A and B inspection.

D.4 Assessment levels

The assessment level(s) given in ~~the blank detail specification~~ Table D.3 and Table D.4 should be selected from Table D.1 and Table D.2.

Table D.1 – Lot-by-lot inspection

Inspection subgroup[d]	EZ		
	IL[a]	n[a]	c[a]
A0	100 %[b]		
A1	S-4	c	0
A2	S-3	[c]	0
B1	S-3	[c]	0
B2	S-2	[c]	0

[a] IL = inspection level

n = sample size

c = permissible number of non-conforming items

[b] The inspection shall be performed after removal of nonconforming items by 100 % testing during the manufacturing process. Whether the lot was accepted or not, all samples for sampling inspection shall be inspected in order to monitor outgoing quality level by nonconforming items per million ($\times 10^{-6}$).

The sampling level shall be established by the manufacturer~~, preferably~~ and should be in accordance with IEC 61193-2:2007, Annex A.

In the case where one or more nonconforming items occur in a sample, this lot shall be rejected, but all nonconforming items shall be counted for the calculation of quality level values. Outgoing quality level by nonconforming items per million ($\times 10^{-6}$) values shall be calculated by accumulating inspection data in accordance with the method given in IEC 61193-2:2007, 6.2.

[c] Number to be tested: sample size shall be determined in accordance with IEC 61193-2:2007, 4.3.2.

[d] The content of the inspection subgroup is described in ~~Clause 2 of the relevant blank detail specification~~ Table D.3.

Table D.2 – Periodic test

Inspection subgroup[b]	EZ		
	p[a]	n[a]	c[a]
C1	3	12	0
C2	3	12	0
C3.1	6	27	0
C3.2	6	15	0
C3.3	3	15	0
C3.4[c]	6	15	0
C4	6	9	0

[a] p = periodicity in months

n = sample size

c = permissible number of non-conforming items

[b] The content of the inspection subgroup is described in ~~Clause 2 of the relevant blank details specification~~ Table D.4.

[c] If required.

D.5 test schedule for quality conformance inspection 6

For quality conformance inspection, the test schedules given in Table D.3 and Table D.4 include sampling, periodicity, severities and requirements. The formation of inspection lots is given in D.1.

Table D.3 – Test schedule for quality conformance inspection (lot by lot)

Lot-by-lot tests						
Test[a]		Conditions of test[b]	D[c] or ND	IL[c]	c[c]	Performance requirements
Group A0 [100 % tests]						
5.6.1	Capacitance	Frequency: … Hz Measuring voltage: … V r.m.s	ND	100 %[d]		Within specified tolerance
5.6.2	Tangent of loss angle (tan δ)	Frequency and measuring voltage same as in 5.6.1				As in 5.6.2
5.6.3	Insulation resistance	See detail specification for the method				As in 5.6.3.4
5.6.4	Voltage proof	See detail specification for the method				No breakdown or flashover
Group A1 [Sampling tests]						
5.5.2	Visual examination		ND	S-4[e]	0	As in 5.5.2 Legible marking and as specified in the detail specification
Group A2 [Sampling tests]						
4.2.6	Dimension[f]		ND	S-3[e]	0	See the detail specification
Group B1 [Special tests]						
5.6.5	Impedance (if required)	Frequency: 100 KHz	D	S-3[e]	0	See detail specification
5.6.6	ESR (if required)	Frequency: 100 KHz				See detail specification
5.11	solderability	See detail specification for the method				
5.11.4	Final inspection, measurements and requirements	Visual examination				As in 5.11.4
5.18	Solvent resistance of the marking (if required)[g]	Solvent: … Solvent temperature: … Method 1 Rubbing material: cotton wool Recovery: …				Legible marking

Lot-by-lot tests						
Test[a]		Conditions of test[b]	D[c] or ND	IL[c]	c[c]	Performance requirements
Group B2 [Special tests]						
5.7	Temperature characteristics of capacitance[g]		ND	S-2[e]	0	$\Delta C/C$: As in 5.7.3

[a] Applicable tests, test conditions, requirements and clause numbers as selected from this document.

[b] The information given in Table D.3 shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed specification given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Table D.1 for lists of symbols and of abbreviated terms.

[d] After 100 % measurement and removal of nonconforming items, a re-inspection shall be performed in order to monitor the outgoing quality level, in accordance with the detail specification. A lot shall be rejected if one or more nonconforming items occur in a sample during re-inspection.

[e] Inspection Levels are selected from IEC 61193-2.

[f] This test may be replaced by in-production testing if the manufacturer installs Statistical Process Control (SPC) on dimensional measurements or other mechanisms to avoid parts exceeding the limits.

[g] This test may be carried out on capacitors mounted on a substrate.

[h] This subgroup may be omitted if a corresponding test is carried out on each manufacturing batch of dielectric material.

Table D.4 – Test schedule for quality conformance inspection (Periodic test)

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p[c]	n[c]	c[c]	Performance requirements
Group C1 [h]							
5.16	Robustness of Termination (only for capacitors with strip terminations)	Test Ua, Force: 2,5 N Test Ub, Method 1, Force: 2,5 N Number of bends: 1 Visual examination	D	3	12	0[d]	No visible damage
5.10.3	Initial measurement	Capacitance					
5.10	Resistance to soldering heat	See detail specification for the method Recovery: 24 h ± 2 h					
5.10.6	Final inspection, measurements and requirements	Visual examination Capacitance					As in 5.10.6 As in 5.10.6
5.17	Component solvent resistance (if required)	Solvent: … Solvent temperature: … Method 2 Recovery: …					See detail specification

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p^c	n^c	c^c	Performance requirements
Group C2 [h]							
5.9	Substrate bending test[e]	Deflection: … Number of bends: …	D	3	12	0[d]	See detail specification
5.9.2	Initial measurement	Capacitance					
5.9.3	Final inspection	Capacitance (with printed board in bent position)					$\Delta C/C \leq 10\ \%$
		Visual examination					No visible damage
Group C3[h]			D				
5.4	Mounting[f]	Substrate material: …					As in IEC 60384-1, 5.5.1
		Visual examination					
		Capacitance					Within specified tolerance
		Tangent of loss angle					As in 5.6.2
		Insulation resistance					As in 5.6.3.4
		Voltage proof					No breakdown or flashover
Group C3.1[h]			D				
5.8	Shear test[g]	Visual inspection		6	27	0[d]	No visible damage
		Special preconditioning as in 5.2					
5.12.3	Initial measurement	Capacitance					
5.12	Rapid change of temperature	T_A = Lower category temperature					
		T_B = Upper category temperature: five cycles					
		Duration t_1 = 30 min					
		Recovery: (24 ± 2) h					
5.12.6	Final inspections, measurements and requirements	Visual examination					No visible damage
		Capacitance					$\Delta C/C$: As in 5.12.6
5.13	Climatic sequence	Special preconditioning as in 5.2					
5.13.3	Initial measurement	Capacitance					
5.13.4	Dry heat	Temperature: upper category temperature					
		Duration: 16 h					
5.13.5	Damp heat, cyclic, test Db, first cycle						

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p[c]	n[c]	c[c]	Performance requirements
5.13.6	Cold	Temperature: lower category temperature					
		Duration: 2 h					
		Visual inspection					No visible damage
5.13.7	Damp heat, cyclic, test Db, remaining cycles	Recovery: 24 h ± 2 h					
5.13.8	Final measurements	Visual examination					No visible damage Legible marking
		Capacitance					$\Delta C/C$: As in 5.13.8
		Tangent of loss angle					As in 5.13.8
		Insulation resistance					As in 5.13.8
Group C3.2[h]			D				
5.14	Damp heat, steady state	Special preconditioning as in 5.2		6	15	0[d]	
5.14.3	Initial measurement	Capacitance					
		Recovery: 24 h ± 2 h					
5.14.6	Final inspections, measurements and requirements	Visual examination					No visible damage Legible marking
		Capacitance					$\Delta C/C$: As in 5.14.6
		Tangent of loss angle					As in 5.14.6
		Insulation resistance					As in 5.14.6
Group C3.3[h]			D				
5.15	Endurance	Special preconditioning as in 5.2		3	15	0[d]	
		Duration: …h					
		Temperature: …°C					
		Voltage: …V					
5.15.3	Initial measurement	Capacitance					
		Recovery: (24 ± 2) h					
5.15.6	Final inspections, measurements and requirements	Visual examination					No visible damage Legible marking
		Capacitance					$\Delta C/C$: As in 5.15.6
		Tangent of loss angle					As in 5.15.6
		Insulation resistance					As in 5.15.6

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p^c	n^c	c^c	Performance requirements
Group C3.4[h]			D				
5.19	Accelerated damp heat, steady state (if required)	Duration: … h		6	15	0[d]	
		Temperature: (85 ± 2) °C					
		Humidity: (85 ± 3) %					
5.19.2	Initial measurement	Insulation resistance					As in 5.19.2
		Recovery: (24 ± 2) h					
5.19.5	Final measurements	Insulation resistance					As in 5.19.5
Group C4 [h]			ND				
5.7	Temperature characteristic of capacitance	Special preconditioning as in 5.2		6	9	0[d]	$\Delta C/C$: As in 5.7.3

[a] Applicable tests, test conditions, requirements and clause numbers as selected from this document.

[b] The information given in Table D.4 shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed specification given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Table D.2 for lists of symbols and of abbreviated terms.

[d] If one non-conforming item is obtained, all the tests of the subgroup shall be repeated on a new sample and then no further non-conforming items are permitted. Release of product may continue during repeat testing.

[e] Not applicable to capacitors, which, in accordance with the detail specification, shall only be mounted on alumina substrates.

[f] The capacitors found non-conformances after mounting shall not be taken into account when calculating the non- conformances for the following tests. They shall be replaced by spare capacitors.

[g] Not applicable to capacitors with strip terminations.

[h] All tests of the sub-group shall be repeated if one or more nonconforming item is obtained. No nonconforming items are permitted in the repeat testing. Release of products may continue during repeat testing.

Annex X
(informative)

Cross-reference for reference to IEC 60384-22:~~2011~~2019

The drafting of this document has resulted in a new structure. Table X.1 indicates the new clause and subclause numbers with respect to IEC 60384-22:~~2011~~2019.

Table X.1 – Reference to IEC 60384-22 for clause/subclause

~~IEC 60384-22:2011 2nd edition Clause/Subclause~~	~~IEC 60384-22:20xx 3rd edition Clause/Subclause~~	~~Notes~~
~~1 1.1 1.2~~	~~1~~	~~Scope and Object are merged into one in accordance with the ISO/IEC Directives Part 2~~
~~1.3~~	~~2~~	~~In accordance with ISO/IEC Directives Part 2~~
~~1.4~~	~~4~~	~~In accordance with the change of clause numbers~~
~~1.5~~	~~3~~	~~In accordance with ISO/IEC Directives Part 2~~
~~1.6~~	~~5~~	~~In accordance with the change of clause numbers~~
~~2~~	~~6~~	~~In accordance with the change of clause numbers~~
~~3~~	~~7~~	~~In accordance with the change of clause numbers~~
~~4~~	~~8~~	~~In accordance with the change of clause numbers~~

IEC 60384-22:2019 3nd edition Clause/Subclause	IEC 60384-22:2024 4th edition Clause/Subclause	Notes
1	1	No change
2	2	No change
3	3	No change
4	7	In accordance with the change of clause numbers
5	6	In accordance with the change of clause numbers
6	4	In accordance with the change of clause numbers
7.1 to 7.4	8.1 to 8.4	In accordance with the change of clause numbers
7.5.1 to 7.5.4	D.1 to D.4	In accordance with the change of clause numbers
8	5	In accordance with the change of clause numbers
Annex A	Annex A	No change
Annex B	Annex B	No change
Annex C	Annex C	Changed from informative to normative
–	D.5	Newly added. Modified from IEC 60384-22-1:2004, Clause 2
Annex X	Annex X	No change

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-22:~~2011~~2019.

Table X.2 – Reference to IEC 60384-22 for figure/table

~~IEC 60384-22:2011 2nd edition Figure/Table~~	~~IEC 60384-22:20xx 3rd edition Figure/Table~~	~~Notes~~
~~Table 6a~~	~~Table 6~~	~~In accordance with the ISO/IEC directives, Part 2 and the change of table numbers~~
~~Table 6b~~	~~Table 7~~	
~~Table 7 to Table 22~~	~~Table 8 to Table 23~~	~~In accordance with the change of table numbers~~
~~For the figure numbers, there was no change.~~		

IEC 60384-22:2019 3rd edition Figure/Table	IEC 60384-22:2024 4th edition Figure/Table	Notes
Table 1 to Table 3	Table 1 to Table 3	No change
Table 4 and Table 5	Table 20 to Table 21	In accordance with the change of table numbers
Table 6 and Table 7	Table D.1 to Table D.2	In accordance with the change of table numbers
-	Table D.3 and Table D.4	Newly added. Modified from IEC 60384-22-1:2004, Table 4
Table 8 to Table 23	Table 4 to Table 19	In accordance with the change of table numbers
Table A.1	Table A.1	No change
Table C.1	Table C.1	No change
–	Table C.2	Newly added
Table C.2	Table C.3	In accordance with the change of table numbers
Table X.1 and Table X.2	Table X.1 and Table X.2	No change
For the figure numbers, there was no change.		

Bibliography

IEC 60063, *Preferred number series for resistors and capacitors*

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60384-14, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60384-22-1:2004, *Fixed capacitors for use in electronic equipment – Part 22-1: Blank detail specification: Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2 – Assessment level EZ*

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

ISO 3:1973, *Preferred numbers – Series of preferred numbers*

IECQ on-line certificate system: available at www.iecq.org

EIA-198-1-F, *Ceramic Dielectric Capacitors Classes I, II, III and IV – Part I: Characteristics and Requirements*

K.W. Plessner: *Ageing of the Dielectric Properties of Barium Titanate Ceramics*, Proceedings of the Physical Society, Section B, Volume 69, Issue 12, pp. 1261 to 1268 (1956)

List of comments

1 This modification in scope clarifies, that deviations to the requirements set forth in this standard are allowed, but only if they are more severe. For example, capacitors which are specified to withstand a substrate bending test with 5 mm bending depth comply to this standard, which requires 1 mm to 3 mm bending depth as test severity.

2 This is the most important change in the new edition. The addition of the reference temperature 25 °C became necessary to include the temperature characteristics specified in EIA-198-1, which are very common in the market. With this extension, the requirements to those capacitors are now precisely given in this standard and included in Clause 5. See Annex C for details.

3 With this change of Annex C from “informative” into “normative” capacitors specified in accordance to EIA-198-1 are formally included in this standard.

4 The extended Table C.1 now provides precise specification of the coding system of temperature characteristics.

Further on it clarifies, that the maximum capacitance change with DC voltage applied shall be specified in the detail specification. This is an important advice to users of the capacitors to check the supplier specifications, because the capacitance deviation with DC voltage applied can be different from product to product.

5 The upper category temperature +175 °C with the numeric symbol “3” is newly added, because this is an important operating temperature in high temperature and power electronics. This change made is also necessary to introduce and define the new code letters “Q” and “L” to cover those applications.

6 Clause D.5 has been added to Annex D to include the test schedule for quality conformance inspection. This previously has been the content of the blank detail specification IEC 60384-22-1, which is intended to be withdrawn. Now this standard contains the complete information for the qualification of the capacitors.

IEC 60384-22

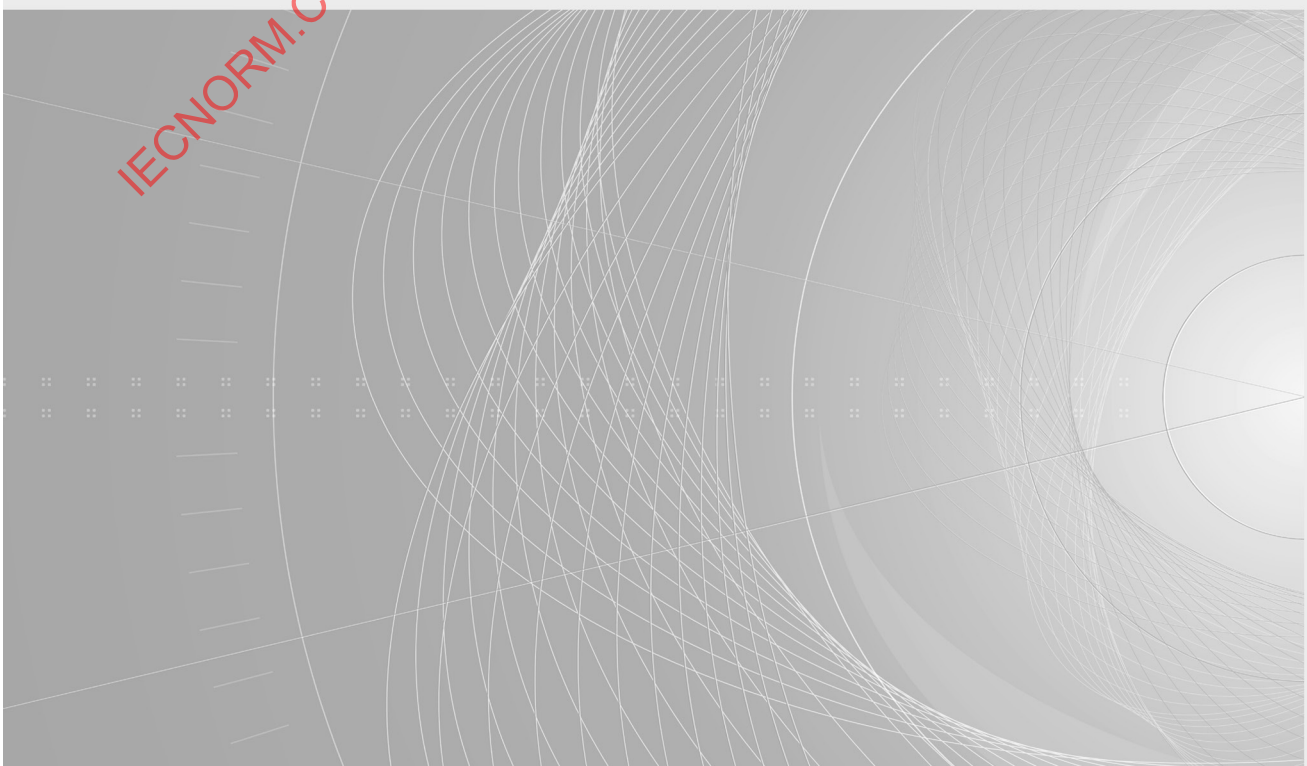
Edition 4.0 2024-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fixed capacitors for use in electronic equipment –
Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

Condensateurs fixes utilisés dans les équipements électroniques –
Partie 22: Spécification intermédiaire – Condensateurs multicouches fixes à diélectriques en céramique pour montage en surface, de Classe 2



IEC 60384-22:2024-06(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

FOREWORD

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IEC 60384-22 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the document has been completely restructured to comply with the ISO/IEC Directives, Part 2 and to make it more useable; tables, figures and references have been revised accordingly; Annex X contains all cross-references of changes in clause/subclause numbers;

b) the requirements of reference temperature 25 °C has been added in Table 5, Table 9, Table 10, Table 12, Table 14 and Table 17;

c) the table of temperature characteristics of capacitance for the reference temperature 25 °C have been added in Table C.1, Table C.2 and Table C.3;

d) the requirement in 5.5.2 (visual examination) has been repeated in 5.9.3, 5.10.6, 5.11.4, 5.12.6, 5.13.8, 5.14.6 and 5.15.6;

e) the deflection D in the very robust designs has been added in 5.9.1;

f) Annex C has been changed informative into normative;

g) Clause D.5 (Test schedule for quality conformance inspection) has been newly added to withdraw the blank detail specification: IEC 60384-22-1.

The text of this International Standard is based on the following documents:

Draft	Report on voting
40/3120/FDIS	40/3139/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60384 series, published under the general title *Fixed capacitors for use in electronic equipment*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 22: Sectional specification – Fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

1 Scope

This part of IEC 60384 is applicable to fixed unencapsulated surface mount multilayer capacitors of ceramic dielectric, Class 2, for use in electronic equipment. These capacitors have metallized connecting pads or soldering strips and are intended to be mounted on printed boards, or directly onto substrates for hybrid circuits.

Capacitors for electromagnetic interference suppression are not included but are covered by IEC 60384-14.

The object of this document is to specify preferred ratings and characteristics and to select from IEC 60384-1:2021 the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of capacitor. Test severities and requirements specified in detail specifications referring to this document provide specific test severities and requirements of an equal or higher performance level. Further information on the conception of generic, sectional and detail specifications can be found in the Introduction of IEC 60384-1:2021.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td – Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60384-1:2021, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 61193-2:2007, *Quality assessment system – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60384-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
surface mount multilayer capacitor
multilayer capacitor whose small dimensions and nature or shape of terminations make it suitable for surface mounting in hybrid circuits and on printed boards

3.2
capacitor of ceramic dielectric, Class 2
capacitor that has a dielectric with a high permittivity and is suitable for by-pass and coupling applications or for frequency-discriminating circuits where low losses and high stability of capacitance are not of major importance

Note 1 to entry: The ceramic dielectric is characterized by a non-linear change of capacitance over the category temperature range (see Table 3).

3.3
subclass
<Class 2> maximum percentage change of capacitance within the category temperature range with respect to the capacitance at the reference temperature 20 °C or 25 °C

Note 1 to entry: The subclass may be expressed in code form (see Table 3 and Annex C).

3.4
category temperature range
ambient temperature range for which the capacitor has been designed to operate continuously

Note 1 to entry: This is given by the lower and upper category temperature (see Table 3 and Annex C).

3.5
rated temperature
T_R
maximum ambient temperature at which the rated voltage can be continuously applied

3.6
rated voltage
U_R
maximum DC voltage that can be applied continuously to a capacitor at any temperature between the lower category temperature and the rated temperature

Note 1 to entry: The maximum DC voltage is the sum of the DC voltage and peak AC voltage or peak pulse voltage applied to the capacitor.

3.7
category voltage
U_C
maximum voltage that can be applied continuously to a capacitor at its upper category temperature

4 Preferred ratings and characteristics

4.1 Preferred characteristics

Preferred climatic categories only shall be given in the preferred characteristics.

The capacitors covered by this document are classified into climatic categories in accordance with the general rules given in IEC 60068-1:2013, Annex A.

For reference temperature 20 °C, the lower and upper category temperatures and the duration of the damp heat, steady state test shall be chosen from the following:

- lower category temperature: −55 °C, −40 °C, −25 °C, −10 °C and +10 °C;
- upper category temperature: +70 °C, +85 °C, +100 °C, +125 °C and +150 °C;
- duration of the damp heat, steady state test (40 °C, 93 % RH): 4, 10, 21 and 56 days.

For reference temperature 25 °C, the lower and upper category temperatures shall be chosen from Table C.1 in Annex C.

The severities of the cold and dry heat tests are the lower and upper category temperatures respectively.

NOTE The resistance to humidity resulting from the above climatic category is for the capacitors in their unmounted state. The climatic performance of the capacitors after mounting is greatly influenced by the mounting substrate, the mounting method (see 5.4) and the final coating.

4.2 Preferred values of ratings

4.2.1 Rated temperature (T_R)

The rated temperature is equal to the upper category temperature for capacitors with the upper category temperature not exceeding 125 °C, unless otherwise stated in the detail specification.

4.2.2 Rated voltage (U_R)

The preferred values of the rated voltage are the values of the R5 series of ISO 3. If other values are needed, they shall be chosen from the R10 series.

The sum of the DC voltage and the peak AC voltage or the peak-to-peak AC voltage, whichever is the greater, applied to the capacitor shall not exceed the rated voltage.

4.2.3 Category voltage (U_C)

The category voltage is equal to the rated voltage for capacitors with the upper category temperature not exceeding 125 °C. Any category voltages which are different from the rated voltage, for capacitors with the upper category temperature exceeding 125 °C or for high-voltage capacitors with rated voltages about 500 V, shall be given in the detail specification.

The preferred values of the category voltage at 125 °C upper category temperature for high volumetric capacitors with a rated voltage of 16 V and less and a rated temperature of 85 °C are given in Table 1.

Table 1 – Preferred values of category voltages

U_R	V	2,5	4	6,3	10	16
U_C	V	1,6	2,5	4	6,3	10

NOTE The numeric values of U_C are calculated by the following:

$$U_C = 0{,}63 \times U_R$$

4.2.4 Preferred values of nominal capacitance and associated tolerance values

4.2.4.1 Preferred values of nominal capacitance

Nominal capacitance values should be taken from the E3, E6 and E12 series given in IEC 60063.

4.2.4.2 Preferred tolerances on nominal capacitance

See Table 2.

Table 2 – Preferred tolerances

Preferred series	Tolerance %	Letter code
E3 and E6	−20/+80	Z
	−20/+50	S
E6	± 20	M
E6 and E12	± 10	K

4.2.5 Temperature characteristic of capacitance

Table 3 shows the temperature characteristic with and without DC voltage applied for the reference temperature 20 °C. The method of coding the subclass is also given; for example a dielectric with a percentage change of ±20 % without DC voltage applied over the temperature range from −55 °C to +125 °C will be defined as a dielectric of subclass 2C1.The temperature characteristics, category temperatures and corresponding codes for the reference temperature 25 °C are given in Annex C. The temperature range for which the temperature characteristic of the dielectric is defined is the same as the category temperature range.

Table 3 – Temperature characteristic of capacitance

Sub-class letter code	Maximum capacitance change within the category temperature range with respect to the capacitance at 20 °C measured with and without a DC voltage applied %		Category temperature range and corresponding number code					
			−55/+150 °C	−55/+125 °C	−55/+85 °C	−40/+85 °C	−25/+85 °C	+10/+85 °C
	without DC voltage applied	with DC voltage applied[a]	0	1	2	3	4	6
2B	±10	Requirements specified in the detail specification						
2C	±20							
2D	+20/−30							
2E	+22/−56							
2F	+30/−80							
2R	±15							

When the upper category temperature is above 125 °C, the limits of capacitance change, both with and without DC voltage applied, should be given in the detail specification.

NOTE Annex C can be referred to for preferred values of the temperature characteristic for the reference temperature of 25 °C.

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

4.2.6 Dimensions

Suggested rules for the specification and coding of dimensions are given in Annex A.

Specific dimensions shall be given in the detail specification.

5 Test and measurement procedures

5.1 General

This Clause 5 supplements the information given in IEC 60384-1:2021, Clause 5 to Clause 10.

5.2 Special preconditioning

Unless otherwise specified in the detail specification, the special preconditioning, when specified in this document before a test or a sequence of test, shall be carried out under the following conditions.

Exposure at upper category temperature or at such higher temperature as may be specified in the detail specification during 1 h, followed by recovery during (24 ± 1) h under standard atmospheric conditions for testing.

NOTE Capacitors lose capacitance continuously with time in accordance with a logarithmic law (this is called ageing). However, if the capacitor is heated to a temperature above the Curie point of its dielectric, then "de-ageing" takes place, i.e. the capacitance lost through "ageing" is regained, and "ageing" recommences from the time when the capacitor recools. The purpose of special preconditioning is to bring the capacitor to a defined state regardless of its previous history (see Clause B.4 for further information).

5.3 Measuring conditions

See IEC 60384-1:2021, 5.2.1.

5.4 Mounting

See IEC 60384-1:2021, 5.5.

5.5 Visual examination and check of dimensions

5.5.1 General

See IEC 60384-1:2021, 7.1, with the details of 5.5.2 and 5.5.3.

5.5.2 Visual examination

A visual examination shall be carried out with suitable equipment with approximately 10× magnification and lighting appropriate to the specimen under test and the quality level required. In case the specimen are very small components, the visual examination may be carried out with higher magnification.

The operator should have available facilities for incident or transmitted illumination as well as an appropriate measuring facility.

5.5.3 Requirements

5.5.3.1 General

Quantitative values for the requirements below may be given in the detail or in the manufacturer's specification.

5.5.3.2 Requirements for the ceramic

Requirements for the ceramic are as follows:

a) Be free of cracks or fissures, except small damages on the surface, that do not deteriorate the performance of the capacitor (examples: see Figure 1 and Figure 2).

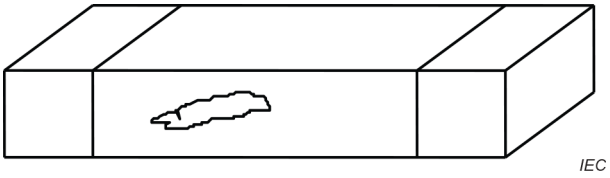
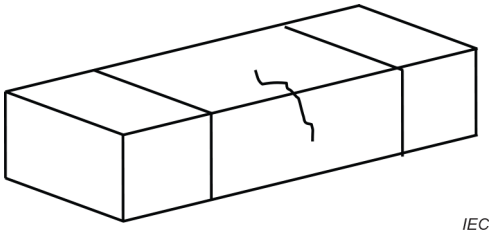


Figure 1 – Fault: crack or fissure



NOTE Crack or fissure on one side or extending from one face to another over a corner.

Figure 2 – Fault: crack or fissure

b) Not exhibit visible separation or delamination between the layers of the capacitor (see Figure 3).

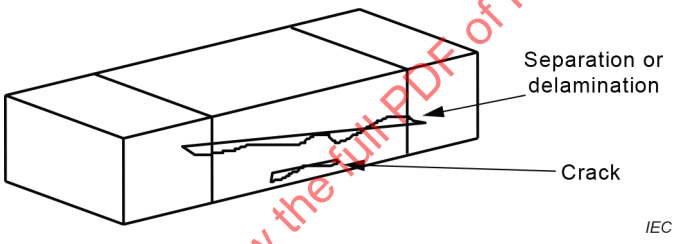


Figure 3 – Separation or delamination

c) Not exhibit exposed electrodes between the two terminations (see Figure 4).

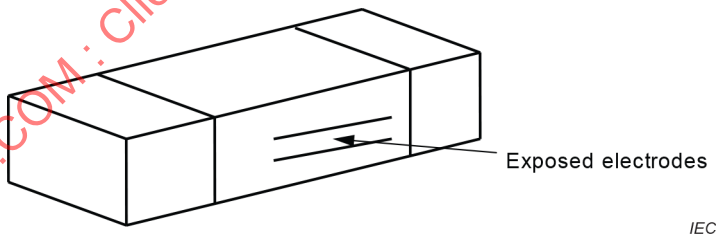


Figure 4 – Exposed electrodes

d) The ceramic body shall be free of any conducting smears (metallization, tinning, etc.) on a central zone between two adjacent terminations which is equal to the minimum distance between those (Annex A, dimension L_4).

5.5.3.3 Requirements for the metallization

Requirements for the metallization are as follows:

a) Not exhibit any visible detachment of the metallized terminations and not exhibit any exposed electrodes (see Figure 4).

b) The principal faces (see Figure 5) are those noted A, B and C.

In the case of capacitors of square section, the faces D and E are also considered principal.

The maximum area of gaps in metallization on each principal face shall not be greater than 15 % of the area of that face; these gaps shall not be concentrated in the same area. The gaps in metallization shall not affect the two principal edges of each extremity of the block (or four edges for square section capacitors). Dissolution of the end face plating (leaching) shall not exceed 25 % of the length of the edge concerned.

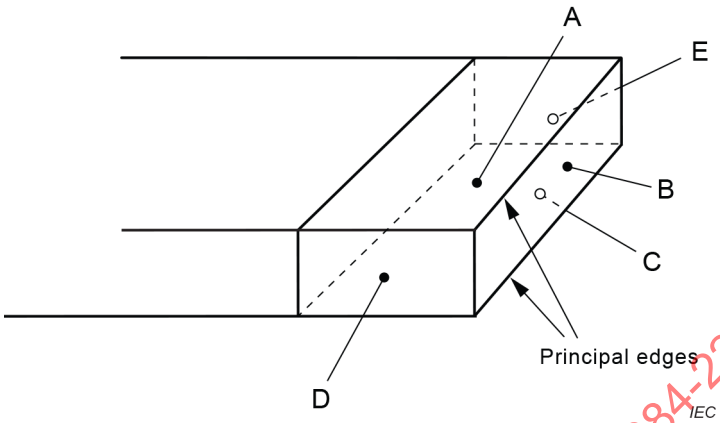


Figure 5 – Principal faces

5.6 Electrical tests

5.6.1 Capacitance

5.6.1.1 General

See IEC 60384-1:2021, 6.3, with the details of 5.6.1.2 and 5.6.1.3.

5.6.1.2 Measuring conditions

See Table 4, unless otherwise specified in the detail specification.

Table 4 – Measuring conditions

Nominal capacitance	Rated voltage U_R	Frequency	Measuring voltage V RMS	Referee voltage V RMS
CN < 100 pF	[a]	1 MHz	1,0 ± 0,2	1,0 ± 0,02
100 pF ≤ CN ≤ 10 µF	U_R > 6,3 V	1 kHz	1,0 ± 0,2	1,0 ± 0,02
	U_R ≤ 6,3 V	1 kHz	0,5 ± 0,2	0,5 ± 0,02
CN > 10 µF	[a]	100 Hz or 120 Hz	0,5 ± 0,2	0,5 ± 0,02

[a] All-rated voltages (U_R).

5.6.1.3 Requirements

The capacitance value as measured in the unmounted state, shall correspond with the rated value taking into account the specified tolerance.

The capacitance as measured in the mounted state in accordance with Group 3 is for reference purposes only in further tests.

For referee measurements, the capacitance value shall be the value extrapolated to an ageing time of 1 000 h, unless otherwise specified in the detail specification (see Annex B for explanations).

5.6.2 Tangent of loss angle (tan δ)

5.6.2.1 General

See IEC 60384-1:2021, 6.4, with the details of 5.6.2.2 and 5.6.2.3.

5.6.2.2 Measuring conditions

The measuring conditions are the same as those of 5.6.1. The inaccuracy of the measuring equipment shall not exceed 1×10^{-3}.

5.6.2.3 Requirements

The tangent of loss angle as measured in the unmounted state shall not exceed the limit given in Table 5.

Table 5 – Tangent of loss angle limits

Reference temperature	Rated voltage U_R	Subclass	Tangent of loss angle
20°C	$U_R \geq 10$ V	All subclass codes	Not exceed 0,035 or value as may be given in the detail specification
	$U_R < 10$ V	2B, 2C, 2R	0,1
		2D, 2E	0,15
		2F	0,2
25°C	$U_R \geq 10$ V	All subclass codes	Not exceed 0,035 or value as may be given in the detail specification
	$U_R < 10$ V	R	0,1
		S	0,1
		T	0,15
		U	0,15
NOTE See 4.2.5 and Annex C for an explanation of the subclass codes.			

The tangent of loss angle as measured in the mounted state in accordance with Group 3 is for reference purposes only in further tests.

5.6.3 Insulation resistance

5.6.3.1 General

See IEC 60384-1:2021, 6.1, with the details of 5.6.3.2 to 5.6.3.4.

5.6.3.2 Preparation for test

Prior to the test, capacitors shall be carefully cleaned to remove any contamination.

Care shall be taken to maintain cleanliness in the test chambers and during post-test measurements. Before the measurement, the capacitors shall be fully discharged. The insulation resistance shall be measured between the terminations.

5.6.3.3 Measuring conditions

See IEC 60384-1:2021, 6.1.2, with the following details.

The measuring voltage may be of any value not greater than U_R, the referee voltage being U_R, for a capacitor with a rated voltage below or equal to 1 kV. For U_R > 1 kV the referee voltage shall be 1 kV.

The insulation resistance (R_i) shall be measured after the voltage has been applied for (60 ± 5) s.

For lot-by-lot testing (Group A), the test may be terminated in a shorter time, if the required value of insulation resistance is reached.

The product of the internal resistance of the voltage source and the nominal capacitance of the capacitor shall not exceed 1 s, unless otherwise specified in the detail specification.

The charge current shall not exceed 0,05 A. For capacitors with rated voltages of 1 kV and above, a lower limit (value) may be given in the detail specification.

5.6.3.4 Requirements

The insulation resistance shall meet the following requirements.

C_N ≤ 25 nF	R_i ≥ 4 000 MΩ
C_N > 25 nF	$R_i \times C_N$ ≥ 100 s

5.6.4 Voltage proof

5.6.4.1 General

See IEC 60384-1:2021, 6.2, with the details of 5.6.4.2 to 5.6.4.4.

5.6.4.2 Test conditions

The product of R_1 and the nominal capacitance C_X shall be smaller than or equal to 1 s.

NOTE R_1 is a charging resistor that includes the internal resistance of the voltage source. More information can be found in IEC 60384-1:2021, 6.2.2.

The charge current shall not exceed 0,05 A.

For capacitors with rated voltages of 1 kV and above, a lower charge current limit value may be given in the detail specification. To protect the capacitors against flashover, the test may be performed in a suitable insulating medium.

5.6.4.3 Test voltages

The test voltages in accordance with Table 6 shall be applied between the measuring points of 6.1.3 and Table 3 in IEC 60384-1:2021, for a period of 1 min for qualification approval testing and for a period of 1 s for the lot-by-lot quality conformance testing.

Table 6 – Test voltages

Rated voltage V	Test voltage V
U_R ≤ 100	2,5 U_R
100 < U_R ≤ 200	1,5 U_R + 100
200 < U_R ≤ 500	1,3 U_R + 100

$500 < U_R < 1\ 000$	1,3 U_R
$U_R \geq 1\ 000$	1,2 U_R

5.6.4.4 Requirement

There shall be no breakdown or flashover during the test.

5.6.5 Impedance (if required by the detail specification)

5.6.5.1 General

See IEC 60384-1:2021, 6.6, with the details of 5.6.5.2 and 5.6.5.3.

5.6.5.2 Measuring conditions

The frequency of measurement: 100 kHz, with a relative tolerance of ±10 %.

5.6.5.3 Requirements

Impedance shall be specified in the detail specification.

5.6.6 Equivalent series resistance [ESR] (if required by the detail specification)

5.6.6.1 General

See IEC 60384-1:2021, 6.4.2, with the details of 5.6.6.2 and 5.6.6.3.

5.6.6.2 Measuring conditions

The frequency of measurement: 100 kHz, with a relative tolerance of ±10 %.

5.6.6.3 Requirements

The ESR shall be specified in the detail specification.

5.7 Temperature characteristic of capacitance (reference temperature 20 °C)

5.7.1 Special preconditioning

See 6.2.

5.7.2 Measuring conditions

See IEC 60384-1:2021, 6.8.1, with the following details.

The capacitors shall be measured in unmounted stage following the steps and conditions given in Table 7.

The measuring steps and conditions for a reference temperature 25 °C are given in Annex C.

Table 7 – Details of measuring conditions

Measuring step	Temperature °C	DC voltage applied
1	20 ± 2	–
2	T_A [a] ± 3	–
3	20 ± 2	–
4	T_B [b] ± 2	–
5	T_B ± 2	×
6	20 ± 2	×
7	T_A ± 3	×
8	20 ± 2	–

Measurements may be made at such intermediate temperatures as to ensure that the requirements of 4.2.5 are met.

Reference capacitance is the capacitance measured at Step 3.

Because of the effects described in the Note in 5.2, the capacitance values measured at temperature reference, Steps 5 to 7, with DC voltage applied, are time dependent. This time dependency is included in the given limits for capacitance change. The capacitance changes between the first and the last measurements at temperature reference, Steps 1 and 8, indicates the amount of ageing involved. In the case of a dispute about the results of measurements with DC voltage applied, it is advisable to agree upon a fixed time interval between measurements at temperature reference, Steps 5 and 7 with DC voltage applied (see IEC 60384-1:2021, 6.8.1.3).

NOTE "–" indicates: no DC voltage applied

"×" indicates: DC voltage applied (if specified in the detail specification)

[a] T_A = Lower category temperature.

[b] T_B = Upper category temperature.

5.7.3 Requirements

Temperature characteristic with and without DC voltage applied shall not exceed the values given in Table 3. The variation of capacitance shall be calculated in accordance with IEC 60384-1:2021, 6.8.3.1.

5.8 Shear test

See IEC 60384-1:2021, 7.7.

A force shall be selected from 1 N, 2 N, 5 N or 10 N and specified in the detail specification.

5.9 Substrate bending test

5.9.1 General

See IEC 60384-1:2021, 7.8.

Unless otherwise specified in the detail specification,

– the deflection D shall be selected from 1 mm, 2 mm or 3 mm, higher deflection values may be given in the detail specification in case of very robust designs.
– the number of bends shall be 1 time,
– the radius of the bending tool shall be 5 mm.

– When the deflection D is 2 mm or less, the radius may be 230 mm.
– the duration in the bent state shall be 5 s.

For 1005M or smaller size, the thickness of substrate should be 0,8 mm.

5.9.2 Initial measurement

The capacitance shall be measured as specified in 5.6.1 and in the detail specification.

5.9.3 Final inspection

The capacitors shall be visually examined and there shall be no visible damage. See 5.5.2.

The change of capacitance with board in bent position shall not exceed 10 %.

5.10 Resistance to soldering heat

5.10.1 General

See IEC 60068-2-58 with the details of 5.10.2 to 5.10.6.

5.10.2 Special preconditioning

See 5.2.

5.10.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.10.4 Test conditions

5.10.4.1 Solder bath method (applicable to 1608M, 2012M and 3216M)

NOTE See Table A.1 for explanation of the size code.

See IEC 60068-2-58, Test Td_2, Method 1, with the following details, if not otherwise specified in the detail specification.

The specimen shall be preheated to a temperature of 110 °C to 140 °C and maintained for 30 s to 60 s.

Solder alloy:	Sn-Pb or Sn-Ag-Cu
Temperature:	260 °C ± 5 °C
Duration of immersion:	10 s ± 1 s
Depth of immersion:	10 mm
Number of immersions:	1

5.10.4.2 Infrared and forced gas convection soldering system

See IEC 60068-2-58, Test Td_2, Method 2, with the following details:

a) the solder paste shall be applied to the test substrate;
b) the thickness of solder deposit shall be specified in the detail specification;
c) the terminations of the specimen shall be placed on the solder paste;

d) solder alloy: Sn-Pb;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 5) °C and maintained at this temperature for (10 ± 1) s;

e) solder alloy: Sn-Ag-Cu;

unless otherwise specified in the detail specification, the reflow temperature profile shall be selected from Table 8 and Figure 6.

Table 8 – Reflow temperature profiles for Sn-Ag-Cu alloy

Alloy composition		T_1 °C	T_2 °C	t_1 s	T_3 °C	t_2 s	T_4 °C	t_3 s
Lead-free solder (Sn-Ag-Cu)	Test	150 ± 5	180 ± 5	120 ± 5	220	60 to 90	250	20 to 40 at T_4 – 5 °C

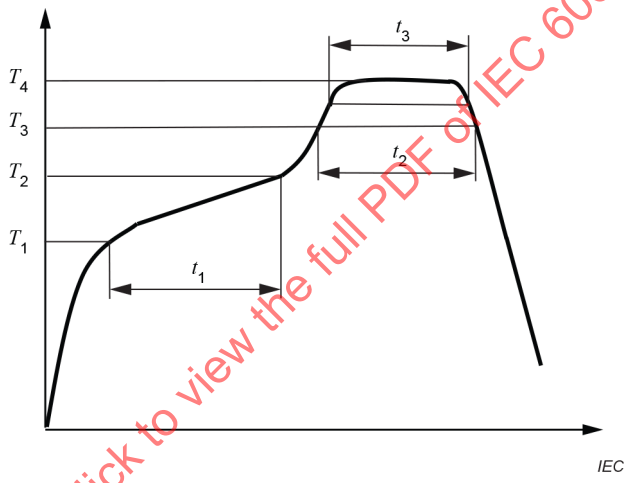


Figure 6 – Reflow temperature profile

f) number of each test: 1, unless otherwise specified in the detail specification.

g) the temperature profile of d) or e) shall be specified in the detail specification.

5.10.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

The flux residues shall be removed with a suitable solvent.

5.10.6 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined and measured and shall meet the following requirements.

Under normal lighting and approximately 10× magnification, there shall be no signs of damage such as cracks. See 5.5.2.

Dissolution of the end face plating (leaching) shall not exceed 25 % of the length of the edge concerned. The detail specification may specify further details.

The capacitance shall be measured in accordance with 5.6.1 and the change shall not exceed the values in Table 9.

Table 9 – Maximum capacitance change

Reference temperature 20 °C	
Subclass	**Requirements**
2B and 2C	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 4.2.5 for an explanation of the subclass codes.	
Reference temperature 25 °C	
Subclass	**Requirements**
R	±10 %
S	±10 %
T	±15 %
U	±20 %
NOTE See Table C.2 for an explanation of the subclass codes.	

5.11 Solderability

5.11.1 General

See IEC 60068-2-58 with the details of 5.11.2 to 5.11.4.

5.11.2 Test conditions

5.11.2.1 Solder bath method (applicable to 1608M, 2012M and 3216M)

NOTE See Table A.1 for explanation of the size code.

See IEC 60068-2-58, Test Td_1, Method 1, with the following details, if not otherwise specified in the detail specification.

The specimen shall be preheated to a temperature of 80 °C to 140 °C and maintained for 30 s to 60 s.

Solder alloy:	Sn-Pb	Sn-Ag-Cu
Temperature:	(235 ± 5) °C	(245 ± 5) °C
Duration of immersion:	(2 ± 0,2) s	(3 ± 0,3) s
Depth of immersion:	10 mm	10 mm
Number of immersions:	1	1

5.11.2.2 Infrared and forced gas convection soldering system

See IEC 60068-2-58, Test Td_1, Method 2, with the following details:

a) the solder paste shall be applied to the test substrate;
b) the thickness of solder deposit shall be specified in the detail specification;
c) the terminations of the specimen shall be placed on the solder paste;

d) solder alloy: Sn-Pb;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in the infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (215 ± 3) °C and maintained at this temperature for (10 ± 1) s;

e) solder alloy: Sn-Ag-Cu;

unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 5) °C to (180 ± 5) °C for 60 s to 120 s in the infrared and forced gas convection soldering system;

the temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 3) °C. The time above 225 °C shall be (20 ± 5) s;

f) the temperature profile of d) or e) shall be specified in the detail specification.

5.11.3 Recovery

The flux residues shall be removed with a suitable solvent.

5.11.4 Final inspection, measurements and requirements

The capacitors shall be visually examined under normal lighting and approximately 10× magnification. There shall be no signs of damage. See 5.5.2.

Both end face and the contact areas shall be covered with a smooth and bright solder coating with no more than a small number of scattered imperfections such as pinholes or unwetted or de-wetted areas. These imperfections shall not be concentrated in one area.

The detail specification may specify further requirements.

5.12 Rapid change of temperature

5.12.1 General

This test shall be applied only to capacitors for which the category temperature is greater 110 °C.

See IEC 60384-1:2021, 8.1, with the details of 5.12.2 to 5.12.6.

The capacitors shall be mounted in accordance with 5.4.

5.12.2 Special preconditioning

See 5.2.

5.12.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.12.4 Number of cycles

The number of cycles: 5

Duration of exposure at the temperature limits: 30 min.

5.12.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.12.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitance shall be measured in accordance with 5.6.1 and the change shall not exceed the value in Table 10.

Table 10 – Maximum capacitance change

Reference temperature 20 °C	
Subclass	**Requirements**
2B and 2C	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 4.2.5 for an explanation of the subclass codes.	
Reference temperature 25 °C	
Subclass	**Requirements**
R	±10 %
S	±10 %
T	±15 %
U	±20 %
NOTE See Table C.2 for an explanation of the subclass codes.	

5.13 Climatic sequence

5.13.1 General

See IEC 60384-1:2021, 8.2, with the details of 5.13.2 to 5.13.8.

5.13.2 Special preconditioning

See 5.2.

5.13.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.13.4 Dry heat

See IEC 60384-1:2021, 8.2.3.

5.13.5 Damp heat, cyclic, Test Db, first cycle

See IEC 60384-1:2021, 8.2.4.

5.13.6 Cold

See IEC 60384-1:2021, 8.2.5, with the following details.

The capacitors shall be visually examined. There shall be no visible damage.

5.13.7 Damp heat, cyclic, Test Db, remaining cycles

5.13.7.1 General

See IEC 60384-1:2021, 8.2.7, with the details of 5.13.7.2 and 5.13.7.3.

5.13.7.2 Test conditions

No voltage applied.

The remaining cycles shall be tested in accordance with Table 11.

Table 11 – Number of damp heat cycles

Category	No. of cycles of 24 h
- / – / 56	5
- / – / 21	1
- / – / 10	1
- / – / 04	0

5.13.7.3 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.13.8 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 12.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 12 shall be met.

Table 12 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements (reference temperature 20°C)			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclasses 2E	Subclasses 2F
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %	$\Delta C/C$ ≤ ± 30 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					
Measurement	**Measuring conditions**	**Requirements (reference temperature 25°C)**			
		Subclasses R	**Subclasses** S	**Subclasses** T	**Subclasses** U
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.14 Damp heat, steady state

5.14.1 General

See IEC 60384-1:2021, 8.3, with the details of 5.14.2 to 5.14.6.

The capacitors shall be mounted in accordance with 5.4.

5.14.2 Special preconditioning

See 5.2.

5.14.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.14.4 Test conditions

No voltage shall be applied, unless otherwise specified in the detail specification.

The severity of the test should be selected from the test conditions as shown in Table 13 and be specified in the detail specification.

The duration time should be selected in accordance with 4.1 and shall be specified in the detail specification.

Table 13 – Test conditions for damp heat, steady state

Severity	Temperature °C	Relative humidity %
1	+85 ± 2	85 ± 3
2	+60 ± 2	93 ± 3
3	+40 ± 2	93 ± 3

When the application of voltage is specified, U_R shall be applied to one half of the lot and no voltage shall be applied to the other half of the lot.

Within 15 min after removal from the damp heat test, the voltage proof test in accordance with 5.6.4 shall be carried out, but with the rated voltage applied.

For safety reasons, different conditions for the application of voltage to capacitors with rated voltages of 1 kV or above may be given in the detail specification.

5.14.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.14.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 14.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made, the capacitors shall be preconditioned in accordance with 5.2 and then the requirement in Table 14 shall be met.

Table 14 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements (reference temperature 20°C)			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclasses 2E	Subclasses 2F
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %	$\Delta C/C$ ≤ ± 30 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	R_i ≥ 1 000 MΩ or $R_i \times C_N$ ≥ 25 s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					

Measurement	Measuring conditions	Requirements (reference temperature 25°C)			
		Subclasses R	Subclasses S	Subclasses T	Subclasses U
Capacitance	5.6.1	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 10 %	$\Delta C/C$ ≤ ± 15 %	$\Delta C/C$ ≤ ± 20 %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	$R_i \geq 1\ 000$ MΩ or $R_i \times C_N \geq 25$ s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.15 Endurance

5.15.1 General

See IEC 60384-1:2021, 8.5, with the details of 5.15.2 to 5.15.6.

The capacitors shall be mounted in accordance with 5.4.

5.15.2 Special preconditioning

See 5.2.

5.15.3 Initial measurement

The capacitance shall be measured in accordance with 5.6.1.

5.15.4 Test conditions

If the category voltage is equal to the rated voltage, the capacitors shall be tested as in Table 15.

Table 15 – Endurance test conditions ($U_C = U_R$)

U_R	$U_R \leq 200$	$200 < U_R \leq 500$	$U_R > 500$
Temperature	Upper category temperature		
Voltage (DC)	1,5 U_R	1,3 U_R	1,2 U_R
Duration	1 000 h	1 500 h	2 000 h

If the category voltage is not equal to the rated voltage, the capacitors shall be tested as in Table 16.

Table 16 – Endurance test conditions ($U_C \neq U_R$)

U_R	$U_R \leq 200$		$200 < U_R \leq 500$		$U_R > 500$	
Temperature	T_R	T_B	T_R	T_B	T_R	T_B
Voltage (DC)	1,5 U_R	1,5 U_C	1,3 U_R	1,3 U_C	1,2 U_R	1,2 U_C
Duration	1 000 h		1 500 h		2 000 h	
Sample	Divided into two parts		Divided into two parts		Divided into two parts	
T_R = Rated temperature. T_B = Upper category temperatures > 85 °C, such as 100 °C.						

5.15.5 Recovery

The capacitors shall recover for 24 h ± 2 h.

5.15.6 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage. See 5.5.2.

The capacitors shall be measured and shall meet the requirements in Table 17.

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 17 shall be met.

Table 17 – Final inspection, measurements and requirements of endurance test

Measurement	Measuring conditions	Requirements (reference temperature 20 °C)			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclasses 2E	Subclasses 2F
Capacitance	5.6.1	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 15$ %	$\Delta C/C \leq \pm 20$ %	$\Delta C/C \leq \pm 30$ %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	$R_i \geq 2\,000$ MΩ or $R_i \times C_N \geq 50$ s (whichever is less of the two values)			
NOTE See 4.2.5 for an explanation of the subclass codes.					
Measurement	Measuring conditions	Requirements (reference temperature 25 °C)			
		Subclasses R	Subclasses S	Subclasses T	Subclasses U
Capacitance	5.6.1	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 10$ %	$\Delta C/C \leq \pm 15$ %	$\Delta C/C \leq \pm 20$ %
Tangent of loss angle	5.6.2	≤ 2 × value of 5.6.2			
Insulation resistance	5.6.3	$R_i \geq 2\,000$ MΩ or $R_i \times C_N \geq 50$ s (whichever is less of the two values)			
NOTE See Table C.2 for an explanation of the subclass codes.					

5.16 Robustness of terminations (only for capacitors with strip termination)

5.16.1 General

See IEC 60384-1:2021, 7.3, with the details of 5.16.2 and 5.16.3.

5.16.2 Test conditions

Unless otherwise specified in the detail specification, the conditions of the tests are as follows:

Test Ua_1: force: 2,5 N;

Test Ub, Method 1: force: 2,5 N;

number of bends: 1.

5.16.3 Final inspection and requirements

The capacitors shall be visually examined. There shall be no visible damage.

5.17 Component solvent resistance (if required)

See IEC 60384-1:2021, 9.4.

5.18 Solvent resistance of the marking (if required)

See IEC 60384-1:2021, 9.5.

5.19 Accelerated damp heat, steady state (if required)

5.19.1 General

See IEC 60384-1:2021, 8.9, with the details of 5.19.2 to 5.19.5.

The capacitors shall be mounted in accordance with 5.4 and IEC 60384-1:2021, 8.9.1.

Half the capacitors shall be connected in series with resistors of 100 kΩ, with a relative tolerance of ±10 % and half in series with resistors of 6,8 kΩ, with a relative tolerance of ±10 %.

5.19.2 Initial measurement

The capacitors shall be measured for insulation resistance with a voltage of 1,5 V ± 0,1 V applied across the capacitor and resistor in series.

The insulation resistance, including the series resistor, shall meet the requirements given in Table 18.

Table 18 – Initial requirements

Measurement	Measuring conditions	Requirements	
Insulation resistance	(1,5 ± 0,1) V	Connected to 100 kΩ resistors	$C_N \leq 25$ nF: $R_i \geq 4\,000$ MΩ $C_N > 25$ nF: $(R_i - 100\ \text{k}\Omega) \times C_N \geq 100$ s
		Connected to 6,8 kΩ resistors	$C_N \leq 25$ nF: $R_i \geq 4\,000$ MΩ $C_N > 25$ nF: $(R_i - 6{,}8\ \text{k}\Omega) \times C_N \geq 100$ s

5.19.3 Conditioning

The capacitors with associated resistors shall be subjected to conditioning at (85 ± 2) °C, (85 ± 3) % relative humidity for the test duration given in Table 19. The voltage given in Table 19 shall be applied to the capacitors connected to 100 kΩ resistors and those connected to 6,8 kΩ resistors. In both cases, the voltage shall be applied across the capacitor/resistor combination.

Care shall be taken to avoid condensation of water on the capacitors or substrates. This can happen if the door is opened during the test before the humidity is lowered.

Table 19 – Conditioning

Connected resistors kΩ	Applied voltage	Duration
100	(1,5 ± 0,1) V or the voltage specified in the detail specification	168 h, 500 h or 1 000 h; as specified in the detail specification
6,8	(50 ± 0,1) V or U_R, whichever is the lower, or the voltage specified in the detail specification	

5.19.4 Recovery

The applied voltage shall be disconnected, and the capacitors and resistors shall be removed from the test chamber and allowed to recover for 24 ± 2 h in standard atmospheric conditions for testing.

5.19.5 Final measurements

The capacitors shall be measured for insulation resistance, as in 5.19.2.

The insulation resistance, including the series resistor, shall be higher than 0,1 times the values given in 5.19.2.

6 Marking

6.1 General

See IEC 60384-1:2021, 4.3, with the details of 6.2 to 6.6.

6.2 Information for marking

The information given in the marking is normally selected from the following list; the relative importance of each item is indicated by its position in the list:

– nominal capacitance;
– rated voltage (DC voltage may be indicated by the symbol: ⎓ [IEC 60417-5031(2002-10)] or ⎓);
– tolerance on nominal capacitance;
– dielectric subclass as applicable (in accordance with 4.2.5 or Annex C);
– year and month (or week) of manufacture;
– manufacturer's name or trade mark;
– climatic category;
– manufacturer's type designation;
– reference to the detail specification.

6.3 Marking on the body

These capacitors are generally not marked on the body. If some marking can be applied, they shall be clearly marked with as many as possible of the items stated in 6.2 as is considered useful. Any duplication of information in the marking on the capacitor should be avoided.

6.4 Requirements for marking

Any marking shall be legible and not easily smeared or removed by rubbing with fingers.

6.5 Marking of the packaging

The packaging containing the capacitor(s) shall be clearly marked with all the information listed in 6.2.

6.6 Additional marking

Any additional marking shall be so applied that no confusion can arise.

7 Information to be given in a detail specification

7.1 General

The detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic, sectional or blank detail specification. When more severe requirements are included, they shall be indicated in the test schedules, for example by an asterisk.

The information given in 7.2 may be presented in tabular form if more convenient.

The information in 7.2 to 7.5 shall be given in each detail specification and the values quoted should be selected from those given in the appropriate clause of this document.

7.2 Outline drawing and dimensions

There shall be an illustration of the capacitors as an aid to easy recognition and for comparison of the capacitors with others.

Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification. All dimensions shall be stated in millimetres, however, when the original dimensions are given in inches, the converted metric dimensions in millimetres shall be added.

Normally the numerical values shall be given for the length, width and height of the body. When necessary, for example when a number of items (sizes and capacitance/voltage ranges) are covered by a detail specification, the dimensions and their associated tolerances shall be placed in a table below the drawing.

When the configuration is other than described above, the detail specification shall state such dimensional information as will adequately describe the capacitors.

7.3 Mounting

The detail specification shall give guidance on methods of mounting for normal use. Mounting for test and measurement purposes (when required) shall be in accordance with 5.4 of this document.

7.4 Rating and characteristics

7.4.1 General

The ratings and characteristics shall be in accordance with the relevant clauses of this document, together with 7.4.2, 7.4.3 and 7.4.4.

7.4.2 Nominal capacitance range

The nominal capacitance range shall be specified as described in 4.2.4.1.

When products approved to the detail specification have different ranges, the following statement should be added: "The range of capacitance values available in each voltage range is given in the register of approvals, available for example on the IECQ on-line certificate system website www.iecq.org".

7.4.3 Particular characteristics

Additional characteristics may be listed, when they are considered necessary to specify adequately the component for design and application purposes.

7.4.4 Soldering

The detail specification shall specify the test methods, severities and requirements applicable for the solderability and the resistance to soldering heat tests.

7.5 Marking

The detail specification shall specify the content of the marking on the capacitor and on the packaging. Deviations from Clause 6 shall be specifically stated in the detail specification.

8 Quality assessment procedures

8.1 Primary stage of manufacture

The primary stage of manufacture is the first common firing of the dielectric-electrode assembly.

8.2 Structurally similar components

Capacitors considered as being structurally similar are capacitors produced with similar processes and materials, though they may be of different case sizes and values.

8.3 Certified records of released lots

The information required in IEC 60384-1:2021, Q.1.5, shall be made available when specified in the detail specification and when requested by a purchaser. After the endurance test, the parameters for which variables information is required are the capacitance change, tan δ and the insulation resistance.

8.4 Qualification approval

8.4.1 General

The procedures for qualification approval testing are given in IEC 60384-1:2021, Clause Q.2.

The schedule to be used for qualification approval testing on the basis of lot-by-lot and periodic tests is given in Annex D. The procedure using a fixed sample size schedule is given in 8.4.2 and 8.4.3.

8.4.2 Qualification approval on the basis of the fixed sample size procedures

The fixed sample size procedure is described in IEC 60384-1:2021, Q.2.4. The sample shall be representative of the range of capacitors for which approval is sought. This range may be different from the complete range covered by the detail specification.

For each temperature characteristic, the sample shall consist of specimens of capacitors of maximum and minimum size and for each of these sizes, the maximum capacitance value for the highest rated voltage and minimum rated voltage of the voltage ranges for which approval is sought. When there are more than four rated voltages, an intermediate voltage shall also be tested. Thus, for the approval of a range, testing is required of either four or six values (capacitance/voltage combinations) for each temperature characteristic. Where the total range consists of fewer than four values, the number of specimens to be tested shall be that required for four values.

In case assessment level EZ is used, spare specimens are permitted as follows:

Two (for six values) or three (for four values) per value may be used as replacements for specimens that are non-conforming because of incidents not attributable to the manufacturer.

The numbers given in Group 0 assume that all groups are applicable. If this is not so, the numbers may be reduced accordingly.

When additional groups are introduced into the qualification approval test schedule, the number of specimens required for Group 0 shall be increased by the same number as that required for the additional groups.

Table 20 gives the number of samples to be tested in each group or subgroup together with the number of permissible non-conformances for the qualification approval test.

8.4.3 Tests

The complete series of tests specified in Table 20 and Table 21 are required for the approval of capacitors covered by one detail specification. The tests of each group shall be carried out in the order given.

The whole sample shall be subjected to the tests of Group 0 and then divided for the other groups.

Non-conforming specimens found during the tests of Group 0 shall not be used for the other groups.

"One non-conforming item" is counted when a capacitor has not satisfied the whole or a part of the tests of a group.

The approval is granted when the number of non-conforming items is zero.

Table 20 and Table 21 together form the fixed sample size test schedule. Table 20 includes the details for the sampling and permissible non-conforming items for the different tests or groups of tests. Table 21 together with the details of the test contained in Clause 5 gives a complete summary of test conditions and performance requirements and indicates where, for example for the test method or conditions of test, a choice shall be made in the detail specification.

The conditions of test and performance requirements for the fixed sample size test schedule shall be identical to those specified in the detail specification for quality conformance inspection.

Table 20 – Fixed sample size test plan for qualification approval
Assessment level EZ

Group No.	Test	Subclause of this document	Number of specimens n[e]	Permissible number of nonconforming items c
0	Visual examination	5.5	132 + 24[f]	0
	Dimensions	5.5		
	Capacitance	5.6.1		
	Tangent of loss angle	5.6.2		
	Insulation resistance	5.6.3		
	Voltage proof	5.6.4		
	Spare specimens		12	
1A	Robustness of termination[g]	5.16	12	0
	Resistance to soldering heat	5.10		
	Component solvent resistance[b]	5.17		
1B	Impedance[b]	5.6.5	12	0
	Equivalent series resistance [ESR][b]	5.6.6		
	Solderability	5.11		
	Solvent resistance of marking[b]	5.18		
2	Substrate bending test[d]	5.9	12	0
3[a]	Mounting	5.4	84 + 24[f]	0[c]
	Visual examination	5.5		
	Capacitance	5.6.1		
	Tangent of loss angle	5.6.2		
	Insulation resistance	5.6.3		
	Voltage proof	5.6.4		
3.1	Shear test [h]	5.8	24	0
	Rapid change of temperature	5.12		
	Climatic sequence	5.13		
3.2	Damp heat, steady state	5.14	24	0
3.3	Endurance	5.15	36	0
3.4	Accelerated damp heat, steady state [b]	5.19	24[f]	0
4	Temperature characteristic of capacitance	5.7	12	0

[a] The values of these measurements serve as initial measurements for the tests of Group 3.
[b] If required in the detail specification.
[c] The capacitors found non-conforming items after mounting shall not be taken into account when calculating the permissible non-conforming for the following tests. They shall be replaced by spare capacitors.
[d] Not applicable to capacitors, which, in accordance with their detail specification, shall only be mounted on alumina substrates.
[e] Capacitance/voltage combinations, see 8.4.2.
[f] Additional capacitors, if Group 3.4 is tested.
[g] Applicable to capacitors with strip terminations.
[h] Not applicable to capacitors with strip terminations.

Table 21 – Test schedule for qualification approval

Test[a]		Conditions of test[a]	D or ND[b]	*n* | *c* (see Table 20)	Performance requirements[a]
GROUP 0			ND	See Table 20	
5.5	Visual examination				As in 5.5.3 Legible marking and as specified in the detail specification
5.5	Dimension (detail)				See the detail specification
5.6.1	Capacitance	Frequency: … Hz Measuring voltage: V RMS			Within specified tolerance
5.6.2	Tangent of loss angle (tan δ)	Frequency and Measuring voltage same as in 5.6.1			As in 5.6.2.3
5.6.3	Insulation resistance	See the detail specification for the method			As in 5.6.3.4
5.6.4	Voltage proof	See detail specification for the method			No breakdown or flashover
GROUP 1A			D	See Table 20	
5.16	Robustness of termination (if applicable)	Test Ua1, Force:2,5 N Test Ub, Method 1, Force:2,5 N Number of bends:1 Visual examination			No visible damage
5.10.3	Initial measurement	Capacitance			
5.10	Resistance to soldering heat	Special preconditioning as in 5.2 See the detail specification for the method Recovery: (24 ± 2) h			
5.10.6	Final inspection, measurement and requirements	Visual examination Capacitance			As in 5.10.6 As in 5.10.6
5.17	Component solvent resistance (if required)	Solvent: … Solvent temperature: Method 2 Recovery: …			See the detail specification
GROUP 1B			D	See Table 20	
5.6.5	Impedance (if required)	Frequency: 100 kHz			See the detail specification
5.6.6	ESR (if required)	Frequency: 100 kHz			See the detail specification
5.11	Solderability	See the detail specification for the method			
5.11.4	Final inspection, measurement and requirements	Visual examination			As in 5.11.4
5.18	Solvent resistance of the marking [c] (if required)	Solvent: … Solvent temperature: … Method 1 Rubbing material: cotton wool Recovery: …			Legible marking

Test[a]		Conditions of test[a]	D or ND[b]	n | c (see Table 20)	Performance requirements[a]
GROUP 2			D	See Table 20	
5.9	Substrate bending test	Deflection: … Number of bends: …			See the detail specification
5.9.2	Initial measurement	Capacitance			
5.9.3	Final inspection	Capacitance (with printed board in bent position)			$\lvert\Delta C/C\rvert$ ≤ 10 %
		Visual examination			No visible damage
GROUP 3			D	See Table 20	
5.4	Mounting	Substrate material: …[d]			
		Visual examination			As in 5.5.3
		Capacitance			Within specified tolerance
		Tangent of loss angle			As in 5.6.2.3
		Insulation resistance			As in 5.6.3.4
		Voltage proof			No breakdown or flashover
GROUP 3.1			D	See Table 20	
5.8	Shear test	Visual examination			No visible damage
5.12.3	Initial measurement	Capacitance			
5.12	Rapid change of temperature	Special preconditioning as in 5.2 T_A = Lower category temperature T_B = Upper category temperature Five cycles Duration t_1 = 30 min Recovery: (24 ± 2) h			
5.12.6	Final inspection, measurement and requirements	Visual examination			No visible damage
		Capacitance			$\Delta C/C$: as in 5.12.6
5.13	Climatic sequence	Special preconditioning as in 5.2			
5.13.3	Initial Measurement	Capacitance			
5.13.4	Dry heat	Temperature: upper category temperature Duration: 16 h			
5.13.5	Damp heat, cyclic, test Db, first cycle				
5.13.6	Cold	Temperature: lower category temperature Duration: 2 h			
		Visual examination			No visible damage
5.13.7	Damp heat, cyclic, test Db, remaining cycles	Recovery: (24 ± 2) h			
5.13.8	Final inspection, measurement and requirements	Visual examination			No visible damage Legible marking
		Capacitance			$\Delta C/C$: as in 5.13.8
		Tangent of loss angle			As in 5.13.8
		Insulation resistance			As in 5.13.8

Test[a]		Conditions of test[a]	D or ND[b]	*n* | *c* (see Table 20)	Performance requirements[a]
GROUP 3.2			D	See Table 20	
5.14	Damp heat, steady state	Special preconditioning as in 5.2			
5.14.3	Initial measurement	Capacitance			
		Recovery: (24 ± 2) h			
5.14.6	Final inspection, measurement and requirements	Visual examination			No visible damage
					Legible marking
		Capacitance			$\Delta C/C$: as in 5.14.6
		Tangent of loss angle			As in 5.14.6
		Insulation resistance			As in 5.14.6
GROUP 3.3			D	See Table 20	
5.15	Endurance	Special preconditioning as in 5.2			
		Duration: … h			
		Temperature: …°C			
		Voltage: …V			
5.15.3	Initial measurement	Capacitance			
		Recovery: (24 ± 2) h			
5.15.6	Final inspection, measurement and requirements	Visual examination			No visible damage
					Legible marking
		Capacitance			$\Delta C/C$: as in 5.15.6
		Tangent of loss angle			As in 5.15.6
		Insulation resistance			As in 5.15.6
GROUP 3.4			D	See Table 20	
5.19	Accelerated damp heat, steady state (if required)	Duration: … h			
		Temperature: (85 ± 2) °C			
		Humidity: (85 ± 3) % RH			
5.19.2	Initial measurement	Insulation resistance			As in 5.19.2
5.19.5	Final measurements	Recovery: (24 ± 2) h			As in 5.19.5
		Insulation resistance			
GROUP 4			ND	See Table 20	
5.7	Temperature characteristic of capacitance	Special preconditioning as in 5.2			$\Delta C/C$: as in 5.7.3

[a] Subclause numbers of test and performance requirements refer to Clause 5.

[b] In this table: D = destructive, ND= non-destructive.

[c] This test may be carried out on capacitors mounted on a substrate.

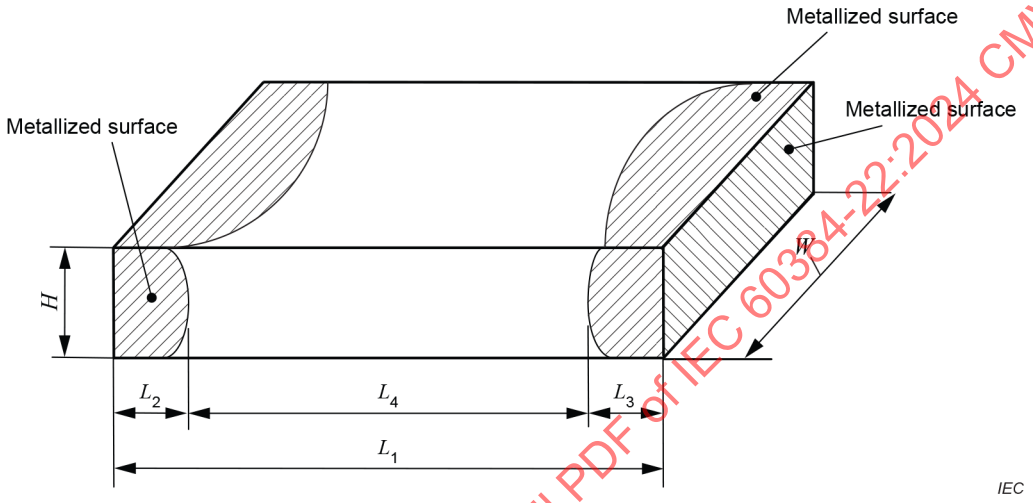
[d] When different substrate materials are used for the individual subgroup, the detail specification shall indicate which substrate material is used in each subgroup.

Annex A
(normative)

Guidance for the specification and coding of dimensions of fixed surface mount multilayer capacitors of ceramic dielectric, Class 2

The principles given in Figure A.1 shall be considered in the dimensioning of the capacitors.

Dimensions are specified in Table A.1.



Dimension W should not exceed dimension L_1.

Dimension H should not exceed dimension W.

If necessary, the thickness of tinning should be specified.

Figure A.1 – Dimensions

Table A.1 – Dimensions

Code	Length L_1	Width W	L_2; L_3 Minimum	L_4 Minimum
0201M	0,25 ± 0,013	0,125 ± 0,013	0,04	0,06
0402M	0,4 ± 0,02	0,2 ± 0,02	0,05	0,1
0603M	0,6 ± 0,03	0,3 ± 0,03	0,1	0,2
1005M	1,0 ± 0,05	0,5 ± 0,05	0,1	0,3
1608M	1,6 ± 0,1	0,8 ± 0,1	0,2	0,5
2012M	2,0 ± 0,1	1,25 ± 0,1	0,2	0,7
3216M	3,2 ± 0,2	1,6 ± 0,15	0,3	1,4
3225M	3,2 ± 0,2	2,5 ± 0,2	0,3	1,4
4532M	4,5 ± 0,3	3,2 ± 0,2	0,3	2,0
5750M	5,7 ± 0,4	5,0 ± 0,4	0,3	2,5
NOTE Dimension in millimetres.				

Other case sizes and dimensions may be specified in the detail specification.

Annex B
(normative)

Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

B.1 General

Most Class 2 dielectrics used for ceramic capacitors have ferroelectric properties and exhibit a Curie temperature.

Above this temperature, the dielectric has the highly symmetric cubic crystal structure whereas below the Curie temperature the crystal structure is less symmetrical. Although in single crystals this phase transition is very sharp, in practical ceramics, it is often spread over a finite temperature range, but in all cases, it is linked with a peak in the capacitance/temperature curve.

Under the influence of thermal vibration, the ions in the crystal lattice continue to move to positions of lower potential energy for a long time after the dielectric has cooled through the Curie temperature. This gives rise to the phenomenon of capacitance ageing, whereby the capacitor continually decreases its capacitance.

However, if the capacitor is heated to a temperature above the Curie temperature, then de-ageing takes place, i.e. the capacitance lost through ageing is regained, and ageing recommences from the time when the capacitor recools.

B.2 Law of capacitance ageing

During the first hour after cooling through the Curie temperature, the loss of capacitance is not well defined, but after this time, it follows a logarithmic law (see K.W. Plessner, Proc. Phys. Soc., vol. 69B, P1261, 1956) which can be expressed in terms of an ageing constant.

The ageing constant k is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a "decade", i.e. a time in which the capacitor increases its age tenfold for example from 1 h to 10 h.

As the law of decrease of capacitance is logarithmic, the percentage loss of capacitance will be $2 \times k$ between 1 h and 100 h age and $3 \times k$ between 1 h and 1 000 h. This can be expressed mathematically by the following equation:

$$C_t = C_1 \left(1 - \frac{k}{100} \times \lg t\right) \tag{B.1}$$

where

C_t is the capacitance t h after the start of the ageing process;

C_1 is the capacitance 1 h after the start of the ageing process;

k is the ageing constant in percent per decade (as defined above);

t is the time in h from the start of the ageing process.

The ageing constant may be declared by the manufacturer for a particular ceramic dielectric, or it may be defined by de-ageing the capacitor and measuring the capacitance at two known times thereafter.

k is then given by the following equation:

$$k = \frac{100 \times \left(C_{t_1} - C_{t_2}\right)}{C_{t_1} \times \lg t_2 - C_{t_2} \times \lg t_1} \tag{B.2}$$

If capacitance measurements are made three or more times, then it is possible to derive k from the slope of a graph where C_t is plotted against lg t.

It is also possible to plot log C against lg t.

During measurements of ageing, the capacitor should be maintained at a constant temperature so that capacitance variations due to the temperature characteristic do not mask those due to ageing.

B.3 Capacitance measurements and capacitance tolerance

Because of ageing, it is necessary to specify a reference age at which the capacitance shall be within the specified tolerance. This is fixed at 1 000 h, since for practical purposes there is not much further loss of capacitance after this time.

In order to calculate the capacitance $C_{1\,000}$ after 1 000 h, the ageing constant shall be known or determined as in Clause B.2, when the following formula may be used:

$$C_{1000} = C_t\left[1 - \frac{k}{100}(3 - \lg t)\right] \tag{B.3}$$

For factory measurements, the loss of capacitance from the age at time of measurement to 1 000 h age will be known and can be off-set by using asymmetric inspection tolerances.

For example, if it is known that the capacitance loss will be 5 %, then the capacitors may be inspected to limits of +25/−15 % instead of 20 %.

Capacitance is normally declared at 20 °C, and it may be necessary to measure at this temperature or correct the results to this temperature. Errors can also arise from heat from the hands, and capacitors should therefore always be handled with tweezers.

B.4 Special preconditioning (see 5.2)

In many of the tests in this document, it is required to measure the capacitance change which results from a given conditioning (for example climatic sequence). In order to avoid the interfering effect of ageing, the capacitor is specially preconditioned before these tests by maintaining it for 1 h at the upper category temperature followed by 24 h at standard atmospheric conditions for testing.

For those capacitors with a Curie temperature below the upper category temperature, this results in de-ageing and the conditioning is also arranged, if possible, to bring the capacitors to an age of 24 h, so that capacitance changes due to ageing are minimized.

If the Curie temperature of the dielectric is above the upper category temperature, then the special preconditioning will not completely de-age the capacitor, but it will nevertheless bring it into a state where its capacitance is not so dependent on its previous history, and the same effect will be achieved, though completely de-aged. In order to de-age such capacitors completely, temperature up to 160 °C can be required. Therefore, in the few cases where complete de-ageing of such capacitors can be required, the detail specification shall be consulted for details and any necessary precautions.

Annex C
(normative)

Temperature characteristics of capacitance of 25 °C

For the temperature characteristics of capacitance for the reference temperature 25 °C (the related EIA-198-1-F), the lower and upper category temperatures shall be chosen from Table C.1.

Table C.2 denotes with a cross the preferred values of the temperature characteristic with and without DC voltage applied. The method of coding the subclass is also given according to Table C.1; for example, a dielectric with a percentage change of ±15 % without DC voltage applied over the temperature range from −55 °C to +125 °C will be defined as dielectric of subclass X7R.

The exact conditions of temperature characteristics of capacitance are shown in Table C.3.

Table C.1 – Temperature characteristics of capacitance

Category Temperature characteristic capacitance				Maximum capacitance change within the category temperature range with respect to the capacitance at 25 °C measured with and without a DC voltage applied		
Lower category temperature		Upper category temperature		%		
Alpha symbol	Low temperature °C	Numeric symbol	High temperature	Sub-class letter code	Without DC voltage applied	With DC voltage applied [a] (if required)
Z	+10	2	+45	A	± 1,0	Requirements specified in the detail specification
Y	-30	4	+65	B	± 1,5	
X	-55	5	+85	C	± .2,2	
		6	+105	D	± 3,3	
		7	+125	E	± 4,7	
		8	+150	F	± 7,5	
		9	+200	P	± 10	
		3	+175[b]	R	± 15	
				S	± 22	
				T	+ 22/- 33	
				U	+ 22/- 56	
				V	+ 22/- 82	
				L[c]	+ 15/- 40	
				Q[c]	+ 15/- 70	

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

[b] Upper category temperature of 175 °C is not defined in EIA-198-1-F.

[c] Maximum capacitance change "L" +15/-40, "Q" +15/-70 are not defined in EIA-198-1-F

Table C.2 – Preferred values of the temperature characteristic of capacitance with and without a DC voltage applied

Sub-class letter code	Maximum capacitance change within the category temperature range with respect to the capacitance at 20 °C measured with and without a DC voltage applied %		Category temperature range and corresponding number code			
			−55/+85 °C	−55/+105 °C	−55/+125 °C	−55/+150 °C
	without DC voltage applied	with DC voltage applied (if required) [a]	X5	X6	X7	X8
R	±15	Requirements specified in the detail specification	x	x	x	x
S	±22			x	x	x
T	+22/−33			x	x	x
U	+22/−56			x	x	x

NOTE "×" indicates preferred.

[a] DC voltage applied is either rated voltage or the voltage specified in the detail specification.

Table C.3 – Measuring conditions of temperature characteristic of capacitance for the reference temperature 25 °C

Method	Measuring step	Temperature °C	DC voltage applied
A	1	25 ± 2	–
	2	T_A ± 2	–
	3	25 ± 2	–
	4	T_B ± 2	–
	5	T_B ± 2	×
	6	25 ± 2	×
	7	T_A ± 2	×
B	1 2 3 4	See above	–

Measurements may be made at such intermediate temperatures as to ensure that the requirements of 4.2.5 are met.

NOTE 1 "–" indicates: no DC voltage applied

"×" indicates: rated voltage

NOTE 2 Reference capacitance is the capacitance measured at Step 3.

T_A = Lower category temperature.

T_B = Upper category temperature.

Annex D
(normative)

Quality conformance inspection

D.1 Formation of inspection lots

D.1.1 Groups A and B inspection

These tests shall be carried out on a lot-by-lot basis.

A manufacturer may aggregate the current production into inspection lots subject to the following safeguards:

a) The inspection lot shall consist of structurally similar capacitors (see 8.2).

b) The sample tested shall be representative of the values and the dimensions contained in the inspection lot:
   – in relation to their number;
   – with a minimum of five of any one value.

c) If there are fewer than five of any one value in the sample the basis for the drawing of samples shall be agreed between the manufacturer and the certification body (CB).

D.1.2 Group C inspection

These tests shall be carried out on a periodic basis.

Samples shall be representative of the current production of the specified periods and shall be divided into small, medium and large sizes. In order to cover the range of approvals in any period, one voltage shall be tested from each group of sizes. In subsequent periods, other sizes and/or voltage ratings in production shall be tested with the aim of covering the whole range.

D.2 Test schedule

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in Table D.3 and Table D.4.

D.3 Delayed delivery

When, in accordance with the procedures of IEC 60384-1:2021, Q.1.7, re-inspection shall be made, solderability and capacitance shall be checked as specified in Groups A and B inspection.

D.4 Assessment levels

The assessment level(s) given in Table D.3 and Table D.4 should be selected from Table D.1 and Table D.2.

Table D.1 – Lot-by-lot inspection

Inspection subgroup[d]	EZ		
	IL[a]	n[a]	c[a]
A0	100 %[b]		
A1	S-4	c	0
A2	S-3	c	0
B1	S-3	c	0
B2	S-2	c	0

[a] IL = inspection level

n = sample size

c = permissible number of non-conforming items

[b] The inspection shall be performed after removal of nonconforming items by 100 % testing during the manufacturing process. Whether the lot was accepted or not, all samples for sampling inspection shall be inspected in order to monitor outgoing quality level by nonconforming items per million ($\times 10^{-6}$).

The sampling level shall be established by the manufacturer and should be in accordance with IEC 61193-2:2007, Annex A.

In the case where one or more nonconforming items occur in a sample, this lot shall be rejected, but all nonconforming items shall be counted for the calculation of quality level values. Outgoing quality level by nonconforming items per million ($\times 10^{-6}$) values shall be calculated by accumulating inspection data in accordance with the method given in IEC 61193-2:2007, 6.2.

[c] Number to be tested: sample size shall be determined in accordance with IEC 61193-2:2007, 4.3.2.

[d] The content of the inspection subgroup is described in Table D.3.

Table D.2 – Periodic test

Inspection subgroup[b]	EZ		
	p[a]	n[a]	c[a]
C1	3	12	0
C2	3	12	0
C3.1	6	27	0
C3.2	6	15	0
C3.3	3	15	0
C3.4[c]	6	15	0
C4	6	9	0

[a] p = periodicity in months

n = sample size

c = permissible number of non-conforming items

[b] The content of the inspection subgroup is described in Table D.4

[c] If required.

D.5 test schedule for quality conformance inspection

For quality conformance inspection, the test schedules given in Table D.3 and Table D.4 include sampling, periodicity, severities and requirements. The formation of inspection lots is given in D.1.

Table D.3 – Test schedule for quality conformance inspection (lot by lot)

Lot-by-lot tests						
Test[a]		Conditions of test[b]	D[c] or ND	IL[c]	c[c]	Performance requirements
Group A0 [100 % tests]						
5.6.1	Capacitance	Frequency: ... Hz Measuring voltage: ... V r.m.s	ND	100 %[d]		Within specified tolerance
5.6.2	Tangent of loss angle (tan δ)	Frequency and measuring voltage same as in 5.6.1				As in 5.6.2
5.6.3	Insulation resistance	See detail specification for the method				As in 5.6.3.4
5.6.4	Voltage proof	See detail specification for the method				No breakdown or flashover
Group A1 [Sampling tests]						
5.5.2	Visual examination		ND	S-4[e]	0	As in 5.5.2 Legible marking and as specified in the detail specification
Group A2 [Sampling tests]						
4.2.6	Dimension[f]		ND	S-3[e]	0	See the detail specification
Group B1 [Special tests]						
5.6.5	Impedance (if required)	Frequency: 100 KHz	D	S-3[e]	0	See detail specification
5.6.6	ESR (if required)	Frequency: 100 KHz				See detail specification
5.11	solderability	See detail specification for the method				
5.11.4	Final inspection, measurements and requirements	Visual examination				As in 5.11.4
5.18	Solvent resistance of the marking (if required)[g]	Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...				Legible marking

Lot-by-lot tests						
Test[a]		Conditions of test[b]	D[c] or ND	IL[c]	c[c]	Performance requirements
Group B2 [Special tests]						
5.7	Temperature characteristics of capacitance[g]		ND	S-2[e]	0	$\Delta C/C$: As in 5.7.3

[a] Applicable tests, test conditions, requirements and clause numbers as selected from this document.

[b] The information given in Table D.3 shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed specification given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Table D.1 for lists of symbols and of abbreviated terms.

[d] After 100 % measurement and removal of nonconforming items, a re-inspection shall be performed in order to monitor the outgoing quality level, in accordance with the detail specification. A lot shall be rejected if one or more nonconforming items occur in a sample during re-inspection.

[e] Inspection Levels are selected from IEC 61193-2.

[f] This test may be replaced by in-production testing if the manufacturer installs Statistical Process Control (SPC) on dimensional measurements or other mechanisms to avoid parts exceeding the limits.

[g] This test may be carried out on capacitors mounted on a substrate.

[h] This subgroup may be omitted if a corresponding test is carried out on each manufacturing batch of dielectric material.

Table D.4 – Test schedule for quality conformance inspection (Periodic test)

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p[c]	n[c]	c[c]	Performance requirements
Group C1 [h]							
5.16	Robustness of Termination (only for capacitors with strip terminations)	Test Ua, Force: 2,5 N Test Ub, Method 1, Force: 2,5 N Number of bends: 1	D	3	12	0[d]	
		Visual examination					No visible damage
5.10.3	Initial measurement	Capacitance					
5.10	Resistance to soldering heat	See detail specification for the method Recovery: 24 h ± 2 h					
5.10.6	Final inspection, measurements and requirements	Visual examination					As in 5.10.6
		Capacitance					As in 5.10.6
5.17	Component solvent resistance (if required)	Solvent: … Solvent temperature: … Method 2 Recovery: …					See detail specification

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p[c]	n[c]	c[c]	Performance requirements
Group C2 [h]							
5.9	Substrate bending test[e]	Deflection: … Number of bends: …	D	3	12	0[d]	See detail specification
5.9.2	Initial measurement	Capacitance					
5.9.3	Final inspection	Capacitance (with printed board in bent position)					$\Delta C/C$ ≤ 10 %
		Visual examination					No visible damage
Group C3[h]			D				
5.4	Mounting[f]	Substrate material: …					As in IEC 60384-1, 5.5.1
		Visual examination					
		Capacitance					Within specified tolerance
		Tangent of loss angle					As in 5.6.2
		Insulation resistance					As in 5.6.3.4
		Voltage proof					No breakdown or flashover
Group C3.1[h]			D				
5.8	Shear test[g]	Visual inspection		6	27	0[d]	No visible damage
		Special preconditioning as in 5.2					
5.12.3	Initial measurement	Capacitance					
5.12	Rapid change of temperature	T_A = Lower category temperature					
		T_B = Upper category temperature: five cycles					
		Duration t_1 = 30 min					
		Recovery: (24 ± 2) h					
5.12.6	Final inspections, measurements and requirements	Visual examination					No visible damage
		Capacitance					$\Delta C/C$: As in 5.12.6
5.13	Climatic sequence	Special preconditioning as in 5.2					
5.13.3	Initial measurement	Capacitance					
5.13.4	Dry heat	Temperature: upper category temperature					
		Duration: 16 h					
5.13.5	Damp heat, cyclic, test Db, first cycle						

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p[c]	n[c]	c[c]	Performance requirements
5.13.6	Cold	Temperature: lower category temperature					
		Duration: 2 h					
		Visual inspection					No visible damage
5.13.7	Damp heat, cyclic, test Db, remaining cycles	Recovery: 24 h ± 2 h					
5.13.8	Final measurements	Visual examination					No visible damage. Legible marking
		Capacitance					$\Delta C/C$: As in 5.13.8
		Tangent of loss angle					As in 5.13.8
		Insulation resistance					As in 5.13.8
Group C3.2[h]			D				
5.14	Damp heat, steady state	Special preconditioning as in 5.2		6	15	0[d]	
5.14.3	Initial measurement	Capacitance					
		Recovery: 24 h ± 2 h					
5.14.6	Final inspections, measurements and requirements	Visual examination					No visible damage
							Legible marking
		Capacitance					$\Delta C/C$: As in 5.14.6
		Tangent of loss angle					As in 5.14.6
		Insulation resistance					As in 5.14.6
Group C3.3[h]			D				
5.15	Endurance	Special preconditioning as in 5.2		3	15	0[d]	
		Duration: …h					
		Temperature: …°C					
		Voltage: …V					
5.15.3	Initial measurement	Capacitance					
		Recovery: (24 ± 2) h					
5.15.6	Final inspections, measurements and requirements	Visual examination					No visible damage
							Legible marking
		Capacitance					$\Delta C/C$: As in 5.15.6
		Tangent of loss angle					As in 5.15.6
		Insulation resistance					As in 5.15.6

Periodic tests							
Test[a]		Conditions of test[b]	D[c] or ND	p^c	n^c	c^c	Performance requirements
Group C3.4[h]			D				
5.19	Accelerated damp heat, steady state (if required)	Duration: … h		6	15	0[d]	
		Temperature: (85 ± 2) °C					
		Humidity: (85 ± 3) %					
5.19.2	Initial measurement	Insulation resistance					As in 5.19.2
		Recovery: (24 ± 2) h					
5.19.5	Final measurements	Insulation resistance					As in 5.19.5
Group C4 [h]			ND				
5.7	Temperature characteristic of capacitance	Special preconditioning as in 5.2		6	9	0[d]	$\Delta C/C$: As in 5.7.3

[a] Applicable tests, test conditions, requirements and clause numbers as selected from this document.

[b] The information given in Table D.4 shall provide a suitable overview of the most relevant parameters of each test, however shall not take precedence over any more detailed specification given in a respective clause of this specification or in a cited normative reference.

[c] Refer to Table D.2 for lists of symbols and of abbreviated terms.

[d] If one non-conforming item is obtained, all the tests of the subgroup shall be repeated on a new sample and then no further non-conforming items are permitted. Release of product may continue during repeat testing.

[e] Not applicable to capacitors, which, in accordance with the detail specification, shall only be mounted on alumina substrates.

[f] The capacitors found non-conformances after mounting shall not be taken into account when calculating the non- conformances for the following tests. They shall be replaced by spare capacitors.

[g] Not applicable to capacitors with strip terminations.

[h] All tests of the sub-group shall be repeated if one or more nonconforming item is obtained. No nonconforming items are permitted in the repeat testing. Release of products may continue during repeat testing.

Annex X
(informative)

Cross-reference for reference to IEC 60384-22:2019

The drafting of this document has resulted in a new structure. Table X.1 indicates the new clause and subclause numbers with respect to IEC 60384-22:2019.

Table X.1 – Reference to IEC 60384-22 for clause/subclause

IEC 60384-22:2019 3rd edition Clause/Subclause	IEC 60384-22:2024 4th edition Clause/Subclause	Notes
1	1	No change
2	2	No change
3	3	No change
4	7	In accordance with the change of clause numbers
5	6	In accordance with the change of clause numbers
6	4	In accordance with the change of clause numbers
7.1 to 7.4	8.1 to 8.4	In accordance with the change of clause numbers
7.5.1 to 7.5.4	D.1 to D.4	In accordance with the change of clause numbers
8	5	In accordance with the change of clause numbers
Annex A	Annex A	No change
Annex B	Annex B	No change
Annex C	Annex C	Changed from informative to normative
—	D.5	Newly added. Modified from IEC 60384-22-1:2004, Clause 2
Annex X	Annex X	No change

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-22:2019.

Table X.2 – Reference to IEC 60384-22 for figure/table

IEC 60384-22:2019 3rd edition Figure/Table	IEC 60384-22:2024 4th edition Figure/Table	Notes
Table 1 to Table 3	Table 1 to Table 3	No change
Table 4 and Table 5	Table 20 to Table 21	In accordance with the change of table numbers
Table 6 and Table 7	Table D.1 to Table D.2	In accordance with the change of table numbers
-	Table D.3 and Table D.4	Newly added. Modified from IEC 60384-22-1:2004, Table 4
Table 8 to Table 23	Table 4 to Table 19	In accordance with the change of table numbers
Table A.1	Table A.1	No change
Table C.1	Table C.1	No change
—	Table C.2	Newly added
Table C.2	Table C.3	In accordance with the change of table numbers
Table X.1 and Table X.2	Table X.1 and Table X.2	No change
For the figure numbers, there was no change.		

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CONDENSATEURS FIXES UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRONIQUES –

Partie 22: Spécification intermédiaire – Condensateurs multicouches fixes à diélectriques en céramique pour montage en surface, de Classe 2

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Cette quatrième édition annule et remplace la troisième édition parue en 2019. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) le document a été entièrement restructuré pour se conformer aux directives ISO/IEC, Partie 2, et pour en faciliter l'utilisation; les tableaux, les figures et les références ont été révisés en conséquence; l'Annexe X comporte toutes les références croisées des changements de numérotation des articles/paragraphes;

b) les exigences relatives à la température de référence de 25 °C ont été ajoutées dans le Tableau 5, le Tableau 9, le Tableau 10, le Tableau 12, le Tableau 14 et le Tableau 17;

c) le tableau des caractéristiques de température de la capacité pour la température de référence de 25 °C a été ajouté dans le Tableau C.1, le Tableau C.2 et le Tableau C.3;

d) l'exigence de 5.5.2 (examen visuel) a été répétée en 5.9.3, en 5.10.6, en 5.11.4, en 5.12.6, en 5.13.8, en 5.14.6 et en 5.15.6;

e) la flèche D dans les modèles très robustes a été ajoutée en 5.9.1;

f) l'Annexe C est passée d'informative à normative;

g) l'Article D.5 (Programme d'essais pour le contrôle de conformité de la qualité) a été ajouté pour retirer la spécification particulière-cadre: IEC 60384-22-1.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
40/3120/FDIS	40/3139/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

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Une liste de toutes les parties de la série IEC 60384, publiées sous le titre général *Condensateurs fixes utilisés dans les équipements électroniques*, se trouve sur le site Web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site Web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. A cette date, le document sera:

- reconduit,
- supprimé, ou
- révisé.

CONDENSATEURS FIXES UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRONIQUES –

Partie 22: Spécification intermédiaire – Condensateurs multicouches fixes à diélectriques en céramique pour montage en surface, de Classe 2

1 Domaine d'application

La présente partie de l'IEC 60384 est applicable aux condensateurs multicouches fixes à diélectriques en céramique pour montage en surface non encapsulés, Classe 2, utilisés dans les équipements électroniques. Ces condensateurs possèdent des pastilles de connexion métallisées ou des bandes de brasure et sont destinés à être montés sur des cartes imprimées ou directement sur des substrats de circuits hybrides.

Les condensateurs d'antiparasitage ne sont pas inclus, mais sont couverts par l'IEC 60384-14.

Le présent document a pour objet de spécifier les valeurs assignées et caractéristiques préférentielles, de sélectionner, en se référant à l'IEC 60384-1:2021, les procédures d'assurance qualité appropriées, les essais et les méthodes de mesure et de donner les exigences de performances générales pour ce type de condensateur. Les sévérités et les exigences des essais spécifiées dans les spécifications particulières se référant au présent document fournissent des sévérités et des exigences d'essai d'un niveau de performance supérieur ou égal. Pour plus d'informations sur la conception des spécifications génériques, intermédiaires et particulières, voir l'Introduction de l'IEC 60384-1:2021.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-58, *Essais d'environnement – Partie 2-58: Essais – Essai Td: Méthodes d'essai de la soudabilité, résistance de la métallisation à la dissolution et résistance à la chaleur de brasage des composants pour montage en surface (CMS)*

IEC 60384-1:2021, *Condensateurs fixes utilisés dans les équipements électroniques – Partie 1: Spécification générique*

IEC 61193-2:2007, *Quality assessment system – Part 2: Selection and use of sampling plans for inspection of electronic components and packages (disponible en anglais seulement)*

3 Termes et définitions

Pour les besoins du présent document, les termes et les définitions de l'IEC 60384-1 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
condensateur multicouche pour montage en surface
condensateur multicouche dont les petites dimensions et la nature ou la forme des connexions de sortie en font un condensateur pouvant être monté en surface dans des circuits hybrides et sur des cartes imprimées

3.2
condensateur à diélectrique en céramique, Classe 2
condensateur qui a un diélectrique à permittivité élevée et adapté pour des applications de contournement et de couplage ou pour des circuits discriminateurs de fréquence lorsque de faibles pertes et une stabilité élevée de capacité ne sont pas de première importance

Note 1 à l'article: Le diélectrique en céramique est caractérisé par la variation non linéaire de capacité sur la plage de températures de catégorie (voir Tableau 3).

3.3
sous-classe
<Classe 2> variation maximale en pourcentage de capacité à l'intérieur de la plage de températures de catégorie par rapport à la capacité à la température de référence de 20 °C ou 25 °C

Note 1 à l'article: La sous-classe peut être exprimée sous forme de code (voir Tableau 3 et Annexe C).

3.4
plage de températures de catégorie
plage des températures ambiantes pour laquelle le condensateur a été conçu pour fonctionner de manière continue

Note 1 à l'article: Cette plage est donnée par la température minimale de catégorie et la température maximale de catégorie (voir Tableau 3 et Annexe C).

3.5
température assignée
T_R
température ambiante maximale à laquelle la tension assignée peut être appliquée de manière continue

3.6
tension assignée
U_R
tension en courant continu maximale qui peut être appliquée de manière continue à un condensateur à n'importe quelle température entre la température minimale de catégorie et la température assignée

Note 1 à l'article: La tension en courant continu maximale est la somme de la tension en courant continu et de la valeur de crête de la tension alternative ou de la valeur de crête de la tension d'impulsion appliquées au condensateur.

3.7
tension de catégorie
U_C
tension maximale pouvant être appliquée de manière continue à un condensateur à sa température maximale de catégorie

4 Valeurs assignées et caractéristiques préférentielles

4.1 Caractéristiques préférentielles

Les catégories climatiques préférentielles doivent être données uniquement dans les caractéristiques préférentielles.

Les condensateurs couverts par le présent document sont classés en catégories climatiques conformément aux règles générales données dans l'IEC 60068-1:2013, Annexe A.

Pour une température de référence de 20 °C, les températures minimale et maximale de catégorie et la durée de l'essai continu de chaleur humide doivent être sélectionnées dans la liste ci-dessous:

- température minimale de catégorie: –55 °C, –40 °C, –25 °C, –10 °C et +10 °C;
- température maximale de catégorie: +70 °C, +85 °C, +100 °C, +125 °C et +150 °C;
- durée de l'essai continu de chaleur humide (température = 40 °C, humidité relative = 93 %): 4, 10, 21 et 56 jours.

Pour la température de référence de 25 °C, les températures de catégorie inférieure et supérieure doivent être choisies dans le Tableau C.1 de l'Annexe C.

Les sévérités pour les essais de froid et de chaleur sèche sont les températures minimale et maximale de catégorie, respectivement.

NOTE La résistance à l'humidité résultant de la catégorie climatique ci-dessus concerne les condensateurs dans l'état non monté. La performance climatique des condensateurs après montage dépend considérablement du substrat de montage, de la méthode de montage (voir 5.4) et du revêtement final.

4.2 Valeurs assignées préférentielles

4.2.1 Température assignée (T_R)

La température assignée est égale à la température maximale de catégorie pour les condensateurs dont la température maximale de catégorie ne dépasse pas 125 °C, sauf indication contraire de la spécification particulière.

4.2.2 Tension assignée (U_R)

Les valeurs préférentielles de la tension assignée sont les valeurs de la série R5 de l'ISO 3. Si d'autres valeurs sont nécessaires, elles doivent être choisies dans la série R10.

La somme de la tension en courant continu et de la plus grande parmi la valeur de crête de la tension alternative et la valeur crête à crête de la tension alternative, appliquée au condensateur ne doit pas dépasser la tension assignée.

4.2.3 Tension de catégorie (U_C)

La tension de catégorie est égale à la tension assignée pour les condensateurs dont la température maximale de catégorie ne dépasse pas 125 °C. Toutes les tensions de catégorie différentes de la tension assignée, pour des condensateurs dont la température maximale de catégorie dépasse 125 °C ou pour des condensateurs à haute tension avec des tensions assignées d'environ 500 V, doivent être fournies par la spécification particulière.

Les valeurs préférentielles de la tension de catégorie à la température maximale de catégorie de 125 °C pour des condensateurs de grand volume, avec une tension assignée inférieure ou égale à 16 V et une température assignée de 85 °C sont données dans le Tableau 1.

Tableau 1 – Valeurs préférentielles de tensions de catégorie

U_R	V	2,5	4	6,3	10	16
U_C	V	1,6	2,5	4	6,3	10
NOTE Les valeurs numériques de U_C sont calculées à l'aide de la formule suivante: $U_C = 0{,}63 \times U_R$						

4.2.4 Valeurs préférentielles de la capacité nominale et des valeurs de tolérance associées

4.2.4.1 Valeurs préférentielles de la capacité nominale

Il convient que les valeurs de capacité nominale proviennent des séries E3, E6 et E12 données dans l'IEC 60063.

4.2.4.2 Tolérances préférentielles sur la capacité nominale

Voir Tableau 2.

Tableau 2 – Tolérances préférentielles

Série préférentielle	Tolérance %	Lettre de codage
E3 et E6	−20/+80	Z
	−20/+50	S
E6	± 20	M
E6 et E12	± 10	K

4.2.5 Caractéristique de température de capacité

Le Tableau 3 représente la caractéristique de température avec et sans tension en courant continu appliquée pour la température de référence de 20 °C. La méthode de codage de la sous-classe est également donnée; par exemple un diélectrique avec un pourcentage de variation de ±20 % sans tension en courant continu appliquée sur la plage de températures allant de −55 °C à +125 °C, est défini comme un diélectrique de sous-classe 2C1. Les caractéristiques de température, les températures de catégorie et les codes correspondants pour la température de référence de 25 °C sont donnés à l'Annexe C. La plage de températures pour laquelle la caractéristique de température du diélectrique est définie est la même que la plage de températures de catégorie.

Tableau 3 – Caractéristique de température de capacité

Lettre de codage de sous-classe	Variation maximale de capacité dans la plage de températures de catégorie par rapport à la capacité à 20 °C mesurée avec et sans application de tension en courant continu %		Plage de températures de catégorie et code de numéro correspondant					
			−55/+150 °C	−55/+125 °C	−55/+85 °C	−40/+85 °C	−25/+85 °C	+10/+85 °C
	sans tension en courant continu appliquée	avec une tension en courant continu appliquée[a]	0	1	2	3	4	6
2B	±10	Exigences spécifiées dans la spécification particulière						
2C	±20							
2D	+20/−30							
2E	+22/−56							
2F	+30/−80							
2R	±15							

Lorsque la température maximale de catégorie est supérieure à 125 °C, il convient que les limites de variation de capacité, avec ou sans tension en courant continu, soient indiquées dans la spécification particulière.

NOTE Une référence à l'Annexe C peut être faite pour les valeurs préférentielles de la caractéristique de température pour la température de référence de 25 °C.

[a] La tension en courant continu appliquée est soit la tension assignée, soit la tension spécifiée dans la spécification particulière.

4.2.6 Dimensions

Les règles proposées pour la spécification et le codage des dimensions sont présentées à l'Annexe A.

Les dimensions spécifiques doivent être données dans la spécification particulière.

5 Procédures d'essai et de mesure

5.1 Généralités

Le présent Article 5 complète les informations données dans l'IEC 60384-1:2021, de l'Article 5 à l'Article 10.

5.2 Préconditionnement spécial

Sauf indication contraire dans la spécification particulière, le préconditionnement spécial, lorsqu'il est indiqué dans le présent document avant un essai ou une séquence d'essais, doit être effectué dans les conditions suivantes.

Exposition à la température maximale de catégorie ou à une température plus élevée telle qu'elle peut être indiquée dans la spécification particulière, pendant 1 h, suivie d'une durée de rétablissement de (24 ± 1) h dans les conditions atmosphériques normales des essais.

NOTE Les condensateurs perdent continuellement de la capacité avec le temps selon une loi logarithmique (c'est le phénomène de vieillissement). Toutefois, si le condensateur est chauffé à une température supérieure à la température du point de Curie de son diélectrique, une "régénération" se produit, c'est-à-dire que la capacité perdue par "vieillissement" est récupérée, et le "vieillissement" reprend à partir du moment où le condensateur recommence à refroidir. L'objet du préconditionnement spécial est d'amener le condensateur à un état défini quel que soit son historique (soir l'Article B.4 pour plus d'informations).

5.3 Conditions de mesure

Voir IEC 60384-1:2021, 5.2.1.

5.4 Montage

Voir IEC 60384-1:2021, 5.5.

5.5 Examen visuel et contrôle des dimensions

5.5.1 Généralités

Voir IEC 60384-1:2021, 7.1, avec les détails de 5.5.2 et 5.5.3.

5.5.2 Examen visuel

L'examen visuel doit être réalisé avec un équipement adapté offrant un grossissement d'environ 10×, un éclairage approprié de l'éprouvette d'essai et le niveau de qualité exigé. Si le spécimen est composé de très petits composants, l'examen visuel peut être effectué avec un grossissement plus élevé.

Il convient que l'opérateur dispose d'équipements pour l'éclairage incident ou transmis, ainsi que d'équipements de mesure appropriés.

5.5.3 Exigences

5.5.3.1 Généralités

Les valeurs quantitatives pour les exigences ci-dessous peuvent être données dans la spécification particulière ou dans la spécification du fabricant.

5.5.3.2 Exigences relatives à la céramique

Les exigences relatives à la céramique sont les suivantes:

a) être exempte de craquelures ou de fissures, à l'exception de dommages minimes en surface qui ne dégradent pas les performances du condensateur (exemples: voir Figure 1 et la Figure 2);

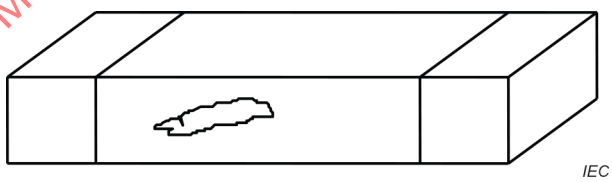
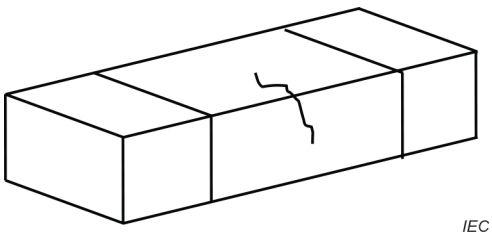


Figure 1 – Défaut: craquelure ou fissure



NOTE Craquelure ou fissure sur un côté ou s'étendant d'une face à une autre en passant par une arête.

Figure 2 – Défaut: craquelure ou fissure

b) ne pas présenter de séparation ou décollement interlaminaire visible entre les couches du condensateur (voir Figure 3).

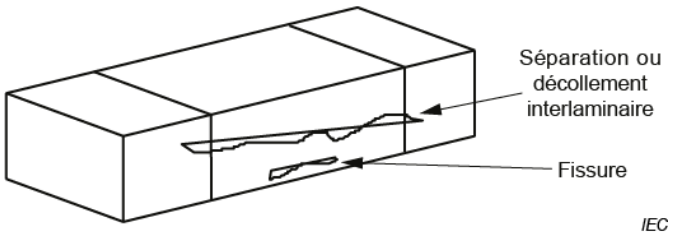


Figure 3 – Séparation ou décollement interlaminaire

c) ne pas présenter d'électrodes exposées entre les deux sorties (voir Figure 4);

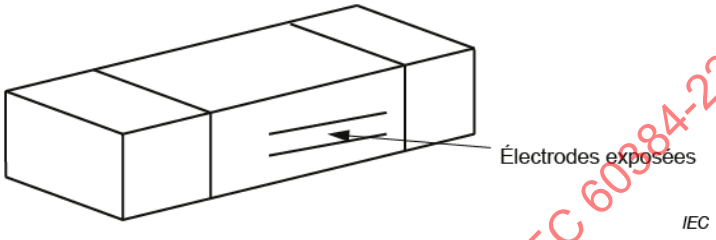


Figure 4 – Électrodes exposées

d) le corps céramique doit être exempt de toute trace conductrice (métallisation, étamage, etc.) sur une zone centrale entre deux sorties adjacentes qui est égale à la distance minimale entre celles-ci (Annexe A, dimension L_4).

5.5.3.3 Exigences relatives à la métallisation

Les exigences relatives à la métallisation sont les suivantes:

a) ne pas présenter de décollement visible des sorties métallisées ni d'électrodes exposées (voir Figure 4);

b) les faces principales (voir Figure 5) sont celles notées A, B et C.

Dans le cas de condensateurs de section carrée, les faces D et E sont également considérées comme principales.

La surface maximale des espaces dans la métallisation sur chaque face principale ne doit pas dépasser 15 % de la surface de cette face et ces espaces ne doivent pas être concentrés dans la même région. Les espaces dans la métallisation ne doivent pas affecter les deux arêtes principales de chaque extrémité du bloc (ou les quatre arêtes dans le cas de condensateurs carrés). La dissolution du revêtement d'extrémité (lixiviation) ne doit pas dépasser 25 % de la longueur de l'arête concernée.

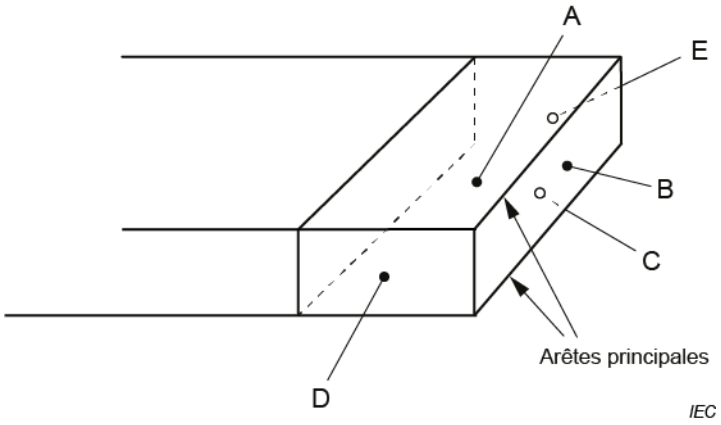


Figure 5 – Faces principales

5.6 Essais électriques

5.6.1 Capacité

5.6.1.1 Généralités

Voir IEC 60384-1:2021, 6.3, avec les détails de 5.6.1.2 et 5.6.1.3.

5.6.1.2 Conditions de mesure

Voir Tableau 4, sauf indication contraire dans la spécification particulière.

Tableau 4 – Conditions de mesure

Capacité nominale	Tension assignée U_R	Fréquence	Tension de mesure V eff	Tension d'arbitrage V eff
CN < 100 pF	[a]	1 MHz	1,0 ± 0,2	1,0 ± 0,02
100 pF ≤ CN ≤ 10 µF	U_R > 6,3 V	1 kHz	1,0 ± 0,2	1,0 ± 0,02
	U_R ≤ 6,3 V	1 kHz	0,5 ± 0,2	0,5 ± 0,02
CN > 10 µF	[a]	100 Hz ou 120 Hz	0,5 ± 0,2	0,5 ± 0,02

[a] Toutes les tensions assignées (U_R).

5.6.1.3 Exigences

La valeur de la capacité, telle que mesurée dans l'état non monté, doit correspondre à la valeur assignée en tenant compte de la tolérance spécifiée.

La capacité telle que mesurée dans l'état monté conformément au Groupe 3 est donnée uniquement à des fins de référence lors des essais ultérieurs.

Pour les mesures d'arbitrage, la valeur de la capacité doit être la valeur extrapolée à une durée de vieillissement de 1 000 h, sauf indication contraire dans la spécification particulière (voir les explications à l'Annexe B).

5.6.2 Tangente de l'angle de perte (tan δ)

5.6.2.1 Généralités

Voir IEC 60384-1:2021, 6.4, avec les détails de 5.6.2.2 et 5.6.2.3.

5.6.2.2 Conditions de mesure

Les conditions de mesure sont les mêmes que celles de 5.6.1. L'imprécision de l'appareil de mesure ne doit pas dépasser 1×10^{-3}.

5.6.2.3 Exigences

La tangente de l'angle de perte, telle que mesurée dans l'état non monté, ne doit pas dépasser la limite donnée au Tableau 5.

Tableau 5 – Limites de la tangente de l'angle de perte

Température de référence	Tension assignée U_R	Sous-classe	Tangente de l'angle de perte
20 °C	$U_R \geq 10$ V	Tous codes de sous-classe	Inférieure ou égale à 0,035 ou une valeur qui peut être donnée dans la spécification particulière
	$U_R < 10$ V	2B, 2C, 2R	0,1
		2D, 2E	0,15
		2F	0,2
25 °C	$U_R \geq 10$ V	Tous codes de sous-classe	Inférieure ou égale à 0,035 ou une valeur qui peut être donnée dans la spécification particulière
	$U_R < 10$ V	R	0,1
		S	0,1
		T	0,15
		U	0,15
NOTE Les codes des sous-classes sont expliqués en 4.2.5 à l'Annexe C.			

La tangente de l'angle de perte telle que mesurée dans l'état monté conformément au Groupe 3 est donnée uniquement à des fins de référence lors des essais ultérieurs.

5.6.3 Résistance d'isolement

5.6.3.1 Généralités

Voir IEC 60384-1:2021, 6.1, en l'associant aux informations données de 5.6.3.2 à 5.6.3.4.

5.6.3.2 Préparation de l'essai

Avant l'essai, les condensateurs doivent être nettoyés avec soin pour éliminer toute contamination.

Les chambres d'essai, comme les lieux dans lesquels s'effectuent les mesures après les essais, doivent être propres. Avant le mesurage, les condensateurs doivent être complètement déchargés. La résistance d'isolement doit être mesurée entre les sorties.

5.6.3.3 Conditions de mesure

Voir IEC 60384-1:2021, 6.1.2, avec les détails suivants:

La tension de mesure peut être d'une valeur quelconque inférieure ou égale à U_R, la tension d'arbitrage étant U_R, pour un condensateur dont la tension assignée est inférieure ou égale à 1 kV. Pour U_R > 1 kV, la tension d'arbitrage doit être de 1 kV.

La résistance d'isolement (R_i) doit être mesurée après avoir appliqué la tension pendant (60 ± 5) s.

Pour les essais lot par lot (Groupe A), l'essai peut être terminé dans un délai plus court, si la valeur exigée de la résistance d'isolement est atteinte.

Le produit de la résistance interne de la source de tension et de la capacité nominale du condensateur ne doit pas dépasser 1 s, sauf indication contraire dans la spécification particulière.

Le courant de charge ne doit pas dépasser 0,05 A. Pour les condensateurs dont les tensions assignées sont supérieures ou égales à 1 kV, une (valeur) limite inférieure peut être donnée dans la spécification particulière.

5.6.3.4 Exigences

La résistance d'isolement doit satisfaire aux exigences suivantes:

C_N ≤ 25 nF	R_i ≥ 4 000 MΩ
C_N > 25 nF	$R_i \times C_N$ ≥ 100 s

5.6.4 Tenue en tension

5.6.4.1 Généralités

Voir IEC 60384-1:2021, 6.2, en l'associant aux informations données de 5.6.4.2 à 5.6.4.4.

5.6.4.2 Conditions d'essai

Le produit de R_1 et de la capacité nominale C_X doit être inférieur ou égal à 1 s.

NOTE R_1 est une résistance de charge qui comprend la résistance interne de la source de tension. Ces informations peuvent être consultées dans l'IEC 60384-1:2021, 6.2.2.

Le courant de charge ne doit pas dépasser 0,05 A.

Pour les condensateurs dont les tensions assignées sont supérieures ou égales à 1 kV, une limite de courant de charge inférieure peut être donnée dans la spécification particulière. Pour protéger les condensateurs contre l'amorçage, l'essai peut être réalisé dans un milieu isolant adapté.

5.6.4.3 Tensions d'essai

Des tensions d'essai conformes au Tableau 6 doivent être appliquées entre les points de mesures de 6.1.3 et du Tableau 3 de l'IEC 60384-1:2021, pendant une durée de 1 min pour les essais d'homologation et pendant une durée de 1 s pour les essais de conformité de la qualité lot par lot.

Tableau 6 – Tensions d'essai

Tension assignée V	Tension d'essai V
$U_R \leq 100$	2,5 U_R
$100 < U_R \leq 200$	1,5 U_R + 100
$200 < U_R \leq 500$	1,3 U_R + 100
$500 < U_R < 1\ 000$	1,3 U_R
$U_R \geq 1\ 000$	1,2 U_R

5.6.4.4 Exigence

Aucun claquage ni contournement électrique ne doit être constaté pendant l'essai.

5.6.5 Impédance (si la spécification particulière l'exige)

5.6.5.1 Généralités

Voir IEC 60384-1:2021, 6.6, avec les détails de 5.6.5.2 et 5.6.5.3.

5.6.5.2 Conditions de mesure

La fréquence de mesure: 100 kHz, avec une tolérance relative de ±10 %.

5.6.5.3 Exigences

L'impédance doit être indiquée dans la spécification particulière.

5.6.6 Résistance série équivalente [ESR] (si la spécification particulière l'exige)

5.6.6.1 Généralités

Voir IEC 60384-1:2021, 6.4.2, avec les détails de 5.6.6.2 et de 5.6.6.3.

5.6.6.2 Conditions de mesure

La fréquence de mesure: 100 kHz, avec une tolérance relative de ±10 %.

5.6.6.3 Exigences

L'ESR doit être indiquée dans la spécification particulière.

5.7 Caractéristique de température de capacité (température de référence de 20 °C)

5.7.1 Préconditionnement spécial

Voir 6.2.

5.7.2 Conditions de mesure

Voir IEC 60384-1:2021, 6.8.1, avec les détails suivants.

Les condensateurs doivent être mesurés dans l'état non monté en suivant les étapes et conditions données dans le Tableau 7.

Les étapes et conditions de mesure d'une température de référence de 25 °C sont données à l'Annexe C.

Tableau 7 – Détails des conditions de mesure

Étape de mesure	Température °C	Tension en courant continu appliquée
1	20 ± 2	–
2	T_A [a] ± 3	–
3	20 ± 2	–
4	T_B [b] ± 2	–
5	T_B ± 2	×
6	20 ± 2	×
7	T_A ± 3	×
8	20 ± 2	–

Des mesures peuvent être effectuées à des températures intermédiaires afin de s'assurer que les exigences de 4.2.5 sont satisfaites.

La capacité de référence est la capacité mesurée à l'Étape 3.

En raison des effets décrits dans la Note au paragraphe 5.2, les valeurs de capacité mesurées à la référence de température, les étapes 5 à 7, avec la tension en courant continu appliquée, dépendent du temps. Cette dépendance temporelle est incluse dans les limites données pour la variation de capacité. Les variations de capacité entre la première et la dernière mesure à la référence de température, Étapes 1 et 8, indiquent l'importance du vieillissement concerné. Dans le cas d'un litige concernant les résultats des mesures avec une tension en courant continu appliquée, il est conseillé de convenir d'un intervalle de temps fixe entre les mesures à la référence de température, les étapes 5 et 7 avec la tension en courant continu appliquée (voir IEC 60384-1:2021, 6.8.1.3).

NOTE "–" indique: aucune tension en courant continu appliquée;

"×" indique: tension en courant continu appliquée (si spécifié dans la spécification particulière).

[a] T_A = Température minimale de catégorie.

[b] T_B = Température maximale de catégorie.

5.7.3 Exigences

La caractéristique de température avec et sans tension en courant continu appliquée ne doit pas dépasser les valeurs données dans le Tableau 3. La variation de capacité doit être calculée conformément à l'IEC 60384-1:2021, 6.8.3.1.

5.8 Essai de cisaillement

Voir IEC 60384-1:2021, 7.7.

Une force doit être choisie parmi 1 N, 2 N, 5 N et 10 N et indiquée dans la spécification particulière.

5.9 Essai de pliage du substrat

5.9.1 Généralités

Voir IEC 60384-1:2021, 7.8.

Sauf indication contraire dans la spécification particulière,

– la flèche D doit être choisie entre 1 mm, 2 mm ou 3 mm, des valeurs de flèche plus élevées peuvent être données dans la spécification particulière dans le cas de conceptions très robustes;
– le nombre de courbures doit être égal à 1;
– le rayon de l'outil de courbure doit être égal à 5 mm;
– lorsque la flèche D est inférieure ou égale à 2 mm, le rayon peut être égal à 230 mm;
– la durée dans l'état courbé doit être de 5 s.

Pour la dimension 1005M ou une dimension inférieure, il convient que l'épaisseur du substrat soit égale à 0,8 mm.

5.9.2 Mesure initiale

La capacité doit être mesurée comme cela est spécifié en 5.6.1 et dans la spécification particulière.

5.9.3 Contrôle final

Les condensateurs doivent être examinés visuellement et il ne doit pas y avoir de dommage visible. Voir 5.5.2.

La variation de capacité avec la carte en position courbée ne doit pas dépasser 10 %.

5.10 Résistance à la chaleur de brasage

5.10.1 Généralités

Voir IEC 60068-2-58 en l'associant aux informations données de 5.10.2 à 5.10.6.

5.10.2 Préconditionnement spécial

Voir 5.2.

5.10.3 Mesure initiale

La capacité doit être mesurée conformément à 5.6.1.

5.10.4 Conditions d'essai

5.10.4.1 Méthode du bain de brasure (applicable à 1608M, 2012M et 3216M)

NOTE Les codes des sous-classes sont expliqués dans le Tableau A.1.

Voir l'IEC 60068-2-58, Essai Td_2, Méthode 1, avec les détails suivants, sauf indication contraire dans la spécification particulière.

Le spécimen doit être préchauffé à une température comprise entre 110 °C et 140 °C et maintenue pendant 30 s à 60 s.

Alliage de brasure: Sn-Pb ou Sn-Ag-Cu
Température: 260 °C ± 5 °C

Durée d'immersion: 10 s ± 1 s

Profondeur d'immersion: 10 mm

Nombre d'immersions: 1

5.10.4.2 Système de brasage par convection gazeuse ou infrarouge

Voir l'IEC 60068-2-58, Essai Td_2, Méthode 2, avec les détails suivants:

a) la pâte à braser doit être appliquée sur le substrat d'essai;

b) l'épaisseur du dépôt de brasure doit être indiquée dans la spécification particulière;

c) les sorties du spécimen doivent être placées sur la pâte à braser;

d) alliage de brasure: Sn-Pb;

sauf indication contraire dans la spécification particulière, le spécimen et le substrat d'essai doivent être préchauffés à une température de (150 ± 10) °C et maintenue pendant 60 s à 120 s dans un système de brasage par convection gazeuse ou infrarouge;

la température du système de refusion doit être augmentée rapidement jusqu'à ce que le spécimen ait atteint une température de (235 ± 5) °C et maintenue pendant (10 ± 1) s;

e) alliage de brasure: Sn-Ag-Cu;

sauf indication contraire dans la spécification particulière, le profil de température de refusion doit être choisi dans le Tableau 8 et la Figure 6;

Tableau 8 – Profils de température de refusion pour alliage Sn-Ag-Cu

Composition de l'alliage		T_1 °C	T_2 °C	t_1 s	T_3 °C	t_2 s	T_4 °C	t_3 s
Brasure sans plomb (Sn-Ag-Cu)	Essai	150 ± 5	180 ± 5	120 ± 5	220	60 à 90	250	20 à 40 à T_4 – 5 °C

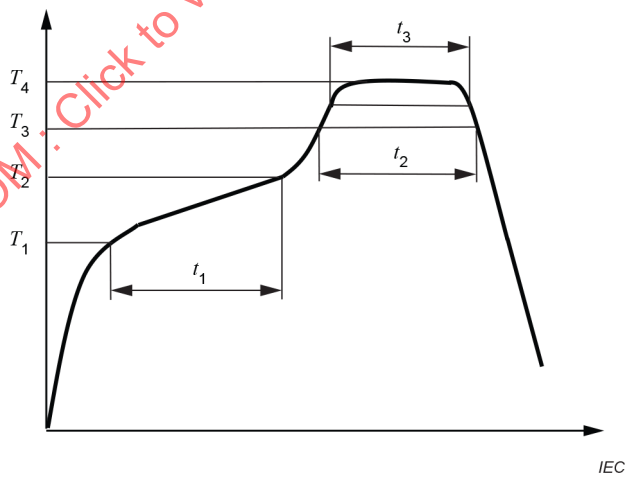


Figure 6 – Profil de température de refusion

f) nombre d'essais: 1, sauf indication contraire dans la spécification particulière;

g) le profil de température de d) ou e) doit être indiqué dans la spécification particulière.

5.10.5 Rétablissement

Les condensateurs doivent se rétablir pendant 24 h ± 2 h.

Les résidus de flux doivent être retirés à l'aide d'un solvant approprié.

5.10.6 Inspection finale, mesures et exigences

Après un rétablissement, les condensateurs doivent être mesurés et examinés visuellement et doivent satisfaire aux exigences suivantes.

Sous un éclairage normal et un grossissement d'environ 10×, aucun signe de dommage, tel que des craquelures, ne doit apparaître. Voir 5.5.2.

La dissolution du revêtement d'extrémité (lixiviation) ne doit pas dépasser 25 % de la longueur de l'arête concernée. La spécification particulière peut spécifier d'autres informations.

La capacité doit être mesurée conformément à 5.6.1 et la variation ne doit pas dépasser les valeurs indiquées dans le Tableau 9.

Tableau 9 – Variation maximale de capacité

Température de référence de 20 °C	
Sous-classe	**Exigences**
2B et 2C	±10 %
2D et 2R	±15 %
2E et 2F	±20 %
NOTE Les codes des sous-classes sont expliqués en 4.2.5.	
Température de référence de 25 °C	
Sous-classe	**Exigences**
R	±10 %
S	±10 %
T	±15 %
U	±20 %
NOTE Les codes des sous-classes sont expliqués en Tableau C.2.	

5.11 Brasabilité

5.11.1 Généralités

Voir l'IEC 60068-2-58 en l'associant aux informations données de 5.11.2 à 5.11.4.

5.11.2 Conditions d'essai

5.11.2.1 Méthode du bain de brasure (applicable à 1608M, 2012M et 3216M)

NOTE Les codes des sous-classes sont expliqués dans le Tableau A.1.

Voir l'IEC 60068-2-58, Essai Td_1, Méthode 1, avec les détails suivants, sauf indication contraire dans la spécification particulière.

Le spécimen doit être préchauffé à une température comprise entre 80 °C et 140 °C et maintenue pendant 30 s à 60 s.

Alliage de brasure:	Sn-Pb	Sn-Ag-Cu
Température:	(235 ± 5) °C	(245 ± 5) °C
Durée d'immersion:	(2 ± 0,2) s	(3 ± 0,3) s
Profondeur d'immersion:	10 mm	10 mm

Nombre d'immersions: 1 1

5.11.2.2 Système de brasage par convection gazeuse ou infrarouge

Voir l'IEC 60068-2-58, Essai Td_1, Méthode 2, avec les détails suivants:

a) la pâte à braser doit être appliquée sur le substrat d'essai;

b) l'épaisseur du dépôt de brasure doit être indiquée dans la spécification particulière;

c) les sorties du spécimen doivent être placées sur la pâte à braser;

d) alliage de brasure: Sn-Pb;

sauf indication contraire dans la spécification particulière, le spécimen et le substrat d'essai doivent être préchauffés à une température de (150 ± 10) °C et maintenue pendant 60 s à 120 s dans un système de brasage par convection gazeuse ou infrarouge;

la température du système de refusion doit être augmentée rapidement jusqu'à ce que le spécimen ait atteint une température de (215 ± 3) °C et maintenue pendant (10 ± 1) s;

e) alliage de brasure: Sn-Ag-Cu;

sauf indication contraire dans la spécification particulière, le spécimen et le substrat d'essai doivent être préchauffés à une température comprise entre (150 ± 5) °C et (180 ± 5) °C et pendant 60 s à 120 s dans un système de brasage par convection gazeuse ou infrarouge;

la température du système de refusion doit être augmentée rapidement jusqu'à ce que le spécimen ait atteint (235 ± 3) °C. La durée au-delà de 225 °C doit être de (20 ± 5) s;

f) le profil de température de d) ou e) doit être indiqué dans la spécification particulière.

5.11.3 Rétablissement

Les résidus de flux doivent être retirés à l'aide d'un solvant approprié.

5.11.4 Inspection finale, mesures et exigences

Le condensateur doit faire l'objet d'examen visuel sous un éclairage normal et avec un grossissement d'environ 10×. Aucun signe de dommage ne doit apparaître. Voir 5.5.2.

Les extrémités et les zones de contact doivent être recouvertes d'une couche de brasure lisse et brillante ne comportant que très peu d'imperfections isolées telles que des piqûres ou des zones non mouillées ou démouillées. Ces imperfections ne doivent pas être concentrées sur une seule zone.

La spécification particulière peut spécifier d'autres exigences.

5.12 Variations rapides de température

5.12.1 Généralités

Cet essai ne doit être appliqué qu'aux condensateurs pour lesquels la température de catégorie est supérieure à 110 °C.

Voir IEC 60384-1:2021, 8.1, en l'associant aux informations données de 5.12.2 à 5.12.6.

Les condensateurs doivent être montés conformément à 5.4.

5.12.2 Préconditionnement spécial

Voir 5.2.

5.12.3 Mesure initiale

La capacité doit être mesurée conformément à 5.6.1.