# IEC 60384-9

Edition 5.0 2024-08
REDLINE VERSION

# INTERNATIONAL STANDARD

colour
inside

## Fixed capacitors for use in electronic equipment –
## Part 9: Sectional specification – Fixed capacitors of ceramic dielectric, Class 2

IEC 60384-9:2024-08 RLV(en)

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## CONTENTS

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# FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

## Part 9: Sectional specification – Fixed capacitors of ceramic dielectric, Class 2

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IEC 60384-9 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2015. 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 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 have been added in Table 7, Table 9, Table 11, Table 13 and Table 15.
c) The table of temperature characteristics of capacitance for the reference temperature 25 °C have been added in Table B.1, Table B.2 and Table B.3.
d) Annex B has been changed from informative to normative.
e) Clause C.5 (Test schedule for quality conformance inspection) has been newly added to withdraw the blank detail specification: IEC 60384-9-1.

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

| Draft | Report on voting |
|---|---|
| 40/3145/FDIS | 40/3162/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 9: Sectional specification – Fixed capacitors of ceramic dielectric, Class 2

## ~~1 General~~

### ~~1.~~1 Scope

This part of IEC 60384 is applicable to fixed capacitors of ceramic dielectric with a defined temperature coefficient (dielectric Class 2), intended for use in electronic equipment, including leadless capacitors but excluding fixed surface mount multilayer capacitors of ceramic dielectric, which are covered by IEC 60384-22 (Class 2).

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

### ~~1.2 Object~~

The object of this document is to ~~prescribe~~ specify preferred ratings and characteristics and to select from IEC 60384-1:~~2008~~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~~ specified in detail specifications referring to ~~this sectional specification shall be of equal or higher performance level because lower performance levels are not permitted~~ 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 60063:1963, *Preferred number series for resistors and capacitors*~~
~~IEC 60063:1963/AMD1:1967~~
~~IEC 60063:1963/AMD2:1977~~

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

IEC 60384-1:~~2008~~2021, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 61193-2:2007, *Quality assessment systems – 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 ~~applicable~~ 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**
**~~fixed capacitors,~~ capacitor of ceramic dielectric, Class 2**
capacitor which 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 the non-linear change of capacitance over the category temperature range (see Table 2).

**3.2**
**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 2 and Annex B).

**3.3**
**rated voltage**
$U_R$
maximum DC voltage that ~~may~~ can be applied continuously to the terminations of a capacitor at the rated temperature

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

~~[SOURCE: IEC 60384-1:2008, 2.2.25, modified (addition of "the terminations of")]~~

## 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 a reference temperature of 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 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 days, 10 days, 21 days, and 56 days |

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

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

## 4.2 Preferred values of ratings

### 4.2.1 Rated temperature

For capacitors covered by this document, the rated temperature is equal to the upper category temperature.

### 4.2.2 Rated voltage ($U_R$)

The preferred values of rated voltage are: (25, 40, 63, 100, 160, 250, 400, 630, 1 000, 1 600, 2 500, 4 000 and 6 300) V. These values conform to the basic series of preferred values R5 given in 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.

~~The sum of the d.c. voltage and the peak a.c. voltage applied to the capacitor should not exceed the rated voltage. The value of the peak alternating voltage should not exceed the value determined by the permissible reactive power.~~

### 4.2.3 Category voltage ($U_C$)

Since the rated temperature is defined as the upper category temperature, the category voltage is equal to the rated voltage, as defined in IEC 60384-1:~~2008~~2021, 3.5.

### 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 E3, E6 and E12 series given in IEC 60063 ~~preferably~~.

#### 4.2.4.2 Preferred tolerances on nominal capacitance

Table 1 denotes the preferred values of tolerance on nominal capacitance.

**Table 1 – Preferred tolerance on nominal capacitance**

| Preferred series | Tolerances<br>% | 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 2 denotes with a cross the preferred values of temperature characteristics with and without d.c. voltage applied. The method of coding the subclass is also given; for example a dielectric with a percentage change of ±20 % without d.c. voltage applied over the temperature range from -55 °C to +125 °C, will be defined as a dielectric of Class 2C1.~~

Table 2 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 Class 2C1. The temperature characteristics, category temperatures and corresponding codes for the reference temperature 25 °C are given in Annex B.

The temperature range, for which the temperature characteristics of the dielectric is defined, is the same as the category temperature range.

**Table 2 – ~~Preferred values of temperature characteristics~~ 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<br>% | | Category temperature range and corresponding number code | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | −55/+150<br>°C | −55/+125<br>°C | −55/+85<br>°C | −40/+85<br>°C | −25/+85<br>°C | +10/+85<br>°C |
| | without DC voltage applied | with DC voltage applied [a] | 0 | 1 | 2 | 3 | 4 | 6 |
| 2B | ±10 | Requirements specified in the detail specification | | ~~-~~ | ~~x~~ | ~~x~~ | ~~x~~ | ~~-~~ |
| 2C | ±20 | | | ~~x~~ | ~~x~~ | ~~x~~ | ~~-~~ | ~~-~~ |
| 2D | +20/−30 | | | ~~-~~ | ~~-~~ | ~~-~~ | ~~x~~ | ~~-~~ |
| 2E | +22/−56 | | | ~~-~~ | ~~x~~ | ~~x~~ | ~~x~~ | ~~x~~ |
| 2F | +30/−80 | | | ~~-~~ | ~~x~~ | ~~x~~ | ~~x~~ | ~~x~~ |
| 2R | ±15 | | | ~~x~~ | ~~-~~ | ~~-~~ | ~~-~~ | ~~-~~ |
| ~~2X~~ | ~~±15~~ | ~~+15/–25~~ | | ~~x~~ | ~~-~~ | ~~-~~ | ~~-~~ | ~~-~~ |

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.

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

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

# 5 Test and measurement procedures

## 5.1 General

This Clause 5 supplements the information given in IEC 60384-1:~~2008~~2021, Clause ~~4~~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 tests, 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 for a period of 1 h, followed by recovery for a period of 24 h ± 1 h at standard atmospheric conditions for testing.

NOTE Class 2 capacitors lose capacitance continuously with time following 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 stage regardless of its previous history (see Clause A.4 for further information).

### 5.3 Visual examination and check of dimensions

See IEC 60384-1:~~2008,~~2021, 7.1.

### 5.4 Electrical tests

### 5.4.1 Capacitance

### 5.4.1.1 General

See IEC 60384-1:~~2008~~2021, 6.3, with the details of 5.4.1.2 and 5.4.1.3.

### 5.4.1.2 Measuring conditions

The capacitance shall be measured in accordance with Table 3 and in accordance with the details given below Table 3.

**Table 3 – Measuring conditions**

| Reference temperature | Subclass | Measuring voltage | Referee voltage [a] |
|---|---|---|---|
| 20 °C | 2B, 2C, 2X | 1,0 ± 0,2 V | 1,0 ± 0,02 V |
| | 2D, 2E, 2F, 2R | 0,3 ± 0,2 V<br>or as specified in the detail specification | 0,3 ± 0,02 V<br>or as specified in the detail specification |
| 25 °C | R,S,T,U | 1,0 ± 0,2 V | 1,0 ± 0,02 V |

[a] In case of dispute about results of measurements, referee voltage is applied.

Frequency: $C_N < 100$ pF $f = 1$ MHz unless otherwise specified in the detail specification.

$C_N \geq 100$ pF $f = 1$ kHz ± 20 % for measuring purposes and 1 kHz for referee tests.

$C_N > 10$ µF $f = 100$ Hz or 120 Hz ± 20 % with measuring voltage 0,5 V ± 0,2 V for measuring purposes and 100 Hz or 120 Hz for referee tests.

### 5.4.1.3 Requirements

The capacitance value shall correspond with the rated value taking into account the specified tolerance.

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 (for explanation see Annex A).

~~If applying the ageing time other than 1 000 h, that may be specified in the detail specification.~~

### 5.4.2 Tangent of loss angle (tan $\delta$)

### 5.4.2.1 General

See IEC 60384-1:~~2008~~2021, 6.4, with the details of 5.4.2.2 to 5.4.2.4.

### 5.4.2.2 Measuring conditions

See 5.4.1.

#### 5.4.2.3 Accuracy

The accuracy of the measuring instruments shall be such that the measuring error does not exceed 0,001.

#### 5.4.2.4 Requirements

The tangent of loss angle shall not exceed 0,035, or such lower value as may be given in the detail specification.

### 5.4.3 Insulation resistance ($R_i$)

#### 5.4.3.1 General

See IEC 60384-1:~~2008~~2021, 6.1, with the details of 5.4.3.2 and 5.4.3.3.

#### 5.4.3.2 Measuring conditions

See IEC 60384-1:~~2008~~2021, 6.1.2, with the following details:

For $U_R$ < 100 V, the measuring voltage may be of any value not greater than $U_R$, the reference voltage being $U_R$.

The voltage shall be applied immediately at the specified value for 1 min ± 5 s for qualification approval testing and periodic tests (Group C). 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.

The insulation resistance ($R_i$) shall be measured at the end of the 1 min period.

#### 5.4.3.3 Requirements

The insulation resistance ($R_i$) shall meet the requirements given in Table 4.

**Table 4 – Insulation resistance requirements**

| Style | Measuring points | $C_N \leq 25$ nF | $C_N > 25$ nF |
|---|---|---|---|
| | | $R_i$ | $R_i \times C_N$ |
| Insulated | 1a and 1c | ≥ 4 000 MΩ | ≥ 100 s |
| Non-insulated | 1a | | |

### 5.4.4 Voltage proof

#### 5.4.4.1 General

See IEC 60384-1:~~2008~~2021, 6.2, with the details of 5.4.4.2 to 5.4.4.4.

#### 5.4.4.2 Test conditions

The product of $R_i$ and the nominal capacitance $C_x$ shall be smaller than or equal to 1 s.

The charge current shall not exceed 0,05 A.

### 5.4.4.3 Test voltage

The voltages in Table 5 shall be applied between the measuring points of IEC 60384-1:~~2008~~2021, Table 3, 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 5 – Test voltages**

| Type | Rated voltage<br>V | Test voltage<br>V |
|---|---|---|
| Leaded multilayer ceramic capacitors | $U_R \leq 100$ | $2{,}5\ U_R$ |
| | $100 < U_R \leq 200$ | $1{,}5\ U_R + 100$ |
| | $200 < U_R \leq 500$ | $1{,}3\ U_R + 100$ |
| | $500 < U_R$ | $1{,}3\ U_R$ |
| Others | $U_R \leq 500$ | $2{,}5\ U_R$ |
| | $U_R > 500$ | $1{,}5\ U_R + 500$ |

~~NOTE~~ If $U_R > 500$ V, then the test voltage for Test C (external insulation) is $1{,}5\ U_R + 500$ V or as specified in the detail specification.

### 5.4.4.4 Requirement

There shall be no breakdown or flashover during the test.

## 5.5 Temperature characteristic of capacitance (reference temperature 20 °C)

### 5.5.1 Special preconditioning

See 5.2.

### 5.5.2 Measuring conditions

See IEC 60384-1:~~2008~~2021, 6.8.1.2 and 6.8.1.3, with Table 6.

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

**Table 6 – Details of measuring conditions**

| Measuring step | Temperature<br>°C | DC voltage applied |
|---|---|---|
| 1 | 20 ± 2 | - |
| 2 | $T_\mathrm{A}$ [a] ± 3 | - |
| 3 | 20 ± 2 | - |
| 4 | $T_\mathrm{B}$ [b] ± 2 | - |
| 5 | $T_\mathrm{B}$ ± 2 | x |
| 6 | 20 ± 2 | x |
| 7 | $T_\mathrm{A}$ ± 3 | x |
| 8 | 20 ± 2 | - |

NOTE "-" indicates: no DC voltage applied.
"x" indicates: DC voltage applied (if specified in the detail specification)

~~NOTE 2~~ Intermediate measurement temperatures are used when ensuring the requirements of 4.2.5.

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

~~NOTE 4~~ 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 change between the first and the last measurements at temperature reference, Steps 1 and 8, indicates the amount of ageing involved. In 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:~~2008~~2021, 6.8.1.3).

[a] $T_\mathrm{A}$ = Lower category temperature.

[b] $T_\mathrm{B}$ = Upper category temperature.

### 5.5.3 Requirements

The variation of capacitance shall be calculated in accordance with IEC 60384-1:~~2008~~2021, 6.8.3.1.

The temperature characteristics with and without DC voltage applied shall not exceed the values given in Table 2.

## 5.6 Robustness of terminations

See IEC 60384-1:~~2008~~2021, 7.3.

## 5.7 Resistance to soldering heat

### 5.7.1 General

See IEC 60384-1:~~2008~~2021, 9.1, with the details of 5.7.2 to 5.7.5.

### 5.7.2 Special preconditioning

See 5.2.

### 5.7.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.7.4 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

### 5.7.5 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The capacitances shall be measured in accordance with 5.4.1, and the capacitance change shall not exceed the values in Table 7.

**Table 7 – Maximum capacitance change**

| Reference temperature 20 °C | |
|---|---|
| **Subclass** | **Requirements** |
| 2B, 2C and 2X | ±10 % |
| 2D and 2R | ±15 % |
| 2E and 2F | ±20 % |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | |
| **Reference temperature 25 °C** | |
| **Subclass** | **Requirements** |
| R | ±10 % |
| S | ±10 % |
| T | ±15 % |
| U | ±20% |
| NOTE 2 See ~~2.2.5~~ Table B.2 for explanation of the subclass codes. | |

## 5.8 Solderability

### 5.8.1 General

See IEC 60384-1:~~2008~~2021, 9.2, with the details of 5.8.2 to 5.8.3.

### 5.8.2 Test conditions

The requirements for the globule test method shall be ~~prescribed~~ specified in the detail specification. When neither the solder bath nor the solder globule method is appropriate the soldering iron test shall be used with soldering iron size A.

### 5.8.3 Final inspection, measurements and requirements

The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations, or see the detail specification for the wetting balance method.

## 5.9 Rapid change of temperature (if required)

### 5.9.1 General

See IEC 60384-1:~~2008~~2021, 8.1, with the details of 5.9.2 to 5.9.5.

### 5.9.2 Special preconditioning

See 5.2.

### 5.9.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.9.4 Test conditions

Number of cycles: 5.

Duration of exposure at the temperature limits: 30 min.

### 5.9.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

## 5.10 Vibration

### 5.10.1 General

See IEC 60384-1:~~2008~~2021, 7.4, with the details of 5.10.2 and 5.10.3.

### 5.10.2 Test conditions

The following degree of severity of test Fc applies:

- 0,75 mm displacement or 100 $m/s^2$, whichever is the lower amplitude, over one of the following frequency ranges: 10 Hz to 55 Hz, 10 Hz to 500 Hz, 10 Hz to 2 000 Hz. The total duration of the test shall be 6 h.

The detail specification shall specify the frequency range and shall also ~~prescribe~~ specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

### 5.10.3 Final inspection, measurements and requirements

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

## 5.11 Bump (repetitive shock)

### 5.11.1 General

See IEC 60384-1:~~2008~~2021, 7.5, with the details of 5.11.2 to 5.11.4.

The detail specification shall state whether the bump (repetitive shock) or the non-repetitive shock test applies.

### 5.11.2 Initial measurements

Not required.

### 5.11.3 Test conditions

The detail specification shall state which of the following preferred severities applies:

| | | | |
|---|---|---|---|
| Total number of bumps: | 1 000 | or | 4 000 |
| Acceleration: | 400 $m/s^2$ | or | 100 $m/s^2$ |
| Pulse duration: | 6 ms | | 16 ms |

The detail specification shall also ~~prescribe~~ specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

### 5.11.4 Final inspection, measurements and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in 5.12.4.

## 5.12 Shock (non-repetitive shock)

### 5.12.1 General

See IEC 60384-1:~~2008~~2021, 7.6, with the details of 5.12.2 to 5.12.4.

The detail specification shall state whether the bump (repetitive shock) or the non-repetitive shock test applies.

### 5.12.2 Initial measurements

Not required.

### 5.12.3 Test conditions

The detail specification shall state which of the preferred severities applies as stated in Table 8.

Pulse-shape: half-sine.

**Table 8 – Preferred severities (of non-repetitive shock)**

| Peak acceleration m/s$^2$ | Corresponding duration of the pulse ms |
|---|---|
| 300 | 18 |
| 500 | 11 |
| 1 000 | 6 |

The detail specification shall also ~~prescribe~~ specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

### 5.12.4 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The capacitance shall be measured in accordance with 5.4.1, the change shall not exceed the values in Table 9.

**Table 9 – Maximum capacitance change**

| Reference temperature 20 °C | |
|---|---|
| **Subclass** | **Requirements** |
| 2B, 2C and 2X | ±10 % |
| 2D and 2R | ±15 % |
| 2E and 2F | ±20 % |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | |
| **Reference temperature 25 °C** | |
| **Subclass** | **Requirements** |
| R | ±10% |
| S | ±10% |
| T | ±15% |
| U | ±20% |
| NOTE 2 See ~~2.2.5~~ Table B.2 for explanation of the subclass codes. | |

## 5.13 Climatic sequence

### 5.13.1 General

See IEC 60384-1:~~2008~~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 measurements

The capacitance shall be measured in accordance with 5.4.1.

### 5.13.4 Dry heat

See IEC 60384-1:~~2008~~2021, 8.2.3.

### 5.13.5 Damp heat, cyclic, Test Db, first cycle

See IEC 60384-1:~~2008~~2021, 8.2.4.

### 5.13.6 Cold

See IEC 60384-1:~~2008~~2021, 8.2.5, with the following detail.

The capacitor shall be visually examined. These shall be no visible damage.

### 5.13.7 Low air pressure

#### 5.13.7.1 General

See IEC 60384-1:~~2008~~2021, 8.2.6, with the details of 5.13.7.2 to 5.13.7.4.

#### 5.13.7.2 Test conditions

The test, if required in the detail specification, shall be carried out at a temperature of 15 °C to 35 °C and a pressure of 8 kPa.

The duration of the test shall be 1 h.

#### 5.13.7.3 Test procedures

Immediately after achieving the low pressure, $U_R$ shall be applied for 1 min to 2 min.

#### 5.13.7.4 Final inspection and requirements

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

### 5.13.8 Damp heat, cyclic, Test Db, remaining cycles

#### 5.13.8.1 General

See IEC 60384-1:~~2008~~2021, 8.2.4, with the details of 5.13.8.2 to 5.13.8.4:

#### 5.13.8.2 Test conditions

The test conditions are shown in Table 10.

No voltage is applied.

**Table 10 – Number of damp heat cycles**

| Category | Number of cycles of 24 h |
|---|---|
| -/-/56 | 5 |
| -/-/21 | 1 |
| -/-/10 | 1 |
| -/-/04 | 0 |

#### 5.13.8.3 Recovery

The capacitors shall recover for 24 h ± 2 h.

#### 5.13.8.4 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the following requirements given in Table 11. If the capacitance value is less than the minimum value permitted, then after the other measurements have been carried out the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 11 shall be met.

**Table 11 – Final inspection measurements and requirements**

| Measurement | Measuring conditions | Requirements (reference temperature 20°C) | | | |
|---|---|---|---|---|---|
| | | Subclasses 2B, 2C and 2X | Subclasses 2D and 2R | Subclasses 2E | Subclasses 2F |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 10$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % | $\Delta C/C \leq \pm 30$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\ 000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | | | | | |
| **Measurement** | **Measuring conditions** | **Requirements (reference temperature 25°C)** | | | |
| | | **Subclasses R** | **Subclasses S** | **Subclasses T** | **Subclasses U** |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\ 000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 2 See Table B.2 for an explanation of the subclass codes. | | | | | |

## 5.14 Damp heat, steady state

### 5.14.1 General

See IEC 60384-1:~~2008~~2021, 8.3, with the details of 5.14.2 to 5.14.6.

### 5.14.2 Special preconditioning

See 5.2.

### 5.14.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.14.4 Test conditions

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

The severity of the test should be selected from the test conditions as shown in Table 12 and as specified in the detail specification.

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

**Table 12 – 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.

### 5.14.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

### 5.14.6 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the requirements given in Table 13. 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 13 shall be met.

**Table 13 – Final inspection, measurements and requirements**

| Measurement | Measuring conditions | Requirements (reference temperature 20°C) | | | |
|---|---|---|---|---|---|
| | | Subclasses 2B, 2C and 2X | Subclasses 2D and 2R | Subclasses 2E | Subclasses 2F |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 10$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % | $\Delta C/C \leq \pm 30$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\,000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | | | | | |
| **Measurement** | **Measuring conditions** | **Requirements (reference temperature 25 °C)** | | | |
| | | **Subclasses R** | **Subclasses S** | **Subclasses T** | **Subclasses U** |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\,000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 2 See ~~2.2.5~~ Table B.2 for an explanation of the subclass codes. | | | | | |

## 5.15 Endurance

### 5.15.1 General

See IEC 60384-1:~~2008~~2021, 8.5, with the details of 5.15.2 to 5.15.6.

### 5.15.2 Special preconditioning

See 5.2.

### 5.15.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.15.4 Test conditions

The capacitors shall be tested in accordance with Table 14.

**Table 14 – Endurance test conditions**

| Type | Temperature | Rated voltage V | Test voltage V | Duration h |
|---|---|---|---|---|
| Leaded multilayer ceramic capacitors | Upper category temperature | $U_R \leq 200$ | 1,5 $U_R$ | 1 000 |
| | | $200 < U_R \leq 500$ | 1,3 $U_R$ | 1 500 |
| | | $500 < U_R$ | 1,2 $U_R$ | 2 000 |
| Others | Upper category temperature | $U_R$ | 1,5 $U_R$ | 1 000 |

### 5.15.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

### 5.15.6 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the requirements given in Table 15. 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 5.4.1 and then the requirement in Table 15 shall be met.

**Table 15 – Final inspection, measurements and requirements**

| ~~Measurement~~ | ~~Measuring conditions~~ | ~~Requirements~~ | | | |
|---|---|---|---|---|---|
| | | ~~Subclasses 2B, 2C and 2X~~ | ~~Subclass 2D and 2R~~ | ~~Subclass 2E~~ | ~~Subclass 2F~~ |
| ~~Capacitance~~ | ~~4.4.1~~ | ~~$\Delta C/C \leq \pm 20$ %~~ | ~~$\Delta C/C \leq \pm 20$ %~~ | ~~$\Delta C/C \leq \pm 20$ %~~ | ~~$\Delta C/C \leq \pm 30$ %~~ |
| ~~Tangent of loss angle~~ | ~~4.4.2~~ | ~~tan $\delta \leq 2 \times$ value of 4.4.2.3~~ | | | |
| ~~Insulation resistance~~ | ~~4.4.3~~ | ~~$R_i \geq 2\ 000$ MΩ or $R_i \times C_N \geq 50$ s (whichever is less)~~ | | | |
| ~~NOTE See 2.2.5 for explanation of the subclass codes.~~ | | | | | |

| Measurement | Measuring conditions | Requirements (reference temperature 20 °C) | | | |
|---|---|---|---|---|---|
| | | Subclasses 2B and 2C | Subclasses 2D and 2R | Subclasses 2E | Subclasses 2F |
| **Capacitance** | 5.4.1 | $\Delta C/C$ ≤ ± 10 % | $\Delta C/C$ ≤ ± 15 % | $\Delta C/C$ ≤ ± 20 % | $\Delta C/C$ ≤ ± 30 % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 2\ 000$ MΩ or $R_i \times C_N \geq 50$ s | | | |
| | | (whichever is less of the two values) | | | |
| NOTE 1 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** | 5.4.1 | $\Delta C/C$ ≤ ± 15 % | $\Delta C/C$ ≤ ± 15 % | $\Delta C/C$ ≤ ± 15 % | $\Delta C/C$ ≤ ± 20 % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 2\ 000$ MΩ or $R_i \times C_N \geq 50$ s | | | |
| | | (whichever is less of the two values) | | | |
| NOTE 2 See Table B.2 for an explanation of the subclass codes. | | | | | |

### 5.16 Component solvent resistance (if applicable)

See IEC 60384-1:~~2008~~2021, 9.4.

### 5.17 Solvent resistance of the marking (if applicable)

See IEC 60384-1:~~2008~~2021, 9.5.

## 6 Marking

### 6.1 General

See IEC 60384-1:~~2008~~2021, 4.3, with the details of 6.2 to 6.5.

### 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:

a) nominal capacitance;

b) rated voltage (DC voltage may be indicated by the symbol: ⎓ [IEC 60417-5031(2002-10)] or — )
c) tolerance on nominal capacitance;
d) the dielectric subclass, see Table 2;
e) year and month (or week) of manufacture;
f) manufacturer's name or trade mark;
g) climatic category;
h) manufacturer's type designation;
i) reference to the detail specification.

Information required under item b) and d) may be given in code form under the manufacturer's, or national, type or style designation.

### 6.3 Marking on the body

The capacitor shall be clearly marked with items a), b) and c) of 6.2 and with as many as possible of the remaining items as is considered necessary. Any duplication of information in the marking on the capacitor should be avoided.

### 6.4 Marking on the packaging

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

### 6.5 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

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 for convenience, be presented in tabular form.

The information in 7.2 to 7.5 shall be given in each detail specification and the values quoted ~~shall preferably~~ 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 capacitor as an aid to easy recognition and for comparison of the capacitor with others.

Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification. All dimensions shall ~~preferably~~ 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 of the body, the width and height of the body and the wire spacing, or for cylindrical types, the body diameter, and the length and diameter of the terminations. When necessary, for example when a number of items (capacitance values/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. When the capacitor is not designed for use on printed boards, this shall be clearly stated in the detail specification.

### 7.3 Mounting

The detail specification shall specify the method of mounting to be applied for normal use and for the application of the vibration and the bump or shock tests. The design of the capacitor may be such that special mounting fixtures are required in its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used in the application of the vibration and the bump or shock tests.

### 7.4 Ratings and characteristics

#### 7.4.1 General

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

#### 7.4.2 Nominal capacitance range

~~See 2.2.4.1.~~

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

For single layer capacitors, the primary stage of manufacture is the metallizing of the dielectric to form the electrode; for multilayer capacitors it 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~~ can be of different case sizes and values.

### 8.3 Certified test records of released lots

The information required in IEC 60384-1:~~2008~~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 $\delta$ and the insulation resistance.

### 8.4 Qualification approval

#### 8.4.1 General

The procedures for qualification approval testing are given in IEC 60384-1:~~2008~~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 ~~3.5~~ Annex C. 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 procedure

The fixed sample size procedure is described in IEC 60384-1:~~2008~~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.

The samples shall consist of specimens having the lowest and highest voltages, and for these voltages the lowest and highest capacitance values. 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). When the range consists of less than four values, the number of specimens to be tested shall be that required for four values.

Spare specimens are permitted as follows.

Two (for six values) or three (for four values) per value may be used as replacements for specimens which 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 3 gives the number of samples to be tested in each group or subgroup together with the number of permissible non-conformances for qualification approval tests.

#### 8.4.3 Tests

The complete series of tests specified in Table 16 and Table 17 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 16 and Table 17 together form the fixed sample size test schedule for which Table 16 includes the details for the sampling and permissible non-conforming item for the different tests or groups of tests. Table 17 together with the details of 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 has to 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 16 – Sampling plan together with numbers of permissible non-conforming items for qualification approval tests, assessment level EZ**

| Group No. | Test | Subclause of this document | Number of specimens $n$[b] | Permissible number of non-conforming items $c$[d] |
|---|---|---|---|---|
| 0 | Visual examination | 5.3 | | |
| | Dimensions | 5.3 | | |
| | Capacitance | 5.4.1 | | |
| | Tangent of loss angle | 5.4.2 | 108 | 0 |
| | Insulation resistance | 5.4.3 | | |
| | Voltage proof | 5.4.4 | | |
| | Spare specimens | | 8 | |
| 1A | Robustness of terminations | 5.6 | 12 | 0 |
| | Resistance to soldering heat | 5.7 | | |
| | Component solvent resistance [c] | 5.16 | | |
| 1B | Solderability | 5.8 | 24 | 0 |
| | Solvent resistance of the marking [c] | 5.17 | | |
| | Rapid change of temperature [a] | 5.9 | | |
| | Vibration | 5.10 | | |
| | Bump or shock [a] | 5.11 or 5.12 | | |
| 1 | Climatic sequence | 5.13 | 36 | 0 |
| 2 | Damp heat, steady state | 5.14 | 24 | 0 |
| 3 | Endurance | 5.15 | 36 | 0 |
| 4 | Temperature characteristic of capacitance | 5.5 | 12 | 0 |

[a] As required in the detail specification.

[b] Capacitance/voltage combinations, see 8.4.2.

[c] If required in the detail specification.

[d] This is the acceptance number, and not exceeded for acceptance.

## Table 17 – Test schedule for qualification approval

| ~~Subclause number and test [a]~~ | ~~D or ND [b]~~ | ~~Conditions of test [a]~~ | ~~Number of specimens ($n$) and number of permissible non-conforming items ($c$) [c]~~ | ~~Performance requirements [a]~~ |
|---|---|---|---|---|
| ~~**Group 0**~~ | ~~ND~~ | | ~~See Table 3~~ | |
| ~~4.3 Visual examination~~ | | | | ~~As in 4.3~~<br>~~Legible marking and as specified in the detail specification~~ |
| ~~4.3 Dimensions (detail)~~ | | | | ~~See detail specification~~ |
| ~~4.4.1 Capacitance~~ | | ~~Frequency: ... kHz or MHz~~<br>~~Measuring voltage: ... V~~ | | ~~Within specified tolerance~~ |
| ~~4.4.2 Tangent of loss angle (tan $\delta$)~~ | | ~~Frequency and measuring voltage (see 4.4.1)~~ | | ~~As in 4.4.2.3~~ |
| ~~4.4.3 Insulation resistance~~ | | ~~See detail specification for the method~~ | | ~~As in 4.4.3.3~~ |
| ~~4.4.4 Voltage proof~~ | | ~~See detail specification for the method~~ | | ~~No breakdown or flashover~~ |
| ~~**Group 1A**~~ | ~~D~~ | | ~~See Table 3~~ | |
| ~~4.6 Robustness of terminations~~ | | ~~Visual examination~~ | | ~~No visible damage~~ |
| ~~4.7.3 Initial measurements~~ | | ~~Capacitance~~ | | |
| ~~4.7 Resistance to soldering heat~~ | | ~~Special preconditioning as in 4.2~~<br>~~See detail specification for the method~~ | | |
| ~~4.7.5 Final measurements~~ | | ~~Visual examination~~<br>~~Capacitance~~ | | ~~No visible damage~~<br>~~Legible marking~~<br>~~$\Delta C/C$ as in 4.7.5~~ |
| ~~4.16 Component solvent resistance (if applicable)~~ | | ~~Solvent: ...~~<br>~~Solvent temp: ...~~<br>~~Method 2~~<br>~~Recovery: ...~~ | | ~~See detail specification~~ |

**~~Table 4~~** ~~*(2 of 4)*~~

| ~~Subclause number and test~~ [a] | ~~D or ND~~ [b] | ~~Conditions of test~~ [a] | ~~Number of specimens ($n$) and number of permissible non-conforming items ($c$)~~ [c] | ~~Performance requirements~~ [a] |
|---|---|---|---|---|
| **~~Group 1B~~** | ~~D~~ | | ~~See Table 3~~ | |
| ~~4.8 Solderability~~ | | ~~See detail specification for the method~~ | | ~~Good tinning as evidenced by free flowing of the solder with wetting of the terminations, or see the detail specification for wetting balance method~~ |
| ~~4.17 Solvent resistance of the marking (if applicable)~~ | | ~~Solvent: ...~~<br>~~Solvent temperature:...~~<br>~~Method 1~~<br>~~Rubbing material: cotton wool~~<br>~~Recovery: ...~~ | | ~~Legible marking~~ |
| ~~4.9 Rapid change of temperature~~ | | ~~Special preconditioning as in 4.2~~ | | |
| ~~4.9.3 Initial measurement~~ | | ~~Capacitance~~<br>~~$T_A$ = Lower category temperature~~<br>~~$T_B$ = Upper category temperature~~<br>~~Five cycles~~<br>~~Duration $t_1$ = 30 min~~<br>~~Recovery: 24 h ± 2 h~~<br>~~Visual examination~~ | | ~~No visible damage~~ |
| ~~4.10 Vibration~~ | | ~~For mounting method see detail specification~~<br>~~Frequency range: from ... Hz to ... Hz~~<br>~~Amplitude: 0,75 mm or acceleration 100 $m/s^2$ (whichever is the less severe)~~<br>~~Total duration: 6 h~~ | | |
| ~~4.10.3 Intermediate inspection~~ | | ~~Visual examination~~ | | ~~No visible damage~~ |
| ~~4.11 Bump (or shock, see 4.12)~~ | | ~~For mounting method see detail specification~~<br>~~Number of bumps: ...~~<br>~~Acceleration: ... $m/s^2$~~<br>~~Duration of pulse: ... ms~~ | | |
| ~~4.12 Shock (or bump, see 4.11)~~ | | ~~For mounting method see detail specification~~<br>~~Acceleration: ... $m/s^2$~~<br>~~Duration of pulse: ... ms~~ | | |
| ~~4.11.4 Final measurements or 4.12.4~~ | | ~~Visual examination~~<br>~~Capacitance~~ | | ~~No visible damage~~<br>~~Legible marking~~<br>~~$\Delta C/C$ as in 4.12.4~~ |

### ~~Table 4~~ ~~*(3 of 4)*~~

| ~~Subclause number and test [a]~~ | ~~D or ND [b]~~ | ~~Conditions of test [a]~~ | ~~Number of specimens $(n)$ and number of permissible non-conforming items $(c)$ [c]~~ | ~~Performance requirements [a]~~ |
|---|---|---|---|---|
| ~~**Group 1**~~ | ~~D~~ | | ~~See Table 3~~ | |
| ~~4.13 Climatic sequence~~ | | ~~Special preconditioning as in 4.2~~ | | |
| ~~4.13.3 Initial measurement~~ | | ~~Capacitance~~ | | |
| ~~4.13.4 Dry heat~~ | | ~~Temperature: upper category temperature~~<br>~~Duration: 16 h~~ | | |
| ~~4.13.5 Damp heat, cyclic, Test Db, first cycle~~ | | | | |
| ~~4.13.6 Cold~~ | | ~~Temperature: lower category temperature~~<br>~~Duration: 2 h~~ | | |
| | | ~~Visual examination~~ | | ~~No visible damage~~ |
| ~~4.13.7 Low air pressure (if required by the detail specification~~ | | ~~Air pressure: 8 kPa~~ | | |
| ~~4.13.7.4 Intermediate inspection~~ | | ~~Visual examination~~ | | ~~No breakdown or flashover~~ |
| ~~4.13.8 Damp heat, cyclic, Test Db, remaining cycles~~ | | | | |
| | | ~~Recovery: 24 h ± 2 h~~ | | |
| ~~4.13.8.4 Final measurements~~ | | ~~Visual examination~~ | | ~~No visible damage~~<br>~~Legible marking~~ |
| | | ~~Capacitance~~ | | ~~$\Delta C/C$ as in 4.13.8.4~~ |
| | | ~~Tangent of loss angle~~ | | ~~As in 4.13.8.4~~ |
| | | ~~Insulation resistance~~ | | ~~As in 4.13.8.4~~ |
| ~~**Group 2**~~ | ~~D~~ | | ~~See Table 3~~ | |
| ~~4.14 Damp heat, steady state~~ | | ~~Special preconditioning as in 4.2~~ | | |
| ~~4.14.3 Initial measurements~~ | | ~~Capacitance~~ | | |
| | | ~~Recovery: 24 h ± 2 h~~ | | |
| ~~4.14.6 Final measurements~~ | | ~~Visual examination~~ | | ~~No visible damage~~<br>~~Legible marking~~ |
| | | ~~Capacitance~~ | | ~~$\Delta C/C$ as in 4.14.6~~ |
| | | ~~Tangent of loss angle~~ | | ~~As in 4.14.6~~ |
| | | ~~Insulation resistance~~ | | ~~As in 4.14.6~~ |

### ~~**Table 4** *(4 of 4)*~~

| ~~**Subclause number and test**~~ [a] | ~~**D or ND**~~ [b] | ~~**Conditions of test**~~ [a] | ~~**Number of specimens ($n$) and number of permissible non-conforming items ($c$)**~~ [c] | ~~**Performance requirements**~~ [a] |
|---|---|---|---|---|
| ~~**Group 3**~~ | ~~D~~ | | ~~See Table 3~~ | |
| ~~4.15 Endurance~~ | | ~~Special preconditioning as in 4.2~~<br>~~Voltage: V~~<br>~~Duration: h~~ | ↓ | |
| ~~4.15.3 Initial measurement~~ | | ~~Capacitance~~<br>~~Recovery: 24 h ± 2 h~~ | | |
| ~~4.15.6 Final measurements~~ | | ~~Visual examination~~ | | ~~No visible damage~~<br>~~Legible marking~~ |
| | | ~~Capacitance~~ | | ~~$\Delta C/C$ as in 4.15.6~~ |
| | | ~~Tangent of loss angle~~ | | ~~As in 4.15.6~~ |
| | | ~~Insulation resistance~~ | | ~~As in 4.15.6~~ |
| ~~**Group 4**~~ | ~~ND~~ | | ~~See Table 3~~ | |
| ~~4.5 Temperature characteristic of capacitance~~ | | ~~Special preconditioning as in 4.2~~ | ↓ | ~~$\Delta C/C$ as in 4.5.3~~ |

~~[a] Subclause numbers of test and performance requirements refer to Clause 4.~~

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

~~[c] This is the acceptance number, and not exceeded for acceptance.~~

| **Test** [a] | **Conditions of test** [a] | **D or ND** [b] | $n$ | $c$ | **Performance requirements** [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 0** | | ND | See Table 16 | | |
| 5.3 Visual examination | | | | | As in 5.3<br>Legible marking and as specified in the detail specification |
| 5.3 Dimension (detail) | | | | | See the detail specification |
| 5.4.1 Capacitance | Frequency: … Hz<br>Measuring voltage: V RMS | | | | Within specified tolerance |
| 5.4.2 Tangent of loss angle (tan $\delta$) | Frequency and Measuring voltage same as in 5.4.1 | | | | As in 5.4.2.4 |
| 5.4.3 Insulation resistance | See detail specification for the method | | | | As in 5.4.3.3 |
| 5.4.4 Voltage proof | See detail specification for the method | | | | No breakdown or flashover |
| **GROUP 1A** | | D | See Table 16 | | |
| 5.6 Robustness of termination | Visual examination | | | | No visible damage |
| 5.7.3 Initial measurement | Capacitance | | | | |
| 5.7 Resistance to soldering heat | Special preconditioning as in 5.2<br>See detail specification for the method | | | | |
| 5.7.5 Final inspection, measurement and requirements | Visual examination | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | $\Delta C/C$ as in 5.7.5 |
| 5.16 Component solvent resistance (if applicable) | Solvent: …<br>Solvent temperature:<br>Method 2<br>Recovery: … | | | | See detail specification |

| **Test** [a] | **Conditions of test** [a] | **D or ND** [b] | *n* | *c* | **Performance requirements** [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 1B** | | D | See Table 16 | | |
| 5.8 Solderability | See detail specification for the method | | | | Good tinning as evidenced by free flowing of the solder with wetting of the terminations, or see the detail specification for wetting balance method |
| 5.17 Solvent resistance of the marking (if applicable) | Solvent: …<br>Solvent temperature:…<br>Method 1<br>Rubbing material: cotton wool<br>Recovery: … | | | | Legible marking |
| 5.9 Rapid change of temperature | Special preconditioning as in 5.2 | | | | |
| 5.9.3 Initial measurement | Capacitance<br>$T_A$ = Lower category temperature<br>$T_B$ = Upper category temperature<br>Five cycles<br>Duration $t_1$ = 30 min<br>Recovery: 24 h ± 2 h<br>Visual examination | | | | No visible damage |
| 5.10 Vibration | For mounting method see detail specification<br>Frequency range: from … Hz to … Hz<br>Amplitude: 0,75 mm or acceleration 100 m/s$^2$ (whichever is the less severe)<br>Total duration: 6 h | | | | |
| 5.10.3 Intermediate inspection | Visual examination | | | | No visible damage |
| 5.11 Bump (or shock, see 5.12) | For mounting method see detail specification<br>Number of bumps: …<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | |
| 5.12 Shock (or bump, see 5.11) | For mounting method see detail specification<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | |
| 5.11.4 or 5.12.4 | Visual examination | | | | No visible damage<br>Legible marking |
| Final inspection, measurements and requirements | Capacitance | | | | $\Delta C/C$ as in 5.12.4 |

| Test [a] | Conditions of test [a] | D or ND [b] | $n$ | $c$ | Performance requirements [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 1** | | D | See Table 16 | | |
| 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<br>Duration: 16 h | | | | |
| 5.13.5 Damp heat, cyclic, Test Db, first cycle | | | | | |
| 5.13.6 Cold | Temperature: lower category temperature<br>Duration: 2 h | | | | |
| | Visual examination | | | | No visible damage |
| 5.13.7 Low air pressure (if required by the detail specification | Air pressure: 8 kPa | | | | |
| 5.13.7.4 Intermediate inspection | Visual examination | | | | No breakdown or flashover |
| 5.13.8 Damp heat, cyclic, Test Db, remaining cycles | Recovery: 24 h ± 2 h | | | | |
| 5.13.8.4 Final inspection, measurements and requirements | Visual examination | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | $\Delta C/C$ as in 5.13.8.4 |
| | Tangent of loss angle | | | | As in 5.13.8.4 |
| | Insulation resistance | | | | As in 5.13.8.4 |
| **Group 2** | | D | See Table 16 | | |
| 5.14 Damp heat, steady state | Special preconditioning as in 5.2 | | | | |
| 5.14.3 Initial measurements | Capacitance | | | | |
| | Recovery: 24 h ± 2 h | | | | |
| 5.14.6 Final inspection, measurements and requirements | Visual examination | | | | No visible damage<br>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** | | D | See Table 16 | | |
| 5.15 Endurance | | | | | |
| | Special preconditioning as in 5.2 | | | | |
| | Voltage: V | | | | |
| | Duration: h | | | | |
| 5.15.3 Initial measurement | Capacitance | | | | |
| | Recovery: 24 h ± 2 h | | | | |
| 5.15.6 Final inspection, measurement and requirements | Visual examination | | | | No visible damage<br>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 |

| **Test** [a] | **Conditions of test** [a] | **D or ND** [b] | $n$ | $c$ | **Performance requirements** [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **Group 4** | | ND | See Table 16 | | |
| 5.5 Temperature characteristic of capacitance | Special preconditioning as in 5.2 | | | | $\Delta C/C$ as in 5.5.3 |

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

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

# Annex A
(~~informative~~normative)

# Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

## A.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.

## A.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 and $3 \times k$ between 1 h and 1 000 h. This ~~may~~ can be expressed mathematically by the following formula:

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

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 aging 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 formula:

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

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 $t$.

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.

## A.3 Capacitance measurements and capacitance tolerance (see 5.4.1)

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 A.2, when the following formula may be used:

$$C_{1\,000} = C_t \times \left[1 - \frac{k}{100}(3 - \lg t)\right] \tag{A.3}$$

For factory measurements, the loss of capacitance from the age at the 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.

## A.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 (e.g. 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 subsequently bringing the capacitors to an age of 24 h. The recovery after 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 minimised.

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 not completely de-aged. In order to de-age such capacitors completely, temperatures 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 B
(normative)

## Temperature characteristics of capacitance of 25 °C

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

Table B.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 B.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 B.3.

**Table B.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 B.2 – Preferred values of the temperature characteristic of 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**<br>% | | **Category temperature range and corresponding number code** | | | |
|---|---|---|---|---|---|---|
| | | | **−55/+85**<br>°C | **−55/+105**<br>°C | **−55/+125**<br>°C | **−55/+150**<br>°C |
| | **without DC voltage applied** | **with DC voltage applied [a]**<br>**(if required)** | **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 |

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

NOTE "×" indicates preferred.

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

| **Method** | **Measuring step** | **Temperature**<br>°C | **DC voltage applied** |
|---|---|---|---|
| **A** | 1 | 25 ± 2 | - |
| | 2 | $T_A \pm 2$ | - |
| | 3 | 25 ± 2 | - |
| | 4 | $T_B \pm 2$ | - |
| | 5 | $T_B \pm 2$ | × |
| | 6 | 25 ± 2 | × |
| | 7 | $T_A \pm 2$ | × |
| **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: DC voltage applied (if specified in the detail specification)

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

$T_A$ = Lower category temperature.

$T_B$ = Upper category temperature.

# Annex C
(normative)

# Quality conformance inspection

## C.1 Formation of inspection lots

### C.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) For Group A, the sample tested shall consist of each of the values and each of the dimensions contained in the inspection lot:

   – in relation to their number;

   – with a minimum of five of any one value.

   For subgroup B2 the sample shall include capacitors of every temperature characteristic represented in the lot.

c) If there are less 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).

### C.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 high, medium and low capacitance values. In subsequent periods, different voltage ratings and capacitance values in production shall be tested with the aim of covering the whole range.

## C.2 Test schedule

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in ~~Clause 2, Table 5 of the blank detail specification~~ Table C.3 and Table C.4.

## C.3 Delayed delivery

When, in accordance with the procedures of IEC 60384-1:~~2008~~2021, Q.1.7, re-inspection ~~has to~~ shall be carried out, solderability and capacitance shall be checked as specified in Groups A and B inspection.

## C.4 Assessment levels

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

**Table C.1 – Lot-by-lot inspection**

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

IL = inspection level;

$n$ = sample size;

$c$ = permissible number of non-conforming items.

[a] 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 according to~~ and should be in accordance with IEC 61193-2:2007, Annex A.

In case 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.

[b] Number to be tested: Sample size shall be determined according to IEC 61193-2:2007, 4.3.2.

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

**Table C.2 – Periodic tests**

| Inspection subgroup [a] | EZ | | |
|---|---|---|---|
| | $p$ | $n$ | $c$ |
| C1A | 6 | 9 | 0 |
| C1B | 6 | 18 | 0 |
| C1 | 6 | 27 | 0 |
| C2 | 6 | 15 | 0 |
| C3 | 3 | 15 | 0 |
| C4 | 12 | 9 | 0 |

$p$ = periodicity in months;

$n$ = sample size;

$c$ = permissible number of non-conforming items.

[a] The content of the inspection subgroup is described in ~~Clause 2 of the relevant blank detail specification~~ Table C.4.

## C.5 Test schedule for quality conformance inspection

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

### Table C.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]** | | | | | |
| 5.4.1 Capacitance | Frequency: … kHz<br>Measuring Voltage: … V<br>As in 5.4.1 | ND | 100 %[d] | | Within specified tolerance<br>As in 5.4.1.3 |
| 5.4.2 Tangent of loss angle | As in 5.4.2 | | | | As in 5.4.2.4 |
| 5.4.3 Insulation resistance ($R_\mathrm{i}$) | As in 5.4.3 | | | | As in 5.4.3.3 |
| 5.4.4 Voltage proof | As in 5.4.4 | | | | As in 5.4.4.4 |
| **Group A1 [Sampling tests]** | | | | | |
| 5.3 Visual examination | | ND | S-4 [e] | 0 | As in 5.3<br>Legible marking and as specified in the detail specification |
| **Group A2 [Sampling tests]** | | | | | |
| 5.3 Dimension (gauging) [f] | | ND | S-3 [e] | 0 | See the detail specification |
| **Group B1 [Special tests]** | | | | | |
| 5.8 solderability | See detail specification for the method | D | S-3 [e] | 0 | Good tinning as evidenced by free flowing of the solder with wetting of the terminations or solder shall flow within … s, as applicable |
| 5.17 Solvent resistance of the marking (if applicable) | Solvent: …<br>Solvent temperature: …<br>Method 1<br>Rubbing material: cotton wool<br>Recovery: … | | | | Legible marking |
| **Group B2 [Special tests] [g]** | | | | | |
| 5.5 Temperature characteristics of capacitance | Special preconditioning as in 5.2<br>Capacitance | ND | S-2 [e] | 0 | $\Delta C/C$: As in 5.5.3 |

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

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

[c] Refer to Table C.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 61193-2:2007.

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

### Table C.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 C1A[e]** | | D | | | | |
| Part of sample of group C1 | | | 6 | 9 | 0[d] | |
| 5.3 Dimensions (detail) | | | | | | See detail specification |
| 5.6 Robustness of terminations | Visual examination | | | | | No visible damage |
| 5.7.2 Initial measurement | Capacitance | | | | | |
| 5.7 Resistance to soldering heat | Special preconditioning as in 5.2<br>Method: … | | | | | |
| 5.7.5 Final inspection, measurements and requirements | Visual examination<br>Capacitance | | | | | No visible damage<br>Legible marking<br>$\Delta C/C$ as in 5.7.5 |
| 5.16 Component solvent resistance (if applicable) | Solvent: …<br>Solvent temperature: …<br>Method 2<br>Recovery: … | | | | | Legible marking |
| **Group C1B[e]** | | D | | | | |
| Other part of sample of subgroup C1 | | | 6 | 18 | 0 [d] | |
| 5.9 Rapid change of temperature (if required) | Special preconditioning as in 5.2 | | | | | |
| 5.9.3 Initial measurement | Capacitance<br>$T_A$ = Lower category temperature<br>$T_B$ = Upper category temperature<br>Five cycles<br>Duration $t_1$ = 30 min<br>Recovery: 24 h ± 2 h<br>Visual examination | | | | | No visible damage |
| 5.10 Vibration | Method of mounting: see 7.3 of this document<br>Frequency range: … Hz to … Hz<br>Amplitude 0,75 mm or acceleration 100 m/s$^2$ (whichever is the less severe)<br>Total duration: 6 h | | | | | |
| 5.11.3 Final inspection, measurements and requirements | Visual examination | | | | | No visible damage |
| 5.11 Bump [repetitive shock (or shock, see 5.12)] | Method of mounting: see 7.3 of this specification<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | | No visible damage |
| 5.12 Shock [non-repetitive shock (or bump, see 5.11)] | Method of mounting: see 7.3 of this specification<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | | No visible damage |

| **Periodic tests** | | | | | | |
|---|---|---|---|---|---|---|
| **Test$^{a}$** | **Conditions of test$^{b}$** | **D$^{c}$ or ND** | $p^{c}$ | $n^{c}$ | $c^{c}$ | **Performance requirements** |
| 5.11.4 or 5.12.4<br>Final inspection, measurements and requirements | Visual examination | | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | | $\Delta C/C$ as in 5.12.4 |
| **Group C1$^{e}$** | | D | | | | |
| Combined sample of specimens of group C1A and C1B | | | | | | |
| 5.13 Climatic sequence | Special preconditioning as in 5.2 | | 6 | 27 | 0$^{d}$ | |
| 5.13.3 Initial measurement | Capacitance | | | | | |
| 5.13.4 Dry heat | Temperature: upper category temperature<br>Duration: 16 h | | | | | |
| 5.13.5 Damp heat, cyclic, test Db, first cycle | | | | | | |
| 5.13.6 Cold | Temperature: lower category temperature<br>Duration: 2 h | | | | | |
| | Visual inspection | | | | | No visible damage |
| 5.13.7 Low air pressure (if required by the detail specification) | Air pressure<br>8 kPa | | | | | |
| 5.13.7.4 Final inspection and requirements | Visual examination | | | | | No breakdown or flashover |
| 5.13.8 Damp heat, cyclic, test Db, remaining cycles | Recovery: 24 h ± 2 h | | | | | |
| 5.13.8.4 Final inspection, measurements and requirements | Visual examination | | | | | No visible damage,<br>Legible marking |
| | Capacitance | | | | | $\Delta C/C$: As in 5.13.8.4 |
| | Tangent of loss angle | | | | | As in 5.13.8.4 |
| | Insulation resistance | | | | | As in 5.13.8.4 |
| **Group C2 $^{e}$** | | | | | | |
| 5.14 Damp heat, steady state | Special preconditioning as in 5.2 | D | 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,<br>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 |

| Periodic tests | | | | | | |
|---|---|---|---|---|---|---|
| **Test[a]** | **Conditions of test[b]** | **D[c] or ND** | $p$[c] | $n$[c] | $c$[c] | **Performance requirements** |
| **Group C3[e]** | | D | | | | |
| 5.15 Endurance | Special preconditioning as in 5.2 | | 3 | 21 | 0[d] | |
| | Duration: …h | | | | | |
| | Temperature: …°C | | | | | |
| | Voltage: …V | | | | | |
| 5.15.3 Initial measurement | Capacitance | | | | | |
| | Recovery: 24 h ± 2 h | | | | | |
| 5.15.6 Final inspections, measurements and requirements | Visual examination | | | | | No visible damage<br>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 C4[e]** | | ND | | | | |
| 5.5 Temperature characteristic of capacitance | Special preconditioning as in 5.2 | | 12 | 9 | 0[d] | |
| | capacitance | | | | | $\Delta C/C$: 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 C.4 shall provide a suitable overview of the most relevant parameters of each test, however, it shall not take precedence over any more detailed specification given in a respective clause of this document or in a cited normative reference.

[c] Refer to Table C.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] 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)

## Comparison of cross-references in relation to IEC 60384-9:2015

The drafting of this document has resulted in a new structure. Table X.1 indicates the new clause and subclause numbers with respect to the previous edition of this document, i.e., IEC 60384-9:2015.

**Table X.1 – Reference to IEC 60384-9:2015 for clauses/subclauses/annexes**

| IEC 60384-9:2015 Fourth edition Clause/Subclause/ Annex | IEC 60384-9:20xx Fifth edition Clause/Annex | Notes |
|---|---|---|
| 1.1<br>1.2 | 1 | Scope and Object are merged into one clause in accordance with the ISO/IEC Directives, Part 2 |
| 1.3 | 2 | In accordance with ISO/IEC Directives, Part 2 |
| 1.4 | 7 | In accordance with the change of clause numbers |
| 1.5 | 3 | In accordance with ISO/IEC Directives, Part 2 |
| 1.6 | 6 | In accordance with the change of clause numbers |
| 2 | 4 | In accordance with the change of clause numbers |
| 3.1 to 3.4 | 8.1 to 8.4 | In accordance with the change of clause numbers |
| 3.5.1 to 3.5.4 | C.1 to C.4 | In accordance with the change of clause numbers |
| 4 | 5 | In accordance with the change of clause numbers |
| Annex A | Annex A | No change |
| – | Annex B | Newly added. |
| – | Annex C | Newly added. Modified from IEC 60384-9-1:2005, Clause 2 |
| Annex X | Annex X | Newly added. |

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-9:2015.

**Table X.2 – Reference to IEC 60384-9 for figure/table**

| IEC 60384-9:2015 Fourth edition Figure/Table | IEC 60384-9:2024 Fifth edition Figure/Table | Notes |
|---|---|---|
| Table 1 | Table 1 | No change |
| Table 2 | Table B.2 | In accordance with the change of table numbers |
| Table 3 and Table 4 | Table 16 to Table 17 | In accordance with the change of table numbers |
| Table 5 and Table 6 | Table C.1 and Table C.2 | In accordance with the change of table numbers |
| Table 7 to Table 19 | Table 3 to Table 15 | |
| – | Table B.1 | Newly added |
| | Table B.3 | Newly added |
| – | Table C.1 and Table C.2 | Newly added. Modified from IEC 60384-9-1:2005, Table 5 |
| – | Table X.1 and Table X.2 | Newly added. |
| This document has no figure. | | |

# Bibliography

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

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

IEC 60384-9-1, *Fixed capacitors for use in electronic equipment – Part 9-1: Blank detail specification: Fixed capacitors of ceramic dielectric, Class 2 – Assessment level EZ*

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

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

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

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

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)

# IEC 60384-9

Edition 5.0 2024-08

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Fixed capacitors for use in electronic equipment – Part 9: Sectional specification – Fixed capacitors of ceramic dielectric, Class 2

## Condensateurs fixes utilisés dans les équipements électroniques – Partie 9: Spécification intermédiaire – Condensateurs fixes à diélectrique en céramique, Classe 2

IEC 60384-9:2024-08(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

## Part 9: Sectional specification –
## Fixed 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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IEC 60384-9 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2015. 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 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 have been added in Table 7, Table 9, Table 11, Table 13 and Table 15.

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

d) Annex B has been changed from informative to normative.

e) Clause C.5 (Test schedule for quality conformance inspection) has been newly added to withdraw the blank detail specification: IEC 60384-9-1.

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

| Draft | Report on voting |
|---|---|
| 40/3145/FDIS | 40/3162/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 9: Sectional specification – Fixed capacitors of ceramic dielectric, Class 2

## 1 Scope

This part of IEC 60384 is applicable to fixed capacitors of ceramic dielectric with a defined temperature coefficient (dielectric Class 2), intended for use in electronic equipment, including leadless capacitors but excluding fixed surface mount multilayer capacitors of ceramic dielectric, which are covered by IEC 60384-22 (Class 2).

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

IEC 61193-2:2007, *Quality assessment systems – 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
### capacitor of ceramic dielectric, Class 2

capacitor which 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 the non-linear change of capacitance over the category temperature range (see Table 2).

### 3.2
### 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 2 and Annex B).

### 3.3
### rated voltage

$U_R$

maximum DC voltage that can be applied continuously to the terminations of a capacitor at the rated temperature

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

## 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 a reference temperature of 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 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 days, 10 days, 21 days, and 56 days |

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

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

### 4.2 Preferred values of ratings

#### 4.2.1 Rated temperature

For capacitors covered by this document, the rated temperature is equal to the upper category temperature.

### 4.2.2 Rated voltage ($U_R$)

The preferred values of rated voltage are: (25, 40, 63, 100, 160, 250, 400, 630, 1 000, 1 600, 2 500, 4 000 and 6 300) V. These values conform to the basic series of preferred values R5 given in 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 ($U_C$)

Since the rated temperature is defined as the upper category temperature, the category voltage is equal to the rated voltage, as defined in IEC 60384-1:2021, 3.5.

### 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

Table 1 denotes the preferred values of tolerance on nominal capacitance.

**Table 1 – Preferred tolerance on nominal capacitance**

| Preferred series | Tolerances<br>% | 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 2 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 Class 2C1. The temperature characteristics, category temperatures and corresponding codes for the reference temperature 25 °C are given in Annex B.

The temperature range, for which the temperature characteristics of the dielectric is defined, is the same as the category temperature range.

**Table 2 – 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.

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

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

## 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 tests, 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 for a period of 1 h, followed by recovery for a period of 24 h ± 1 h at standard atmospheric conditions for testing.

NOTE Class 2 capacitors lose capacitance continuously with time following 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 stage regardless of its previous history (see Clause A.4 for further information).

### 5.3 Visual examination and check of dimensions

See IEC 60384-1:2021, 7.1.

### 5.4 Electrical tests

#### 5.4.1 Capacitance

#### 5.4.1.1 General

See IEC 60384-1:2021, 6.3, with the details of 5.4.1.2 and 5.4.1.3.

#### 5.4.1.2 Measuring conditions

The capacitance shall be measured in accordance with Table 3 and in accordance with the details given below Table 3.

**Table 3 – Measuring conditions**

| Reference temperature | Subclass | Measuring voltage | Referee voltage [a] |
|---|---|---|---|
| 20 °C | 2B, 2C, 2X | 1,0 ± 0,2 V | 1,0 ± 0,02 V |
| | 2D, 2E, 2F, 2R | 0,3 ± 0,2 V<br>or as specified in the detail specification | 0,3 ± 0,02 V<br>or as specified in the detail specification |
| 25 °C | R,S,T,U | 1,0 ± 0,2 V | 1,0 ± 0,02 V |

[a] In case of dispute about results of measurements, referee voltage is applied.

Frequency: $C_N$ < 100 pF $f$ = 1 MHz unless otherwise specified in the detail specification.

$C_N$ ≥ 100 pF $f$ = 1 kHz ± 20 % for measuring purposes and 1 kHz for referee tests.

$C_N$ > 10 µF $f$ = 100 Hz or 120 Hz ± 20 % with measuring voltage 0,5 V ± 0,2 V for measuring purposes and 100 Hz or 120 Hz for referee tests.

#### 5.4.1.3 Requirements

The capacitance value shall correspond with the rated value taking into account the specified tolerance.

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 (for explanation see Annex A).

### 5.4.2 Tangent of loss angle (tan $\delta$)

#### 5.4.2.1 General

See IEC 60384-1:2021, 6.4, with the details of 5.4.2.2 to 5.4.2.4.

#### 5.4.2.2 Measuring conditions

See 5.4.1.

#### 5.4.2.3 Accuracy

The accuracy of the measuring instruments shall be such that the measuring error does not exceed 0,001.

#### 5.4.2.4 Requirements

The tangent of loss angle shall not exceed 0,035, or such lower value as may be given in the detail specification.

### 5.4.3 Insulation resistance ($R_i$)

#### 5.4.3.1 General

See IEC 60384-1:2021, 6.1, with the details of 5.4.3.2 and 5.4.3.3.

#### 5.4.3.2 Measuring conditions

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

For $U_R$ < 100 V, the measuring voltage may be of any value not greater than $U_R$, the reference voltage being $U_R$.

The voltage shall be applied immediately at the specified value for 1 min ± 5 s for qualification approval testing and periodic tests (Group C). 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.

The insulation resistance ($R_i$) shall be measured at the end of the 1 min period.

#### 5.4.3.3 Requirements

The insulation resistance ($R_i$) shall meet the requirements given in Table 4.

**Table 4 – Insulation resistance requirements**

| **Style** | **Measuring points** | **$C_N$ ≤ 25 nF** | **$C_N$ > 25 nF** |
|---|---|---|---|
| | | **$R_i$** | **$R_i \times C_N$** |
| Insulated | 1a and 1c | ≥ 4 000 MΩ | ≥ 100 s |
| Non-insulated | 1a | | |

### 5.4.4 Voltage proof

#### 5.4.4.1 General

See IEC 60384-1:2021, 6.2, with the details of 5.4.4.2 to 5.4.4.4.

#### 5.4.4.2 Test conditions

The product of $R_i$ and the nominal capacitance $C_x$ shall be smaller than or equal to 1 s.

The charge current shall not exceed 0,05 A.

#### 5.4.4.3 Test voltage

The voltages in Table 5 shall be applied between the measuring points of IEC 60384-1:2021, Table 3, 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 5 – Test voltages**

| Type | Rated voltage<br>V | Test voltage<br>V |
|---|---|---|
| Leaded multilayer ceramic capacitors | $U_R \leq 100$ | $2{,}5\ U_R$ |
| | $100 < U_R \leq 200$ | $1{,}5\ U_R + 100$ |
| | $200 < U_R \leq 500$ | $1{,}3\ U_R + 100$ |
| | $500 < U_R$ | $1{,}3\ U_R$ |
| Others | $U_R \leq 500$ | $2{,}5\ U_R$ |
| | $U_R > 500$ | $1{,}5\ U_R + 500$ |
| If $U_R > 500$ V, then the test voltage for Test C (external insulation) is $1{,}5\ U_R + 500$ V or as specified in the detail specification. | | |

#### 5.4.4.4 Requirement

There shall be no breakdown or flashover during the test.

## 5.5 Temperature characteristic of capacitance (reference temperature 20 °C)

### 5.5.1 Special preconditioning

See 5.2.

### 5.5.2 Measuring conditions

See IEC 60384-1:2021, 6.8.1.2 and 6.8.1.3, with Table 6.

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

**Table 6 – Details of measuring conditions**

| Measuring step | Temperature<br>°C | DC voltage applied |
|---|---|---|
| 1 | 20 ± 2 | - |
| 2 | $T_A$ [a] ± 3 | - |
| 3 | 20 ± 2 | - |
| 4 | $T_B$ [b] ± 2 | - |
| 5 | $T_B$ ± 2 | x |
| 6 | 20 ± 2 | x |
| 7 | $T_A$ ± 3 | x |
| 8 | 20 ± 2 | - |

NOTE "-" indicates: no DC voltage applied.
"x" indicates: DC voltage applied (if specified in the detail specification)

Intermediate measurement temperatures are used when ensuring the requirements of 4.2.5.

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 change between the first and the last measurements at temperature reference, Steps 1 and 8, indicates the amount of ageing involved. In 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).

[a] $T_A$ = Lower category temperature.

[b] $T_B$ = Upper category temperature.

#### 5.5.3 Requirements

The variation of capacitance shall be calculated in accordance with IEC 60384-1:2021, 6.8.3.1.

The temperature characteristics with and without DC voltage applied shall not exceed the values given in Table 2.

### 5.6 Robustness of terminations

See IEC 60384-1:2021, 7.3.

### 5.7 Resistance to soldering heat

#### 5.7.1 General

See IEC 60384-1:2021, 9.1, with the details of 5.7.2 to 5.7.5.

#### 5.7.2 Special preconditioning

See 5.2.

#### 5.7.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.7.4 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

### 5.7.5 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The capacitances shall be measured in accordance with 5.4.1, and the capacitance change shall not exceed the values in Table 7.

**Table 7 – Maximum capacitance change**

| Reference temperature 20 °C | |
|---|---|
| **Subclass** | **Requirements** |
| 2B, 2C and 2X | ±10 % |
| 2D and 2R | ±15 % |
| 2E and 2F | ±20 % |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | |
| **Reference temperature 25 °C** | |
| **Subclass** | **Requirements** |
| R | ±10 % |
| S | ±10 % |
| T | ±15 % |
| U | ±20% |
| NOTE 2 See Table B.2 for explanation of the subclass codes. | |

## 5.8 Solderability

### 5.8.1 General

See IEC 60384-1:2021, 9.2, with the details of 5.8.2 to 5.8.3.

### 5.8.2 Test conditions

The requirements for the globule test method shall be specified in the detail specification. When neither the solder bath nor the solder globule method is appropriate the soldering iron test shall be used with soldering iron size A.

### 5.8.3 Final inspection, measurements and requirements

The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations, or see the detail specification for the wetting balance method.

## 5.9 Rapid change of temperature (if required)

### 5.9.1 General

See IEC 60384-1:2021, 8.1, with the details of 5.9.2 to 5.9.5.

### 5.9.2 Special preconditioning

See 5.2.

### 5.9.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.9.4 Test conditions

Number of cycles: 5.

Duration of exposure at the temperature limits: 30 min.

### 5.9.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

## 5.10 Vibration

### 5.10.1 General

See IEC 60384-1:2021, 7.4, with the details of 5.10.2 and 5.10.3.

### 5.10.2 Test conditions

The following degree of severity of test Fc applies:

- 0,75 mm displacement or 100 m/s$^2$, whichever is the lower amplitude, over one of the following frequency ranges: 10 Hz to 55 Hz, 10 Hz to 500 Hz, 10 Hz to 2 000 Hz. The total duration of the test shall be 6 h.

The detail specification shall specify the frequency range and shall also specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

### 5.10.3 Final inspection, measurements and requirements

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

## 5.11 Bump (repetitive shock)

### 5.11.1 General

See IEC 60384-1:2021, 7.5, with the details of 5.11.2 to 5.11.4.

The detail specification shall state whether the bump (repetitive shock) or the non-repetitive shock test applies.

### 5.11.2 Initial measurements

Not required.

### 5.11.3 Test conditions

The detail specification shall state which of the following preferred severities applies:

| | | | |
|---|---|---|---|
| Total number of bumps: | 1 000 | or | 4 000 |
| Acceleration: | 400 m/s$^2$ | or | 100 m/s$^2$ |
| Pulse duration: | 6 ms | | 16 ms |

The detail specification shall also specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

#### 5.11.4 Final inspection, measurements and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in 5.12.4.

### 5.12 Shock (non-repetitive shock)

#### 5.12.1 General

See IEC 60384-1:2021, 7.6, with the details of 5.12.2 to 5.12.4.

The detail specification shall state whether the bump (repetitive shock) or the non-repetitive shock test applies.

#### 5.12.2 Initial measurements

Not required.

#### 5.12.3 Test conditions

The detail specification shall state which of the preferred severities applies as stated in Table 8.

Pulse-shape: half-sine.

**Table 8 – Preferred severities (of non-repetitive shock)**

| Peak acceleration m/s$^2$ | Corresponding duration of the pulse ms |
|---|---|
| 300 | 18 |
| 500 | 11 |
| 1 000 | 6 |

The detail specification shall also specify the mounting method to be used. For capacitors with axial leads and intended to be mounted by the leads only, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

#### 5.12.4 Final inspection, measurements and requirements

The capacitors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The capacitance shall be measured in accordance with 5.4.1, the change shall not exceed the values in Table 9.

**Table 9 – Maximum capacitance change**

| Reference temperature 20 °C | |
|---|---|
| **Subclass** | **Requirements** |
| 2B, 2C and 2X | ±10 % |
| 2D and 2R | ±15 % |
| 2E and 2F | ±20 % |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | |
| **Reference temperature 25 °C** | |
| **Subclass** | **Requirements** |
| R | ±10% |
| S | ±10% |
| T | ±15% |
| U | ±20% |
| NOTE 2 See Table B.2 for 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 measurements

The capacitance shall be measured in accordance with 5.4.1.

### 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 detail.

The capacitor shall be visually examined. These shall be no visible damage.

### 5.13.7 Low air pressure

#### 5.13.7.1 General

See IEC 60384-1:2021, 8.2.6, with the details of 5.13.7.2 to 5.13.7.4.

#### 5.13.7.2 Test conditions

The test, if required in the detail specification, shall be carried out at a temperature of 15 °C to 35 °C and a pressure of 8 kPa.

The duration of the test shall be 1 h.

#### 5.13.7.3 Test procedures

Immediately after achieving the low pressure, $U_R$ shall be applied for 1 min to 2 min.

#### 5.13.7.4 Final inspection and requirements

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

### 5.13.8 Damp heat, cyclic, Test Db, remaining cycles

#### 5.13.8.1 General

See IEC 60384-1:2021, 8.2.4, with the details of 5.13.8.2 to 5.13.8.4:

#### 5.13.8.2 Test conditions

The test conditions are shown in Table 10.

No voltage is applied.

**Table 10 – Number of damp heat cycles**

| Category | Number of cycles of 24 h |
|---|---|
| -/-/56 | 5 |
| -/-/21 | 1 |
| -/-/10 | 1 |
| -/-/04 | 0 |

#### 5.13.8.3 Recovery

The capacitors shall recover for 24 h ± 2 h.

#### 5.13.8.4 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the following requirements given in Table 11. If the capacitance value is less than the minimum value permitted, then after the other measurements have been carried out the capacitor shall be preconditioned in accordance with 5.2 and then the requirement in Table 11 shall be met.

### Table 11 – Final inspection measurements and requirements

| **Measurement** | **Measuring conditions** | **Requirements (reference temperature 20°C)** | | | |
|---|---|---|---|---|---|
| | | **Subclasses 2B, 2C and 2X** | **Subclasses 2D and 2R** | **Subclasses 2E** | **Subclasses 2F** |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 10$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % | $\Delta C/C \leq \pm 30$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\,000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | | | | | |
| **Measurement** | **Measuring conditions** | **Requirements (reference temperature 25°C)** | | | |
| | | **Subclasses R** | **Subclasses S** | **Subclasses T** | **Subclasses U** |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 1\,000$ MΩ or $R_i \times C_N \geq 25$ s<br>(whichever is less of the two values) | | | |
| NOTE 2 See Table B.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.

### 5.14.2 Special preconditioning

See 5.2.

### 5.14.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

### 5.14.4 Test conditions

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

The severity of the test should be selected from the test conditions as shown in Table 12 and as specified in the detail specification.

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

**Table 12 – Test conditions for damp heat, steady state**

| Severity | Temperature<br>°C | Relative humidity<br>% |
|---|---|---|
| 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.

### 5.14.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

### 5.14.6 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the requirements given in Table 13. 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 13 shall be met.

**Table 13 – Final inspection, measurements and requirements**

| Measurement | Measuring conditions | Requirements (reference temperature 20°C) | | | |
|---|---|---|---|---|---|
| | | Subclasses 2B, 2C and 2X | Subclasses 2D and 2R | Subclasses 2E | Subclasses 2F |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm$ 10 % | $\Delta C/C \leq \pm$ 15 % | $\Delta C/C \leq \pm$ 20 % | $\Delta C/C \leq \pm$ 30 % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq$ 1 000 MΩ or $R_i \times C_N \geq$ 25 s<br>(whichever is less of the two values) | | | |
| NOTE 1 See 4.2.5 for explanation of the subclass codes. | | | | | |
| **Measurement** | **Measuring conditions** | **Requirements (reference temperature 25 °C)** | | | |
| | | **Subclasses R** | **Subclasses S** | **Subclasses T** | **Subclasses U** |
| **Capacitance** | 5.4.1 | $\Delta C/C \leq \pm$ 15 % | $\Delta C/C \leq \pm$ 15 % | $\Delta C/C \leq \pm$ 15 % | $\Delta C/C \leq \pm$ 20 % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq$ 1 000 MΩ or $R_i \times C_N \geq$ 25 s<br>(whichever is less of the two values) | | | |
| NOTE 2 See Table B.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.

#### 5.15.2 Special preconditioning

See 5.2.

#### 5.15.3 Initial measurement

The capacitance shall be measured in accordance with 5.4.1.

#### 5.15.4 Test conditions

The capacitors shall be tested in accordance with Table 14.

**Table 14 – Endurance test conditions**

| Type | Temperature | Rated voltage<br>V | Test voltage<br>V | Duration<br>h |
|---|---|---|---|---|
| Leaded multilayer ceramic capacitors | Upper category temperature | $U_R \leq 200$ | 1,5 $U_R$ | 1 000 |
| | | $200 < U_R \leq 500$ | 1,3 $U_R$ | 1 500 |
| | | $500 < U_R$ | 1,2 $U_R$ | 2 000 |
| Others | Upper category temperature | $U_R$ | 1,5 $U_R$ | 1 000 |

#### 5.15.5 Recovery

The capacitors shall recover for a period of 24 h ± 2 h.

#### 5.15.6 Final inspection, measurements and requirements

The capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall be measured and shall meet the requirements given in Table 15. 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 5.4.1 and then the requirement in Table 15 shall be met.

**Table 15 – 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** | 5.4.1 | $\Delta C/C \leq \pm 10$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % | $\Delta C/C \leq \pm 30$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 2\ 000$ MΩ or $R_i \times C_N \geq 50$ s | | | |
| | | (whichever is less of the two values) | | | |
| NOTE 1 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** | 5.4.1 | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 15$ % | $\Delta C/C \leq \pm 20$ % |
| **Tangent of loss angle** | 5.4.2 | ≤ 2 × value of 5.4.2.3 | | | |
| **Insulation resistance** | 5.4.3 | $R_i \geq 2\ 000$ MΩ or $R_i \times C_N \geq 50$ s | | | |
| | | (whichever is less of the two values) | | | |
| NOTE 2 See Table B.2 for an explanation of the subclass codes. | | | | | |

### 5.16 Component solvent resistance (if applicable)

See IEC 60384-1:2021, 9.4.

### 5.17 Solvent resistance of the marking (if applicable)

See IEC 60384-1:2021, 9.5.

## 6 Marking

### 6.1 General

See IEC 60384-1:2021, 4.3, with the details of 6.2 to 6.5.

### 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:

a) nominal capacitance;

b) rated voltage (DC voltage may be indicated by the symbol: ⎓ [IEC 60417-5031(2002-10)] or — );

c) tolerance on nominal capacitance;

d) the dielectric subclass, see Table 2;

e) year and month (or week) of manufacture;

f) manufacturer's name or trade mark;

g) climatic category;

h) manufacturer's type designation;

i) reference to the detail specification.

Information required under item b) and d) may be given in code form under the manufacturer's, or national, type or style designation.

### 6.3 Marking on the body

The capacitor shall be clearly marked with items a), b) and c) of 6.2 and with as many as possible of the remaining items as is considered necessary. Any duplication of information in the marking on the capacitor should be avoided.

### 6.4 Marking on the packaging

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

### 6.5 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

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 for convenience, be presented in tabular form.

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 capacitor as an aid to easy recognition and for comparison of the capacitor 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 of the body, the width and height of the body and the wire spacing, or for cylindrical types, the body diameter, and the length and diameter of the terminations. When necessary, for example when a number of items (capacitance values/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. When the capacitor is not designed for use on printed boards, this shall be clearly stated in the detail specification.

### 7.3 Mounting

The detail specification shall specify the method of mounting to be applied for normal use and for the application of the vibration and the bump or shock tests. The design of the capacitor may be such that special mounting fixtures are required in its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used in the application of the vibration and the bump or shock tests.

### 7.4 Ratings and characteristics

#### 7.4.1 General

The ratings and characteristics shall be in accordance with the relevant clauses of this document, together with the provisions of 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

For single layer capacitors, the primary stage of manufacture is the metallizing of the dielectric to form the electrode; for multilayer capacitors it 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 can be of different case sizes and values.

### 8.3 Certified test 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 $\delta$ 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 C. 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 procedure

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.

The samples shall consist of specimens having the lowest and highest voltages, and for these voltages the lowest and highest capacitance values. 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). When the range consists of less than four values, the number of specimens to be tested shall be that required for four values.

Spare specimens are permitted as follows.

Two (for six values) or three (for four values) per value may be used as replacements for specimens which 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 3 gives the number of samples to be tested in each group or subgroup together with the number of permissible non-conformances for qualification approval tests.

### 8.4.3 Tests

The complete series of tests specified in Table 16 and Table 17 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 16 and Table 17 together form the fixed sample size test schedule for which Table 16 includes the details for the sampling and permissible non-conforming item for the different tests or groups of tests. Table 17 together with the details of 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 has to 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 16 – Sampling plan together with numbers of permissible non-conforming items for qualification approval tests, assessment level EZ**

| Group No. | Test | Subclause of this document | Number of specimens $n^{b}$ | Permissible number of non-conforming items $c^{d}$ |
|---|---|---|---|---|
| 0 | Visual examination | 5.3 | | |
| | Dimensions | 5.3 | | |
| | Capacitance | 5.4.1 | | |
| | Tangent of loss angle | 5.4.2 | 108 | 0 |
| | Insulation resistance | 5.4.3 | | |
| | Voltage proof | 5.4.4 | | |
| | Spare specimens | | 8 | |
| 1A | Robustness of terminations | 5.6 | 12 | 0 |
| | Resistance to soldering heat | 5.7 | | |
| | Component solvent resistance [c] | 5.16 | | |
| 1B | Solderability | 5.8 | 24 | 0 |
| | Solvent resistance of the marking [c] | 5.17 | | |
| | Rapid change of temperature [a] | 5.9 | | |
| | Vibration | 5.10 | | |
| | Bump or shock [a] | 5.11 or 5.12 | | |
| 1 | Climatic sequence | 5.13 | 36 | 0 |
| 2 | Damp heat, steady state | 5.14 | 24 | 0 |
| 3 | Endurance | 5.15 | 36 | 0 |
| 4 | Temperature characteristic of capacitance | 5.5 | 12 | 0 |

[a] As required in the detail specification.

[b] Capacitance/voltage combinations, see 8.4.2.

[c] If required in the detail specification.

[d] This is the acceptance number, and not exceeded for acceptance.

**Table 17 – Test schedule for qualification approval**

| Test [a] | Conditions of test [a] | D or ND [b] | *n* | *c* | Performance requirements [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 0** | | ND | See Table 16 | | |
| 5.3 Visual examination | | | | | As in 5.3<br>Legible marking and as specified in the detail specification |
| 5.3 Dimension (detail) | | | | | See the detail specification |
| 5.4.1 Capacitance | Frequency: … Hz<br>Measuring voltage: V RMS | | | | Within specified tolerance |
| 5.4.2 Tangent of loss angle (tan $\delta$) | Frequency and Measuring voltage same as in 5.4.1 | | | | As in 5.4.2.4 |
| 5.4.3 Insulation resistance | See detail specification for the method | | | | As in 5.4.3.3 |
| 5.4.4 Voltage proof | See detail specification for the method | | | | No breakdown or flashover |
| **GROUP 1A** | | D | See Table 16 | | |
| 5.6 Robustness of termination | Visual examination | | | | No visible damage |
| 5.7.3 Initial measurement | Capacitance | | | | |
| 5.7 Resistance to soldering heat | Special preconditioning as in 5.2<br>See detail specification for the method | | | | |
| 5.7.5 Final inspection, measurement and requirements | Visual examination<br>Capacitance | | | | No visible damage<br>Legible marking<br>$\Delta C/C$ as in 5.7.5 |
| 5.16 Component solvent resistance (if applicable) | Solvent: …<br>Solvent temperature:<br>Method 2<br>Recovery: … | | | | See detail specification |

| Test [a] | Conditions of test [a] | D or ND [b] | *n* | *c* | Performance requirements [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 1B** | | D | See Table 16 | | |
| 5.8 Solderability | See detail specification for the method | | | | Good tinning as evidenced by free flowing of the solder with wetting of the terminations, or see the detail specification for wetting balance method |
| 5.17 Solvent resistance of the marking (if applicable) | Solvent: …<br>Solvent temperature:…<br>Method 1<br>Rubbing material: cotton wool<br>Recovery: … | | | | Legible marking |
| 5.9 Rapid change of temperature | Special preconditioning as in 5.2 | | | | |
| 5.9.3 Initial measurement | Capacitance | | | | |
| | $T_A$ = Lower category temperature | | | | |
| | $T_B$ = Upper category temperature | | | | |
| | Five cycles | | | | |
| | Duration $t_1$ = 30 min | | | | |
| | Recovery: 24 h ± 2 h | | | | |
| | Visual examination | | | | No visible damage |
| 5.10 Vibration | For mounting method see detail specification | | | | |
| | Frequency range:<br>from … Hz to … Hz<br>Amplitude: 0,75 mm or<br>acceleration 100 m/s$^2$<br>(whichever is the less severe)<br>Total duration: 6 h | | | | |
| 5.10.3 Intermediate inspection | Visual examination | | | | No visible damage |
| 5.11 Bump (or shock, see 5.12) | For mounting method see detail specification | | | | |
| | Number of bumps: …<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | |
| 5.12 Shock (or bump, see 5.11) | For mounting method see detail specification | | | | |
| | Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | |
| 5.11.4 or 5.12.4 | Visual examination | | | | No visible damage<br>Legible marking |
| Final inspection, measurements and requirements | Capacitance | | | | $\Delta C/C$ as in 5.12.4 |

| Test [a] | Conditions of test [a] | D or ND [b] | $n$ | $c$ | Performance requirements [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **GROUP 1** | | D | See Table 16 | | |
| 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<br>Duration: 16 h | | | | |
| 5.13.5 Damp heat, cyclic, Test Db, first cycle | | | | | |
| 5.13.6 Cold | Temperature: lower category temperature<br>Duration: 2 h | | | | |
| | Visual examination | | | | No visible damage |
| 5.13.7 Low air pressure (if required by the detail specification | Air pressure: 8 kPa | | | | |
| 5.13.7.4 Intermediate inspection | Visual examination | | | | No breakdown or flashover |
| 5.13.8 Damp heat, cyclic, Test Db, remaining cycles | Recovery: 24 h ± 2 h | | | | |
| 5.13.8.4 Final inspection, measurements and requirements | Visual examination | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | $\Delta C/C$ as in 5.13.8.4 |
| | Tangent of loss angle | | | | As in 5.13.8.4 |
| | Insulation resistance | | | | As in 5.13.8.4 |
| **Group 2** | | D | See Table 16 | | |
| 5.14 Damp heat, steady state | Special preconditioning as in 5.2 | | | | |
| 5.14.3 Initial measurements | Capacitance | | | | |
| | Recovery: 24 h ± 2 h | | | | |
| 5.14.6 Final inspection, measurements and requirements | Visual examination | | | | No visible damage<br>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** | | D | See Table 16 | | |
| 5.15 Endurance | | | | | |
| | Special preconditioning as in 5.2 | | | | |
| | Voltage: V | | | | |
| | Duration: h | | | | |
| 5.15.3 Initial measurement | Capacitance | | | | |
| | Recovery: 24 h ± 2 h | | | | |
| 5.15.6 Final inspection, measurement and requirements | Visual examination | | | | No visible damage<br>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 |

| Test [a] | Conditions of test [a] | D or ND [b] | $n$ | $c$ | Performance requirements [a] |
|---|---|---|---|---|---|
| | | | (see Table 16) | | |
| **Group 4** | | ND | See Table 16 | | |
| 5.5 Temperature characteristic of capacitance | Special preconditioning as in 5.2 | | | | $\Delta C/C$ as in 5.5.3 |

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

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

# Annex A
(normative)

# Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

## A.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.

## A.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 and $3 \times k$ between 1 h and 1 000 h. This can be expressed mathematically by the following formula:

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

where

$C_\mathrm{t}$ is the capacitance $t$ h after the start of the ageing process;

$C_1$ is the capacitance 1 h after the start of the aging 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 formula:

$$k = \frac{100 \times (C_{t_1} - C_{t_2})}{C_{t_1} \times \lg t_2 - C_{t_2} \times \lg t_1} \qquad \text{(A.2)}$$

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 $t$.

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.

## A.3 Capacitance measurements and capacitance tolerance (see 5.4.1)

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 A.2, when the following formula may be used:

$$C_{1\,000} = C_t \times \left[1 - \frac{k}{100}(3 - \lg t)\right] \qquad \text{(A.3)}$$

For factory measurements, the loss of capacitance from the age at the 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.

## A.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 (e.g. 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 subsequently bringing the capacitors to an age of 24 h. The recovery after 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 minimised.

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 not completely de-aged. In order to de-age such capacitors completely, temperatures up to 160 °C can be required, and this temperature could be deleterious to the encapsulation. 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 B
(normative)

## Temperature characteristics of capacitance of 25 °C

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

Table B.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 B.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 B.3.

**Table B.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 B.2 – Preferred values of the temperature characteristic of 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 [a] (if required) | 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 |

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

NOTE "×" indicates preferred.

### Table B.3 – Measuring conditions of temperature characteristic of capacitance for the reference temperature of 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: DC voltage applied (if specified in the detail specification)

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

$T_A$ = Lower category temperature.

$T_B$ = Upper category temperature.

# Annex C
(normative)

# Quality conformance inspection

## C.1 Formation of inspection lots

### C.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) For Group A, the sample tested shall consist of each of the values and each of the dimensions contained in the inspection lot:
   - in relation to their number;
   - with a minimum of five of any one value.

   For subgroup B2 the sample shall include capacitors of every temperature characteristic represented in the lot.

c) If there are less 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).

### C.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 high, medium and low capacitance values. In subsequent periods, different voltage ratings and capacitance values in production shall be tested with the aim of covering the whole range.

## C.2 Test schedule

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

## C.3 Delayed delivery

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

## C.4 Assessment levels

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

**Table C.1 – Lot-by-lot inspection**

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

IL = inspection level;
*n* = sample size;
*c* = permissible number of non-conforming items.

[a] 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 case 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.

[b] Number to be tested: Sample size shall be determined according to IEC 61193-2:2007, 4.3.2.

[c] The content of the inspection subgroup is described in Table C.3.

**Table C.2 – Periodic tests**

| Inspection subgroup [a] | EZ | | |
|---|---|---|---|
| | *p* | *n* | *c* |
| C1A | 6 | 9 | 0 |
| C1B | 6 | 18 | 0 |
| C1 | 6 | 27 | 0 |
| C2 | 6 | 15 | 0 |
| C3 | 3 | 15 | 0 |
| C4 | 12 | 9 | 0 |

*p* = periodicity in months;
*n* = sample size;
*c* = permissible number of non-conforming items.

[a] The content of the inspection subgroup is described in Table C.4.

## C.5 Test schedule for quality conformance inspection

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

### Table C.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]** | | | | | |
| 5.4.1 Capacitance | Frequency: … kHz<br>Measuring Voltage: … V<br>As in 5.4.1 | ND | 100 %[d] | | Within specified tolerance<br>As in 5.4.1.3 |
| 5.4.2 Tangent of loss angle | As in 5.4.2 | | | | As in 5.4.2.4 |
| 5.4.3 Insulation resistance ($R_i$) | As in 5.4.3 | | | | As in 5.4.3.3 |
| 5.4.4 Voltage proof | As in 5.4.4 | | | | As in 5.4.4 |
| **Group A1 [Sampling tests]** | | | | | |
| 5.3 Visual examination | | ND | S-4 [e] | 0 | As in 5.3<br>Legible marking and as specified in the detail specification |
| **Group A2 [Sampling tests]** | | | | | |
| 5.3 Dimension (gauging) [f] | | ND | S-3 [e] | 0 | See the detail specification |
| **Group B1 [Special tests]** | | | | | |
| 5.8 solderability | See detail specification for the method | D | S-3 [e] | 0 | Good tinning as evidenced by free flowing of the solder with wetting of the terminations or solder shall flow within … s, as applicable |
| 5.17 Solvent resistance of the marking (if applicable) | Solvent: …<br>Solvent temperature: …<br>Method 1<br>Rubbing material: cotton wool<br>Recovery: … | | | | Legible marking |
| **Group B2 [Special tests] [g]** | | | | | |
| 5.5 Temperature characteristics of capacitance | Special preconditioning as in 5.2<br>Capacitance | ND | S-2 [e] | 0 | $\Delta C/C$: As in 5.5.3 |

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

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

[c] Refer to Table C.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 61193-2:2007.

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

## Table C.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 C1A[e]** | | D | | | | |
| Part of sample of group C1 | | | 6 | 9 | 0[d] | |
| 5.3 Dimensions (detail) | | | | | | See detail specification |
| 5.6 Robustness of terminations | Visual examination | | | | | No visible damage |
| 5.7.2 Initial measurement | Capacitance | | | | | |
| 5.7 Resistance to soldering heat | Special preconditioning as in 5.2<br>Method: … | | | | | |
| 5.7.5 Final inspection, measurements and requirements | Visual examination | | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | | $\Delta C/C$ as in 5.7.5 |
| 5.16 Component solvent resistance (if applicable) | Solvent: …<br>Solvent temperature: …<br>Method 2<br>Recovery: … | | | | | Legible marking |
| **Group C1B[e]** | | D | | | | |
| Other part of sample of subgroup C1 | | | 6 | 18 | 0 [d] | |
| 5.9 Rapid change of temperature (if required) | Special preconditioning as in 5.2 | | | | | |
| 5.9.3 Initial measurement | Capacitance<br>$T_A$ = Lower category temperature<br>$T_B$ = Upper category temperature<br>Five cycles<br>Duration $t_1$ = 30 min<br>Recovery: 24 h ± 2 h | | | | | |
| | Visual examination | | | | | No visible damage |
| 5.10 Vibration | Method of mounting: see 7.3 of this document<br>Frequency range: … Hz to … Hz<br>Amplitude 0,75 mm or acceleration 100 m/s$^2$ (whichever is the less severe)<br>Total duration: 6 h | | | | | |
| 5.11.3 Final inspection, measurements and requirements | Visual examination | | | | | No visible damage |
| 5.11 Bump [repetitive shock (or shock, see 5.12)] | Method of mounting: see 7.3 of this specification<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | | No visible damage |
| 5.12 Shock [non-repetitive shock (or bump, see 5.11)] | Method of mounting: see 7.3 of this specification<br>Acceleration: … m/s$^2$<br>Duration of pulse: … ms | | | | | No visible damage |

| **Periodic tests** | | | | | | |
|---|---|---|---|---|---|---|
| **Test**[a] | **Conditions of test**[b] | **D**[c] **or ND** | $p$[c] | $n$[c] | $c$[c] | **Performance requirements** |
| 5.11.4 or 5.12.4<br>Final inspection, measurements and requirements | Visual examination | | | | | No visible damage<br>Legible marking |
| | Capacitance | | | | | $\Delta C/C$ as in 5.12.4 |
| **Group C1**[e] | | D | | | | |
| Combined sample of specimens of group C1A and C1B | | | | | | |
| 5.13 Climatic sequence | Special preconditioning as in 5.2 | | 6 | 27 | 0[d] | |
| 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 inspection | | | | | No visible damage |
| 5.13.7 Low air pressure (if required by the detail specification) | Air pressure<br>8 kPa | | | | | |
| 5.13.7.4 Final inspection and requirements | Visual examination | | | | | No breakdown or flashover |
| 5.13.8 Damp heat, cyclic, test Db, remaining cycles | Recovery: 24 h ± 2 h | | | | | |
| 5.13.8.4 Final inspection, measurements and requirements | Visual examination | | | | | No visible damage,<br>Legible marking |
| | Capacitance | | | | | $\Delta C/C$: As in 5.13.8.4 |
| | Tangent of loss angle | | | | | As in 5.13.8.4 |
| | Insulation resistance | | | | | As in 5.13.8.4 |
| **Group C2** [e] | | | | | | |
| 5.14 Damp heat, steady state | Special preconditioning as in 5.2 | D | 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,<br>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 |

| Periodic tests | | | | | | |
|---|---|---|---|---|---|---|
| **Test**[a] | **Conditions of test**[b] | **D**[c] **or ND** | $p$[c] | $n$[c] | $c$[c] | **Performance requirements** |
| **Group C3**[e] | | D | | | | |
| 5.15 Endurance | Special preconditioning as in 5.2 | | 3 | 21 | 0[d] | |
| | Duration: ...h | | | | | |
| | Temperature: ...°C | | | | | |
| | Voltage: ...V | | | | | |
| 5.15.3 Initial measurement | Capacitance | | | | | |
| | Recovery: 24 h ± 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 |
| **Group C4**[e] | | ND | | | | |
| 5.5 Temperature characteristic of capacitance | Special preconditioning as in 5.2 | | 12 | 9 | 0[d] | |
| | capacitance | | | | | $\Delta C/C$: 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 C.4 shall provide a suitable overview of the most relevant parameters of each test, however, it shall not take precedence over any more detailed specification given in a respective clause of this document or in a cited normative reference.

[c] Refer to Table C.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] 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)

## Comparison of cross-references in relation to IEC 60384-9:2015

The drafting of this document has resulted in a new structure. Table X.1 indicates the new clause and subclause numbers with respect to the previous edition of this document, i.e., IEC 60384-9:2015.

### Table X.1 – Reference to IEC 60384-9:2015 for clauses/subclauses/annexes

| **IEC 60384-9:2015 Fourth edition Clause/Subclause/ Annex** | **IEC 60384-9:20xx Fifth edition Clause/Annex** | **Notes** |
|---|---|---|
| 1.1<br>1.2 | 1 | Scope and Object are merged into one clause in accordance with the ISO/IEC Directives, Part 2 |
| 1.3 | 2 | In accordance with ISO/IEC Directives, Part 2 |
| 1.4 | 7 | In accordance with the change of clause numbers |
| 1.5 | 3 | In accordance with ISO/IEC Directives, Part 2 |
| 1.6 | 6 | In accordance with the change of clause numbers |
| 2 | 4 | In accordance with the change of clause numbers |
| 3.1 to 3.4 | 8.1 to 8.4 | In accordance with the change of clause numbers |
| 3.5.1 to 3.5.4 | C.1 to C.4 | In accordance with the change of clause numbers |
| 4 | 5 | In accordance with the change of clause numbers |
| Annex A | Annex A | No change |
| – | Annex B | Newly added. |
| – | Annex C | Newly added. Modified from IEC 60384-9-1:2005, Clause 2 |
| Annex X | Annex X | Newly added. |

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-9:2015.

### Table X.2 – Reference to IEC 60384-9 for figure/table

| **IEC 60384-9:2015 Fourth edition Figure/Table** | **IEC 60384-9:2024 Fifth edition Figure/Table** | **Notes** |
|---|---|---|
| Table 1 | Table 1 | No change |
| Table 2 | Table B.2 | In accordance with the change of table numbers |
| Table 3 and Table 4 | Table 16 to Table 17 | In accordance with the change of table numbers |
| Table 5 and Table 6 | Table C.1 and Table C.2 | In accordance with the change of table numbers |
| Table 7 to Table 19 | Table 3 to Table 15 | |
| – | Table B.1 | Newly added |
| | Table B.3 | Newly added |
| – | Table C.1 and Table C.2 | Newly added. Modified from IEC 60384-9-1:2005, Table 5 |
| – | Table X.1 and Table X.2 | Newly added. |
| This document has no figure. | | |

# Bibliography

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

IEC 60384-9-1, *Fixed capacitors for use in electronic equipment – Part 9-1: Blank detail specification: Fixed capacitors of ceramic dielectric, Class 2 – Assessment level EZ*

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

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

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

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

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)

# SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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# CONDENSATEURS FIXES UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRONIQUES –

## Partie 9: Spécification intermédiaire – Condensateurs fixes à diélectrique en céramique, classe 2

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L'IEC 60384-9 a été établie par le comité d'études 40 de l'IEC: Condensateurs et résistances pour équipements électroniques. Il s'agit d'une Norme internationale.

Cette cinquième édition annule et remplace la quatrième édition parue en 2015. 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 donne les références croisées des modifications apportées par rapport à la version précédente, avec numéros d'article/de paragraphe correspondants;
b) les exigences relatives à la température de référence de 25 °C ont été ajoutées dans le Tableau 7, le Tableau 9, le Tableau 11, le Tableau 13 et le Tableau 15;
c) les caractéristiques de température pour la capacité, à la température de référence de 25 °C, ont été ajoutées dans le Tableau B.1, le Tableau B.2 et le Tableau B.3;
d) l'Annexe B est passée d'informative à normative;
e) l'Article C.5 (Programme d'essais pour le contrôle de conformité de la qualité) a été ajouté afin de pouvoir retirer la spécification particulière-cadre: IEC 60384-9-1.

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

| Projet | Rapport de vote |
|---|---|
| 40/3145/FDIS | 40/3162/RVD |

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

La version française de cette norme n'a pas été soumise au vote.

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

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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 9: Spécification intermédiaire – Condensateurs fixes à diélectrique en céramique, classe 2

## 1 Domaine d'application

La présente partie de l'IEC 60384 s'applique aux condensateurs fixes à diélectriques en céramique avec un coefficient de température défini (classe diélectrique 2), destinés à être utilisés dans les équipements électroniques, y compris les condensateurs sans plomb, à l'exclusion des condensateurs multicouches fixes à diélectriques en céramique pour montage en surface, qui sont couverts par l'IEC 60384-22 (classe 2).

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 les procédures d'assurance de la qualité appropriées, les essais et les méthodes de mesure en se référant à l'IEC 60384-1:2021 et de fournir des exigences de performances générales pour ce type de condensateur. Les sévérités et les exigences des essais stipulées 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. Des informations supplémentaires sur la conception des spécifications génériques, intermédiaires et particulières sont données dans 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 60384-1:2021, *Condensateurs fixes utilisés dans les équipements électroniques – Partie 1: Spécification générique*

IEC 61193-2:2007, *Quality assessment systems – 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 à diélectrique en céramique, classe 2**
condensateur qui possède un diélectrique à haute permittivité et qui convient aux applications de dérivation et de couplage ou aux circuits distinctifs de fréquence où de faibles pertes et une grande stabilité de capacité ne sont pas d'une importance majeure

Note 1 à l'article: Le diélectrique en céramique est caractérisé par la variation non linéaire de capacité sur la gamme de température de la catégorie (voir le Tableau 2).

**3.2**
**sous-classe**
<classe 2> variation maximale en pourcentage de capacité à l'intérieur de la gamme de température de la 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 le Tableau 2 et l'Annexe B).

**3.3**
**tension assignée**
$U_R$
tension continue maximale pouvant être appliquée continuellement aux sorties d'un condensateur utilisé à la température assignée

Note 1 à l'article: La tension continue maximale est la somme de la tension continue et de la valeur de crête de la tension alternative ou de la valeur de crête de la tension d'impulsion appliquées au condensateur.

## 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 à l'Annexe A de l'IEC 60068-1:2013.

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 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 (40 °C, 93 % d'humidité relative): | 4 jours, 10 jours, 21 jours et 56 jours |

Pour la température de référence de 25 °C, les températures de catégorie minimale et maximale doivent être choisies dans le Tableau B.1 de l'Annexe B.

Les sévérités des essais de froid et de chaleur sèche sont respectivement les températures de catégorie minimale et maximale.

### 4.2 Valeurs assignées préférentielles

#### 4.2.1 Température assignée

Pour les condensateurs couverts par le présent document, la température assignée est égale à la température maximale de catégorie.

### 4.2.2 Tension assignée ($U_R$)

Les valeurs préférentielles des tensions assignées sont: (25, 40, 63, 100, 160, 250, 400, 630, 1 000, 1 600, 2 500, 4 000 et 6 300) V. Ces valeurs sont conformes à la série de base de valeurs préférentielles R5 donnée dans l'ISO 3. Si d'autres valeurs sont nécessaires, elles doivent être choisies dans la série R10. La tension appliquée au condensateur, correspondant à la somme de la tension en courant continu et de la tension de crête en courant alternatif ou de la tension de crête à crête en courant alternatif, la valeur retenue étant la plus élevée des deux, ne doit pas dépasser la tension assignée.

### 4.2.3 Tension de catégorie ($U_C$)

Puisque la température assignée est définie comme la température de catégorie supérieure, la tension de la catégorie est égale à la tension assignée, telle qu'elle est définie dans l'IEC 60384-1:2021, paragraphe 3.5.

### 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

Le Tableau 1 présente les valeurs préférentielles de tolérance sur la capacité nominale.

**Tableau 1 – Tolérances préférentielles sur la capacité nominale**

| Série préférentielle | Tolérances<br>% | 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 pour la capacité

Le Tableau 2 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 une variation en pourcentage de ±20 % sans tension en courant continu appliquée sur la plage de températures allant de −55 °C à +125 °C, sera défini comme un diélectrique de la 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 B.

La plage de températures, pour laquelle les caractéristiques de température du diélectrique sont définies, est la même que la plage de températures de catégorie.

**Tableau 2 – Caractéristique de température pour la 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 continue<br>% | | Plage de températures de catégorie et code de numéro correspondant | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | −55/+150<br>°C | −55/+125<br>°C | −55/+85<br>°C | −40/+85<br>°C | −25/+85<br>°C | +10/+85<br>°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.

[a] La tension en courant continu appliquée correspond soit à la tension assignée, soit à la tension spécifiée dans la spécification particulière.

NOTE Voir l'Annexe B pour les valeurs préférentielles des caractéristiques de température pour la température de référence de 25 °C.

## 5 Procédures d'essai et de mesure

### 5.1 Généralités

Le présent Article 5 complète les informations de l'IEC 60384-1:2021, de l'Article 5 à l'Article 10.

### 5.2 Préconditionnement spécial

Sauf spécification contraire dans la spécification particulière, le préconditionnement spécial, lorsqu'il est spécifié dans le présent document avant un essai ou une séquence d'essais, doit être effectué dans les conditions suivantes: exposition à une température maximale de catégorie ou à une température aussi élevée que spécifiée, le cas échéant, dans la spécification particulière pendant une durée de 1 h, suivie d'une reprise pendant une durée de 24 h ± 1 h dans des conditions atmosphériques normales pour les essais.

NOTE Les condensateurs de classe 2 perdent leur capacité en continu avec le temps selon une loi logarithmique (c'est ce que l'on désigne par vieillissement). Toutefois, si le condensateur est chauffé à une température supérieure au point de Curie de son diélectrique, une régénération est constatée, c'est-à-dire que la capacité perdue par le vieillissement est récupérée, le vieillissement reprend dès que le condensateur recommence à se refroidir.

Le préconditionnement spécial a pour but d'amener le condensateur à un stade défini, quel que soit son historique précédent (voir l'Article A.4 pour plus d'informations).

### 5.3 Examen visuel et contrôle des dimensions

Voir l'IEC 60384-1:2021, 7.1.

## 5.4 Essais électriques

### 5.4.1 Capacité

#### 5.4.1.1 Généralités

Voir l'IEC 60384-1:2021, 6.3, avec les détails de 5.4.1.2 et 5.4.1.3.

#### 5.4.1.2 Conditions de mesure

La capacité doit être mesurée conformément au Tableau 3 et conformément aux informations données après le Tableau 3.

**Tableau 3 – Conditions de mesure**

| Température de référence | Sous-classe | Tension de mesure | Tension de référence [a] |
|---|---|---|---|
| 20 °C | 2B, 2C, 2X | 1,0 V ± 0,2 V | 1,0 V ± 0,02 V |
|  | 2D, 2E, 2F, 2R | 0,3 V ± 0,2 V<br>ou comme indiqué dans la spécification particulière | 0,3 V ± 0,02 V<br>ou comme indiqué dans la spécification particulière |
| 25 °C | R, S, T, U | 1,0 V ± 0,2 V | 1,0 V ± 0,02 V |

[a] En cas de litige concernant les résultats des mesures, la tension de référence est appliquée.

Fréquence: $C_N < 100$ pF $f = 1$ MHz sauf indication contraire dans la spécification particulière;

$C_N \geq 100$ pF $f = 1$ kHz ± 20 % à des fins de mesure et 1 kHz pour les essais de référence;

$C_N > 10$ µF $f = 100$ Hz ou 120 Hz ± 20 % avec une tension de mesure de 0,5 V ± 0,2 V; à des fins de mesure, et 100 Hz ou 120 Hz pour les essais de référence.

#### 5.4.1.3 Exigences

La valeur de capacité doit correspondre à la valeur assignée en tenant compte de la tolérance spécifiée.

Pour les mesures de référence, la valeur de capacité doit être la valeur extrapolée à un temps de vieillissement de 1 000 h, sauf indication contraire dans la spécification particulière (pour l'explication, voir l'Annexe A).

### 5.4.2 Tangente de l'angle de perte (tan $\delta$)

#### 5.4.2.1 Généralités

Voir l'IEC 60384-1:2021, 6.4, avec les informations données de 5.4.2.2 à 5.4.2.4.

#### 5.4.2.2 Conditions de mesure

Voir 5.4.1.

#### 5.4.2.3 Précision

La précision des instruments de mesure doit être telle que l'erreur de mesure ne dépasse pas 0,001.

#### 5.4.2.4 Exigences

La tangente de l'angle de perte ne doit pas dépasser 0,035, ou une valeur inférieure qui peut être donnée dans la spécification particulière.

### 5.4.3 Résistance d'isolement ($R_i$)

#### 5.4.3.1 Généralités

Voir l'IEC 60384-1:2021, 6.1, avec les informations données en 5.4.3.2 et 5.4.3.3.

#### 5.4.3.2 Conditions de mesure

Voir l'IEC 60384-1:2021, 6.1.2, avec les détails suivants:

Pour $U_R$ < 100 V, la tension de mesure peut être d'une valeur ne dépassant pas $U_R$, la tension de référence étant $U_R$.

La tension doit être appliquée immédiatement à la valeur spécifiée pendant 1 min ± 5 s pour les essais d'homologation et les essais périodiques (Groupe C). 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 seconde, sauf spécification contraire figurant dans la spécification particulière.

Le courant de charge ne doit pas dépasser 0,05 A.

La résistance d'isolement ($R_i$) doit être mesurée à la fin de la durée de 1 min.

#### 5.4.3.3 Exigences

La résistance d'isolement ($R_i$) doit satisfaire aux exigences données dans le Tableau 4.

**Tableau 4 – Exigences relatives à la résistance d'isolement**

| **Style** | **Points de mesure** | **$C_N$ ≤ 25 nF** | **$C_N$ > 25 nF** |
|---|---|---|---|
| | | **$R_i$** | **$R_i \times C_N$** |
| Isolé | 1a et 1c | ≥ 4 000 MΩ | ≥ 100 s |
| Non isolé | 1a | | |

### 5.4.4 Tension de tenue

#### 5.4.4.1 Généralités

Voir l'IEC 60384-1:2021, 6.2, avec les informations données de 5.4.4.2 à 5.4.4.4.

#### 5.4.4.2 Conditions d'essai

Le produit de $R_i$ et la capacité nominale $C_x$ doivent être inférieurs ou égaux à 1 s.

Le courant de charge ne doit pas dépasser 0,05 A.

#### 5.4.4.3 Tension d'essai

Les tensions du Tableau 5 doivent être appliquées entre les points de mesures 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 5 – Tensions d'essai**

| Type | Tension assignée<br>V | Tension d'essai<br>V |
|---|---|---|
| Condensateurs céramiques multicouches au plomb | $U_R \leq 100$ | $2{,}5\ U_R$ |
| | $100 < U_R \leq 200$ | $1{,}5\ U_R + 100$ |
| | $200 < U_R \leq 500$ | $1{,}3\ U_R + 100$ |
| | $500 < U_R$ | $1{,}3\ U_R$ |
| Autres | $U_R \leq 500$ | $2{,}5\ U_R$ |
| | $U_R > 500$ | $1{,}5\ U_R + 500$ |
| Si $U_R > 500$ V, la tension d'essai pour l'essai C (isolation externe) est de $1{,}5\ U_R + 500$ V ou comme stipulé dans la spécification particulière. | | |

#### 5.4.4.4 Exigence

Aucun claquage ni contournement électrique ne doit être constaté pendant l'essai.

### 5.5 Caractéristique de température pour la capacité (température de référence de 20 °C)

#### 5.5.1 Préconditionnement spécial

Voir 5.2.

#### 5.5.2 Conditions de mesure

Voir l'IEC 60384-1:2021, 6.8.1.2 et 6.8.1.3, avec le Tableau 6.

Les étapes et conditions de mesure d'une température de référence de 25 °C sont données à l'Annexe B.

**Tableau 6 – Détails des conditions de mesure**

| Étape de mesure | Température<br>°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 | x |
| 6 | 20 ± 2 | x |
| 7 | $T_A$ ± 3 | x |
| 8 | 20 ± 2 | - |

NOTE "-" indique: aucune tension en courant continu appliquée.
"x" indique: tension en courant continu appliquée (si stipulé dans la spécification particulière)

Des températures de mesure intermédiaires sont utilisées lorsque les exigences de 4.2.5 sont à satisfaire.

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, pour les étapes 5 à 7 pour lesquelles une tension en courant continu est appliquée, dépendent du temps. Cette dépendance temporelle est incluse dans les limites données pour la variation de capacité. La variation de capacité entre la première et la dernière mesure à la référence de température, Étapes 1 et 8, indique 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 l'IEC 60384-1:2021, 6.8.1.3).

[a] $T_A$ = Température de catégorie inférieure.

[b] $T_B$ = Température maximale de catégorie.

### 5.5.3 Exigences

La variation de capacité doit être calculée conformément à l'IEC 60384-1:2021, 6.8.3.1.

Les caractéristiques de température avec et sans tension en courant continu appliquée ne doivent pas dépasser les valeurs données dans le Tableau 2.

## 5.6 Robustesse des sorties

Voir l'IEC 60384-1:2021, 7.3.

## 5.7 Résistance à la chaleur de brasage

### 5.7.1 Généralités

Voir l'IEC 60384-1:2021, 9.1, avec les informations données de 5.7.2 à 5.7.5.

### 5.7.2 Préconditionnement spécial

Voir 5.2.

### 5.7.3 Mesure initiale

La capacité doit être mesurée conformément à 5.4.1.

### 5.7.4 Rétablissement

Les condensateurs doivent récupérer pendant 24 h ± 2 h.

### 5.7.5 Inspection finale, mesures et exigences

Les condensateurs doivent être soumis à un examen visuel. Aucun dommage ne doit être constaté et le marquage doit être lisible.

Les capacités doivent être mesurées conformément à 5.4.1; leur variation ne doit pas dépasser les valeurs indiquées dans le Tableau 7.

**Tableau 7 – Variation de capacité maximale**

| **Température de référence de 20 °C** | |
|---|---|
| **Sous-classe** | **Exigences** |
| 2B, 2C et 2X | ±10 % |
| 2D et 2R | ±15 % |
| 2E et 2F | ±20 % |
| NOTE 1 Voir 4.2.5 pour l'explication des codes de sous-classe. | |
| **Température de référence de 25 °C** | |
| **Sous-classe** | **Exigences** |
| R | ±10 % |
| S | ±10 % |
| T | ±15 % |
| U | ±20 % |
| NOTE 2 Voir le Tableau B.2 pour l'explication des codes de sous-classe. | |

## 5.8 Brasabilité

### 5.8.1 Généralités

Voir l'IEC 60384-1:2021, 9.2, avec les informations données de 5.8.2 à 5.8.3.

### 5.8.2 Conditions d'essai

Les exigences relatives à la méthode d'essai de la goutte de brasure doivent être spécifiées dans la spécification particulière. Lorsque ni la méthode du bain de brasage ni celle de la goutte de brasure n'est appropriée, l'essai au fer à braser doit être utilisé avec une taille A de fer à braser.

### 5.8.3 Inspection finale, mesures et exigences

Les sorties doivent être examinées pour contrôler le bon état de l'étamage mis en évidence par l'écoulement de la brasure avec un bon mouillage des sorties, ou voir la spécification particulière pour la méthode de l'équilibre de mouillage.

## 5.9 Variations rapides de température (si cela est exigé)

### 5.9.1 Généralités

Voir l'IEC 60384-1:2021, 8.1, avec les informations données de 5.9.2 à 5.9.5.

### 5.9.2 Préconditionnement spécial

Voir 5.2.

### 5.9.3 Mesure initiale

La capacité doit être mesurée conformément à 5.4.1.

### 5.9.4 Conditions d'essai

Nombre de cycles: 5.

Durée d'exposition aux limites de température: 30 min.

### 5.9.5 Rétablissement

Les condensateurs doivent récupérer pendant 24 h ± 2 h.

## 5.10 Vibrations

### 5.10.1 Généralités

Voir l'IEC 60384-1:2021, 7.4, avec les informations données en 5.10.2 et 5.10.3.

### 5.10.2 Conditions d'essai

Le degré de sévérité suivant de l'essai Fc s'applique:

- 0,75 mm de déplacement ou 100 m/s$^2$, l'amplitude retenue étant la plus basse des deux, sur l'une des plages de fréquences suivantes: 10 Hz à 55 Hz, 10 Hz à 500 Hz, 10 Hz à 2 000 Hz. La durée totale de l'essai doit être de 6 h.

La spécification particulière doit indiquer la plage de fréquences et doit également spécifier la méthode de montage à utiliser. Pour les condensateurs à sorties axiales et destinés à être montés par leurs seuls fils de sortie, la distance entre le corps et le point de montage doit être de 6 mm ± 1 mm.

### 5.10.3 Inspection finale, mesures et exigences

Les condensateurs doivent être soumis à un examen visuel. Aucun dommage visible ne doit être constaté.

## 5.11 Secousses (chocs répétitifs)

### 5.11.1 Généralités

Voir l'IEC 60384-1:2021, 7.5, avec les informations données de 5.11.2 à 5.11.4.

La spécification particulière doit indiquer si l'essai de secousses (chocs répétitifs) ou de chocs non répétitifs s'applique.

### 5.11.2 Mesure initiale

Non exigée.

### 5.11.3 Conditions d'essai

La spécification particulière doit indiquer laquelle des sévérités préférentielles suivantes s'applique:

| | | | |
|---|---|---|---|
| nombre total de secousses: | 1 000 | ou | 4 000 |
| accélération: | 400 m/s$^2$ | ou | 100 m/s$^2$ |
| durée des impulsions: | 6 ms | | 16 ms |

La spécification particulière doit également spécifier la méthode de montage à utiliser. Pour les condensateurs à sorties axiales et destinés à être montés par leurs seuls fils de sortie, la distance entre le corps et le point de montage doit être de 6 mm ± 1 mm.

### 5.11.4 Inspection finale, mesures et exigences

Les condensateurs doivent être mesurés et inspectés visuellement et doivent satisfaire aux exigences indiquées en 5.12.4.

## 5.12 Choc (chocs non répétitifs)

### 5.12.1 Généralités

Voir l'IEC 60384-1:2021, 7.6, avec les informations données de 5.12.2 à 5.12.4.

La spécification particulière doit indiquer si l'essai de secousses (chocs répétitifs) ou de chocs non répétitifs s'applique.

### 5.12.2 Mesure initiale

Non exigée.

### 5.12.3 Conditions d'essai

La spécification particulière doit indiquer les sévérités préférentielles qui s'appliquent, telles qu'elles sont indiquées dans le Tableau 8.

Forme de l'impulsion: semi-sinusoïdale.

**Tableau 8 – Sévérités préférentielles (d'un choc non répétitif)**

| Accélération de crête m/s$^2$ | Durée correspondante de l'impulsion ms |
|---|---|
| 300 | 18 |
| 500 | 11 |
| 1 000 | 6 |

La spécification particulière doit également spécifier la méthode de montage à utiliser. Pour les condensateurs à sorties axiales et destinés à être montés par leurs seuls fils de sortie, la distance entre le corps et le point de montage doit être de 6 mm ± 1 mm.

### 5.12.4 Inspection finale, mesures et exigences

Les condensateurs doivent être soumis à un examen visuel. Aucun dommage ne doit être constaté et le marquage doit être lisible.

La capacité doit être mesurée conformément à 5.4.1 et la variation ne doit pas être supérieure aux valeurs figurant dans le Tableau 9.

**Tableau 9 – Variation de capacité maximale**

| **Température de référence de 20 °C** | |
|---|---|
| **Sous-classe** | **Exigences** |
| 2B, 2C et 2X | ±10 % |
| 2D et 2R | ±15 % |
| 2E et 2F | ±20 % |
| NOTE 1 Voir 4.2.5 pour l'explication des codes de sous-classe. | |
| **Température de référence de 25 °C** | |
| **Sous-classe** | **Exigences** |
| R | ±10 % |
| S | ±10 % |
| T | ±15 % |
| U | ±20 % |
| NOTE 2 Voir le Tableau B.2 pour l'explication des codes de sous-classe. | |

## 5.13 Séquence climatique

### 5.13.1 Généralités

Voir l'IEC 60384-1:2021, 8.2, avec les informations données de 5.13.2 à 5.13.8.

### 5.13.2 Préconditionnement spécial

Voir 5.2.

### 5.13.3 Mesure initiale

La capacité doit être mesurée conformément à 5.4.1.

### 5.13.4 Chaleur sèche

Voir l'IEC 60384-1:2021, 8.2.3.

### 5.13.5 Chaleur humide, cyclique, essai Db, premier cycle

Voir l'IEC 60384-1:2021, 8.2.4.

### 5.13.6 Froid

Voir l'IEC 60384-1:2021, 8.2.5, avec les détails suivants.

Le condensateur doit être soumis à un examen visuel. Aucun dommage visible ne doit être constaté.