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INTERNATIONAL STANDARD

Fixed capacitors for use in electronic equipment – Part 15: Sectional specification: Fixed tantalum capacitors with non-solid or solid electrolyte

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CONTENTS

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 15: Sectional specification: Fixed tantalum capacitors with non-solid or solid electrolyte

FOREWORD

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International Standard IEC 60384-15 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This second edition cancels and replaces the first edition published in 1982, Amendment 1:1987 and Amendment 2:1992, and constitutes a technical revision.

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

a) Revision of the structure in accordance with ISO/IEC Directives, Part 2:2016 (seventh edition) to the extent practicable, and harmonization between other similar kinds of documents.
b) In addition, Clause 4 and all the tables have been reviewed in order to prevent duplications and contradictions.

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

FDIS	Report on voting
40/2523/FDIS	40/2535/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all parts of the IEC 60384 series, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 15: Sectional specification: Fixed tantalum capacitors with non-solid or solid electrolyte

1 General

1.1 Scope

This part of IEC 60384 applies to through-hole/leaded polar and bipolar tantalum electrolyte capacitors with solid and non-solid electrolyte for use in electronic equipment.

It includes capacitors for long-life applications and capacitors for general-purpose applications.

Capacitors for special purpose application may need additional requirements.

This document covers two basic sub-families:

- Sub-family 1: Fixed non-solid electrolyte tantalum capacitors with porous anode.
- Sub-family 2: Fixed solid electrolyte tantalum capacitors with porous anode.

1.2 Object

The object of this document is to prescribe preferred ratings and characteristics and to select from IEC 60384-1:2016 the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of capacitor. Test severities and requirements prescribed in detail specifications referring to this sectional specification shall be of equal or higher performance level, because lower performance levels are not permitted.

1.3 Normative references

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

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

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

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

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

IEC 60417, *Graphical symbols for use on equipment*

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

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

1.4 Information to be given in a detail specification

1.4.1 General

Detail specifications shall be derived from the 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 1.4.2 may, for convenience, be presented in tabular form.

The following information shall be given in each detail specification and the values quoted shall preferably be selected from those given in the appropriate clause of this sectional specification.

1.4.2 Outline drawing and dimensions

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

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

The numerical values of the body shall be given as follows:

- for general: the length, width and height;
- for cylindrical body: the diameter and length.

The numerical values of the terminals shall be given as follows:

- for general: the spacing;
- for leaded terminals: the diameter and spacing.

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

1.4.3 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 bump or shock tests.

1.4.4 Ratings and characteristics

1.4.4.1 General

The ratings and characteristics shall be given in accordance with the relevant clauses of this specification, together with the information in 1.4.4.2, 1.4.4.3 and 1.4.4.4.

1.4.4.2 Nominal capacitance range

See 2.2.1.

When products approved to the detail specification have different capacitance ranges, the following statement should be added:

”The nominal capacitance range 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”.

1.4.4.3 Particular characteristics

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

1.4.4.4 Soldering

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

1.4.5 Marking

The detail specification shall specify the content of the marking on the capacitor and on the packaging. When there are deviations from 1.6, these shall be given in the detail specification.

1.5 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

1.5.1
capacitance
<electrolytic capacitor> equivalent circuit having capacitance and resistance in series measured with alternating current, approximately sinusoidal waveform at a specified frequency

1.5.2
capacitor
<long-life grade> capacitors intended for applications where a high degree of stability of characteristics over a long life is essential

1.5.3
capacitor
<general-purpose grade> capacitors intended for applications where the high performance level of long-life grade capacitors is not required

1.6 Marking

1.6.1 General

See IEC 60384-1:2016, 2.4, with the details of 1.6.2, 1.6.3 and 1.6.4.

1.6.2 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) polarity of the terminations (unless identified by the construction);
b) nominal capacitance;
c) rated voltage (d.c. voltage may be indicated by the symbol: ⎓ (IEC 60417-5031:2002) or ———);
d) tolerance on nominal capacitance;
e) year and month (or year and week) of manufacture;
f) manufacturer's name and/or trade mark;
g) manufacturer's type designation;
h) reference to the detail specification.

1.6.3 Marking on capacitors

The capacitor shall be clearly marked with a), b) and c) of 1.6.2 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.

1.6.4 Marking on packaging

The packaging containing the capacitors should be clearly marked with all of the information listed in 1.6.2 as necessary.

2 Preferred ratings and characteristics

2.1 Preferred characteristics

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

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

The lower and upper category temperature shall be taken from the following:

- lower category temperature: −55 °C;
- upper category temperature: +85 °C and +125 °C.
- duration of the damp heat, steady state test: 21 and 56 days.

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

2.2 Preferred values of ratings

2.2.1 Nominal capacitance (C_N)

Preferred values of nominal capacitance are shown in microfarad (µF).

Preferred values of nominal capacitance shall be taken from the E12 series of IEC 60063 and their decimal multiples. These values are:

1,0 – 1,2 – 1,5 – 1,8 – 2,2 – 2,7 – 3,3 – 3,9 – 4,7 – 5,6 – 6,8 – 8,2;

and their decimal multiples (×10^n, n: integer).

2.2.2 Tolerance on nominal capacitance

Preferred values of tolerances on rated capacitance are:

±5 % , ±10 % , ±20 %

2.2.3 Rated voltage (U_R)

Preferred values of rated direct voltages taken from the R10, R20 and R40 series of ISO 3 are:

- from R 10: 1,0 – 1,25 – 1,6 – 2,0 – 2,5 – 3,15 – 4,0 – 5,0 – 6,3 – 8,0;
- from R 20: 3,5[1];
- from R 40: 3,0 – 7,5;

and their decimal multiples (×10^n, n: integer).

2.2.4 Category voltage (U_C)

The category voltages for capacitors having an upper category temperature of 125 °C are given in Table 1.

2.2.5 Reverse voltage

If required, the value of reverse voltage, which a polar capacitor can withstand continuously at any temperature between the lower category temperature and the rated temperature, shall be included in the detail specification.

2.2.6 Surge voltage (U_{RS} or U_{CS})

The surge voltage shall be a minimum of 1,15 times the rated or category voltage rounded off to the nearest volt given in Table 1.

Table 1 – Rated, category and surge voltages

Values in volts

U_R	2	3	4	6,3	10	16	20	25	35	40	50	63	75	100	125
U_C	1,3	2	2,6	4,2	6,7	10,7	13,4	16,7	23,4	26,8	33,5	42,2	50,2	67	83,7
U_{RS}	2,3	3,4	4,6	7,2	11,5	18,4	23	28,7	40,2	46	57,5	74,4	86,2	115	143,7
U_{CS}	1,4	2,3	3	4,8	7,7	12,3	15,4	19,2	26,9	30,8	38,5	48,5	57,7	77	96,2

Key

U_R: Rated voltage

U_C: Category voltage

U_{RS}: Surge voltage to rated voltage

U_{CS}: Surge voltage to category voltage

2.2.7 Ripple (if required)

Ripple current and/or ripple voltage shall be specified in the detail specification.

[1] ISO 3 indicates the value 3,55 for R 20

2.2.8 Rated temperature

The standard value of the rated temperature is +85 °C unless otherwise specified in the detail specification.

3 Quality assessment procedures

3.1 Primary stage of manufacture

For capacitors with solid electrolyte, the primary stage of manufacturing is the formation of the oxide layer.

3.2 Structurally similar components

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

3.3 Certified test records of released lots

The information required in IEC 60384-1:2016, Q.1.5, shall be made available when prescribed in the detail specification and when requested by a purchaser. After the endurance test, the required parameters are the capacitance change, tangent of loss angle and leakage current.

3.4 Qualification approval procedures

3.4.1 General

The procedures for qualification approval testing are given in IEC 60384-1:2016, 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. The procedure using a fixed sample size schedule is given in 3.4.2 and 3.4.3.

3.4.2 Qualification approval on the basis of the fixed sample size procedure

The fixed sample size procedure is described in IEC 60384-1:2016, Q.2.4. The sample shall be representative of the range of capacitors for which approval is sought. The samples may be the whole or part of the range given in the detail specification.

The sample shall consist of four specimens having the maximum and minimum voltages and for these voltages the maximum and minimum case size. When there are more than four case sizes, an intermediate case size shall also be tested. In each of these case size/voltage combinations (values), the maximum capacitance shall be chosen. Thus, for the approval of a range, testing is required of either four or six values. When the range consists of fewer 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 6 values) or three (for 4 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 2 gives the number of samples to be tested in each group or subgroup together with the permissible number of non-conforming items for qualification approval tests.

3.4.3 Tests

The complete series of tests specified in Table 2 and Table 3 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.

Specimens found to be non-conforming in the tests of Group 0 shall not be used for the other groups.

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

Table 2 and Table 3 together form the fixed sample size test schedule for the qualification approval on the basis of the fixed sample size procedure.

Table 2 gives the number of samples and permissible non-conforming items for each tests or test groups.

Table 3 gives a summary of the test conditions and performance requirements, and choices of the test conditions and performance requirements in the detail specification.

The test conditions and performance requirements for the qualification approval on the basis of the fixed sample size procedure should be identical to those for quality conformance inspection given in the detail specification.

Table 2 – Sampling plan for qualification approval tests

Group no.	Test	Subclause	Number of specimens n [b]	Permissible number of non-conforming items c
0	Visual examination	4.1	104+8 [c]	0
	Dimensions	4.1		
	Leakage current	4.2.1		
	Capacitance	4.2.2		
	Tangent of loss angle	4.2.3		
	Impedance [a]	4.2.4		
	Insulation resistance of the external insulation [a]	4.2.5		
	Voltage proof of the external insulation [a]	4.2.6		
	High surge current [a]	4.19		
	Spare specimens		8	
1A	Robustness of terminations	4.3	12	0
	Resistance to soldering heat	4.4		
	Component solvent resistance	4.17		
1B	Solderability	4.5	24	0
	Solvent resistance of the marking	4.18		
	Rapid change of temperature	4.6		
	Vibration	4.7		
	Bump [a]	4.8		
	Shock [a]	4.9		
1	Climatic sequence	4.10	36	0
2	Damp heat, steady state	4.11	20	0
3	Endurance	4.12	20	0
4A	Surge voltage	4.13	8	0
4B	Reverse voltage [a]	4.14	8	0
5	Characteristics at high and low temperature	4.15	12	0
	Charge and discharge [a]	4.16		

[a] If required.

[b] For case size/ voltage combinations, see 3.4.2.

[c] Spare specimens.

Table 3 – Test schedule for qualification approval *(1 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test [a] and measurements	Number of specimens (n) and number of permissible non-conforming items (c)	Performance requirements[a]
Group 0	ND		See Table 2	
4.1 Visual examination		See 4.1		Legible marking and as specified in the detail specification
4.1 Dimensions (detail)		See 4.1		See detail specification
4.2.1 Leakage current		See 4.2.1.2		≤ the initial limit specified in the detail specification (at 20°C, 85°C and 125°C)
4.2.2 Capacitance		See 4.2.2.2		Within specified tolerance
4.2.3 Tangent of loss angle		See 4.2.3.2		≤ the initial limit specified in the detail specification
4.2.4 Impedance [c]		See 4.2.4.3		
Initial measurement		See 4.2.4.2		See detail specification
Measurement at lower category temperature		See 4.2.4.4		See detail specification
4.2.5 Insulation resistance of the external insulation [c]		See 4.2.5.2		≥ 100 MΩ
4.2.6 Voltage proof of the external insulation [c]		See 4.2.6.2		No breakdown or flashover during the test
4.19 High surge current [d]		See IEC 60384-1:2016, 4.39		
Group 1A	D		See Table 2	
4.3 Robustness of terminations		See 4.3.3		
4.3.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.3.5 Final inspections				
Visual examination		See 4.1		The terminations shall withstand 4 successive bends.
Capacitance		See 4.2.2.2		See detail specification
4.4 Resistance to soldering heat		See IEC 60384-1:2016, 4.14		
4.4.3 Final inspections				
Visual examination		See 4.1		Legible marking and as specified in the detail specification
Capacitance		See 4.2.2.2		See detail specification
4.17 Component solvent resistance		See IEC 60384-1:2016, 4.31		
Group 1B	D		See Table 2	
4.5 Solderability		See 4.5.2		
4.5.3 Final inspection				
Visual examination		See 4.1		Good tinning as evidenced by free flowing of the solder with wetting of the terminations

Table 3 *(2 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test [a] and measurements	Number of specimens (*n*) and number of permissible non-conforming items (*c*)	Performance requirements[a]
Group 1B (continued)	D		See Table 2	
4.18 Solvent resistance of the marking		See IEC 60384-1: 2016, 4.32		
4.6 Rapid change of temperature		See 4.6.3		
4.6.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.6.4 Recovery		See 4.6.4		
4.6.5 Final inspection				
Capacitance		See 4.2.2.2		See detail specification
4.7 Vibration		See 4.7.2		
4.7.3 Final inspections				
Visual examination		See 4.1		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte
Leakage current		See 4.2.1.2		See detail specification
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification
4.8 Bump [c]		See 4.8.3		
4.8.2 Mounting		See 4.8.2		
4.8.4 Final inspections				
Visual examination		See 4.1		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte
Leakage current		See 4.2.1.2		See detail specification
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification
4.9 Shock [c]		See 4.9.3		
4.9.2 Mounting		See 4.8.2		
4.9.4 Final inspections				
Visual examination		See 4.1		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte
Leakage current		See 4.2.1.2		See detail specification
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification

Table 3 *(3 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test [a] and measurements	Number of specimens (n) and number of permissible non-conforming items (c)	Performance requirements[a]
Group 1	D		See Table 2	
4.10 Climatic sequence		See 4.10.3		
4.10.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.10.3 Dry heat		See 4.10.3		
4.10.4 Damp heat, cyclic, Test Db, first cycle		See IEC 60384-1:2016, 4.21.4		
4.10.5 Cold		See IEC 60384-1:2016, 4.21.5		
4.10.6 Low air pressure [c]		See 4.10.6.2		
4.10.7 Damp heat, cyclic, Test Db, remaining cycles		See IEC 60384-1:2016, 4.21.7.		
4.10.8 Recovery		See 4.10.8		
4.10.9 Sealing [c]		See IEC 60384-1:2016, 4.20		
4.10.10 Final inspections				
Visual examination		See 4.1		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte
				Legible marking
Leakage current		See 4.2.1.2		≤ initial limit
Capacitance		See 4.2.2.2		For general-purpose grade: $\lvert\Delta C/C\rvert$ ≤ 12 % of the value measured in 4.10.2
				For long-life grade: $\lvert\Delta C/C\rvert$ ≤ 5 % of the value measured in 4.10.2
				$\lvert\Delta C/C\rvert$ ≤ 8 % of the value measured in 4.3.2 or 4.6.2 [c]
Tangent of loss angle		See 4.2.3.2		≤ initial limit
Group 2	D		See Table 2	
4.11 Damp heat, steady state		See IEC 60384-1:2016, 4.22		
4.11.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.11.3 Recovery		See 4.11.3		
4.11.4 Final inspections				
Visual examinations		See 4.1		No visible damage and for nonsolid electrolytic capacitors no leakage of electrolyte
				Legible marking
Leakage current		See 4.2.1.2		≤ the initial limit

Table 3 *(4 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test [a] and measurements	Number of specimens (n) and number of permissible non-conforming items (c)	Performance requirements[a]
Group 2 (continued)	D		See Table 2	
4.11.4 Final inspections (continued)				
Capacitance		See 4.2.2.2		Sub-family 1: For general-purpose grade: $\|\Delta C/C\|$ ≤ 12 % of the value measured in 4.11.2 For long-life grade: $\|\Delta C/C\|$ ≤ 8 % of the value measured in 4.11.2 Sub-family 2: $\|\Delta C/C\|$ ≤ the initial limit
Insulation resistance of the external insulation [c]		See 4.2.5.2		No breakdown or flashover
Voltage proof of the external insulation [c]		See 4.2.6.2		≥100 MΩ
Group 3	D		See Table 2	
4.12 Endurance		See 4.12.3		
4.12.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.12.4 Recovery		See 4.12.4		
4.12.5 Final inspections				
Visual examinations		See 4.1		No visible damage Legible marking
Leakage current		See 4.2.1.2		≤1,25 times the initial limit
Capacitance		See 4.2.2.2		$\|\Delta C/C\|$ compared to values measured in 4.12.2:

Sub-family	U_R [e]	85°C	125°C [c]
1	≤160	≤20 %	≤25 %
	>160	≤15 %	≤20 %
2	≤160	≤15 %	≤25 %
	>160	≤10 %	≤20 %

Tangent of loss angle		See 4.2.3.2		Sub-family 1: ≤1,3 times the initial limit Sub-family 2: ≤initial limit

Table 3 *(5 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test [a] and measurements	Number of specimens (n) and number of permissible non-conforming items (c)	Performance requirements[a]
Group 4A	D		See Table 2	
4.13 Surge voltage		See 4.13.3		
4.13.2 Initial inspection				
Capacitance		See 4.2.2.2		Within specified tolerance
4.13.4 Final inspections				
Visual examinations		See 4.1		No visible damage
Leakage current		See 4.2.1.2		≤initial limit
Capacitance		See 4.2.2.2		≤initial limit
Tangent of loss angle		See 4.2.3.2		≤initial limit
Group 4B	D		See Table 2	
4.14 Reverse voltage [c]		See 4.14.3		
4.14.4 Final inspections				
Visual examinations		See 4.1		No visible damage
Leakage current		See 4.2.1.2		≤initial limit
Capacitance		See 4.2.2.2		≤initial limit
Tangent of loss angle		See 4.2.3.2		≤initial limit
Group 5	D		See Table 2	
4.15 Characteristics at high and low temperature		See IEC 60384-1: 2016, 4.29		
Step 1: 20 °C				
Leakage current [f]		See 4.2.1.2		
Capacitance [f]		See 4.2.2.2		
Tangent of loss angle [f]		See 4.2.3.2		
Impedance (at the same frequency as Step 2) [c f]		See 4.2.4.3		
Step 2: lower category temperature				
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification
Step 3: 20 °C				
Leakage current		See 4.2.1.2		
Capacitance		See 4.2.2.2		
Tangent of loss angle		See 4.2.3.2		
Impedance [c]		See 4.2.4.3		
Step 4: rated temperature				
Leakage current		See 4.2.1.2		See detail specification
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle [c]		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification

Table 3 *(6 of 6)*

Subclause number and test[a], inspection items	D or ND[b]	Conditions of test[a] and measurements	Number of specimens (n) and number of permissible non-conforming items (c)	Performance requirements[a]
Group 5 (continued)	D		See Table 2	
4.15				
Step 5: upper category temperature				
Leakage current		See 4.2.1.2		See detail specification
Capacitance		See 4.2.2.2		See detail specification
Tangent of loss angle [c]		See 4.2.3.2		See detail specification
Impedance [c]		See 4.2.4.3		See detail specification
Step 6: 20 °C				
Leakage current		See 4.2.1.2		
Capacitance		See 4.2.2.2		
Tangent of loss angle [c]		See 4.2.3.2		
Impedance [c]		See 4.2.4.3		
4.16 Charge and discharge [c]		See IEC 60384-1: 2016, 4.27		
4.16.5 Final inspections				
Visual examinations		See 4.1		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte
Leakage current		See 4.2.1.2		≤the initial limit
Capacitance		See 4.2.2.2		Sub-family 1: $\lvert\Delta C/C\rvert \leq$ 10% of the value measured in 4.2.2 Sub-family 2: $\lvert\Delta C/C\rvert \leq$ 5% of the value measured in 4.2.2
Tangent of loss angle		See 4.2.3.2		≤the initial limit

[a] The value of these measurements after mounting serve as initial measurements for the tests after measurement of each subgroups.

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

[c] If required.

[d] If required for solid electrolyte capacitors only.

[e] U_R = rated voltage in volts.

[f] For use as reference value.

3.5 Quality conformance inspection

3.5.1 Formation of inspection lots

3.5.1.1 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 3.2).

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

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

3.5.1.2 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-voltage ratings or case sizes. In order to cover the range of approvals in any period, one case size shall be tested from each voltage group. In subsequent periods, other case sizes and/or voltages in production shall be tested with the aim of covering the whole range.

3.5.2 Test schedule

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in the blank detail specification.

3.5.3 Delayed delivery

When according to the procedures of IEC 60384-1:2016, Q.1.7, re-inspection should be made, solderability and for sub-families 1: leakage current and for sub-family 2: capacitance, shall be checked as specified in Groups A and B inspection.

3.5.4 Assessment levels

The assessment level(s) given in the blank detail specification shall preferably be selected from Table 4 and Table 5.

Table 4 – Lot-by-Lot inspection

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

[a] The content of the inspection subgroup is described in the blank detail specification.

[b] IL = inspection level

n = sample size

c = permissible number of non-conforming items

[c] After removal of nonconforming items by 100 % testing during the manufacturing process, sampling inspection shall be performed 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 IEC 61193-2:2007, Annex A. In case one or more nonconforming items occur in a sample, this lot shall be rejected, but the whole sample shall be inspected and 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 according to the method given in IEC 61193-2:2007, 6.2.

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

Table 5 – Periodic Inspection

Inspection subgroup [a]	EZ		
	p [b]	n [b]	c [b]
C1	3	12	0
C2	3	12	0
C3	3	78	0
C4	6	12	0
C5	3	24	0

[a] The content of the inspection subgroup is described in Clause 2 of the blank detail specification.

[b] p = periodicity in months
n = sample size
c = permissible number of non-conforming items

4 Test and measurement procedures

NOTE This clause supplements the information given in IEC 60384-1:2016, Clause 4.

4.1 Visual inspection and check of dimensions

See IEC 60384-1:2016, 4.4.

4.2 Electrical tests

4.2.1 Leakage current

4.2.1.1 General

See IEC 60384-1:2016, 4.9, with the details of 4.2.1.2 and 4.2.1.3.

4.2.1.2 Measuring conditions

The voltage appropriate to the test temperature shall be applied across the capacitor and its protective resistor. The protective resistor shall be between 1 000 Ω and 10 000 Ω.

In the case of bipolar capacitors, the duration of the electrification periods before the measurement made in each direction is 5 min.

4.2.1.3 Requirement

See Table 3.

4.2.2 Capacitance

4.2.2.1 General

See IEC 60384-1:2016, 4.7, with the details of 4.2.2.2 and 4.2.2.3.

4.2.2.2 Measuring conditions

The capacitance shall be measured at a frequency of 100 Hz or 120 Hz. The peak alternating voltage actually applied across the capacitor shall be between 0,1 V and 1,0 V.

A d.c. bias voltage of 2,1 V to 2,5 V may be applied during the measurement (unless otherwise prescribed in the detail specification), except for bi-polar capacitors which shall be measured without an applied d.c. voltage.

Suitable measurement techniques shall be used to minimize errors due to connections between the measuring apparatus and the capacitors.

4.2.2.3 Requirement

See Table 3.

4.2.3 Tangent of loss angle (tan δ)

4.2.3.1 General

See IEC 60384-1:2016, 4.8, with the details of 4.2.3.2 and 4.2.3.3.

4.2.3.2 Measuring conditions

The measurement shall be made under the conditions of 4.2.2.2.

4.2.3.3 Requirement

See Table 3.

4.2.4 Impedance (if required)

4.2.4.1 General

See IEC 60384-1:2016, 4.10, with the details of 4.2.4.2, 4.2.4.3, 4.2.4.4 and 4.2.4.5.

4.2.4.2 Initial inspection

The frequency of the measuring voltage shall be chosen from one of the following frequencies: 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, and 1 MHz, and shall be that at which the lowest value of impedance is likely to occur.

The tolerance on all frequencies for measuring purposes shall not exceed ±20 %.

The value of the measuring frequency shall be prescribed in the detail specification.

4.2.4.3 Measuring conditions

When required in the detail specification, the impedance shall be determined at the required temperature and frequency. If the peak a.c. voltage exceeds 0,5 V on polar types, a direct polarizing voltage of 2,1 V to 2,5 V may be applied.

The application of voltage shall be such as to cause no readable change in impedance due to the change in the temperature of the capacitor.

The error of measurement shall not exceed ±5 % of the requirement, or 0,1 Ω, whichever is the greater.

Great care shall be exercised in making these measurements when the impedance values are low.

4.2.4.4 Measurement at lower category temperature

The frequency shall be 100 Hz or 120 Hz unless otherwise specified in the detail specification.

4.2.4.5 Requirement

See Table 3.

4.2.5 Insulation resistance of the external insulation (if required)

4.2.5.1 General

See IEC 60384-1:2016, 4.5, with the following details.

4.2.5.2 Measuring conditions

A metal foil shall be wrapped closely around the full length of the body of the capacitor, protruding by at least 5 mm from each end, provided a minimum space of 1 mm can be maintained between the metal foil and the terminations. The ends of the foil shall not be folded over the ends of the capacitor. If the 1 mm space cannot be maintained the protrusion of the foil shall be reduced as may be necessary to establish the 1 mm space.

When applicable, the V-block method is permitted as an alternative.

A direct voltage of 100 V ± 15 V shall be applied between the metal foil or the V-block and the termination connected to the capacitor body for a minimum of 1 min or for the time required to obtain a stable reading. At the end of this period the insulation resistance shall be measured.

4.2.5.3 Requirement

See Table 3.

4.2.6 Voltage proof of the external insulation (if required)

4.2.6.1 General

See IEC 60384-1:2016, 4.6, with the details of 4.2.6.2 and 4.2.6.3.

4.2.6.2 Measuring conditions

A metal foil shall be wrapped closely around the body of the capacitor, protruding by at least 5 mm from each end, provided a minimum space of 1 mm can be maintained between the metal foil and the terminations. The ends of the foil shall not be folded over the ends of the capacitor. If the 1 mm space cannot be maintained, the protrusion of the foil shall be reduced as may be necessary to establish the 1 mm space.

When applicable, the V-block method is permitted as an alternative.

A direct voltage gradually increasing at a rate of 100 V/s to a maximum of 1 000 V shall be applied between the metal foil or the V-block and the termination connected to the capacitor body.

The voltage of 1 000 V shall be applied for 1 min ± 5 s.

4.2.6.3 Requirement

See Table 3.

4.3 Robustness of terminations

4.3.1 General

See IEC 60384-1:2016, 4.13, with the details of 4.3.2, 4.3.3 and 4.3.4.

4.3.2 Initial inspection

See Table 3.

4.3.3 Test Ua1, Ub and Uc applicable

See IEC 60384-1:2016, 4.13.2 (Test Ua1), 4.13.3 (Test Ub) and 4.13.4 (Test Uc).

Which test condition(s) is (are) applied shall be described in detail specification.

However, capacitors with external welds on wire leads shall be subjected only to the procedure of Test Ua_1 and to the bending test described in the detail specification.

4.3.4 Special bending test

4.3.4.1 General

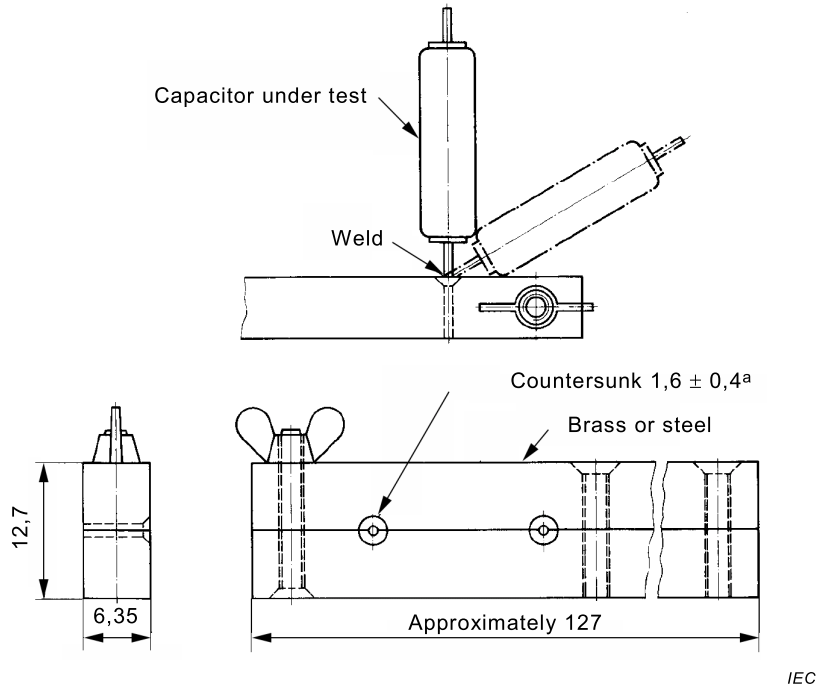
This examination shall determine the ability of the termination to withstand the bonding likely to be applied during normal assembly operation.

4.3.4.2 Test condition

See Figure 1 with the following detail.

4.3.4.3 Apparatus

Dimensions in millimetres



[a] The diameter of the hole should be 0,025 mm less than the diameter of the termination.

Figure 1 – Apparatus of special bending test

4.3.4.4 Test procedure

The termination shall be inserted into the hole in the fixture (Figure 1) so that the lower side of the weld on the soldered joint is approximately flush with the surface of the fixture. The case shall be forced over in such a manner that the tantalum stub is maintained in its axial position as closely as possible while bending the termination until the end of the case just touches the top surface of the fixture.

When the case is returned to its normal position, one bend will have been completed.

Subsequent bends shall be made in alternate directions.

4.3.4.5 Requirements

See Table 3.

4.4 Resistance to soldering heat

4.4.1 General

See IEC 60384-1:2016, 4.14, with the details of 4.4.2 and 4.4.3.

4.4.2 Conditions

No pre-drying.

4.4.3 Final inspections and requirements

See Table 3.

4.5 Solderability

4.5.1 General

See 60384-1:2016, 4.15, with the details of 4.5.2 and 4.5.3.

4.5.2 Test conditions

No ageing.

The test method (the globule test method, the bath method or soldering iron test method) shall be prescribed in the detail specification.

The requirements of the globule test method shall be prescribed in the detail specification.

Where neither the solder bath nor the solder globule method is appropriate, the soldering iron test shall be used with soldering iron size A.

4.5.3 Final inspections and requirements

See Table 3.

4.6 Rapid change of temperature

4.6.1 General

See IEC 60384-1:2016, 4.16, with the following details.

4.6.2 Initial inspection

See Table 3.

4.6.3 Test conditions

The capacitors shall be subjected to test Na (see IEC 60068-2-14) for 5 cycles. The duration of the exposure at each temperature limit shall be 30 min.

4.6.4 Recovery

The recovery period shall be max. 16 h.

4.6.5 Final inspections and requirements

See Table 3.

4.7 Vibration

4.7.1 General

See IEC 60384-1:2016, 4.17, with the details of 4.7.2 and 4.7.3.

4.7.2 Test condition

Test Fc (see IEC 60068-2-6) shall be applied with one of the following severities in Table 6 as prescribed by the detail specification.

Table 6 – Vibration test frequencies

Frequency Hz	Amplitude or acceleration (whichever is the lower acceleration)	Duration h
10 to 55	0,35 mm or 49 m/s^2 (5 g)	3 × 0,5
10 to 55	0,75 mm or 98 m/s^2 (10 g)	3 × 2
10 to 500	0,75 mm or 98 m/s^2 (10 g)	3 × 2
10 to 2 000	0,75 mm or 98 m/s^2 (10 g)	3 × 2

The detail specification shall specify the severity (frequency/amplitude or acceleration/ duration) and shall also prescribe 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.

4.7.3 Final inspections and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in Table 3.

4.8 Bump

4.8.1 General

See IEC 60384-1:2016, 4.18, with the details of 4.8.2, 4.8.3 and 4.8.4.

Whether the bump or the shock test applies shall be described in the detail specification.

4.8.2 Mounting

See detail specification.

For capacitors with axial leads, the following applies:

- mounting: mounted by the leads only;
- the distance between the body and the mounting point: be 6 mm ± 1 mm.

4.8.3 Test conditions

Test conditions are as follows:

- peak acceleration: 390 m/s^2;
- potal number of bumps: 1 000 times for general-purpose grade capacitors;
  4 000 times for long-life grade capacitors;
- duration of pulse: see detail specification.

4.8.4 Final inspections and requirements

See Table 3.

4.9 Shock

4.9.1 General

See IEC 60384-1: 2016, 4.19, with the details of 4.9.2, 4.9.3 and 4.9.4.

Whether the bump or the shock test applies shall be described in the detail specification.

4.9.2 Mounting

See the detail specification.

For capacitors with axial leads the following applies:

- mounting: mounted by the leads only;
- the distance between the body and the mounting point is 6 mm ± 1 mm.

4.9.3 Test conditions

See the detail specification with the following items:

- Pulse shape: half-sine
- Peak acceleration: see Table 7
- Duration of pulse: see Table 7

Table 7 – Shock peak acceleration/pulse duration

Peak acceleration m/s^2(g)	Corresponding duration of the pulse ms
294 (30)	18
490 (50)	11
981 (100)	6

The detail specification shall also prescribe 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.

4.9.4 Final inspections and requirements

See Table 3.

4.10 Climatic sequence

4.10.1 General

See 60384-1:2016, 4.21, with the details of 4.10.2 to 4.10.10.

4.10.2 Initial inspection

See Table 3.

4.10.3 Dry heat

See IEC 60384-1:2016, 4.21.3, with the following details.

- Temperature: upper category temperature;
- Duration: 16 h.

4.10.4 Damp heat, cyclic, Test Db, first cycle

See IEC 60384-1:2016, 4.21.4.

4.10.5 Cold

See IEC 60384-1:2016, 4.21.5, with the following details.

- Temperature: lower category temperature;
- Duration: 2 h.

4.10.6 Low air pressure (if required)

4.10.6.1 General

See IEC 60384-1:2016, 4.21.6, with the details of 4.10.6.2.

4.10.6.2 Test conditions

Test conditions are as follows:

- temperature: +5 °C to +35 °C;
- air pressure: 8,5 kPa;
- duration of test: 5 min;
- applied voltage: rated voltage is applied during the last minute of test.

4.10.7 Damp heat, cyclic, Test Db, remaining cycles

See IEC 60384-1:2016, 4.21.7.

4.10.8 Recovery

If the capacitors have been immersed in a liquid, they shall be shaken to remove excess liquid.

The recovery period shall be 1 h to 2 h under the standard atmospheric conditions.

4.10.9 Sealing (if required)

See IEC 60384-1: 2016, 4.20, with the following details.

The test shall be applied at the end of the climatic sequence.

4.10.10 Final inspections and requirements

See Table 3.

4.11 Damp heat, steady state

4.11.1 General

See IEC 60384-1:2016, 4.22, with the details of 4.11.2 and 4.11.3.

4.11.2 Initial inspection

See Table 3.

4.11.3 Final inspections and requirements

See Table 3.

4.12 Endurance

4.12.1 General

See IEC 60384-1:2016, 4.23, with the details of 4.12.2, 4.12.3, 4.12.4 and 4.12.5.

4.12.2 Initial inspection

See Table 3.

4.12.3 Test conditions

Test conditions are as follows:

- Duration: 2 000 h for long-life grade capacitors;
  1 000 h for general-purpose grade capacitors.
- Ambient temperature: upper category temperature.
- Applied voltage: category voltage, unless otherwise specified in the detail specification.

NOTE When the category voltage and/or temperatures are different from the rated voltage and/or temperatures, the sample tested is divided into two parts and submitted to the rated and category voltages and temperatures respectively.

During the test of bipolar capacitors, the applied voltage shall be reversed in polarity at intervals of 168 h ± 24 h.

When specified in the detail specification, a sinusoidal alternating voltage with frequency of 50 Hz, 60 Hz, 100 Hz or 120 Hz, as specified, may be superimposed on the d.c. voltage provided that the peak voltage does not exceed the value of the rated direct voltage and that the rated ripple current is not exceeded.

a) For solid electrolyte capacitors only, the test voltage shall be applied gradually (not less than 2 min but not more than 5 min) either by a slow build-up of voltage or through a

resistor which shall be shorted out within 5 min. The impedance seen from the terminals of each capacitor shall not exceed 3 Ω.

b) For non-solid electrolyte capacitors, the test voltage shall be supplied by a regulated power supply free from surges, having a low internal resistance, and shall be applied to each capacitor or capacitor section through a separate resistor. The value of this resistor shall be so chosen that a short-circuit of one of the capacitors or capacitor sections will have no influence on the rest of the sample, but the resistance value shall not exceed 1 000 Ω.

4.12.4 Recovery

The recovery period shall be less than 16 h.

4.12.5 Final inspections and requirements

See Table 3.

4.13 Surge voltage

4.13.1 General

See IEC 60384-1:2016, 4.26, with the details of 4.13.2, 4.13.3 and 4.13.4.

4.13.2 Initial inspection

See Table 3.

4.13.3 Test conditions

The capacitors shall be subjected to 1 000 cycles, each consisting of a charge as described below, followed by a no-load period of 5 min and 30 s.

A voltage, equal to the surge voltage, shall be applied during 30 s through a resistor with a value so that the total resistance in series with the capacitor and voltage source is 1 000 Ω ± 100 Ω.

The test shall be carried out at the test temperatures given in Table 8.

Table 8 – Test temperature

Upper category temperature	Test temperature
≤85 °C	All specimens are at upper category temperature
>85 °C	50 % of the specimens at 85 °C and the remaining 50 % at the upper category temperature

Each surge voltage cycle shall be performed in such a manner that the capacitor is discharged through the resistor of approximately 1 000 Ω at the end of the 30 s application.

The test shall be terminated on the discharge portion of the cycle. For bipolar capacitors, the polarity shall be reversed after 500 cycles.

4.13.4 Final inspections and requirements

See Table 3.

4.14 Reverse voltage (if required)

4.14.1 General

See the details in 4.14.2, 4.14.3 and 4.14.4.

4.14.2 Initial inspection

Not required.

4.14.3 Test conditions

Test conditions are as follows:

a) Sub-family 1:
   - Temperature: rated temperature;
   - Applied voltage: a voltage of 3 V d.c., unless otherwise specified in the detail specification, shall be supplied in reverse voltage polarity direction to each capacitor through a resistor of 1 000 Ω ± 100 Ω;
   - Duration: 125 h in the reverse polarity direction with the test reverse voltage, followed by 125 h in the forward polarity direction with the rated voltage.

b) Sub-family 2:
   - Temperature: rated temperature;
   - Applied voltage: 0,1 × rated voltage, but with max. 3 V d.c., unless otherwise specified in the detail specification, shall be supplied in reverse voltage polarity direction;

     The voltage applied to each capacitor shall be from a voltage source with a minimum impedance of 0,1 Ω/V with a maximum of 3 Ω.

     (The voltage shall be applied gradually as described in 4.12.3 a).
   - Duration: 125 h in the reverse polarity direction with test reverse voltage followed by 125 h in the forward polarity direction with the rated voltage.

4.14.4 Final inspections and requirements

See Table 3.

4.15 Characteristics at high and low temperature

4.15.1 General

See IEC 60384-1:2016, 4.29, with the details in 4.15.2.

4.15.2 Final inspections and requirements

The capacitors shall be measured at each temperature step and shall meet the requirements given in Table 3.

4.16 Charge and discharge (if required)

4.16.1 General

See IEC 60384-1:2016, 4.27, with the details in 4.16.2, 4.16.3, 4.16.4 and 4.16.5.

4.16.2 Initial inspection

Not required.

4.16.3 Test conditions

At an ambient temperature of 20 °C, unless otherwise specified in the detail specification, the capacitors shall be subjected to the specified number of cycles, each cycle consisting of a charge according to a), followed by a discharge according to b).

The detail specification shall state the cases where an increase of the cycling period is required, leaving the charging time unchanged so as not to exceed the maximum permissible heat generated in the capacitor.

a) Charge
   - Applied voltage: rated direct voltage;
   - Internal resistance of the voltage source plus external series;
   - Resistor: see detail specification;
   - Duration: 0,5 s.

b) Discharge
   - No voltage applied;
   - Discharge resistor: see detail specification;
   - Duration: 0,5 s.

c) Number of cycles: 10^6 cycles.

4.16.4 Recovery

The recovery period shall be 24 h.

4.16.5 Final inspections and requirements

See Table 3.

4.17 Component solvent resistance

See IEC 60384-1:2016, 4.31.

4.18 Solvent resistance of the marking

See IEC 60384-1:2016, 4.32.

4.19 High surge current (if required)

4.19.1 General

If required for solid electrolyte capacitors only, see IEC 60384-1:2016, 4.39, with the details in 4.19.2 and 4.19.3.

4.19.2 Initial inspection

Not required.

4.19.3 Final inspections and requirements

Final inspections and requirements are those for the subsequent tests in Group 0 or in the blank detail specification or Group A, as appropriate.

Bibliography

IEC 60068-2-54:2006, *Environmental testing – Part 2-54: Tests – Test Ta: Solderability testing of electronic components by the wetting balance method*

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