INTERNATIONAL STANDARD

IEC 60384-9

QC 300700

Third edition
2005-05

Fixed capacitors for use in electronic equipment –

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

This third edition cancels and replaces the second edition published in 1988 and amendment 1 (2000). This third edition is a result of maintenance activities related to the previous edition. All changes that have been agreed upon can be categorized as minor revisions.

The text of this standard is based on the following documents:

FDIS	Report on voting
40/1530/FDIS	40/1550/RVD

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

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

IEC 60384 consists of the following parts, under the general title *Fixed capacitors for use in electronic equipment:*

Part 1: Generic specification

Part 2: Sectional specification: Fixed metallized polyethylene-terephthalate film dielectric d.c. capacitors

Part 3: Sectional specification: Fixed tantalum chip capacitors

Part 4: Sectional specification: Aluminium electrolytic capacitors with solid and non-solid electrolyte

Part 5: Sectional specification: Fixed mica dielectric d.c. capacitors with a rated voltage not exceeding 3000 V – Selection of methods of test and general requirements

Part 6: Sectional specification: Fixed metallized polycarbonate film dielectric d.c. capacitors

Part 7: Sectional specification: Fixed polystyrene film dielectric metal foil d.c. capacitors

Part 8: Sectional specification: Fixed capacitors of ceramic dielectric, Class 1

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

Part 11: Sectional specification: Fixed polyethylene-terephthalate film dielectric metal foil d.c. capacitors

Part 12: Sectional specification: Fixed polycarbonate film dielectric metal foil d.c. capacitors

Part 13: Sectional specification: Fixed polypropylene film dielectric metal foil d.c. capacitors

Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

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

Part 16: Sectional specification: Fixed metallized polypropylene film dielectric d.c. capacitors

Part 17: Sectional specification: Fixed metallized polypropylene film dielectric a.c. and pulse capacitors

Part 18: Sectional specification: Fixed aluminium electrolytic chip capacitors with solid and non-solid electrolyte

Part 19: Sectional specification: Fixed metallized polyethylene-terephthalate film dielectric chip d.c. capacitors

Part 20: Sectional specification: Fixed metallized polyphenylene sulfide film dielectric chip d.c. capacitors

Part 21: Sectional specification: Fixed surface mount multilayer capacitors of ceramic dielectric, Class 1

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

Part 23: Sectional specification: Fixed surface mount metallized polyethylene naphthalate film dielectric d.c. capacitors[1]

Part 24: Sectional specification – Surface mount fixed tantalum electrolytic capacitors with conductive polymer solid electrolyte①

Part 25: Sectional specification – Surface mount fixed aluminium electrolytic capacitors with conductive polymer solid electrolyte①

[1] To be published.

The QC number that appears on the front cover of this publication is the specification number in the IECQ Quality Assessment System for Electronic Components.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication 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 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.[2]

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

1.2 Object

The object of this standard is to prescribe preferred ratings and characteristics and to select from IEC 60384-1:1999, 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 referenced documents are indispensable for the application 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*
Amendment No. 1 (1967)
Amendment No. 2 (1977)

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

IEC 60384-1:1999, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification.*

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

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

1.4 Information to be given in a detail specification

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.

NOTE The information given in 1.4.1 may for convenience, be presented in tabular form.

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[2] Which are covered by IEC 60384-22 (Class 2).

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.

1.4.1 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.

1.4.2 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 capacitors shall be mounted by their normal means. 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.

1.4.3 Ratings and characteristics

The ratings and characteristics shall be in accordance with the relevant clauses of this specification, together with the following:

1.4.3.1 Rated capacitance range

See 2.2.4.1

NOTE When products approved to the detail specification have different ranges, the following statement should be added: "The range of values available in each voltage range is given in IEC QC 001005".

1.4.3.2 Particular characteristics

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

1.4.3.3 Soldering

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

1.4.4 Marking

The detail specification shall specify the content of the marking on the capacitor and on the package. Deviations from 1.6 of this sectional specification, shall be specifically stated.

1.5 Terms and definitions

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

1.5.1
fixed capacitors 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. The ceramic dielectric is characterized by the non-linear change of capacitance over the category temperature range (see Table 2)

1.5.2
subclass
maximum percentage change of capacitance within the category temperature range with respect to the capacitance at 20 °C

NOTE The subclass may be expressed in code form (see Table 2).

1.5.3
rated voltage (U_R)
maximum d.c. voltage which may be applied continuously to the terminations of a capacitor at the rated temperature

NOTE 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.

1.6 Marking

See IEC 60384-1, 2.4 with the following details:

1.6.1 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) rated capacitance;

b) rated voltage (d.c. voltage may be indicated by the symbol ⎓ or ⎓);

c) tolerance on rated 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.

NOTE Information required under 1.6.1 b) and 1.6.1 d) may be given in code form under manufacturer's, or national, type or style designation.

1.6.1 The capacitor shall be clearly marked with a), b) and c) above 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

1.6.2 The package containing the capacitor(s) shall be clearly marked with all the information listed in 1.6.1.

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

2 Preferred ratings and characteristics

2.1 Preferred characteristics

The values given in detail specifications shall preferably be selected from the following:

2.1.1 Preferred climatic categories

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

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 and +125 °C
Duration of the damp heat, steady state test:	4, 10, 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 Rated temperature

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

2.2.2 Rated voltage (U_R)

The preferred values of rated voltage are: 25 – 40 – 63 – 100 – 160 – 250 – 400 – 630 – 1000 – 1 600 – 2 500 and 4 000 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.

2.2.3 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, 2.2.17.

2.2.4 Preferred values of rated capacitance and associated tolerance values

2.2.4.1 Preferred values of rated capacitance

Rated capacitance values shall be taken from the series of IEC 60063; the E3, E6 and E12 series are preferred.

2.2.4.2 Preferred tolerances on rated capacitance

Table 1 – Preferred tolerance on rated capacitance

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

2.2.5 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 – Preferred values of temperature characteristics

Sub-class letter code	Maximum capacitance change in per cent within the category temperature range with respect to the capacitance at 20 °C measured with and without a d.c. voltage applied		Category temperature range and corresponding number code				
			-55/+125 °C	-55/+85 °C	-40/+85 °C	-25/+85 °C	-10/+85 °C
	Without d.c. voltage applied	With d.c.[a] voltage applied	1	2	3	4	6
2B	±10		-	x	x	x	-
2C	±20		x	x	x	-	-
2D	+20/–30	As specified in the detail specification	-	-	-	x	-
2E	+22/–56		-	x	x	x	x
2F	+30/–80		-	x	x	x	x
2R	±15		x	-	-	-	-
2X	±15	+15/–25	x	-	-	-	-

a The applied voltage is the rated d.c. voltage or as specified in the detail specification.

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

3 Quality assessment procedures

3.1 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.

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 records of released lots

The information required in IEC 60384-1, 3.9 shall be made available when prescribed in the detail specification and when requested by a purchaser. After the endurance test, the parameters for which variables information is required are the capacitance change, tan δ and the insulation resistance.

3.4 Qualification approval

The procedures for qualification approval testing are given in IEC 60384-1, 3.5.

The schedule to be used for qualification approval testing on the basis of lot-by-lot and periodic tests is given in 3.5 of this specification. The procedure using a fixed sample size schedule is given in 3.4.1 and 3.4.2 below.

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

The fixed sample size procedure is described in IEC 60384-1, 3.5.3 b). The sample shall be representative of the range of capacitors for which approval is sought. This may or may not be 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 which 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.

3.4.2 Tests

The complete series of tests specified in Table 3 and Table 4 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 does not exceed the specified number of permissible non-conforming items for each group or subgroup and the total number of permissible non-conforming items.

NOTE Tables 3 and 4 together form the fixed sample size test schedule for which Table 3 includes the details for the sampling and permissible non-conforming item for the different tests or groups of test, whereas Table 4 together with the details of test contained in Clause 4 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 in the detail specification for quality conformance inspection.

Table 3 – Sampling plan together with numbers of permissible non-conforming items for qualification approval tests, assessment level EZ

Group No.	Test	Subclause of this publication	Number of specimens *n* [b]	Permissible number of non-conforming items *c*
0	Visual examination Dimensions Capacitance Tangent of loss angle Insulation resistance Voltage proof Spare specimens	4.2 4.2 4.3.1 4.3.2 4.3.3 4.3.4	108 8	0
1A	Robustness of terminations Resistance to soldering heat Component solvent resistance [c]	4.5 4.6 4.15	12	0
1B	Solderability Solvent resistance of the marking [c] Rapid change of temperature [a)] Vibration Bump or shock [a]	4.7 4.16 4.8 4.9 4.10 or4.11	24	0
1	Climatic sequence	4.12	36	0
2	Damp heat, steady state	4.13	24	0
3	Endurance	4.14	36	0
4	Temperature characteristic of capacitance	4.4	12	0

[a] As required in the detail specification.

[b] Capacitance/voltage combinations, see 3.4.1.

[c] If required in the detail specification.

Table 4 – 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)	Performance requirements [a]
Group 0	ND		See Table 3	
4.2 Visual examination			↓	As in 4.2 Legible marking and as specified in the detail specification
4.2 Dimensions (detail)				See detail specification
4.3.1 Capacitance		Frequency: ... kHz Measuring voltage: ... V		Within specified tolerance
4.3.2 Tangent of loss angle (tan δ)		Frequency and measuring voltage same as in 4.3.1		As in 4.3.2.2
4.3.3 Insulation resistance		See detail specification for the method		As in 4.3.3.2
4.3.4 Voltage proof		See detail specification for the method		No breakdown or flashover
Group 1A	D		See Table 3	
4.5 Robustness of terminations		Visual examination	↓	No visible damage
4.6.2 Initial measurements		Capacitance		
4.6 Resistance to soldering heat		Special preconditioning as in 4.1 See detail specification for the method (1A or 1B)		
4.6.4 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$ as in 4.6.4
4.15 Component solvent resistance (if applicable)		Solvent: ... Solvent temp: ... Method 2 Recovery: ...		See detail specification

Table 4 *(continued)*

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)	Performance requirements [a]
Group 1B	D		See Table 3	
4.7 Solderability		See detail specification for the method		Good tinning as evidenced by free flowing of the solder with wetting of the terminations or solder shall flow within ...s, as applicable
4.16 Solvent resistance of the marking (if applicable)		Solvent: ... Solvent temperature:... Method: 1 Rubbing material: cotton wool Recovery: ...		Legible marking
4.8 Rapid change of temperature		Special preconditioning as in 4.1		
4.8.2 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
4.9 Vibration		For mounting method see detail specification		
		Frequency range: from ... Hz to ... Hz Amplitude: 0,75 mm or acceleration 100 m/s^2 (whichever is the less severe) Total duration: 6 h		
4.9.2 Intermediate inspection		Visual examination		No visible damage
4.10 Bump (or shock, see 4.11)		For mounting method see detail specification		
		Number of bumps: ... Acceleration: ... m/s^2 Duration of pulse: ... ms		
4.11 Shock (or bump, see 4.10)		For mounting method see detail specification		
		Acceleration: ... m/s^2 Duration of pulse: ... ms		
4.10.3 or 4.11.3 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$ as in 4.11.3

Table 4 *(continued)*

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)	Performance requirements [a]
Group 1	D		See Table 3	
4.12 Climatic sequence		Special preconditioning as in 4.1		
4.12.1.1 Initial measurement		Capacitance		
4.12.2. Dry heat		Temperature: upper category temperature Duration: 16 h		
4.12.3 Damp heat, cyclic, test Db, first cycle				
4.12.4 Cold		Temperature: lower category temperature Duration: 2 h		
		Visual examination		No visible damage
4.12.5 Low air pressure (if required by the detail specification		Air pressure: 8 kPa		
4.12.5.3 Intermediate inspection		Visual examination		No breakdown or flashover
4.12.6 Damp heat, cyclic, test Db, remaining cycles				
		Recovery: 24 h ± 2 h		
4.12.6.3 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$ as in 4.12.6.3
		Tangent of loss angle		As in 4.12.6.3
		Insulation resistance		As in 4.12.6.3
Group 2	D		See Table 3	
4.13 Damp heat, steady state		Special preconditioning as in 4.1		
4.13.2 Initial measurements		Capacitance		
		Recovery: 24 h ± 2 h		
4.13.5 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$ as in 4.13.5
		Tangent of loss angle		As in 4.13.5
		Insulation resistance		As in 4.13.5

Table 4 *(continued)*

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)	Performance requirements [a]
Group 3	D		See Table 3	
4.14 Endurance		Special preconditioning as in 4.1		
		Voltage: V		
		Duration: h		
4.14.2 Initial measurement		Capacitance		
		Recovery: 24 h ± 2 h		
4.14.5 Final measurements		Visual examination		No visible damage Legible marking
		Capacitance		$\Delta C/C$ as in 4.14.5
		Tangent of loss angle		As in 4.14.5
		Insulation resistance		As in 4.14.5
Group 4	ND		See Table 3	
4.4 Temperature characteristic of capacitance		Special preconditioning as in 4.1		$\Delta C/C$ as in 4.4.3

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

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

3.5 Quality conformance inspection

3.5.1 Formation of inspection lots

a) 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:

1) The inspection lot shall consist of structurally similar capacitors (see 3.2);

2a) 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.

2b) 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 National Supervising Inspectorate.

b) 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.

3.5.2 Test schedule

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in Table 5 of the blank detail specification, IEC 60384-9-1.

3.5.3 Delayed delivery

When according to the procedures of IEC 60384-1, 3.10, re-inspection has to be made, solderability and 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 the following Tables 5 and 6:

Table 5 – Lot-by-lot inspection

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

[a] *IL* = inspection level

n = sample size

c = permissible number of non-conforming items

[b] 100 % testing shall be followed by re-inspection by sampling in order to monitor outgoing quality level by non-conforming items per million (10^{-6}).The sampling level shall be established by the manufacturer. For the calculation of 10^{-6} values, any parametric failure shall be counted as a non-conforming item. In case one or more non-conforming items occur in a sample, this lot shall be rejected.

[c] Number to be tested: sample size as directly allotted to the code letter for *IL* in Table IIA of IEC 60410.

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

Table 6 – Periodic tests

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

[a] p = periodicity in months

n = sample size

c = permissible number of non-conforming items

[b] The content of the inspection subgroup is described in clause 2 of the relevant blank detail specification.

4 Test and measurement procedures

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

4.1 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 made under the following conditions: exposure at upper category temperature or at such higher temperature as may be specified in the detail specification during 1 h, followed by recovery during 24 h ± 1 h at standard atmospheric conditions for testing.

NOTE Class 2 capacitors lose capacitance continuously with time according to 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).

4.2 Visual examination and check of dimensions

See IEC 60384-1, 4.4.

4.3 Electrical tests

4.3.1 Capacitance

See IEC 60384-1, 4.7 with the following details:

4.3.1.1 Measuring conditions

Table 7 – Measuring conditions

Subclass	Measuring voltage	Referee voltage
2B, 2C, 2X	1,0 ± 0,2 V	1,0 ± 0,02 V
2D, 2E, 2F, 2R	0,3 ± 0,2 V or as specified in the detail specification	0,3 ± 0,02 V or as specified in the detail specification

– Frequency: $C_R \leq 100$ pF f = 1 MHz unless otherwise specified in the detail specification

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

4.3.1.2 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. (for explanation see Annex A).

4.3.2 Tangent of loss angle (tan δ)

See IEC 60384-1, 4.8 with the following details:

4.3.2.1 Measuring conditions

Same as in 4.3.1

4.3.2.2 Accuracy

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

4.3.2.3 Requirements

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

4.3.3 Insulation resistance (R_i)

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

4.3.3.1 Measuring conditions

See IEC 60384-1, 4.5.2 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 rated capacitance of the capacitor shall not exceed 1 s unless otherwise prescribed 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.

4.3.3.2 Requirements

The insulation resistance (R_i) shall be equal to or greater than the following requirements:

Table 8 – Insulation resistance requirements

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

4.3.4 Voltage proof

See IEC 60384-1, 4.6 with the following details:

4.3.4.1 Test conditions

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

The charge current shall not exceed 0,05 A.

4.3.4.2 The voltages in Table 9 shall be applied between the measuring points of Table 3 in IEC 60384-1 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 9 – Test voltages

Type	Rated voltage V	Test voltage 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 relevant specification.		

4.3.4.3 Requirement

There shall be no breakdown or flashover during the test.

4.4 Temperature characteristic of capacitance

4.4.1 Special preconditioning

See 4.1.

4.4.2 Measuring conditions

See IEC 60384-1,4.24.1.2 and 4.24.1.3 with the following details

Table 10 – Measuring conditions

Temperature °C	References within the temperature cycle	DC voltage(U_R) applied
20 ± 2	a	-
T_A ± 3	b	-
20 ± 2	d	-
T_B ± 2	f	-
T_B ± 2	f	x
20 ± 2	g	x
T_A ± 3	b	x
20 ± 2	a	-

NOTE 1 T_A = Lower category temperature.
T_B = Upper category temperature.

NOTE 2 - indicates: no d.c. voltage applied.
X indicates: d.c.voltage applied.

NOTE 3 Measurements shall be made at such intermediate temperatures as to ensure that the requirements of 2.2.5 are met.

NOTE 4 The reference capacitance is that measured at “d”.

NOTE 5 Because of the effects described in the note to 4.1, the capacitance values measured at temperature reference "f", "g" and "b" with d.c. 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 "a" indicates the amount of ageing involved. In case of dispute about results of measurements with d.c. voltage applied, it is advisable to agree upon a fixed time interval between measurements at temperature reference "f" and "b".

4.4.3 Requirements

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

4.5 Robustness of terminations

See IEC 60384-1, 4.13.

4.6 Resistance to soldering heat

See IEC 60384-1, 4.14, with the following details:

4.6.1 Special preconditioning

See 4.1.

4.6.2 Initial measurement

The capacitance shall be measured according to 4.3.1.

4.6.3 **Recovery:** 24 h ± 2h.

4.6.4 Final inspection, measurements and requirements

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

The capacitances shall be measured according to 4.3.1, and the change shall not exceed the values in Table 11.

Table 11 – Maximum capacitance change

Subclass	Requirements
2B, 2C and 2X	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 2.2.5 for explanation of the subclass codes	

4.7 Solderability

See IEC 60384-1, 4.15, with the following details:

4.7.1 Conditions:.

The requirements for the globule test method shall be prescribed 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.

4.7.2 The performance requirements are given in Table 4.

4.8 Rapid change of temperature

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

4.8.1 Special preconditioning

See 4.1.

4.8.2 Initial measurement

The capacitance shall be measured according to 4.3.1.

4.8.3 Number of cycles: 5

Duration of exposure at the temperature limits: 30 min.

4.8.4 Recovery: 24 h ± 2 h.

4.9 Vibration

See IEC 60384-1, 4.17, with the following details:

4.9.1 The following degree of severity of test Fc apply:

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 shall be 6 h.

The detail specification shall specify the frequency range 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.

4.9.2 Final inspection, measurements and requirements

See Table 4.

4.10 Bump

See IEC 60384-1, 4.18 with the following details:

The detail specification shall state whether the bump or the shock test applies.

4.10.1 Initial measurements

Not required.

4.10.2 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	or	16 ms

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.

4.10.3 Final inspection, measurements and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in 4.11.3.

4.11 Shock

See IEC 60384-1, 4.19 with the following details:

The detail specification shall state whether the bump or the shock test applies.

4.11.1 Initial measurements

Not required.

4.11.2 The detail specification shall state which of the preferred severities as stated in Table 12:

Pulse-shape: half-sine

Table 12 – Preferred severities

Peak acceleration m/s^2	Corresponding duration of the pulse ms
300	18
500	11
1 000	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.

4.11.3 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 according to 4.3.1, the change shall not exceed the values in Table 13.

Table 13 – Maximum capacitance change

Subclass	Requirements
2B, 2C and 2X	±10 %
2D and 2R	±15 %
2E and 2F	±20 %
NOTE See 2.2.5 for explanation of the subclass codes.	

4.12 Climatic sequence

See IEC 60384-1, 4.21, with the following details:

4.12.1 Special preconditioning

See 4.1.

4.12.1.1 Initial measurements

The capacitance shall be measured in accordance with 4.3.1.

4.12.2 Dry heat

See IEC 60384-1, 4.21.2.

4.12.3 Damp heat, cyclic, Test Db, first cycle

See IEC 60384-1, 4.21.3.

4.12.4 Cold

See IEC 60384-1, 4.21.4, with the following details:

4.12.4.1 Final inspection and requirements

The capacitor shall be visually examined and shall meet the requirements given in Table 4.

4.12.5 Low air pressure

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

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

The duration of the test shall be 1 h.

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

4.12.5.3 Final inspection and requirements

The capacitors shall be visually examined and shall meet the requirements given in Table 4.

4.12.6 Damp heat, cyclic, Test Db, remaining cycles

See IEC 60384-1, 4.21.6, with the following details:

4.12.6.1 Conditions of test

No voltage applied.

Table 14 – Number of damp heat cycles

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

4.12.6.2 Recovery: 24 h ± 2 h

4.12.6.3 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 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 according to 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	4.3.1	$\Delta C/C \leq \pm$ 10 %	$\Delta C/C \leq \pm$ 15 %	$\Delta C/C \leq \pm$ 20 %	$\Delta C/C \leq \pm$ 30 %
Tangent of loss angle	4.3.2	tan $\delta \leq$ 2 x value of 4.3.2.2			
Insulation resistance	4.3.3	$R_i \geq$ 1 000 MΩ or $R_i \times C_R \geq$ 25 s (whichever is the less)			
NOTE See 2.2.5 for explanation of the subclass codes.					

4.13 Damp heat, steady state

See IEC 60384-1, 4.22, with the following details:

4.13.1 Special preconditioning

See 4.1.

4.13.2 Initial measurement

The capacitance shall be measured according to 4.3.1.

4.13.3 Conditions of test

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

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

4.13.4 **Recovery:** 24 h ± 2 h

4.13.5 Final inspection, measurements and requirements

The capacitors shall be visually examined.

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

The capacitors shall be measured and shall meet the following requirements given in Table 16. If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned according to 4.1 and then the requirement in Table 16 shall be met.

Table 16 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements			
		Subclasses 2B, 2C and 2X	Subclass 2D and 2R	Subclass 2E	Subclass 2F
Capacitance	4.3.1	$\Delta C/C \leq \pm$ 10 %	$\Delta C/C \leq \pm$ 15 %	$\Delta C/C \leq \pm$ 20 %	$\Delta C/C \leq \pm$ 30 %
Tangent of loss angle	4.3.2	tan $\delta \leq$ 2 x value of 4.3.2.2			
Insulation resistance	4.3.3	$R_i \geq$ 1 000 MΩ or $R_i \times C_R \geq$ 25 s (whichever is less)			
NOTE See 2.2.5 for explanation of the subclass codes.					

4.14 Endurance

See IEC 60384-1, 4.23, with the following details:

4.14.1 Special preconditioning

See 4.1.

4.14.2 Initial measurement

The capacitance shall be measured according to 4.3.1.

4.14.3 Conditions of test

Table 17 – Conditions of test

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

4.14.4 Recovery: 24 h ± 2 h.

4.14.5 Final inspection, measurements and requirements

The capacitors shall be visually examined.

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

The capacitors shall be measured and shall meet the following requirements given in Table 18. If the capacitance value is less than the minimum value permitted, then after the other measurements have been made the capacitor shall be preconditioned according to 4.1 and then the requirement in Table 18 shall be met.

Table 18 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements			
		Subclasses 2B, 2C and 2X	Subclass 2D and 2R	Subclass 2E	Subclass 2F
Capacitance	4.3.1	$\Delta C/C \leq \pm$ 20 %	$\Delta C/C \leq \pm$ 20 %	$\Delta C/C \leq \pm$ 20 %	$\Delta C/C \leq \pm$ 30 %
Tangent of loss angle	4.3.2	tan $\delta \leq$ 2 x value of 4.3.2.2			
Insulation resistance	4.3.3	$R_i \geq$ 2 000 MΩ or $R_i \times C_R \geq$ 50 s (whichever is less)			
NOTE See 2.2.5 for explanation of the subclass codes.					

4.15 Component solvent resistance (if applicable)

See IEC 60384-1, 4.31.

4.16 Solvent resistance of the marking (if applicable)

See IEC 60384-1, 4.32.

Annex A
(normative)

Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

A.1 Introduction

Most ceramic dielectrics, Class 2, used for ceramic capacitors have ferro-electric 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 The 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. 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 k between 1 h and 100 h age and 3k between 1 h and 1 000 h age. This may be expressed mathematically by the following equation:

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

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 determined by de-ageing the capacitor and measuring the capacitance at two known times thereafter.

k is then given by the following equation:

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

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

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

A.3 Capacitance measurements and capacitance tolerance (see 4.3.1)

Because of ageing it is necessary to specify a reference age at which the capacitance shall be within the prescribed 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_{1000} after 1 000 h the ageing constant must be known or determined as in the previous clause, when the following formula may be used:

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

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

For example, if it is known that the capacitance loss will be 5 % then the capacitors may be inspected to limits of $^{+25}_{-15}$ % instead of ±20 %.

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

A.4 Special preconditioning (see 4.1)

In many of the tests in this standard, 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 completely de-aged. In order to de-age such capacitors completely, temperatures up to 160 °C may be required, and this temperature could be deleterious to the encapsulation. Therefore, in the few cases where complete de-ageing of such capacitors may be required, the detail specification shall be consulted for details and any necessary precautions.

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