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Fixed capacitors for use in electronic equipment –

Part 22:

Sectional specification:

**Fixed surface mount multilayer capacitors
of ceramic dielectric, Class 2**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –**Part 22: Sectional specification:
Fixed surface mount multilayer capacitors
of ceramic dielectric, Class 2**

FOREWORD

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

This standard and its related publications (CEI 60384-21, IEC 60384-21-1 and IEC 60384-22-1) cancel and replace IEC 60384-10 (1989) and its Amendments 1 (1993) and 2 (2000) as well as IEC 60384-10-1 (1989) and its Amendment 1 (1993).

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

FDIS	Report on voting
40/1422/FDIS	40/1453/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.

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- withdrawn;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 standard may be issued at a later date.

The contents of the corrigendum of September 2004 have been included in this copy.

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

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

1 General

1.1 Scope

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

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

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, 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 1 (1967)

Amendment 2 (1977)

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-58:1999, *Environmental testing – Part 2-58: Tests – Test Td – Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

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

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

IEC QC 001005: *Register of firms, products and services approved under the IECQ system, including ISO 9000*

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.

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 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.

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

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

1.4.2 Mounting

The detail specification shall give guidance on methods of mounting for normal use. Mounting for test and measurement purposes (when required) shall be in accordance with 4.3 of this sectional specification.

1.4.3 Rating 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 capacitance values available in each voltage range is given in IECQ 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 sectional specification, the terms and definitions given in IEC 60384-1, as well as the following apply.

1.5.1

surface mount capacitor

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

1.5.2

fixed capacitors, 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 a non linear change of capacitance over the category temperature range (see Table 3).

1.5.3

subclass

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

The subclass may be expressed in code form (see Table 3)

1.5.4

category temperature range

range of ambient temperatures for which the capacitor has been designed to operate continuously; this is given by the lower and upper category temperature

1.5.5

rated temperature

maximum ambient temperature at which the rated voltage may be continuously applied

1.5.6

rated voltage (d.c.)

U_R

maximum direct voltage or peak value of pulse voltage which may be applied continuously to a capacitor at any temperature between the lower category temperature and the rated temperature

NOTE The sum of the d.c. voltage and the peak a.c. voltage or the peak to peak a.c. voltage, whichever is the greater, applied to the capacitor shall not exceed the rated voltage. The value of the peak a.c. voltage shall not exceed the value determined by the permissible reactive power.

1.5.7

category voltage

U_C

maximum voltage which may be applied continuously to a capacitor at its upper category temperature

1.6 Marking

See 2.4 of IEC 60384-1 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 ($\overline{\text{---}}$ or ---);
- c) tolerance on rated capacitance;
- d) dielectric subclass as applicable (according to 2.2.5);
- 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.

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

1.6.3 Any marking shall be legible and not easily smeared or removed by rubbing with the finger.

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

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

2 Preferred rating and characteristics

2.1 Preferred characteristics

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

2.1.1 Preferred climatic categories

The capacitors covered by this sectional 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: $-55\text{ }^{\circ}\text{C}$, $-40\text{ }^{\circ}\text{C}$, $-25\text{ }^{\circ}\text{C}$, $-10\text{ }^{\circ}\text{C}$ and $+10\text{ }^{\circ}\text{C}$

Upper category temperature: $+70\text{ }^{\circ}\text{C}$, $+85\text{ }^{\circ}\text{C}$, $+100\text{ }^{\circ}\text{C}$, $+125\text{ }^{\circ}\text{C}$ and $+150\text{ }^{\circ}\text{C}$

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.

NOTE The resistance to humidity resulting from the above climatic category is for the capacitors in their unmounted state. The climatic performance of the capacitors after mounting is greatly influenced by the mounting substrate, the mounting method (see 4.3) and the final coating.

2.2 Preferred values of ratings

2.2.1 Rated temperature

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

2.2.2 Rated voltage (U_R)

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

2.2.3 Category voltage (U_C)

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

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

Table 1 – Preferred values of category voltages

U_R	V	2,5	4	6,3	10	16
U_C	V	1,6	2,5	4	6,3	10
NOTE The numeric values of U_C are calculated by the following: $U_C = 0,63 \times U_R$						

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

See Table 2.

Table 2 – Preferred tolerances

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

2.2.5 Temperature characteristic of capacitance

Table 3 denotes with a cross the preferred values of the temperature characteristic with and without a 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 subclass 2C1.

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

Table 3 – Temperature characteristic of capacitance

Sub-class letter code	Maximum capacitance change within the category temperature range with respect to the capacitance at 20 °C measured with and without a d.c. voltage applied %		Category temperature range and corresponding number code					
			−55/+150 °C	−55/+125 °C	−55/+85 °C	−40/+85 °C	−25/+85 °C	+10/+85 °C
	Without d.c. voltage applied	With d.c. voltage applied ¹	0	1	2	3	4	6
2B	±10	Requirements specified in the detail specification			x	x	x	
2C	±20			x	x	x		
2D	+20/−30			x			x	
2E	+22/−56				x	x	x	x
2F	+30/−80				x	x	x	x
2R	±15		x	x	x		x	
d.c. voltage applied is either rated voltage or the voltage specified in the detail specification.								
"x" indicates preferred.								
When the upper category temperature is above 125 °C, the limits of capacitance change, both with and without d.c. voltage applied shall be given in the detail specification.								

2.2.6 Dimensions

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

Specific dimensions shall be given in the detail specification.

3 Quality assessment procedures

3.1 Primary stage of manufacture

The primary stage of manufacture 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, through 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, $\tan \delta$ 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 sectional specification. The procedure using a fixed sample size schedule is given in 3.4.1 and 3.4.2.

3.4.1 Qualification Approval on the basis of the fixed sample size procedures

The fixed sample size procedure is described in item b) of 3.5.3 of IEC 60384-1. 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.

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

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

Two (for six values) or three (for four values) per value 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 4 gives the number of samples to be tested in each group or subgroup together with the number of the number of permissible non-conformances for the qualification approval test.

3.4.2 Tests

The complete series of tests specified in Tables 4 and 5 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 (according to Table 4) 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 do not exceed the specified number of permissible non-conforming items for each group or subgroup and the total number of permissible non-conformances.

NOTE Tables 4 and 5 together form the fixed sample size test schedule. Table 4 includes the details for the sampling and permissible non-conforming items for the different tests or groups of tests. Table 5 together with the details of the 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 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.

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Table 4 – Fixed sample size test plan for qualification approval, assessment level EZ

Group No.	Test	Subclause of this publication	Number of specimens n^e	Permissible number of non-conforming items c
0	Visual examination Dimensions Capacitance Tangent of loss angle Insulation resistance Voltage proof Spare specimens	4.4 4.4 4.5.1 4.5.2 4.5.3 4.5.4	132 + 24 ^f 12	0
1A	Robustness of termination ^g Resistance to soldering heat Component solvent resistance ^b	4.15 4.9 4.16	12 12	0
1B	Impedance ^b Equivalent series resistance [ESR] ^b Solderability Solvent resistance of marking ^b	4.5.5 4.5.6 4.10 4.17	12	0
2	Substrate bending test ^d	4.8	12	0
3 ^a	Mounting Visual examination Capacitance Tangent of loss angle Insulation resistance Voltage proof	4.3 4.4 4.5.1 4.5.2 4.5.3 4.5.4	84 + 24 ^f	0 ^c
3.1	Shear test ^h Rapid change of temperature Climatic sequence	4.7 4.11 4.12	24	0
3.2	Damp heat, steady state	4.13	24	0
3.3	Endurance	4.14	36	0
3.4	Accelerated damp heat, steady state ^b	4.18	24 ^f	0
4	Temperature characteristic of capacitance	4.6	12	0

^a The values of these measurements serve as initial measurements for the tests of Group 3.
^b If required in the detail specification.
^c The capacitors found to be non-conforming after mounting shall not be taken into account when calculating the permissible non-conforming for the following tests. They shall be replaced by spare capacitors.
^d Not applicable to capacitors, which according to their detail specification shall only be mounted on alumina substrates.
^e Capacitance/voltage combinations, see 3.4.1.
^f Additional capacitors if group 3.4 is tested.
^g Applicable to capacitors with strip terminations.
^h Not applicable to capacitors with strip terminations.

Table 5 – Tests schedule for qualification approval

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (<i>n</i>) and number of non- conforming items (<i>c</i>)	Performance requirements (see NOTE 1)
GROUP 0	ND		See Table 4	
4.4 Visual examination				As in 4.4.2
4.4 Dimension (detail)				Legible marking and as specified in the detail specification
4.5.1 Capacitance		Frequency: ... Hz Measuring voltage: ... V r.m.s		See the detail specification Within specified tolerance
4.5.2 Tangent of loss angle (tan δ)		Frequency and measuring voltage same as in 4.5.1		As in 4.5.2
4.5.3 Insulation resistance		See detail specification for the method		As in 4.5.3.3
4.5.4 Voltage proof		See detail specification for the method		No breakdown or flashover
GROUP 1A	D		See Table 4	
4.15 Robustness of termination (if applicable)		Test Ua1, force: 2,5 N Test Ub, method 1, force: 2,5 N Number of bends: 1 Visual examination		No visible damage
4.9.2 Initial measurement		Capacitance		
4.9 Resistance to soldering heat		Special preconditioning as in 4.1 See detail specification for the method Recovery: (24 $\pm$ 2) h		
4.9.5 Final measurement		Visual examination Capacitance		As in 4.9.5 As in 4.9.5
4.16 Component solvent resistance (if applicable)		Solvent: ... Solvent temperature: ... Method 2 Recovery: ...		See detail specification
GROUP 1B	D		See Table 4	
4.5.5 Impedance (if required)		Frequency: 100 kHz		See detail specification
4.5.6 ESR (if required)		Frequency: 100 kHz		See detail specification
4.10 Solderability		See detail specification for the method		
4.10.3 Final measurements		Visual examination		As in 4.10.3

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (<i>n</i>) and number of non- conforming items (<i>c</i>)	Performance requirements (see NOTE 1)
4.17 Solvent resistance of the marking ^a (if required)	D	Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...		Legible marking
GROUP 2 4.8 Substrate bending test 4.8.1 Initial measurement 4.8.2 Final inspection	D	Deflection: ... Number of bends: ... Capacitance Capacitance (with printed board in bent position) Visual examination	See Table 4	See detail specification $ \Delta C/C \leq 10\%$ No visible damage
GROUP 3 4.3 Mounting	D	Substrate material: ... ^b Visual examination Capacitance Tangent of loss angle Insulation resistance Voltage proof	See Table 4	As in 4.4.2 Within specified tolerance As in 4.5.2 As in 4.5.3.3 No breakdown or flashover
GROUP 3.1 4.7 Shear test 4.11.2 Initial measurement 4.11 Rapid change of temperature 4.11.5 Final measurements 4.12 Climatic sequence 4.12.2 Initial measurement 4.12.3 Dry heat 4.12.4 Damp heat, cyclic, test Db, first cycle	D	Visual examination Capacitance Special preconditioning as in 4.1 T_A = Lower category temperature T_B = Upper category temperature Five cycles Duration $t_1 = 30$ min Recovery: (24 ± 2) h Visual examination Capacitance Special preconditioning as in 4.1 Capacitance Temperature: upper category temperature Duration: 16 h	See Table 4	No visible damage No visible damage $\Delta C/C$: as in 4.11.5

Subclause number and test (see NOTE 1)	D or ND	Conditions of test (see NOTE 1)	Number of specimens (<i>n</i>) and number of non- conforming items (<i>c</i>)	Performance requirements (see NOTE 1)
4.12.5 Cold 4.12.6 Damp heat, cyclic, test Db, remaining cycles 4.12.7 Final measurements	D	Temperature: lower category temperature Duration: 2 h Visual examination Recovery: (24 ± 2) h Visual examination Capacitance Tangent of loss angle Insulation resistance	See Table 4	No visible damage No visible damage Legible marking $\Delta C/C$: as in 4.12.7 As in 4.12.7 As in 4.12.7
GROUP 3.2 4.13 Damp heat, steady state 4.13.2 Initial measurement 4.13.5 Final measurements	D	Special preconditioning as in 4.1 Capacitance Recovery: (24 ± 2) h Visual examination Capacitance Tangent of loss angle Insulation resistance	See Table 4	No visible damage Legible marking $\Delta C/C$: as in 4.13.5 As in 4.13.5 As in 4.13.5
GROUP 3.3 4.14 Endurance 4.14.2 Initial measurement 4.14.5 Final measurements	D	Special preconditioning as in 4.1 Duration: ... h Temperature: ... °C Voltage: ... V Capacitance Recovery: (24 ± 2) h Visual examination Capacitance Tangent of loss angle Insulation resistance	See Table 4	No visible damage Legible marking $\Delta C/C$: as in 4.14.5 As in 4.14.5 As in 4.14.5
GROUP 3.4 4.18 Accelerated damp heat, steady state (if required) 4.18.1 Initial measurement 4.18.4 Final measurements	D	Duration: ... h Temperature: (85 ± 2) °C Humidity: (85 ± 3) % Insulation resistance Recovery: (24 ± 2) h Insulation resistance	See Table 4	As in 4.18.1 As in 4.18.4
GROUP 4 4.6 Temperature characteristic of capacitance	ND	Special preconditioning as in 4.1	See Table 4	$\Delta C/C$: as in 4.6.3
NOTE 1 Subclause numbers of test and performance requirements refer to Clause 4. NOTE 2 In this table: D = destructive, ND= non-destructive.				

- ^a This test may be carried out on capacitors mounted on a substrate.
- ^b When different substrate materials are used for the individual subgroup, the detail specification shall indicate which substrate material is used in each subgroup.

3.5 Quality conformance inspection

3.5.1 Formation of inspection lots

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

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

3.5.2 The schedule

The schedule for the lot-by-lot and periodic tests for Quality Conformance Inspection is given in Clause 2, Table 4 of the blank detail specification, for example in IEC 60384-22-1.

3.5.3 Delayed delivery

When, according to the procedures of 3.10 of IEC 60384-1, re-inspection has to be made, solderability and capacitance shall be checked as specified in Group A and B inspection.

3.5.4 Assessment levels

The assessment level(s) given in the blank detail specification shall preferably be selected from Tables 6a and 6b.

Table 6a – 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 (ppm). The sampling level shall be established by the manufacturer. For the calculation of ppm 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 6b – Periodic test

Inspection subgroup ^c					EZ						
					<i>p</i> ^a	<i>n</i> ^a	<i>c</i> ^a				
C1					3	12	0				
C2					3	12 ^b	0				
C3.1					6	27	0				
C3.2					6	15	0				
C3.3					3	15	0				
C3.4					6	15 ^b	0				
C4					6	9	0				

^a *p* = periodicity in months

n = sample size

c = permissible number of non-conforming items

^b Additional capacitors if Subgroup C3.4 is tested

^c 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 Clause 4 of IEC 60384-1.

4.1 Special preconditioning

Unless otherwise specified in the detail specification, the special pre-conditioning, when specified in this sectional specification before a test or a sequence of test, 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 ± 1) h under standard atmospheric condition for testing.

NOTE 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 state regardless of its previous history. (See Clause B.4 for further information).

4.2 Measuring conditions

See 4.2.1 of IEC 60384-1.

4.3 Mounting

See 4.33 of IEC 60384-1.

4.4 Visual examination and check of dimensions

See 4.4 of IEC 60384-1, with the following details:

4.4.1 Visual examination

A visual examination shall be carried out with suitable equipment with approximately 10× magnification and lighting appropriate to the specimen under test and the quality level required.

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

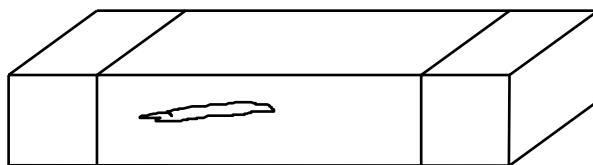
4.4.2 Requirements

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

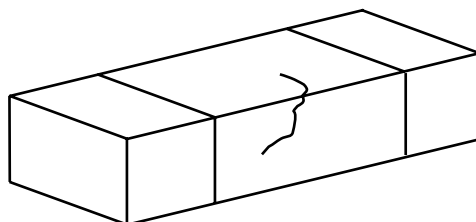
The capacitor shall:

4.4.2.1 For the ceramic:

- 1) Be free of cracks or fissures, except small damages on the surface, which do not deteriorate the performance of the capacitor. (Examples: see Figures 1 and 2).



IEC 753/04

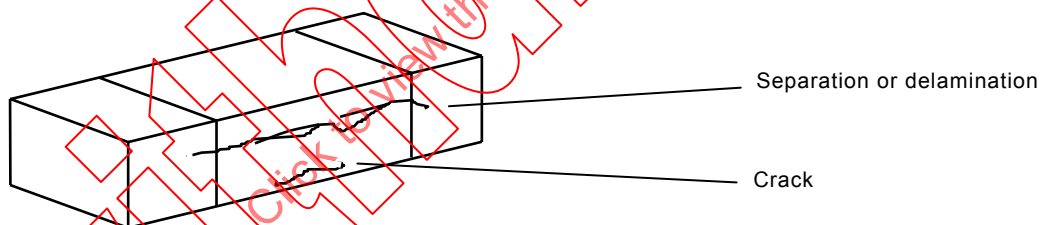
Figure 1 – Fault: crack or fissure

IEC 754/04

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

Figure 2 – Fault: crack or fissure

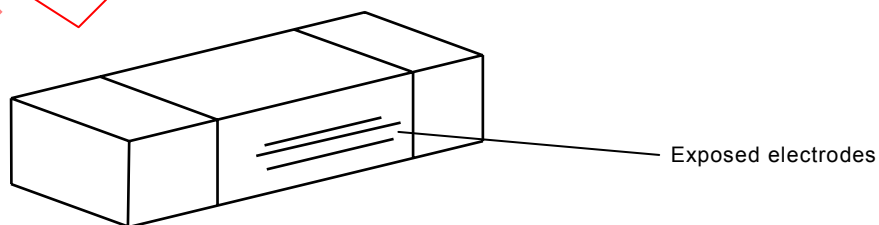
- 2) Not exhibit visible separation or delamination between the layers of the capacitor (see Figure 3).



IEC 755/04

Figure 3 – Separation or delamination

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



IEC 756/04

Figure 4 – Exposed electrodes

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

4.4.2.2 For the metallization

- 1) Not exhibit any visible detachment of the metallized terminations and not exhibit any exposed electrodes (see Figure 4).
- 2) The principal faces (see Figure 5) are those noted A, B and C.

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

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

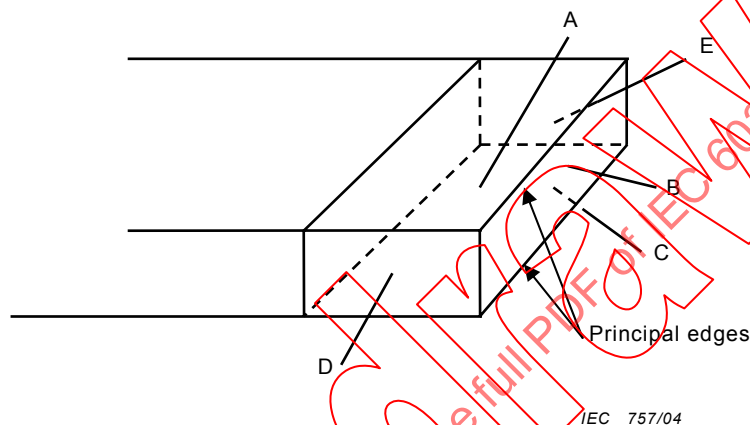


Figure 5 – Principal faces

4.5 Electrical tests

4.5.1 Capacitance

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

4.5.1.1 Measuring conditions

See Table 7, unless otherwise specified in the detail specification.

Table 7 – Measuring conditions

Rated capacitance	Rated voltage (U_R)	Frequency	Measuring voltage (V r.m.s.)	Referee voltage (V r.m.s.)
$C_R \leq 100 \text{ pF}$	a)	1 MHz	$1,0 \pm 0,2$	$1,0 \pm 0,02$
$100 \text{ pF} < C_R \leq 10 \text{ }\mu\text{F}$	$U_R > 6,3 \text{ V}$	1 kHz	$1,0 \pm 0,2$	$1,0 \pm 0,02$
	$U_R \leq 6,3 \text{ V}$	1 kHz	$0,5 \pm 0,2$	$0,5 \pm 0,02$
$C_R > 10 \text{ }\mu\text{F}$	a)	100 Hz or 120 Hz	$0,5 \pm 0,2$	$0,5 \pm 0,02$

a) All rated voltages (U_R).

4.5.1.2 Requirements

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

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

For referee measurements, the capacitance value shall be the value extrapolated to an ageing time of 1 000 h (see Annex B for an explanation).

4.5.2 Tangent of loss angle ($\tan \delta$)

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

4.5.2.1 Measuring conditions

The measuring conditions are the same as 4.5.1. The inaccuracy of the measuring instruments shall not exceed 1×10^{-3} .

4.5.2.2 Requirements

The tangent of loss angle, as measured in the unmounted state, shall not exceed the limit given in Table 8.

Table 8 – Tangent of loss angle limits

Rated voltage U_R	Subclass	Tangent of loss angle %
$U_R \geq 10$ V	All subclass codes	Not exceed 0,035 or value as may be given in the detail specification
$U_R < 10$ V	2B, 2C, 2R	0,1
	2D, 2E	0,15
	2F	0,2
NOTE See 2.2.5 for an explanation of the subclass codes.		

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

4.5.3 Insulation resistance (R_i)

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

4.5.3.1

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

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

4.5.3.2 Measuring conditions

See 4.5.2 of IEC 60384-1, with the following details:

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

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

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

The product of the internal resistance of the voltage source and the 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. For capacitors with rated voltages of 1 kV and above, a lower limit value may be given in the detail specification.

4.5.3.3 Requirements

$C_R \leq 25$ nF	$R_i \geq 4\,000$ M Ω
$C_R > 25$ nF	$R_i \times C_R \geq 100$ s

4.5.4 Voltage proof

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

4.5.4.1 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.

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

4.5.4.2 Test voltages

The test voltages according to Table 9 shall be applied between the measuring points of Table 3 in 4.5.3 of 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

Rated voltage V	Test voltage V
$U_R \leq 100$	$2,5 U_R$
$100 < U_R \leq 200$	$1,5 U_R + 100$
$200 < U_R \leq 500$	$1,3 U_R + 100$
$U_R > 500$	$1,3 U_R$

4.5.4.3 Requirement

There shall be no breakdown or flashover during the test.

4.5.5 Impedance (if required by the detail specification)

See 4.10 of IEC 60384-1, with the following details:

4.5.5.1 Measuring conditions

The frequency of measurement: 100 kHz $\pm$ 10 %.

4.5.5.2 Requirements

Impedance shall be specified in the detail specification.

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

See 4.8.2 of IEC 60384-1, with the following details:

4.5.6.1 Measuring conditions

The frequency of measurement: 100 kHz $\pm$ 10 %.

4.5.6.2 Requirements

The ESR shall be specified in the detail specification.

4.6 Temperature characteristic of capacitance

4.6.1 Special preconditioning

See 4.1.

4.6.2 Measuring conditions

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

The capacitors shall be measured in the unmounted state as well as the conditions of Table 10.

Table 10 – Details of measuring conditions

Temperature °C	Reference within temperature cycle	d.c. voltage applied
20 ± 2	a	-
θ_1 ¹⁾ ± 3	b	-
20 ± 2	d	-
θ_2 ²⁾ ± 2	f	-
θ_2 ± 2	f	×
20 ± 2	g	×
θ_1 ± 3	b	×
20 ± 2	a	-
NOTE 1 "-" indicates: no d.c. voltage applied "×" indicates: d.c. voltage applied (if specified in the detail specification) NOTE 2 Measurements shall be made at such intermediate temperatures as to ensure that the requirements of 2.2.5 are met. NOTE 3 Reference capacitance is the capacitance measured at "d". NOTE 4 Because of the effects described in the Note in 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 a dispute about the 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". 1) θ_1 = Lower category temperature. 2) θ_2 = Upper category temperature.		

4.6.3 Requirements

Temperature characteristic with and without d.c. voltage applied shall not exceed the values given in Table 3.

4.7 Shear test

See 4.34 of IEC 60384-1.

4.8 Substrate bending test

See 4.35 of IEC 60384-1. The deflection *D* and the number of bends shall be specified in the detail specification.

4.8.1 Initial measurement

Capacitance: for reference see Table 5, group 2.

4.8.2 Final inspection

Capacitance (with board in bent position): for reference see Table 5, group 2.

Visual examination: for reference see Table 5, group 2.

4.9 Resistance to soldering heat

See IEC 60068-2-58 with the following details:

4.9.1 Special preconditioning

See 4.1.

4.9.2 Initial measurement

The capacitance shall be measured according to 4.5.1.

4.9.3 Test conditions

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

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

See Clauses 5 and 6 of IEC 60068-2-58, with the following details, if not otherwise specified in the detail specification:

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

Temperature:	260 °C ± 5 °C
Duration of immersion:	10 s ± 1 s
Depth of immersion:	10 mm
Number of immersions:	1

4.9.3.2 Infrared and forced gas convection soldering system

See Clauses 7 and 8 of IEC 60068-2-58, with the following details:

- the solder paste shall be applied to the test substrate;
- the thickness of solder deposit shall be specified in the detail specification;
- the terminations of the specimen shall be placed on the solder paste;
- unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in infrared and forced gas convection soldering systems;
- the temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 5) °C and maintained at this temperature for (10 ± 1) s. Number of tests: 2;
- the temperature profile shall be specified in the detail specification.

4.9.4 Recovery

The capacitors shall recover for 24 h ± 2 h.

The flux residues shall be removed with a suitable solvent.

4.9.5 Final inspection, measurements and requirements

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

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

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

The capacitance shall be measured according to 4.5.1 and the change shall not exceed the values in Table 11:

Table 11 – Maximum capacitance change

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

4.10 Solderability

See IEC 60068-2-58 with the following details:

4.10.1 Test conditions

See Clauses 5 and 6 of IEC 60068-2-58, with the following details:

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

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

See Clauses 5 and 6 of IEC 60068-2-58, with the following details, if not otherwise specified in the detail specification:

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

Temperature: (235 ± 5) °C

Duration of immersion: (2 ± 0,2) s

Depth of immersion: 10 mm

Number of immersions: 1

4.10.1.2 Infrared and forced gas convection soldering system

See Clauses 7 and 8 of IEC 60068-2-58 with the following details:

- the solder paste shall be applied to the test substrate;
- the thickness of solder deposit shall be specified in the detail specification;
- the terminations of the specimen shall be placed on solder paste;
- unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in the infrared and forced gas convection soldering system;
- the temperature of reflow system shall be quickly raised until the specimen has reached (215 ± 3) °C and maintained at this temperature for (10 ± 1) s;
- temperature profile shall be specified in the detail specification.

4.10.2 Recovery

The flux residues shall be removed with a suitable solvent.

4.10.3 Final inspection, measurements and requirements

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

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

The detail specification may prescribe further requirements.

4.11 Rapid change of temperature

(Applicable only to capacitors for which the category temperature is greater 110 °C).

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

The capacitors shall be mounted according to 4.3.

4.11.1 Special preconditioning

See 4.1.

4.11.2 Initial measurement

The capacitance shall be measured according to 4.5.1.

4.11.3 Number of cycles: 5

Duration of exposure at the temperature limits: 30 min.

4.11.4 Recovery: 24 h ± 2 h

4.11.5 Final inspection, measurements and requirements

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

The capacitance shall be measured according to 4.5.1 and the change shall not exceed the values in Table 12.

Table 12 – Maximum capacitance change

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

4.12 Climatic sequence

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

4.12.1 Special preconditioning

See 4.1.

4.12.2 Initial measurement

The capacitance shall be measured according to 4.5.1.

4.12.3 Dry heat

See 4.21.2 of IEC 60384-1.

4.12.4 Damp heat, cyclic, Test Db, first cycle

See 4.21.3 of IEC 60384-1.

4.12.5 Cold

See 4.21.4 of IEC 60384-1, with the following details.

4.12.5.1 Final inspection and requirements

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

4.12.6 Damp heat, cyclic, Test Db, remaining cycles

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

4.12.6.1 Conditions of test

No voltage applied.

Table 13 – Number of damp heat cycles

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

4.12.6.2 Recovery

The capacitors shall recover for (24 ± 2) h.

4.12.7 Final inspection, measurements and requirements

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

The capacitors shall be measured and shall meet the following requirements:

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 14 shall be met.

Table 14 – Final inspection, measurements and requirements

Measurement	Measuring conditions	Requirements			
		Subclasses 2B and 2C	Subclasses 2D and 2R	Subclass 2E	Subclass 2F
Capacitance	4.5.1	$\Delta C/C \leq \pm 10 \%$	$\Delta C/C \leq \pm 15 \%$	$\Delta C/C \leq \pm 20 \%$	$\Delta C/C \leq \pm 30 \%$
Tangent of loss angle	4.5.2	$\leq 2 \times$ value of 4.5.2			
Insulation resistance	4.5.3	$R_i \geq 1\,000\text{ M}\Omega$ or $R_i \times C_R \geq 25\text{ s}$ (whichever is the less)			
NOTE See 2.2.5 for an explanation of the subclass codes.					

4.13 Damp heat, steady state

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

The capacitors shall be mounted according to 4.3.

4.13.1 Special preconditioning

See 4.1.

4.13.2 Initial measurement

The capacitance shall be measured according to 4.5.1.

4.13.3 Conditions of test

No voltage shall be 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.

Within 15 min after removal from the damp heat test, the voltage proof test according to 4.5.4 shall be carried out, but with the rated voltage applied.

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

4.13.4 Recovery

The capacitors shall recover for $24\text{ h} \pm 2\text{ h}$.

4.13.5 Final inspection, measurements and requirements

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

The capacitors shall be measured and shall meet the following requirements:

If the capacitance value is less than the minimum value permitted, then after the other measurements have been made, the capacitors shall be preconditioned according to 4.1 and then the requirement in Table 15 shall be met.