

INTERNATIONAL STANDARD

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QC 300300

Fourth edition
2007-03

Fixed capacitors for use in electronic equipment –

Part 4:

Sectional specification –

**Aluminium electrolytic capacitors with
solid (MnO₂) and non-solid electrolyte**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –**Part 4: Sectional specification –
Aluminium electrolytic capacitors with solid (MnO₂)
and non-solid electrolyte**

FOREWORD

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International Standard IEC 60384-4 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This fourth edition cancels and replaces the third edition published in 1998 and its amendment 1 (2000). This edition constitutes a minor revision related to tables, figures and references.

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

CDV	Report on voting
40/1759/CDV	40/1819/RVC

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

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

The committee has decided that the contents of this 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- withdrawn,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.

The contents of the corrigendum of June 2007 have been included in this copy.

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 4: Sectional specification – Aluminium electrolytic capacitors with solid (MnO₂) and non-solid electrolyte

1 General

1.1 Scope

This part of IEC 60384 applies to aluminium electrolytic capacitors with solid (MnO₂) and non-solid electrolyte primarily intended for d.c. applications for use in electronic equipment. It covers capacitors for long-life applications and capacitors for general-purpose applications.

Capacitors for special-purpose applications may need additional requirements.

Capacitors for fixed surface mount aluminium electrolytic capacitors are not included but they are covered by IEC 60384-18.

1.2 Object

The principal object of this standard is to prescribe preferred ratings and characteristics and to select from IEC 60384-1 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, *Preferred number series for resistors and capacitors*

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

IEC 60068-2-17, *Environmental testing – Part 2-17: Tests – Test Q: Sealing*

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

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

IEC 60384-4-1, *Fixed capacitors for use in electronic equipment – Part 4-1: Blank detail specification – Fixed aluminium electrolyte capacitors with non-solid electrolyte – Assessment level EZ*

IEC 60384-4-2, *Fixed capacitors for use in electronic equipment – Part 4-2: Blank detail specification – Fixed aluminium electrolyte capacitors with solid (MnO₂) electrolyte – Assessment level EZ*

ISO 3, *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 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 millimeters; 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 capacitor. 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 2.2.1.

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 test.

1.4.4 Marking

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

1.5 Terms and definitions

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

1.5.1

capacitance of an electrolytic capacitor

capacitance of an equivalent circuit having capacitance and resistance in series measured with alternating current approximately sinusoidal waveform at a specified frequency

1.5.2

long-life grade capacitors

capacitors intended for applications where a high degree of stability of characteristics over a long life is essential. The materials are chosen and the manufacture carried out so that improved performance is obtained with consequent increase in life

1.5.3

general-purpose grade capacitors

capacitors intended for applications where the high performance level of long-life grade capacitors is not required

1.5.4

reverse voltage (for polar capacitors only)

voltage applied to the capacitor terminals in the reverse polarity direction

1.6 Marking

According to 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: --- or —);
- c) category voltage and category temperatures (for long-life grade capacitors only);
- d) polarity of the terminations: for multi-section capacitors, the rated capacitance and rated voltage of the sections connected to each termination shall be shown in an unambiguous way. The termination of a capacitor section which is intended for direct connection to the rectifier (so-called reservoir section) shall be marked with the number 1 or with the colour red;
- e) tolerance on rated capacitance;

- f) reference to the grade (for long-life grade capacitors only). The abbreviation LL may be used for marking purposes;
- g) year and month (or week) of manufacture;
- h) manufacturer's name or trade mark;
- i) climatic category;
- j) manufacturer's type designation;
- k) reference to the detail specification.

1.6.2 The capacitor shall be clearly marked with a), b), c), d), e) and f) above 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.

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

1.6.4 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 temperature 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:	+85 °C, +100 °C, +105 °C and +125 °C
Duration of the damp-heat steady-state test:	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 capacitance (C_R)

Preferred values of rated capacitance are chosen from the E3 series of IEC 60063 and their decimal multiples.

If other values are needed, they shall preferably be chosen from the E6 series.

2.2.2 Tolerance on rated capacitance

Preferred values of tolerances on rated capacitance are:

–10/+10 %	–10/+75 %
–10/+30 %	–10/+100 %
–10/+50 %	–20/+20 %

2.2.3 Rated voltage (U_R)

Preferred values of rated direct voltages taken from the R5 and R10 series of ISO 3 are:

For voltage values <250 V: 1 V, 1,6 V, 2,5 V, 4 V, 6,3 V and their decimal multiples (R5 series), also 35 V, 50 V, 80 V and 200 V;

For voltage values ≥250 V: 250 V, 315 V, 350 V, 400 V, 450 V and 500 V (250 V, 315 V, 400 V and 500 V are in accordance with the R10 series; 350 V and 450 V are permitted in addition).

2.2.4 Category voltage (U_C)

The category voltage is equal to the rated voltage, unless otherwise stated in the detail specification.

2.2.5 Ripple voltage

An alternating voltage may be applied provided that the peak voltage resulting from the alternating voltage superimposed on the direct voltage does not exceed the value of rated direct voltage and that the rated ripple current (see 2.2.8) and the permissible reverse voltage (see detail specification) are not exceeded.

2.2.6 Reverse voltage

The permissible reverse voltage shall be given in the detail specification.

2.2.7 Surge voltage ratio

The surge voltage shall be 1,15 times the rated or category voltage for rated voltages ≤315 V or 1,10 times the rated or category voltage for rated voltages >315 V.

See also 4.14.

2.2.8 Rated ripple current

The rated ripple current at 100 Hz or 120 Hz and at upper category temperature shall be given in the detail specification. Alternatively, for capacitors for switched mode power supply application, the rated ripple current shall be stated at the relevant frequency.

NOTE This value is determined by the dimensions of the capacitor and several other factors, for example, the tangent of loss angle and the permissible temperature rise.

See also 2.2.5.

3 Quality assessment procedures

3.1 Primary stage of manufacture

For capacitors with solid electrolyte, the primary stage of manufacture is the etching or formation of the anode body.

For capacitors with non-solid electrolyte, the primary stage of manufacture is the capacitor manufacturer's evaluation of the formed anode foil.

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 3.9 of IEC 60384-1 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 leakage current.

3.4 Qualification approval procedures

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

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

Sampling

The fixed sample size procedure is described in 3.5.3b) 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.

The sample shall consist of specimens having the lowest and highest voltages and, for these voltages, the smallest and largest case size. When the range of rated voltages exceeds 200 V, an intermediate voltage shall also be tested. In each of these case size/voltage combinations (values), the highest capacitance shall be chosen. Thus, for the approval of a range, testing is required of either four or six values. When the range consists of less than four values, the number of specimens to be tested shall be that required for four values.

Spare specimens are permitted as follows.

- a) One per value which may be used to replace the permitted defective in Group 0.
- b) One per value which may be used as replacements for specimens which are defective 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 1 gives the number of samples to be tested in each group or subgroup together with the permissible number of nonconforming items for qualification approval tests.

3.4.2 Tests

The complete series of tests specified in Tables 1 and 2 are required for the approval of capacitors covered by one detail specification. The tests of each group shall be carried out in the order given.

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

Specimens found to be a nonconforming item during the tests of Group 0 shall not be used for the other groups.

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

Approval is granted when the number of nonconforming items does not exceed the specified number of permissible nonconforming items for each group or subgroup and the total number of permissible nonconforming items.

NOTE Tables 1 and 2 together form the fixed sample size test schedule, for which Table 1 includes the details for the sampling and permissible nonconforming items for the different tests or groups of tests, whereas Table 2 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 should be made in the detail specification.

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

Table 1 – 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 nonconforming items c
0	High surge current ^a Visual examination Dimensions Leakage current Capacitance Tangent of loss angle Impedance ^b Spare specimens	4.21 4.2 4.2 4.3.1 4.3.2 4.3.3 4.3.4	120 + 12 ^f + 12 ^g 12	0
1A	Robustness of terminations Resistance to soldering heat ^c	4.4 4.5	12 12	0
1B	Solderability ^c Rapid change of temperature Vibration Bump or shock ^b	4.6 4.7 4.8 4.9 or 4.10	12	0
1	Climatic sequence	4.11	24	0
2	Damp heat, steady state	4.12	12	0
3	Endurance	4.13	36	0
4A	Surge voltage	4.14	12	0
4B	Reverse voltage ^b Pressure relief ^b	4.15 4.16	12 ^f	0
5A	Storage at high temperature Voltage transient overload ^d	4.17 4.22	12	0
5B	Storage at low temperature ^b	4.18	12 ^g	0
6	Characteristics at high and low temperature Charge and discharge ^b	4.19 4.20	12	0
^a For solid electrolyte capacitors only and if required in the detail specification. ^b If required in the detail specification. ^c Not applicable to capacitors with screw terminations or other terminations, not designed to be soldered, as stated in the detail specifications. ^d For non-solid electrolyte capacitors only and if required in the detail specification. ^e For case size/voltage combinations, see 3.4.1. ^f Additional capacitors if Group No. 4B is tested. ^g Additional capacitors if Group No. 5B is tested.				

Table 2 – Test schedule for qualification approval

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 0 4.2.1 High surge current ^c 4.2 Visual examination 4.2 Dimensions (detail) 4.3.1 Leakage current 4.3.2 Capacitance 4.3.3 Tangent of loss angle 4.3.4 Impedance (if applicable)	ND	Protective resistance: ... Ω Frequency:... Hz Frequency:... Hz Frequency:... Hz	See Table 1	No visible damage Legible marking and as specified in the detail specification See detail specification As in 4.3.1.2 Within specified tolerance As in 4.3.3.2 Within limits specified in the detail specification
Group 1A 4.4.1 Initial measurement 4.4 Robustness of terminations 4.5 Resistance to soldering heat ^d 4.5.2 Final measurements	D	Capacitance Method and severity as prescribed in the detail specification Visual examination No pre-drying See detail specification for the method (1A or 1B) Visual examination Capacitance	See Table 1	No visible damage No visible damage Legible marking $\Delta C/C \leq 5\%$ of value measured in 4.4.1
Group 1B 4.6 Solderability ^d	D	See detail specification for the method	See Table 1	Good tinning as evidenced by free flowing of the solder with wetting of the terminations or meet the required parameter(s) in the detail specification as applicable
^a Subclause numbers of test and performance requirements refer to Clause 4. ^b In this table, D = destructive, ND = non-destructive. ^c For solid electrolyte capacitors only and if prescribed by the detail specification. ^d Not applicable to capacitors with screw terminations or other terminations, not designed to be soldered, as stated in the detail specification.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 1B (continued)			See Table 1	
4.7 Rapid change of temperature		T_A = Lower category temperature T_B = Upper category temperature Five cycles Duration t_1 =... min Recovery: 16 h		
4.7.1 Initial measurement	D	Capacitance		No visible damage
4.7.3 Final measurements		Solid electrolyte: Visual examination Leakage current Tangent of loss angle Impedance (if required) Non-solid electrolyte: Visual examination		As in 4.3.1 As in 4.3.3 As specified in the detail specification No leakage of electrolyte or other visible damage
4.8 Vibration		For mounting method, see detail specification Frequency range: from... Hz to... Hz Amplitude:... mm or acceleration 100 m/s ² (whichever is the less severe) Total duration:... h		
4.8.2 Final measurements		Visual examination Capacitance		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte Legible marking $\Delta C/C \leq 5$ % of value measured in 4.7.1, unless otherwise prescribed in the detail specification
4.9 Bump (or shock, see 4.10)		For mounting method, see detail specification Number of bumps:... Acceleration: 400 m/s ² Duration of pulse: 6 ms		
^a Subclause numbers of test and performance requirements refer to Clause 4.				
^b In this table, D = destructive, ND = non-destructive.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 1B (continued)			See Table 1	
4.10 Shock (or bump, see 4.9)		For mounting method, see detail specification Acceleration: ... m/s ² Duration of pulse: ... ms		
4.9.2 or 4.10.2 Final measurements		Visual examination Capacitance		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte $\Delta C/C \leq 5\%$ of values measured in 4.3.2, unless otherwise specified in the detail specification
Group 1	D		See Table 1	
4.11 Climatic sequence				
4.11.1 Dry heat		Temperature: upper category temperature Duration: 16 h		
4.11.2 Damp heat, cyclic, Test Db, first cycle				
4.11.3 Cold	D	Temperature: lower category temperature Duration: 2 h		
4.11.4 Low air pressure (if required by the detail specification)		Air pressure: 8 kPa		
4.11.4.3 Intermediate measurement		Visual examination		No breakdown, flashover or harmful deformation of the case
4.11.5 Damp heat, cyclic, Test Db, remaining cycles				
4.11.6 Sealing (if required by the detail specification)		Method: ...		
4.11.7 Final measurements		Visual examination		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte Legible marking
^a Subclause numbers of test and performance requirements refer to Clause 4.				
^b In this table, D = destructive, ND = non-destructive.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 1 (continued) 4.11.7 (continued)	D	Leakage current Capacitance Tangent of loss angle	See Table 1	As in 4.3.1 $\Delta C/C$ for: Solid electrolyte: Long-life grade: $\leq 5\%$ General-purpose grade: $\leq 10\%$ Non-solid electrolyte: $\leq 10\%$ of value measured in 4.5.2, 4.9.2 or 4.10.2 as applicable $\leq 1,2$ times limit of 4.3.3
Group 2 4.12 Damp heat, steady state 4.12.1 Initial measurement 4.12.2 Final measurements	D	Capacitance Visual examination Leakage current Capacitance Tangent of loss angle Impedance Insulation resistance of the external insulation (if applicable) Voltage proof of the external insulation (if applicable)	See Table 1	No visible damage, and for non-solid electrolyte capacitor, no leakage of electrolyte Legible marking As in 4.3.1 $\Delta C/C$ for: Solid electrolyte: Long-life grade: $\leq 5\%$ General-purpose grade: $\leq 10\%$ Non-solid electrolyte: Long-life grade: $\leq 10\%$ General-purpose grade: $\leq 20\%$ of value measured in 4.12.1 $\leq 1,2$ times limit in 4.3.3 $\leq 1,2$ times the limit in the detail specification $\geq 100\text{ M}\Omega$ No breakdown or flashover

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

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

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (n) and number of permissible nonconforming items (c)	Performance requirements ^a								
Group 3	D		See Table 1									
4.13 Endurance		Duration: Long-life grade :: ... h General-purpose grade :: ... h Temperature: upper category temperature Applied voltage:... V Recovery: 16 h min.										
4.13.1 Initial measurement		Capacitance										
4.13.3 Final measurements		Solid electrolyte capacitors Visual examination Leakage current Capacitance Tangent of loss angle Impedance Insulation resistance of the external insulation (if applicable) Voltage proof of the external insulation (if applicable) Non-solid electrolyte capacitors Visual examination Leakage current Capacitance		No visible damage Legible marking As in 4.3.1 $\Delta C/C \leq 10\%$ of value measured in 4.13.1 $\leq 1,2$ times the limit specified in 4.3.3 $\leq 1,2$ times the limit in the detail specification $\geq 100\text{ M}\Omega$ No breakdown or flashover No leakage of electrolyte or other visible damage Legible marking As in 4.3.1 $\Delta C/C$ compared to values measured in 4.13.1: Long-life grade:								
				<table><tr><th>Rated voltage (V)</th><th>$\Delta C/C$ (%)</th></tr><tr><td>$U_R \leq 6,3$</td><td>+15 to –30</td></tr><tr><td>$6,3 < U_R \leq 160$</td><td>± 20</td></tr><tr><td>$160 < U_R$</td><td>± 15</td></tr></table>	Rated voltage (V)	$\Delta C/C$ (%)	$U_R \leq 6,3$	+15 to –30	$6,3 < U_R \leq 160$	± 20	$160 < U_R$	± 15
Rated voltage (V)	$\Delta C/C$ (%)											
$U_R \leq 6,3$	+15 to –30											
$6,3 < U_R \leq 160$	± 20											
$160 < U_R$	± 15											

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

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

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (n) and number of permissible nonconforming items (c)	Performance requirements ^a
Group 3 (continued) 4.13.3 (continued)		Capacitance <		

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 4B	D		See Table 1	
4.15 Reverse voltage (if required)		Duration: 125 h at upper category temperature with a) <i>for solid electrolyte capacitors</i> : a direct voltage of 0,15 U_C in reverse polarity direction or b) <i>for non-solid electrolyte capacitors</i> : voltage 1 V d.c. in reverse polarity direction, unless otherwise specified in the detail specification, followed by 125 h at upper category temperature with category voltage in forward polarity direction		
4.15.1 Initial measurement		Capacitance		
4.15.3 Final measurements		Leakage current Capacitance		As in 4.3.1 $\Delta C/C$ for Solid electrolyte : $\leq 10\%$ Non-solid electrolyte : See detail specification, of value measured in 4.15.1
4.16 Pressure relief (if required)		Tangent of loss angle Test method:...		As in 4.3.3 Device shall open without danger of explosion or fire
Group 5A	ND		See Table 1	
4.17 Storage at high temperature		Temperature: upper category temperature Duration: 96 h $\pm$ 4 h Recovery: 16 h min.		
4.17.1 Initial measurement		Capacitance		
4.17.3 Final measurements		Visual examination Leakage current		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte Solid electrolyte capacitors : As in 4.3.1 Non-solid electrolyte capacitors : ≤ 2 times the limit of 4.4.1
^a Subclause numbers of test and performance requirements refer to Clause 4.				
^b In this table, D = destructive, ND = non-destructive.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 5A (continued)			See Table 1	
4.17.3 (continued)		Capacitance		$\Delta C/C$ for: Solid electrolyte: $\leq 5\%$ Non-solid electrolyte: $\leq 10\%$ of value measured in 4.17.1
		Tangent of loss angle		Solid electrolyte: As in 4.3.3 Non-solid electrolyte: $\leq 1,2$ times the limit of 4.3.3
4.22 Voltage transient overload ^d		Items in 4.40 of IEC 60384-1 to be specified by the detail specification		
4.22.1 Initial measurement		Capacitance		
4.22.2 Final measurements		Visual examination		See detail specification
		Capacitance		See detail specification
		Leakage current		See detail specification
		Tangent of loss angle		See detail specification
		Other parameters		See detail specification
Group 5B^c	ND		See Table 1	
4.18 Storage at low temperature (for non-solid electrolyte capacitors only)		Duration: 16 h or 4 h after thermal stability has been reached (whichever is the shorter) Temperature: $-40\text{ }^{\circ}\text{C}$ Recovery: 16 h min.		
4.18.1 Initial measurement		Capacitance		
4.18.2 Final measurements		Visual examination		No visible damage and no leakage of electrolyte Legible marking
		Leakage current		As in 4.3.1
		Capacitance		$\Delta C/C \leq 10\%$ of value measured in 4.18.1
		Tangent of loss angle		As in 4.3.3
^a Subclause numbers of test and performance requirements refer to Clause 4.				
^b In this table, D = destructive, ND = non-destructive.				
^c Group 5B is only applicable to capacitors with a lower category temperature of $-25\text{ }^{\circ}\text{C}$ and $-10\text{ }^{\circ}\text{C}$.				
^d For non-solid electrolyte capacitors only and if required in the detail specification.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (<i>n</i>) and number of permissible nonconforming items (<i>c</i>)	Performance requirements ^a
Group 6 4.19 Characteristics at high and low temperature	D	The capacitors shall be measured at each temperature step Solid electrolyte capacitors: Step 1: 20 °C Capacitance^c Impedance (at the same frequency as Step 2) Tangent of loss angle^c Step 2: Lower category temperature Capacitance^c Impedance Tangent of loss angle^c Step 3: Upper category temperature Leakage current Capacitance^c Tangent of loss angle^c Non-solid electrolyte capacitors: Step 1: 20 °C Capacitance^c Tangent of loss angle^c Impedance (at same frequency as Step 2) Step 2: Lower category temperature	See Table 1	For use as reference value For use as reference value $\Delta C/C \leq 20$ % of value measured in Step 1 Ratio with respect to value in Step 1: ≤ 2 times ≤ 2 times the limit of 4.3.3. At 125 °C (with U_R): ≤ 15 times the limit of 4.3.1 At 125 °C (with U_C): ≤ 8 times the limit of 4.3.1 At 105 °C (with U_R): $\leq 12,5$ times the limit of 4.3.1 At 85 °C (with U_R): ≤ 10 times the limit of 4.3.1 $\Delta C/C \leq 20$ % of value measured in Step 1 $\leq$ limit of 4.3.3 For use as reference value For use as reference value
^a Subclause numbers of test and performance requirements refer to Clause 4. ^b In this table, D = destructive, ND = non-destructive. ^c If applicable.				

Table 2 (continued)

Subclause number and test ^a	D or ND ^b	Conditions of test ^a	Number of specimens (n) and number of permissible nonconforming items (c)	Performance requirements ^a										
Group 6 (continued)	D		See Table 1											
4.19 (continued)		Impedance		Ratio with respect to the value in Step 1										
				<table><tr><th>Rated voltage V</th><th>Ratio of impedance</th></tr><tr><td>$U_R \leq 6,3$</td><td>≤ 10</td></tr><tr><td>$6,3 < U_R \leq 16$</td><td>≤ 8</td></tr><tr><td>$16 < U_R \leq 160$</td><td>≤ 6</td></tr><tr><td>$160 < U_R$</td><td>≤ 10</td></tr></table>	Rated voltage V	Ratio of impedance	$U_R \leq 6,3$	≤ 10	$6,3 < U_R \leq 16$	≤ 8	$16 < U_R \leq 160$	≤ 6	$160 < U_R$	≤ 10
Rated voltage V	Ratio of impedance													
$U_R \leq 6,3$	≤ 10													
$6,3 < U_R \leq 16$	≤ 8													
$16 < U_R \leq 160$	≤ 6													
$160 < U_R$	≤ 10													
		Step 3: Upper category temperature												
		Leakage current		At 125 °C: ≤ 10 times the limit of 4.3.1 At 105 °C: ≤ 8 times the limit of 4.3.1 At 100 °C: ≤ 8 times the limit of 4.3.1 At 85 °C: ≤ 5 times the limit of 4.3.1										
		Capacitance ^c		See detail specification										
		Tangent of loss angle ^c		See detail specification										
4.20 Charge and discharge (if required)		Temperature: 20 °C												
		Number of cycles:												
		$U_R \leq 160$ V: 10^6												
		$U_R > 160$ V: under consideration												
		Duration of charge: 0,5 s												
		Duration of discharge: 0,5 s												
4.20.1 Initial measurement		Capacitance												
4.20.3 Final measurements		Visual examination		No visible damage and for non-solid electrolyte capacitors no leakage of electrolyte										
		Capacitance		$\Delta C/C$ for: Solid electrolyte: ≤ 5 % Non-solid electrolyte: ≤ 10 % of value measured in 4.20.1										

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

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

^c If applicable.

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) The sample tested shall be representative of the values and dimensions contained in the inspection lot:
 - in relation to their number;
 - with a minimum of five of any one value.
- 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-voltage ratings. In order to cover the range of approvals in any period one case size shall be tested from each voltage group. In subsequent periods, other case sizes and/or voltage ratings 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 4 of the blank detail specification, IEC 60384-4-1 or IEC 60384-4-2, as applicable.

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 3 and 4.

Table 3 – Lot-by-lot inspection

Inspection subgroup ^a	DZ ^b			EZ			FZ ^b			GZ ^b		
	IL ^c	n ^c	c ^c	IL ^c	n ^c	c ^c	IL ^c	n ^c	c ^c	IL ^c	n ^c	c ^c
A0				100 % ^d								
A1				S-3	e	0						
A2				S-3	e	0						
B1				S-3	e	0						
B2				S-3	e	0						

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

^b Assessment levels DZ, FZ and GZ are under consideration.

^c IL = inspection level

n = sample size

c = permissible number of nonconforming items

^d 100 % testing shall be followed by re-inspection by sampling in order to monitor outgoing quality level by nonconforming 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 nonconforming item. In case one or more nonconforming items occur in a sample, this lot shall be rejected.

^e Number to be tested: sample size as directly allotted to the code letter for IL in Table 2A of IEC 60410.

Table 4 – Periodic inspection

Inspection subgroup ^a	DZ ^b			EZ			FZ ^b			GZ ^b		
	p ^c	n ^c	c ^c	p ^c	n ^c	c ^c	p ^c	n ^c	c ^c	p ^c	n ^c	c ^c
C1A				6	9	0						
C1B				6	18	0						
C1				6	27	0						
C2				6	9	0						
C3				3	21	0						
C4A				12	6	0						
C4B				12	6	0						
C5A				6	12	0						
C5B				12	6	0						
C6				6	15	0						

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

^b Assessment levels DZ, FZ and GZ are under consideration.

^c p = periodicity in months

n = sample size

c = permissible number of nonconforming items

4 Test and measurement procedures

4.1 Pre-conditioning (for non-solid electrolyte capacitors only)

Before starting the test programme, all capacitors shall be pre-conditioned by the application of the rated voltage from a direct voltage source having a low internal resistance, such as a regulated power supply. The voltage shall be applied to the capacitor through a resistor the value of which shall be approximately 100 Ω for rated voltages up to and including 100 V, and approximately 1 000 Ω for rated voltages above 100 V.

The voltage shall be maintained for 1 h after its value across the capacitor has become equal to the rated voltage with a tolerance of $\pm 3\%$. After this pre-conditioning, the capacitors shall be discharged through a resistor of approximately 1 Ω per applied volt.

The tests in 3.4.2 shall be made after the capacitors have been stored for a period of 12 h to 48 h during which no voltage shall be applied. No further pre-conditioning as described above shall be applied during the test programme.

4.2 Visual examination and check of dimensions

See 4.4 of IEC 60384-1.

4.3 Electrical tests

4.3.1 Leakage current

According to 4.9 of IEC 60384-1, with the following details:

4.3.1.1 Measuring conditions

The rated voltage shall be applied across the capacitor and its protective resistor. Unless otherwise stated in the detail specification, the protective resistor shall be approximately 100 Ω for rated voltages ≤ 100 V and approximately 1 000 Ω for rated voltages > 100 V.

4.3.1.2 Requirements

- a) For non-solid electrolyte capacitors, the leakage current shall not exceed the values given in Table 5.

Table 5 – Leakage current requirements

<i>CU</i> product μC	Leakage current μA	
	Long-life grade capacitors	General-purpose grade capacitors
$\leq 1\ 000$	0,01 <i>CU</i> or 1 μA (whichever is the greater)	0,05 <i>CU</i> or 5 μA (whichever is the greater)
$> 1\ 000$	0,006 <i>CU</i> + 4 μA	0,03 <i>CU</i> + 20 μA

C = rated capacitance in microfarads; *U* = rated voltage in volts

- b) For solid electrolyte capacitors, the leakage current shall not exceed:

for long-life grade capacitors: $\leq 0,1\ CU$

for general-purpose grade capacitors: $\leq 0,15\ CU$

4.3.2 Capacitance

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

4.3.2.1 Measuring conditions

Measuring voltage: max. 0,5 V r.m.s. or such lower voltage as is required, in order not to exceed the rated ripple current.

A d.c. bias voltage of 1,1 V to 1,5 V for types with a rated voltage of $\leq 2,5$ V, 2,1 V to 2,5 V for types with a rated voltage of $> 2,5$ V may be applied during the measurement.

The frequency of the measuring voltage shall be 100 Hz or 120 Hz.

A different frequency may be applied provided that the measured capacitance is corrected to a value of 100 Hz or 120 Hz. The detail specification shall state the frequency to be applied.

4.3.2.2 Requirement

The capacitance shall be within the rated tolerance.

4.3.3 Tangent of loss angle ($\tan \delta$) or equivalent series resistance (ESR)

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

4.3.3.1 Measuring conditions

The measurement shall be under the conditions of 4.3.2.1. The inaccuracy of the measuring equipment shall not exceed 0,01 absolute value.

4.3.3.2 Requirements

The limits for tangent of loss angle or for the equivalent series resistance ESR shall be specified in the detail specification.

4.3.4 Impedance

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

4.3.4.1 Initial measurement

The frequency of the measuring voltage shall be chosen from one of the following frequencies: 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz, and shall be that at which the lowest value of impedance is likely to occur. The tolerance on all frequencies for measuring purposes shall not exceed ± 20 %. The value of the measuring frequency shall be prescribed in the detail specification.

4.3.4.2 Measuring conditions

The voltage used for the measurement shall be as small as practicable and shall be applied for a time short enough to avoid undue heating of the capacitor.

To demonstrate that the voltage is sufficiently small, it shall be applied to one of the capacitors in each sample for 1 min during which time there shall be no readable change in the impedance of the capacitor.

The error of measurement shall not exceed 5 % of the requirement of 0,02 Ω , whichever is the greater.

4.3.4.3 Measurement at lower category temperature

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

4.3.4.4 Requirements

The impedance shall meet the requirements of the detail specification.

4.3.5 Insulation resistance of the external insulation (if applicable)

According to 4.5 of IEC 60384-1, with the following details.

4.3.5.1 Measuring conditions

A metal foil shall be wrapped closely around the full length of the body of the capacitor, protruding by at least 5 mm from each end, provided a distance of not less than 0,5 mm can be maintained between the metal foil and the terminations. The ends of the foil shall not be folded over the ends of the capacitor. If the 0,5 mm distance cannot be maintained, the protrusion of the foil shall be reduced as may be necessary to establish the 0,5 mm distance.

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

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

4.3.5.2 Requirement

The insulation resistance shall be not less than 100 M Ω .

4.3.6 Voltage proof of the external insulation (if applicable)

According to 4.6 of IEC 60384-1, with the following details.

4.3.6.1 Measuring conditions

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

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

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

The voltage of 1 000 V shall be applied for 1 min $\pm$ 5 s.

4.3.6.2 Requirement

There shall be no breakdown or flashover during the test.

4.4 Robustness of terminations

According to 4.13 of IEC 60384-1, with the following details.

The detail specification shall specify the test method and degree of severity to be used.

Torque for nominal thread diameter of 8 mm:

Severity 1: 5 Nm

Severity 2: 2,5 Nm

4.4.1 Initial measurement

The capacitance shall be measured according to 4.3.2.

4.5 Resistance to soldering heat

(Not applicable to capacitors with screw terminations or other terminations not designed to be soldered, as stated in the detail specification.)

According to 4.14 of IEC 60384-1, with the following details:

4.5.1 Conditions

No pre-drying.

4.5.2 Final inspection, measurements and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in Table 2.

4.6 Solderability

(Not applicable to capacitors with screw terminations or other terminations not designed to be soldered, as stated in the detail specification.)

According to 4.15 of IEC 60384-1, with the following details:

Temperature of the solder bath:

235 °C ± 5 °C for Sn-Pb solder

245 °C ± 5 °C for Sn-Ag-Cu solder

250 °C ± 5 °C for Sn-Cu solder

When the solder bath method is not appropriate, the soldering iron shall be used with soldering iron Size A.

When the wetting balance method is appropriate, the detail specification may refer to IEC 60068-2-54.

4.6.1 The requirement is given in Table 2.

4.7 Rapid change of temperature

According to 4.16 of IEC 60384-1, with the following details.

4.7.1 Initial measurement

The capacitance shall be measured according to 4.3.2.

4.7.2 Conditioning

The capacitors shall be subjected to test Na for 5 cycles. The duration t_1 of the exposure at each temperature limit shall be 30 min or 3 h as specified in the detail specification. The recovery period shall be 16 h.

4.7.3 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined and measured and shall meet the requirements given in Table 2.

4.8 Vibration

According to 4.17 of IEC 60384-1, with the following details:

4.8.1 Test Fc shall be applied with one of the following severities as prescribed by the detail specification.

Table 6 – Amplitude and acceleration options

Frequency Hz	Amplitude or acceleration (whichever is the lower acceleration)	Duration h
10-55	0,35 mm or 50 m/s ²	3 × 0,5
10-55	0,75 mm or 100 m/s ²	3 × 2
10-500	0,75 mm or 100 m/s ²	3 × 2
10-2 000	0,75 mm or 100 m/s ²	3 × 2

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.

4.8.2 Final inspection, measurements and requirements

The capacitors shall be visually examined and measured and shall meet the requirements given in Table 2.

4.9 Bump

According to 4.18 of IEC 60384-1, with the following details:

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

4.9.1 Total number of bumps: 1 000 for general-purpose grade capacitors
4 000 for long-life grade capacitors