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Edition 2.0 2015-10
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Fixed electric double-layer capacitors for use in electric and electronic equipment –
Part 1: Generic specification

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIXED ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN ELECTRIC AND ELECTRONIC EQUIPMENT –

Part 1: Generic specification

FOREWORD

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International Standard IEC 62391-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This second edition cancels and replaces the first edition published in 2006 and constitutes a technical revision.

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

a) enhancement of the scope to include electric (high power) application;
b) implementation of Annex Q, replacing Clause 3 in the first edition;
c) in addition, minor revisions related to tables, figures and references.

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

FDIS	Report on voting
40/2393/FDIS	40/2415/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.

A list of all parts of IEC 62391 under the general title *Fixed electric double-layer capacitors for use in electric and electronic equipment* can be found in the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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- withdrawn,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.

The contents of the corrigenda of December 2016 and June 2019 have been included in this copy.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

FIXED ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN ELECTRIC AND ELECTRONIC EQUIPMENT –

Part 1: Generic specification

~~1 General~~

1 Scope

This part of IEC 62391 applies to fixed electric double-layer capacitors (hereafter referred to as capacitor(s)) mainly used in d.c. circuits of electric and electronic equipment.

This part of IEC 62391 establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications of electronic components for quality assessment or any other purpose.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050 (all parts), *International Electrotechnical Vocabulary*

IEC 60062, *Marking codes for resistors and capacitors*

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

IEC 60068-1:~~1988~~ 2013, *Environmental testing – Part 1: General and guidance*
~~Amendment 1 (1992)~~

IEC 60068-2-1:~~1990~~ 2007, *Environmental testing – Part 2-1: Tests – Tests A: Cold*
~~Amendment 1 (1993)~~
~~Amendment 2 (1994)~~

IEC 60068-2-2:~~1974~~ 2007, *Environmental testing – Part 2-2: Tests – Tests B: Dry Heat*
~~Amendment 1 (1993)~~
~~Amendment 2 (1994)~~

IEC 60068-2-6:~~1995~~ 2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14:~~1984~~ 2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*
~~Amendment 1 (1986)~~

IEC 60068-2-20:~~1979~~ 2008, *Environmental testing – Part 2-20: Tests – Test T: ~~Soldering~~ Test methods for solderability and resistance to soldering heat of devices of with leads*
~~Amendment 2 (1987)~~

IEC 60068-2-21:~~1999~~ 2006, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-45:1980, *Environmental testing – Part 2-45: Tests – Test XA and guidance: Immersion in cleaning solvents*
Amendment 1:1993

~~IEC 60068-2-47:1999, *Environmental testing – Part 2-47: Test methods – Mounting of components, equipment and other articles for vibration, impact and similar dynamic tests*~~

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

IEC 60068-2-58:~~2004~~ 2015, *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 60068-2-69:2007, *Environmental testing – Part 2-69: Tests – Test Te: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method*

IEC 60068-2-78:~~2001~~ 2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60294:~~1969~~ 2012, *Measurement of the dimensions of a cylindrical component* ~~*having two*~~ *with axial terminations*

IEC 60617 (all parts) ~~[DB][1]~~, *Graphical symbols for diagrams*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60717:~~1981~~ 2012, *Method for the determination of the space required by capacitors and resistors with unidirectional terminations*

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

~~IEC 61760-1:1998, *Surface mounting technology – Part 1: Standard method for the specification of surface mounting components (SMDs)*~~

~~QC001002-3, *Rules of procedure – Part 3: Approval procedures*~~

~~ISO 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units*~~

~~[1] DB" refers to the IEC on-line database.~~

3 Terms and definitions

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

3.1
type
group of components having similar design features and ~~the similarity of whose~~ manufacturing techniques, ~~enables~~ enabling them to be ~~grouped~~ considered together, either for qualification approval or for quality conformance inspection~~; they are generally covered by a single detail specification~~

Note 1 to entry: In some cases, components described in several detail specifications may be considered as belonging to the same type.

[SOURCE: IEC 60384-1:2008, 2.2.39 – modified, the remark on "single detail specification" was deleted from the definition and the Note was rephrased.]

3.2
style
subdivision of a type, generally based on dimensional factors

Note 1 to entry: A style may include several variants, generally of a mechanical order.

~~**2.2.3**~~
~~**grade**~~
~~term to indicate an additional general characteristic concerning the intended application of the component which may only be used in combination with one or more words (e.g. long life grade) and not by a single letter or number~~

3.3
class
classification of the capacitor by the capacitance value and the internal resistance value depending upon the application

3.4
family
<electronic components> group of components which predominantly displays a particular physical attribute and/or fulfils a defined function

3.5
subfamily
<electronic components> group of components within a family manufactured by similar technological methods

3.6
d.c. capacitor
capacitor designed essentially for application with direct voltage

Note 1 to entry: A d.c. capacitor may not be suitable for use on a.c. supplies.

3.7
~~**rated**~~ **nominal capacitance**
~~C_R~~ C_N
designated capacitance value usually indicated on the capacitor

3.8
category temperature range
range of ambient temperatures for which the capacitor has been designed to operate continuously

Note 1 to entry: This is given by the lower and upper category temperature.

3.9
lower category temperature
minimum ambient temperature for which a capacitor has been designed to operate continuously

3.10
upper category temperature
~~maximum~~ highest ambient temperature ~~for~~ including internal heating in which a capacitor ~~has been~~ is designed to operate continuously

[SOURCE: IEC 61881-3:2012, 3.17, modified – The note to entry has been deleted.]

3.11
rated temperature
maximum ambient temperature at which the rated voltage may be continuously applied

3.12
rated voltage ~~(d.c.)~~
U_R
maximum ~~direct~~ d.c. voltage or peak value of pulse voltage which may be applied continuously or repetitively to a capacitor at any temperature between the lower category temperature and the rated temperature

3.13
category voltage
U_C
maximum voltage which may be applied continuously to a capacitor at its upper category temperature

3.14
temperature derated voltage
maximum voltage that may be applied continuously to a capacitor when it is at any temperature between the rated temperature and the upper category temperature

Note 1 to entry: Information on the voltage/temperature dependence at temperatures between the rated temperature and the upper category temperature ~~should, if applicable, be~~ is given in the ~~relevant~~ detail specification.

3.15
surge voltage ratio
quotient of the maximum instantaneous voltage which may be applied to the terminations of the capacitor for a specified time at any temperature within the category temperature range and the rated voltage or the temperature derated voltage, as appropriate

Note 1 to entry: The number of times per hour that this voltage may be applied ~~should be~~ is specified in the detail specification.

3.16
rated ripple voltage
r.m.s. value of the maximum allowable alternating voltage at a specified frequency superimposed on the d.c. voltage at which the capacitor may be operated continuously at a specified temperature

Note 1 to entry: The sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor ~~should~~ does not exceed the rated voltage or temperature derated voltage, as applicable.

3.17
reverse voltage
<~~for~~ polar capacitors ~~only~~> voltage applied to the capacitor terminations in the reverse polarity direction

3.18
rated ripple current
r.m.s. value of the maximum allowable alternating current of a specified frequency, at which the capacitor may be operated continuously at a specified temperature

3.19
time constant
product of the internal resistance (including circuit resistance) and the capacitance

Note 1 to entry: The time constant is normally expressed in seconds.

3.20
internal resistance
resistance component in an equivalent series circuit of capacitance and resistance of a capacitor

Note 1 to entry: The internal resistance is given in ohms (Ω).

3.21
IR drop
voltage drop between the capacitor terminals that is generated at the start of discharge and quantified by the product of the discharge current and the internal resistance of the capacitor

3.22
maximum temperature of a capacitor
temperature at the hottest point of its external surface

Note 1 to entry: The terminations are considered as a part of the external surface.

3.23
minimum temperature of a capacitor
temperature at the coldest point of the external surface

Note 1 to entry: The terminations are considered to be part of the external surface.

3.24
minimum storage temperature
minimum ambient temperature which the capacitor should withstand in the non-operating condition without damage

3.25
maximum storage temperature
maximum ambient temperature which ~~is equal to the upper category temperature of~~ the capacitor withstands in the non-operating condition without damage

[SOURCE: IEC 60384-1:2008, 2.2.11]

3.26
temperature characteristic of capacitance
maximum reversible variation of capacitance produced over a given temperature range within the category temperature range

Note 1 to entry: The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

Note 2 to entry: The temperature characteristic of capacitance is normally expressed as a percentage of the capacitance related to a reference temperature of 20 °C.

3.27
visible damage
visible damage which reduces the usability of the capacitor for its intended purpose

3.28
leakage current
value of the current that flows through a capacitor after a charge for a fixed period of time

Note 1 to entry: Leakage current is given in amperes (A).

3.29
maintain voltage
self discharge
voltage held while being left for a fixed period of time under no load after a charge for a fixed period of time

3.30
temperature rise
<capacitor> increase of temperature ~~rise~~ of the capacitor relative to the ambient temperature resulting from the losses in the capacitor due to operation under ~~a.c.~~ charge and/or ~~pulse~~ discharge conditions

3.31
insulated capacitor
capacitor in which all terminations of a section may be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

3.32
uninsulated capacitor
capacitor in which one or more of the terminations of a section cannot be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

3.33
surface mount capacitor
fixed capacitor whose small dimensions and nature or shape of terminations make it suitable for use in hybrid circuits and on printed boards

3.34
passive flammability
flammability caused by external heating of the component

Note 1 to entry: Passive flammability can be caused by flames for example.

3.35
active flammability
flammability (self-ignition) caused by internal heating of the component

Note 1 to entry: Active flammability can be caused by sparking due to insufficient internal contact for example.

3.36
category of passive flammability
category ~~of passive flammability is~~ given by the maximum burning time after a specified time of flame application

3.37
mass
mass of the ~~component~~ capacitor with all fixed parts

3.38
volume
~~component~~ volume of the capacitor body excluding terminations

4 ~~Technical data~~ General items

4.1 Unit and symbols

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following documents:

– IEC 60027;
– IEC 60050;
– IEC 60617;
– ISO ~~1000~~ 80000-1

When further items are required they should be derived in accordance with the principles of the publications listed above.

4.2 Preferred values and class

4.2.1 General

~~Each sectional specification shall prescribe~~ The preferred values appropriate to the subfamily~~; for rated capacitance, see also 2.3.2~~ shall be prescribed in the sectional specification.

NOTE It is not possible to specify the preferred values of rated voltage due to the nature of the capacitor.

4.2.2 Preferred values of ~~rated~~ nominal capacitance

The preferred values of ~~rated~~ nominal capacitance shall be taken from the R series specified in IEC 60063.

4.2.3 Class

The class of the capacitor shall be classified according to capacitance and internal resistance (application). See Annex A for details.

4.3 Marking

4.3.1 General

~~The sectional specification shall indicate~~ The identification criteria and other information to be ~~shown~~ marked on the capacitor and/or ~~packing~~ packaging shall be indicated in the sectional specification.

The order of marking priority for small size capacitors shall be specified in the detail specification.

4.3.2 Coding

When coding is used for capacitance value, tolerance or date of manufacture, the method shall be selected from those given in IEC 60062.

4.4 Quality assessment procedures

~~3.1 General~~

~~When this standard, and any related standards are used for the purpose of a full quality assessment system such as IEC Quality Assessment System for Electronic Components (IECQ), compliance with IEC QC 001002-3 is required.~~

~~3.2 Primary stage of manufacture~~

~~The primary stage of manufacture shall be specified in the sectional specification.~~

~~3.3 Structurally similar components~~

~~The structurally similar components shall be specified in the sectional specification.~~

~~3.4 Declaration of conformity~~

~~The declaration of conformity shall be specified in the sectional specification.~~

~~3.5 Test schedule and requirement for initial assessment~~

~~The test schedule and requirement for initial assessment shall be specified in the sectional specification.~~

See Annex Q.

5 Tests and measurement ~~procedures~~

5.1 General

The sectional and/or blank detail specification shall indicate the tests to be made, which measurements are to be made before and after each test or subgroup of tests, and the sequence in which they shall be made. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any quality assessment system include methods other than those specified in the above specifications, they shall be fully described.

Limits given in all specifications are absolute limits. The principle to take measurement uncertainty into account ~~shall be applied (see Annex C to Clause 2 of IEC QC 001002-3)~~ is given in Annex F.

5.2 ~~Standard atmospheric conditions~~ Test and measurement requirements

5.2.1 ~~Standard atmospheric conditions for testing~~ Test conditions

Unless otherwise specified, all tests ~~and measurements~~ shall be made under standard atmospheric conditions for testing as given in IEC 60068-1:2013, 4.3:

– temperature: 15 °C to 35 °C;

– relative humidity: 25 % to 75 %;

– air pressure: 86 kPa to 106 kPa.

~~Before the measurements are made, the capacitor shall be stored at the measuring temperature for a time sufficient to allow the entire capacitor to reach this temperature. The period as prescribed for recovery at the end of a test is normally sufficient for this purpose.~~

~~When measurements are made at a temperature other than the specified temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in 4.2.3) and such other conditions as are prescribed in this specification.~~

~~When tests are conducted in a sequence, the final measurements of one test may be taken as the initial measurements for the succeeding test.~~

~~During measurements the capacitor shall not be exposed to draughts, direct sunlight or other influences likely to cause error.~~

~~4.2.2 Recovery conditions~~

~~Unless otherwise specified, recovery shall take place under the standard atmospheric conditions for testing (4.2.1).~~

~~If recovery under closely controlled conditions is necessary, the controlled recovery conditions of 5.4.1 of IEC 60068-1 shall be used.~~

~~Unless otherwise specified in the relevant specification, a duration of 1 h to 2 h shall be used.~~

~~4.2.3 Referee conditions~~

~~For referee purposes, one of the standard atmospheric conditions for referee tests taken from 5.2 of IEC 60068-1, as given in Table 1 below, shall be selected:~~

~~Table 1 – Reference test: standard atmospheric conditions~~

~~Temperature~~ ~~°C~~	~~Relative humidity~~ ~~%~~	~~Air pressure~~ ~~kPa~~
~~20 ± 1~~	~~63 to 67~~	~~86 to 106~~
~~23 ± 1~~	~~48 to 52~~	~~86 to 106~~
~~25 ± 1~~	~~48 to 52~~	~~86 to 106~~
~~27 ± 1~~	~~63 to 67~~	~~86 to 106~~

~~4.2.4 Reference conditions~~

~~For reference purposes, the standard atmospheric conditions for reference given in 5.1 of IEC 60068-1 apply:~~

- ~~temperature: 20 °C;~~
- ~~air pressure: 101,3 kPa.~~

5.2.2 Measurement conditions

Unless otherwise specified, all measurements shall be made under standard atmospheric conditions for testing as given in IEC 60068-1:2013, 4.3 with following exception:

– temperature: 20 °C ± 2 °C.

All measurements shall be made after thermal equilibrium is accomplished, see 5.2.4.

5.2.3 Voltage treatment

The capacitor shall be charged up to U_R and be held for 30 min by means of a d.c. source. The capacitor shall be discharged through a suitable discharge device.

5.2.4 Thermal treatment

The capacitors shall be stored at the temperature specified in 5.2.2 for a time sufficient to allow the entire capacitor to reach this temperature (thermal equilibrium, see Annex C).

5.3 Drying

Unless otherwise specified in the ~~relevant~~ detail specification, the capacitor shall be conditioned for 96 h ± 4 h by heating in a circulating air oven at a temperature of 55 °C ± 2 °C and a relative humidity not exceeding 20 %.

The capacitor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

5.4 Visual examination and check of dimensions

5.4.1 Visual examination

The condition, workmanship and finish shall be satisfactory, as checked by visual examination.

Marking shall be legible, as checked by visual examination and shall conform to the requirements of the detail specification.

5.4.2 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, and shall comply with the values prescribed ~~in the detail specification~~.

When applicable, measurements shall be made in accordance with IEC 60294 or IEC 60717.

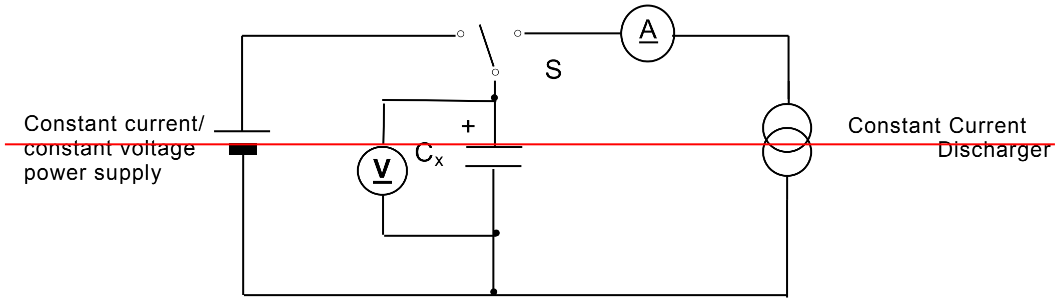
5.4.3 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

~~4.5 Capacitance~~

~~4.5.1 Constant current discharge method~~

~~4.5.1.1 Measuring circuit~~



~~**Key**~~

~~A d.c. ammeter~~

~~V d.c. voltmeter~~

~~S changeover switch~~

~~C_x capacitor under test~~

~~**Figure 1 – Circuit for constant current discharge method**~~

~~4.5.1.2 Measuring method~~

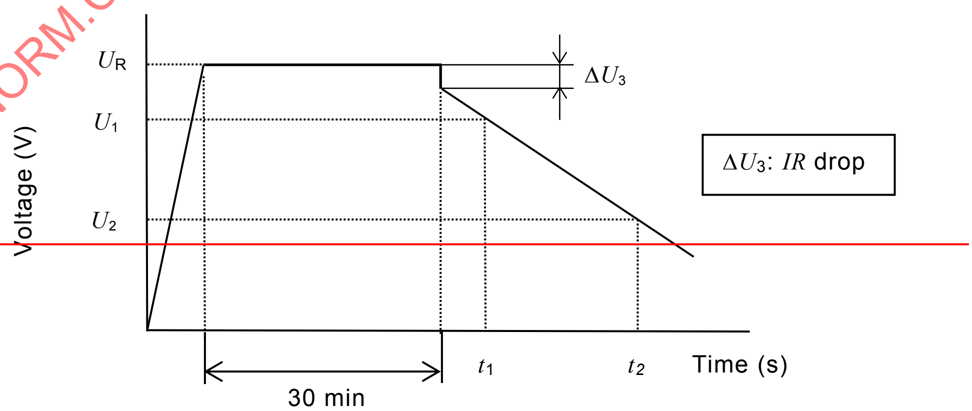
~~a) If the d.c. voltage of the constant current/constant voltage power supply is not specified in the individual standards, set at the rated voltage (U_R).~~

~~b) Set the constant current value of the constant current discharger to the discharge current specified in Table 2.~~

~~c) Turn the switch S to the d.c. power supply, and unless otherwise specified in the individual standards, apply voltage and charge for 30 min after the constant current/ constant voltage power supply has achieved the rated voltage.~~

~~d) After a charge for 30 min has finished, change over the switch S to the constant current discharger, and discharge with a constant current.~~

~~e) Unless otherwise specified in the individual standards, measure the time t_1 and t_2 where the voltage between capacitor terminals at the time of discharge reduces from U_1 to U_2 as shown in Figure 2, and calculate the capacitance value by the following formula:~~



~~**Figure 2 – Voltage characteristic between capacitor terminals**~~

$$\cancel{C = \frac{I \times (t_2 - t_1)}{U_1 - U_2}}$$

~~where~~

~~C is the capacitance (F);~~

~~I is the discharge current (A);~~

~~U_1 is the measurement starting voltage (V);~~

~~U_2 is the measurement end voltage (V);~~

~~t_1 is the time from discharge start to reach U_1 (s);~~

~~t_2 is the time from discharge start to reach U_2 (s).~~

~~f) The discharge current I and the voltages U_1 and U_2 at the time of discharge voltage drop shall be as per Table 2. The method classification shall be in accordance with the individual standards.~~

~~Table 2 – Discharge conditions~~

~~Classification~~	~~Class 1~~	~~Class 2~~	~~Class 3~~	~~Class 4~~
~~Application~~	~~Memory backup~~	~~Energy storage~~	~~Power~~	~~Instantaneous power~~
~~Charge time~~	~~30 min~~	~~30 min~~	~~30 min~~	~~30 min~~
~~I (mA)~~	~~$1 \times C$~~	~~$0{,}4 \times CU_R$~~	~~$4 \times CU_R$~~	~~$40 \times CU_R$~~
~~U_1~~	~~The value to be 80 % of the charging voltage ($0{,}8 \times U_R$)~~			
~~U_2~~	~~The value to be 40 % of the charging voltage ($0{,}4 \times U_R$)~~			
~~NOTE C is the rated capacitance in F (Farad), and U_R is the rated voltage in V (Volt).~~				

~~NOTE The discharge current I shall be set in accordance with the following:~~

~~a) If ΔU_3 exceeds 5 % ($0{,}05 \times U_R$) of the charging voltage in the initial characteristics, the current value may be reduced by one half, one fifth or one tenth.~~

~~b) The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.~~

~~c) The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.~~

~~**4.5.1.3** The relevant specification shall prescribe~~

~~a) method classification;~~

~~b) applied voltage other than the rated voltage;~~

~~c) charging time other than 30 min;~~

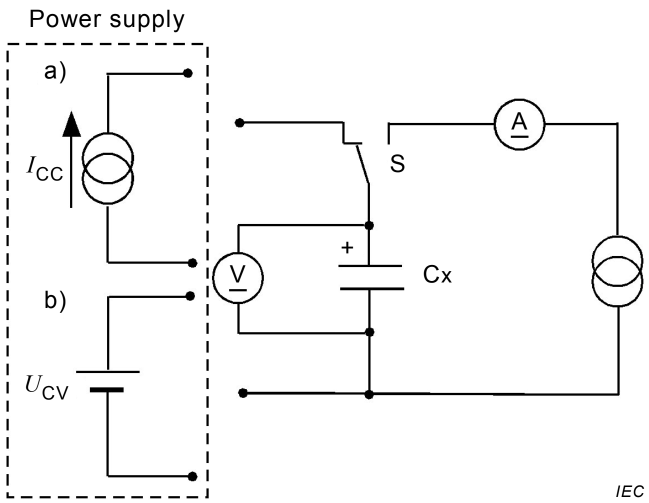
~~d) constant current discharge value other than that in Table 2;~~

~~e) U_1 and U_2 at the time of discharge voltage drop other than those in Table 2.~~

5.5 Measurement method 1 for capacitance and internal resistance (constant current discharge)

5.5.1 Basic circuit for measuring

The capacitance and the internal resistance shall be measured by using the constant current charging and discharging methods. The basic circuit for measurement is given in Figure 1.



Key

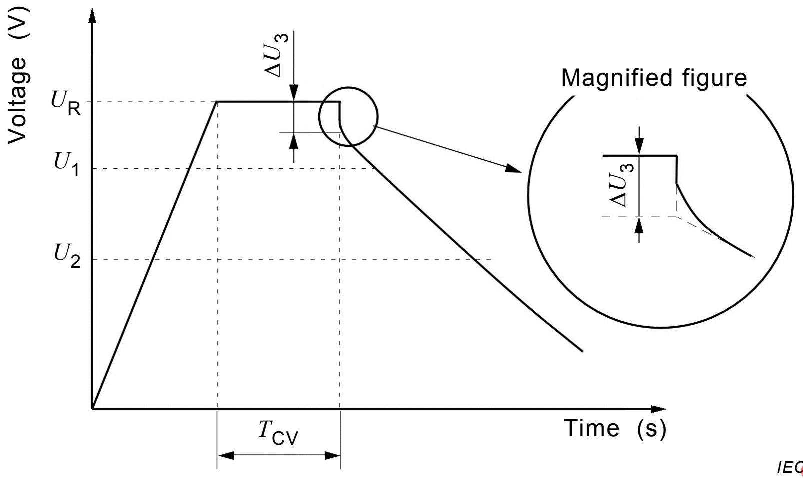
I_{CC}	constant-current
U_{CV}	constant-voltage
A	d.c. ammeter
V	d.c. voltage recorder
S	changeover switch
Cx	capacitor under test
	constant current discharger
a)	power supply for constant current ~~charging~~
b)	power supply for constant voltage ~~charging~~

Figure 1 – Basic circuit for measuring

5.5.2 Measuring equipment

The measuring equipment shall be capable of constant current charging, constant voltage charging, constant current discharging, and continuous measurement monitoring of the current and the voltage between the capacitor terminals as a function of discharging time as shown in Figure 2. The measuring equipment shall be able to set and measure the current and the voltage with the accuracy equal to ±1 % or less.

The power supply shall provide constant charge current for the capacitor charge with 95 % efficiency, and setting function of the constant voltage charge duration. The constant current discharger shall provide constant discharging current as specified in Table 1 or Table 2, respectively. The d.c. voltage recorder shall be capable of conducting measurements, and it shall record with a 5 mV resolution and sampling rate of 100 ms or less.



Key

U_R rated voltage (V)

U_1 calculation start voltage (V)

U_2 calculation end voltage (V)

ΔU_3 voltage drop (V)

T_{CV} constant voltage charging duration (min)

Figure 2 – Voltage–time characteristics between capacitor terminals in capacitance and internal resistance measurement

5.5.3 Measuring procedure

5.5.3.1 General

The measurement shall be carried out by analysing voltage-time characteristics between capacitor terminals.

The measuring method shall be either in accordance with 5.5.3.2 or 5.5.3.3 corresponding to the class (refer to Annex A) and shall be specified in the detail specification.

Preconditioning of voltage treatment as in 5.2.3 and thermal treatment as in 5.2.4 shall be carried out, and, if specified in the detail specification, drying as in 5.3 may be carried out before measurement.

The voltage between capacitor terminals shall be measured and recorded as a function of time throughout the measuring procedure.

5.5.3.2 Measuring method 1A (class 1, 2, 3 and 4)

Unless otherwise specified in the detail specification, the measuring conditions shall be as shown in Table 1. The constant charging current (I_{cc}) shall be able to charge the capacitor with 95 % charging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_N) by I_{cc} (= U_R /38 R_N). The constant discharge currents are set for capacitance measurement and internal resistance respectively, corresponding to the nominal capacitance of the capacitor.

The measuring procedure shall be as follows:

a) the capacitor shall be charged with the constant charging current;

b) when the output voltage of the power supply reaches the specified value, the charging of the capacitor shall be continued with the constant voltage;

c) then the capacitor shall be discharged through the constant current discharger;

d) then the time shall be measured from the start of discharge to the point at which the voltage between the capacitor terminals becomes U_1 and U_2, respectively (see Figure 2).

Table 1 – Measuring conditions for measuring method 1A

Measuring conditions	**Class** Application			
	Class 1 Memory backup	**Class 2** Energy storage	**Class 3** Power	**Class 4** Instantaneous power
Constant current charging mA	95 % charging efficiency [a]			
Constant voltage charging time min	30			
Constant discharge current for capacitance measurement [b] mA	$1 \times C_N$	$0,4 \times C_N U_R$	$4 \times C_N U_R$	$40 \times C_N U_R$
Constant discharge current for internal resistance measurement [c] mA	$10 \times C_N$	$4 \times C_N U_R$	$40 \times C_N U_R$	$400 \times C_N U_R$
U_1	$0,8 \times U_R$			
U_2	$0,4 \times U_R$			

For class 3 and class 4, measuring method 1B may be used.

The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.

The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.

NOTE C_N is the nominal capacitance in farad (F) and U_R is the rated voltage in volt (V).

[a] For the general concept of charging/discharging efficiency, see Annex D.

[b] If ΔU_3 exceeds 5 % of the charging voltage ($0,05 \times U_R$) in the initial characteristics, discharge current value may be reduced by one half, one fifth or one tenth.

[c] If ΔU_3 exceeds 20 % of the charging voltage ($0,2 \times U_R$) in the initial characteristics, discharge current value may be reduced by one half, one fifth or one tenth.

5.5.3.3 Measuring method 1B (class 3, 4 and 5)

Unless otherwise specified in the detail specification, the measuring conditions shall be as shown in Table 2. The constant charging current (I_{cc}) shall be able to charge the capacitor with 95 % charging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_N) by I_{cc} (= U_R /38 R_N). The constant discharge current (I_d) shall be able to discharge the capacitor with 95 % discharging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_n) by I_d (= U_R /40R_n).

The measuring procedure shall be as follows:

a) the capacitor shall be charged with the constant charging current;

b) when the output voltage of the power supply reaches the specified value, the charging of the capacitor shall be continued with the constant voltage;

c) then the capacitor shall be discharged through the constant current discharger;

d) then the time shall be measured from the start of discharge to the point at which the voltage between the capacitor terminals becomes U_1 and U_2, respectively (see Figure 2).

Table 2 – Measuring conditions for measuring method 1B

Measuring conditions	**Class** Application		
	Class 3 Power	**Class 4** Instantaneous power	**Class 5** High power
Constant current charging mA	95 % charging efficiency [a]		
Constant voltage charging time min	5		
Constant current discharging	95 % discharging efficiency [a]		
U_1	$0,8 \times U_R$		
U_2	$0,4 \times U_R$		

For class 3 and class 4, measuring method 1A may be used.

The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.

The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.

[a] For the general concept of charging/discharging efficiency, see Annex D.

5.5.4 Calculation methods for capacitance

5.5.4.1 General

The capacitance shall be calculated by the straight line approximation method or the energy conversion method.

5.5.4.2 Straight line approximation method (measuring method 1A)

The capacitance C of a capacitor shall be calculated by the following formula:

$$C = \frac{I_d \times (t_2 - t_1)}{U_1 - U_2}$$

where

C is the capacitance of capacitor (F);

I_d is the discharge current (A);

U_1 is the measuring start voltage (V);

U_2 is the measuring end voltage (V);

t_1 is the time at which the terminal voltage of the capacitor reaches the value U_1 from the start of the discharge;

t_2 is the time at which the terminal voltage of the capacitor reaches the value U_2 from the start of the discharge.

5.5.4.3 Energy conversion method (measuring method 1B)

The capacitance C of a capacitor shall be calculated by the following formula:

$$C = \frac{2W}{U_1^2 - U_2^2}$$

where

C is the capacitance of the capacitor (F);

W is the measured discharged energy (J), from start voltage U_1 to end voltage U_2;

U_1 is the measured start voltage;

U_2 is the measured end voltage.

5.5.5 Calculation methods for internal resistance

5.5.5.1 General

The internal resistance shall be calculated by the least square internal resistance calculation method or the intersection line internal resistance calculation method.

5.5.5.2 Intersection line internal resistance calculation method (measuring method 1A)

The internal resistance R of a capacitor shall be calculated by the following formula:

$$R = \frac{\Delta U_3}{I_d}$$

where

R is the internal resistance of the capacitor (Ω);

I_d is the discharge current (A);

ΔU_3 is the voltage drop (V).

NOTE The voltage drop is read by drawing an auxiliary line while extending the straight part of the time-varying voltages between the capacitor terminals obtained from the voltage recorder shown in Figure 2.

5.5.5.3 Least square internal resistance calculation method (measuring method 1B)

The internal resistance R of a capacitor shall be calculated by the following formula:

$$R = \frac{\Delta U_3}{I_d}$$

where

R is the internal resistance of the capacitor (Ω);

I_d is the discharge current (A);

ΔU_3 is the voltage drop (V).

Apply the straight-line approximation to the voltage drop characteristics from the calculation start voltage (U_1) to the calculation end voltage (U_2) by using the least squares method. Obtain the intercept (voltage value) of the straight line at the discharge start time. ΔU_3 is the difference of voltages (V) between the intercept voltage value and the set value of constant voltage charging (V).

5.5.6 Conditions to be prescribed in the detail specification

The detail specification shall prescribe:

a) the classification of method;

b) the applied voltage other than the rated voltage;

c) charging time other than 30 min (see Table 2) or 5 min (see Table 3);

d) constant current discharge value other than that in Table 2 or Table 3;

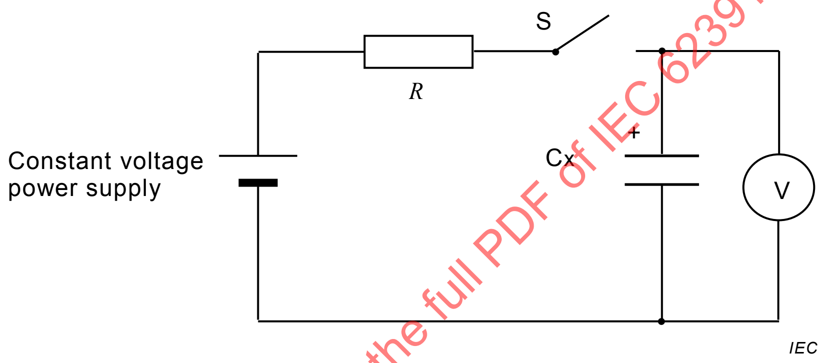
e) U_1 and U_2 at the time of discharge voltage drop other than those in Table 2 or Table 3.

5.6 Measurement method 2 for capacitance and internal resistance

5.6.1 Constant resistance charging method for capacitance measurement

5.6.1.1 Measuring circuit

Measurements shall be acrried out using the measuring circuit shown in Figure 3.



Key

R series resistance

S switch

V d.c. voltmeter

Cx capacitor under test

Figure 3 – Circuit for constant resistance charging method

5.6.1.2 Measuring method

The measuring procedure shall be as follows:

a) prior to measurement, short-circuit between capacitor terminals for 30 min or more ~~and~~ to ensure discharge sufficiently;

b) set the value of R in such a way that the time constant τ settles at 60 s to 120 s;

c) measure the time constant τ when d.c. voltage U_R is applied, and calculate the capacitance value by the following formula:

$$C = \frac{\tau}{R}$$

where

C is the capacitance (F);

τ is the time constant: charging time up to 0,632 × U_R (s);

R is the series resistance (Ω).

5.6.1.3 Conditions to be prescribed in the detail specification

The ~~relevant~~ detail specification shall prescribe:

a) the applied voltage other than the rated voltage;

b) the series resistance R when the time constant is other than 60 s to 120 s.

~~**4.6 Internal resistance**~~

5.6.2 AC internal resistance measuring method

5.6.2.1 Measuring circuit

Measurements shall be carried out using the measuring circuit shown in Figure 4.

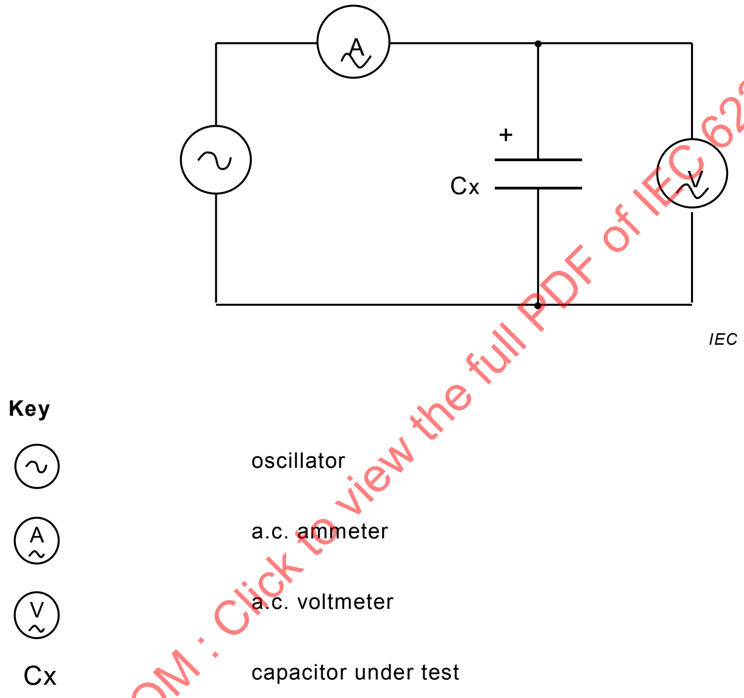


Figure 4 – Circuit for a.c. resistance method

5.6.2.2 Measuring method

The measuring procedure shall be as follows:

a) the measuring frequency shall be 1 kHz;

b) The a.c. current shall be from 1 mA to 10 mA.

c) the internal resistance R_a of a capacitor shall be calculated by the following formula:

$$R_a = \frac{U}{I}$$

where

R_a is the a.c. internal resistance (Ω);

U is the ~~effective~~ root-mean-square value of a.c. voltage (V ~~r.m.s.~~);

I is the ~~effective~~ root-mean-square value of a.c. current (A ~~r.m.s.~~).

~~4.6.2 DC resistance method~~

~~4.6.2.1 Measuring method~~

~~a) Use the measuring circuit, shown in Figure 1 in 4.5.1.1 (Constant current discharge method). If the applied voltage is not specified in the individual standards, set at the rated voltage. Use a voltage recorder to measure the voltage between capacitor terminals.~~

~~b) Turn the switch S to the d.c. power supply and unless otherwise specified in the individual standards, apply voltage and charge for 30 min after the constant current/ constant voltage power supply has achieved the rated voltage.~~

~~c) After a charge for 30 min has finished, change over the switch S to the constant current discharger. Unless otherwise specified in the individual standards, discharge with a constant current specified in Table 3.~~

~~d) Record the time-varying voltages between the capacitor terminals with a voltage recorder.~~

~~e) Draw an auxiliary line while extending the straight part of the time-varying voltages between the capacitor terminals obtained from the voltage recorder, read the voltage drop~~ $\cancel{\Delta U_3}$ ~~obtained from the intersection of the auxiliary line and the time base at the time of discharge start shown in Figure 5, and then calculate the internal resistance~~ $\cancel{R_d}$ ~~by the following formula.~~

$$\cancel{R_d = \frac{\Delta U_3}{I}}$$

~~where~~

$\cancel{R_d}$ ~~is the d.c. internal resistance (Ω);~~

$\cancel{\Delta U_3}$ ~~is the drop voltage (V);~~

$\cancel{I}$ ~~is the discharge current (A).~~

~~f) The discharge current~~ $\cancel{I}$ ~~shall be as per Table 3. The method classification shall be in accordance with the individual standards.~~

~~Table 3 – Discharge current~~

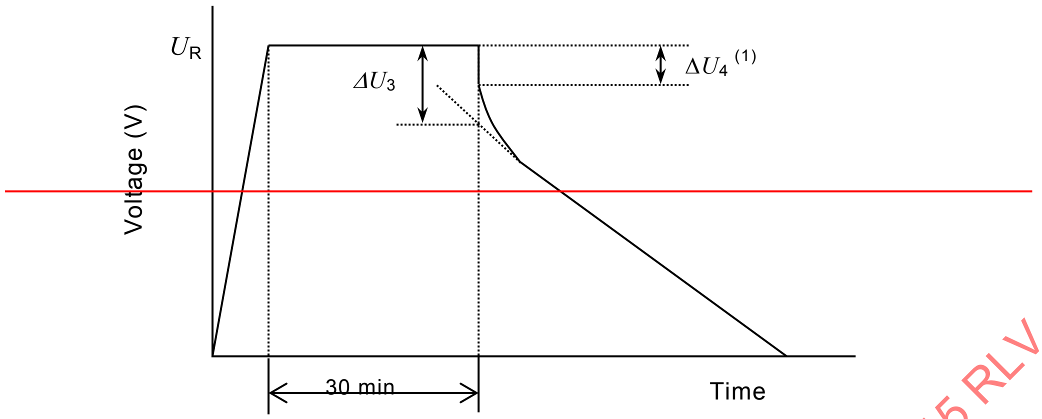
~~Classification~~	~~Class 1~~	~~Class 2~~	~~Class 3~~	~~Class 4~~
$\cancel{I}$ ~~(mA)~~	~~10 ×~~ $\cancel{C}$	~~4 ×~~ $\cancel{CU_R}$	~~40 ×~~ $\cancel{CU_R}$	~~400 ×~~ $\cancel{CU_R}$
~~NOTE~~ $\cancel{C}$ ~~is the rated capacitance in F (Farad), and~~ $\cancel{U_R}$ ~~is the rated voltage in V (Volt).~~				

~~NOTE The discharge current~~ $\cancel{I}$ ~~shall be set in accordance with the following:~~

~~a) If~~ $\cancel{\Delta U_3}$ ~~exceeds 20 % (0,20 ×~~ $\cancel{U_R}$~~) of the charging voltage, the current value may be reduced by one half, one fifth or one tenth.~~

~~b) The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.~~

~~c) The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.~~



~~(1) The drop voltage does not indicate the voltage ΔU_4 that drops instantaneously at the time of discharge start, but the dropped voltage ΔU_3 obtained from the intersection of the auxiliary line extended from the straight part and the time base at the time of discharge start.~~

~~**Figure 5 – Voltage characteristic between capacitor terminals**~~

~~**4.6.2.2** The relevant specification shall prescribe~~

~~a) method classification;~~

~~b) applied voltage other than the rated voltage;~~

~~c) charging time other than 30 min;~~

~~d) discharge current value other than that in Table 3.~~

5.7 Leakage current

5.7.1 Measuring method

The measuring procedure shall be as follows.

a) ~~Discharge duration.~~

Before this measurement is carried out, the capacitors shall be fully discharged. The discharge procedure shall take 1 h to 24 h and shall be specified in the ~~relevant~~ detail specification.

b) The leakage current shall be measured, unless otherwise prescribed in the ~~relevant~~ detail specification, using the direct voltage (U_R) appropriate to the test temperature. The electrification period after maximum 30 min charge-up time to reach 95 % of the applied voltage shall be selected from 30 min, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h or 48 h and shall be specified in the ~~relevant~~ detail specification.

c) A steady source of power such as a regulated power supply shall be used.

d) Unless otherwise specified in the ~~relevant~~ detail specification, apply the voltage to a capacitor through a protective resistor of 1 000 Ω or less.

5.7.2 Items to be specified in the detail specification

The ~~relevant~~ detail specification shall ~~prescribe~~ specify the following items:

a) the leakage current limit at a reference temperature of 20 °C, and at other specified temperatures;

b) when necessary, the correction factor: if the measurements are made at a temperature other than 20 °C, but within the range of temperatures covered by the standard atmospheric conditions for testing;

c) the electrification time;

d) the resistance value of protective resistors other than 1 000 Ω.

5.8 ~~Self-discharge~~ Maintain voltage

5.8.1 Measuring method

The measuring method shall be as follows (see Figure 5).

a) Before this measurement is carried out, the capacitors shall be fully discharged. The discharge procedure shall take 1 h to 24 h and shall be specified in the ~~relevant~~ detail specification.

b) Apply the rated voltage U_R directly to the capacitor terminals, without using a protective resistor. Unless otherwise specified by the ~~relevant~~ detail specifications, the charging time shall be 8 h, including maximum 30 min charge-up time to reach 95 % of the applied voltage.

c) Disconnect the capacitor terminals from the voltage source. Unless otherwise specified in the detail specification, the capacitor shall be kept under standard conditions for 16 h, 24 h, 48 h or 96 h.

d) The internal resistance of the d.c. voltmeter used shall be ~~at least~~ 1 MΩ or higher.

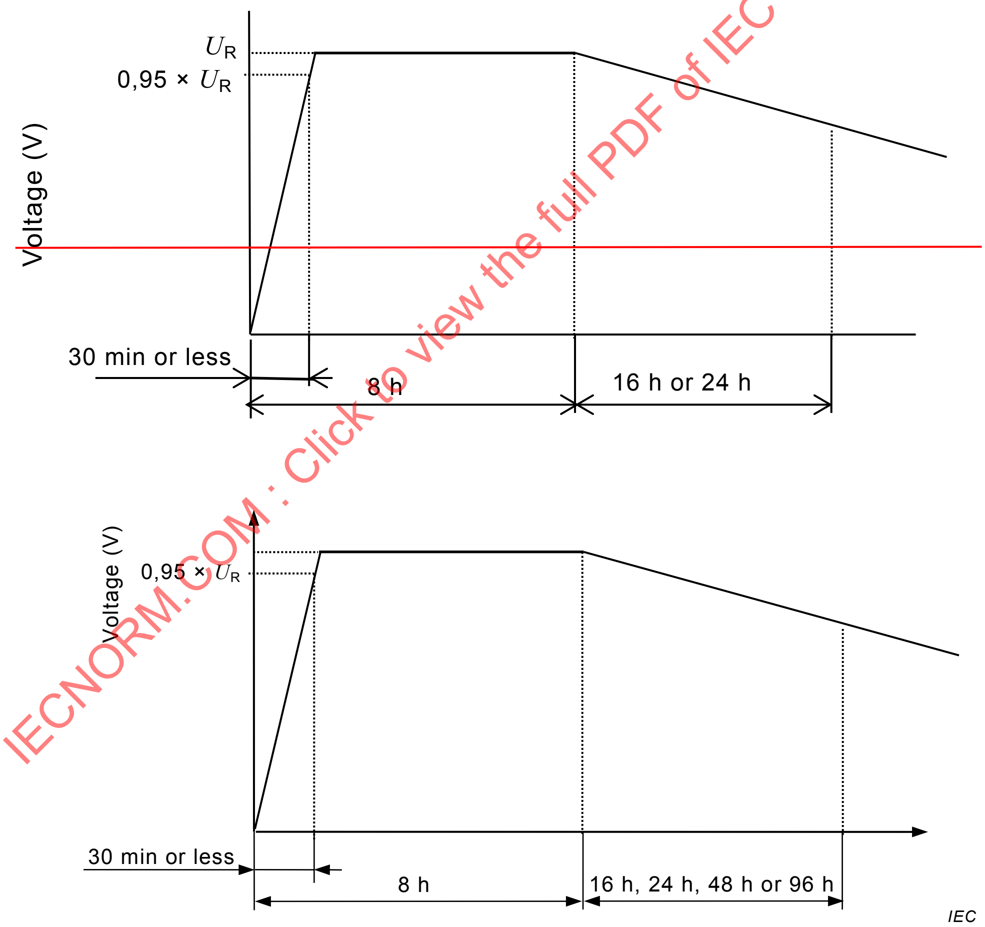


Figure 5 – ~~Self-discharge~~ Maintain voltage test diagram

5.8.2 Calculation of voltage maintenance rate

The voltage maintenance rate A shall be calculated by the following formula:

$$A = \frac{U_{\text{end}}}{U_{\text{R}}} \times 100$$

where

A is the voltage maintenance rate (%);

U_{end} is the voltage between open capacitor terminals after 72 h (T_{OC1}) have elapsed (V);

U_{R} is the rated voltage (V).

5.8.3 Conditions to be prescribed in the detail specification

The ~~relevant~~ detail specification shall prescribe:

a) the discharge duration;

b) an applied voltage other than the rated voltage;

c) a charging time other than 8 h;

d) the time period between disconnecting the capacitor from the charging voltage and the measurement.

5.9 Robustness of terminations

~~The capacitors shall be subjected to Tests Ua1, Ub, Uc and Ud of IEC 60068-2-21, as applicable.~~

5.9.1 Test Ua1 – Tensile

The capacitors shall be subjected to IEC 60068-2-21, Test Ua1, as applicable.

The force applied shall be:

– for terminations other than wire terminations: 20 N;

– for wire terminations, see Table 3.

Table 3 – Tensile force

Nominal cross-sectional area (S) ~~(see note)~~ [a] mm²	Corresponding diameter (d) for circular section wires mm	Force with tolerance of ±10 % N
$S \leq 0{,}05$	$d \leq 0{,}25$	1
$0{,}05 < S \leq 0{,}1$	$0{,}25 < d \leq 0{,}35$	2,5
$0{,}1 < S \leq 0{,}2$	$0{,}35 < d \leq 0{,}5$	5
$0{,}2 < S \leq 0{,}5$	$0{,}5 < d \leq 0{,}8$	10
$0{,}5 < S \leq 1{,}2$	$0{,}8 < d \leq 1{,}25$	20
$1{,}2 < S$	$1{,}25 < d$	40

~~NOTE~~ [a] For circular-section wires, strips or pins, the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the ~~relevant~~ detail specification. For stranded wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the ~~relevant~~ detail specification.

5.9.2 Test Ub – Bending (half of the sample)

The capacitors shall be subjected to IEC 60068-2-21, Test Ub, as applicable.

Method 1: Two consecutive bends shall be applied in each direction. This test shall not apply if, in the detail specification, the terminations are described as rigid.

5.9.3 Test Uc – Torsion (remaining sample)

The capacitors shall be subjected to IEC 60068-2-21, Test Uc, as applicable.

Method A, severity 2 (two successive rotations of 180 °) shall be used.

This test shall not apply if in the detail specification the terminations are described as rigid and to components with unidirectional terminations designed for printed wiring applications.

5.9.4 Test Ud – Torque (for terminations with threaded studs or screws and for integral mounting devices)

The capacitors shall be subjected to IEC 60068-2-21, Test Ud, as applicable.

The degree of severity to be used shall be specified in the detail specification (see Table 4).

Table 4 – Torque

Nominal thread diameter mm		2,6	3	3,5	4	5	6	8
Torque Nm	Severity 1	0,4	0,5	0,8	1,2	2,0	2,5	5
	Severity 2	0,2	0,25	0,4	0,6	1,0	1,25	2,5

5.9.5 Visual examination

After each of these tests, the capacitors shall be visually examined. There shall be no visible damage.

5.10 Resistance to soldering heat

5.10.1 Preconditioning and initial measurement

When prescribed by the ~~relevant~~ detail specification the capacitors shall be dried using the method of 5.3.

The capacitors shall be measured as prescribed in the ~~relevant~~ detail specification.

5.10.2 Test

Unless otherwise stated in the ~~relevant~~ detail specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the detail specification.

a) For all capacitors except those of items b) and c) below: IEC 60068-2-20, Test Tb, method 1~~A~~ (solder bath) ~~apply with:~~

~~– temperature of the solder bath: 260 °C ± 5 °C;~~

~~– depth of immersion from the seating plane~~ $\cancel{2\,^{0}_{-0,5}}$ ~~mm, using a thermal insulating screen of 1,5 mm ± 0,5 mm thickness;~~

~~– immersion time: 5 s or 10 s, as specified in the detail specification.~~

b) For capacitors not designed for use in printed boards but with connections intended for soldering as indicated by the detail specification:

1) IEC 60068-2-20, Test Tb, method 1~~B~~ (solder bath)~~, with:~~

~~– temperature of the solder bath: 350 °C ± 10 °C;~~

~~– depth of immersion from the component body: $3{,}5^{\ 0}_{-0{,}5}$ mm;~~

~~– immersion time: 3,5 s ± 0,5 s. The whole process of immersion, dwell in the bath and withdrawal shall be completed in not more than 5 s nor less than 3,5 s; or~~

2) IEC 60068-2-20, Test Tb, method 2 (soldering iron)~~, with:~~

~~– temperature of the soldering iron: 350 °C;~~

~~– soldering time: 10 s ± 1 s.~~

~~The size of the soldering iron and the point of application shall be specified in the detail specification.~~

c) For surface mount capacitors, IEC 60068-2-58,~~ Test Td,~~ reflow or solder bath method ~~apply~~. ~~The relevant specification shall prescribe the severity and attitude to be used for the resistance to soldering heat test consistent with the surface mounting classification (see IEC 61760-1).~~

5.10.3 Recovery

The period of recovery shall, unless otherwise specified by the detail specification, be not less than 1 h ~~n~~or more than 2 h, except for surface mount capacitors, for which the period of recovery shall be 24 h ± 2 h be carried out by 5.3.

5.10.4 Final inspection, measurements and requirements

For all capacitors, except surface mount capacitors, the following shall apply:

– when the test has been carried out, the capacitors shall be visually examined;

– there shall be no visible damage and the marking shall be legible;

– the capacitors shall then be measured as prescribed in the~~ relevant~~ detail specification.

Surface mount capacitors shall be visually examined and measured and shall meet the requirements as prescribed in the~~ relevant~~ detail specification.

5.11 Solderability

5.11.1 General

~~NOTE~~ This test shall not be applicable to those terminations which the detail specification describes as not designed for soldering.

5.11.2 Preconditioning

The~~ relevant~~ detail specification shall prescribe whether ageing is to be applied. If accelerated ageing is required, one of the ageing procedures given in IEC 60068-2-20~~ or a 4 h dry heat test at 155 °C (other test conditions as in Test Ta of IEC 60068-2-20)~~ shall be applied.

Unless otherwise stated in the~~ relevant~~ detail specification, the test shall be carried out with non-activated flux.

5.11.3 Capacitors with leads

5.11.3.1 General

Capacitors shall be subjected to Test Ta of IEC 60068-2-20 either using the solder bath method (method 1), or the soldering iron method (method 2)~~, or the solder globule method (Method 3)~~ as prescribed by the detail specification.

When the solder bath method (method 1) is specified, the following requirements apply.

5.11.3.2 Test conditions

~~Bath temperature: 235 °C ± 5 °C~~

~~Immersion time: 2,0 s ± 0,5 s~~

Unless otherwise stated in the detail specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the detail specification.

a) For all capacitors except those of items b) and c) below
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath)

      Depth of immersion (from the seating plane or component body): $2\,^{0}_{-0,5}$ mm, using a thermal insulating screen of 1,5 mm ± 0,5 mm thickness;
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron);
   3) IEC 60068-2-54.

b) For capacitors not designed for use in printed boards, but with connections intended for soldering as indicated by the detail specification:
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath);

      Depth of immersion (from the seating plane or component body): $3{,}5\,^{0}_{-0,5}$ mm;
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron).

c) For surface mount capacitors:
   1) IEC 60068-2-58, reflow or solder bath method;
   2) IEC 60068-2-69, solder bath or solder globule method.

~~4.11.1.3~~ When the solder bath method is not applicable, the ~~relevant~~ detail specification shall define ~~both~~ the test method, test conditions and the requirements.

~~NOTE When the solder globule method is used, the requirement shall include the soldering time.~~

5.11.3.3 Final inspection, measurements and requirements

The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

5.11.4 Surface mount capacitors

5.11.4.1 General

Capacitors shall be tested in accordance with Test Td of IEC 60068-2-58. The ~~relevant~~ detail specification shall prescribe the severity and attitude to be used for wetting, dewetting or resistance to dissolution ~~or~~ of metallization ~~consistent with the surface mounting classification (see IEC 61760-1)~~.

The detail specification shall also indicate the specific areas of the specimen to be examined after wetting.

5.11.4.2 Final inspection, measurements and requirements

The surface mount capacitors shall meet the requirements as prescribed in the ~~relevant~~ detail specification.

5.12 Rapid change of temperature

5.12.1 Initial measurement

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.12.2 Test

The capacitors shall be subjected to Test Na of IEC 60068-2-14, using the degree of severity as prescribed in the ~~relevant~~ detail specification.

5.12.3 Final inspection, measurements and requirements

~~After recovery,~~ The capacitors shall be visually examined. There shall be no visible damage.

5.13 Vibration

5.13.1 Initial measurement

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.13.2 Test

The capacitors shall be subjected to Test Fc of IEC 60068-2-6, using the mounting method and the degree of severity prescribed in the ~~relevant~~ detail specification.

~~4.13.3~~ When specified in the detail specification, during the last 30 min of the vibration test an electrical measurement shall be made in each direction of movement to check intermittent contact, or open- or short-circuit.

The method of measurement shall be prescribed in the detail specification.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

5.13.3 Final measurement and requirements

After the test, the capacitors shall be visually examined. There shall be no visible damage. When capacitors are tested as specified in 5.17.4, the requirements shall be stated in the detail specification.

~~4.13.5~~ The measurements prescribed in the ~~relevant~~ detail specification shall then be made.

5.14 Damp heat, steady state

5.14.1 Initial measurement

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.14.2 Test

The capacitors shall be subjected to Test Cab of IEC 60068-2-78, using the degree of severity corresponding to the detail specification.

5.14.3 Final measurement

The measurements prescribed in the ~~relevant~~ detail specification shall then be made.

5.15 Endurance

5.15.1 Initial measurements

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.15.2 Test

~~The tests of IEC 60068-2-2 apply as follows:~~

~~d.c. tests – Test Ba;~~

~~The test specimens may be inserted in the oven at any temperature between room ambient temperature and the specified oven temperature, but the voltage shall not be applied to the capacitor before it has reached the oven temperature.~~

~~4.15.3 The relevant specification shall prescribe:~~

~~a) duration of the test (e.g. hours);~~

~~b) test temperature (e.g. room, rated or upper category temperature);~~

~~c) voltage or current to be applied (see also 4.15.4).~~

~~When capacitors have to meet additional requirements for electric shock hazard protection, additional test conditions for endurance testing shall be prescribed in the relevant specification.~~

~~4.15.4 Unless otherwise specified in the relevant specification, the voltage to be applied during the test shall be selected from the following:~~

~~d.c. tests~~

~~The test shall be carried out at a multiplying factor times the rated voltage (d.c.) at temperatures up to the rated temperature. The test temperature and the value of the multiplying factor shall be specified in the relevant specification. For tests at upper category temperature the derating factor for the voltage shall be given as well.~~

~~4.15.5 The capacitors shall be placed in the test chamber in such a manner that:~~

~~a) for heat dissipating capacitors, no capacitor is within 25 mm of any other capacitor;~~

~~b) for non-heat dissipating capacitors, no capacitor is within 5 mm of any other capacitor.~~

5.15.2.1 General

IEC 60068-2-2:2007, Test Bb, shall be applied with the following exceptions:

– capacitors may be inserted in the test chamber at any temperature between room ambient temperature and the specified test temperature;

– a specified voltage shall be applied to the capacitor during the test, but the voltage shall not be applied to the capacitor before it has reached the chamber temperature.

The capacitors shall be placed in the test chamber in such way that no capacitor is located within 5 mm from any other capacitor.

5.15.2.2 Test conditions

The test conditions shall be as follows:

a) applied voltage : rated voltage;

b) test temperature : upper category temperature;

c) test duration : 1 000 h or as specified in the detail specification.

5.15.3 Final measurement, inspection and requirements

After the specified period, the capacitors shall be allowed to cool to standard atmospheric conditions for testing and where specified in the ~~relevant~~ detail specification, the capacitors shall be subjected to recovery.

~~4.15.7~~ The capacitors shall then be visually examined.

~~4.15.8~~ The measurements prescribed in the ~~relevant~~ detail specification shall then be carried out. A capacitor shall be considered to have failed when the requirements of the ~~relevant~~ detail specification during or at the end of the test are not satisfied.

5.16 Storage

5.16.1 Storage at high temperature

5.16.1.1 Initial measurement

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.16.1.2 Test conditions

The capacitors shall be subjected to IEC 60068-2-2:2007, Test ~~Ba~~ Bb, using the following severities:

– test temperature : upper category temperature;

– test duration : 96 h ± 4 h.

5.16.1.3 Final measurement

After recovery for at least 16 h, the measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.16.2 Storage at low temperature

5.16.2.1 Initial measurement

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.16.2.2 Test conditions

The capacitors shall be subjected to IEC 60068-2-1:2007, Test Ab. The capacitors shall be stored at – 40 °C for either a period of 4 h after thermal stability has been reached, or for 16 h, whichever is the shorter period.

5.16.2.3 Final measurement

After recovery for at least 16 h, the measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.17 Characteristics at high and low temperature

5.17.1 General

The capacitors shall be subjected to the procedures of the dry heat and cold test (5.17.3 and 5.17.4 respectively) with the following details.

5.17.2 Test procedure

The degree of severity for these tests shall be the same as for the dry heat and cold tests. Tests at intermediate temperatures may be prescribed by the ~~relevant~~ detail specification.

~~Measurements shall be made at each of the specified temperatures after the capacitor has reached thermal stability.~~

~~The condition of thermal stability is judged to be reached when two readings of a characteristic, taken in an interval of not less than 5 min, do not differ by an amount greater than that which can be attributed to the measuring apparatus.~~

The measurements prescribed in the detail specification shall be made.

5.17.3 Dry heat

The capacitors shall be subjected to IEC 60068-2-2:2007, Test ~~Ba~~ Bb, for 16 h using the degree of severity of the upper category temperature, as prescribed in the detail specification.

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the ~~relevant~~ detail specification shall be made.

~~After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.~~

5.17.4 Cold

The capacitors shall be subjected to IEC 60068-2-1:2007, Test ~~Aa~~ Ab for 2 h, using the degree of severity of the lower category temperature, as prescribed in the ~~relevant~~ detail specification.

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the ~~relevant~~ detail specification shall be made.

~~After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.~~

5.17.5 Final measurement and requirements

The capacitors shall not exceed the limits prescribed in the ~~relevant~~ detail specification.

5.18 Component solvent resistance

5.18.1 Initial measurements

The measurements prescribed in the ~~relevant~~ detail specification shall be made.

5.18.2 Test

The components shall be subjected to IEC 60068-2-45:1980, Test XA, with the following details:

a) solvent to be used : ~~see 3.1.2 of IEC 60068-2-45~~ 2-propanol;

b) solvent temperature : 23 °C ± 5 °C, unless otherwise specified in the detail specification;

c) conditioning : Method 2 (without rubbing);

d) recovery time : ~~48h~~ 2 h or more (see Annex C), unless otherwise stated in the detail specification.

5.18.3 Requirements

The measurements prescribed in the ~~relevant~~ detail specification shall then be carried out and the specified requirements shall be met.

5.19 Solvent resistance of marking

5.19.1 Test

The components shall be subjected to IEC 60068-2-45:1980, Test XA, with the following details:

a) solvent to be used : ~~see 3.1.2 of IEC 60068-2-45~~ 2-propanol;

b) solvent temperature : 23 °C ± 5 °C;

c) conditioning : method 1 (with rubbing);

d) rubbing material : cotton wool;

e) recovery time : not applicable, unless otherwise stated in the detail specification.

5.19.2 Requirements

After the test, the marking shall be legible.

5.20 Passive flammability

5.20.1 Test procedure

The capacitors shall be tested according to the following procedure.

a) The test shall be carried out according to IEC 60695-11-5.

b) The capacitor under test shall be held in the flame in the position which best promotes burning (if this position is not given in the detail specification, it shall be evaluated by pre-testing). Each specimen shall only be exposed once to the flame.

c) The smallest, a medium (in the case of more than four case sizes), and the biggest case size shall be tested. Of each case size, three specimens of the maximum and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

~~4.20.2 The capacitor under test shall be held in the flame in the position which best promotes burning (if this position is not given in the detail specification it shall be evaluated by pre-testing). Each specimen shall only be exposed once to the flame.~~

~~4.20.3 The smallest, a medium (in the case of more than four case sizes), and the biggest case size shall be tested. Of each case size, three specimens of the maximum and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.~~

~~4.20.4~~ For the time of exposure to flame and burning time, see Table 5. If applicable, the detail specification shall specify the category of passive flammability.

5.20.2 Requirements

The burning time of any specimen shall not exceed the time specified in Table 5.

Burning droplets or glowing parts falling down shall not ignite the tissue paper.

Table 5 – Severities and requirements

Category of flammability	Severities Flame exposure time, in seconds, for capacitor volume ranges [a] mm^3				Maximum burning time s
	volume ≤ 250	250 < volume ≤ 500	500 < volume ≤ 1 750	1 750 < volume ≤ 12 000	
A	15	30	60	120	3
B	10	20	30	60	10
C	5	10	20	30	30

[a] Test severities for capacitor volumes above 12 000 mm^3 are under consideration.

5.21 Pressure relief (if applicable)

5.21.1 ~~d.c.~~ Test

~~Applied voltage:~~ Unless otherwise specified in the ~~relevant~~ detail specification, ~~over voltage obtained with constant current of minimum 10 mA /F~~ d.c. voltage of an amplitude necessary to produce a current of 10 mA/F or more shall be applied to the capacitor in the forward direction.

5.21.2 Requirements

The pressure relief device shall open in such a way as to avoid any danger of explosion or fire.

Annex A
(normative)

Classification according to capacitance and internal resistance

A.1 General

This annex describes classification of the capacitor, according to the capacitance value and internal resistance value depending upon the application.

A.2 Classification by capacitance and internal resistance

Measurements of capacitance and internal resistance by the constant current discharge method and the d.c. resistance method, respectively require much (long) measuring time depending on the product ratings provided that the measuring conditions are standardized with the specificity of these measuring methods. Therefore, it is necessary to select efficient measuring conditions. For this reason, the following application classification has been considered, classifying into four measuring conditions (see Figure A.1).

In the meantime, it has been suggested that the same discharge current condition may be appropriate for capacitance and internal resistance for every application of the ~~four methods~~ five classes. However, classification was made in terms of accuracy in measurement. Note that the same measuring conditions may be used for capacitance and internal resistance within the scope of the capacitors that can obviously achieve accurate measurements.

Class 1 (memory backup)

This class is suitable for those capacitors which are mainly used for RAM memory backup with magnitude of discharge current ~~units ranging~~ from nA to μA. The characteristics of the capacitors for this application have relatively low capacitance and high internal resistance.

Class 2 (energy storage)

This class is suitable for those energy storage capacitors which mainly require a long time operation~~, requiring the~~ with magnitude of discharge current ~~units ranging~~ from mA to A. The capacitors for this application have high capacitance in characteristics without any consideration of internal resistance. This class handles higher internal resistance compared with the power application in Class 3.

Class 3 (power)

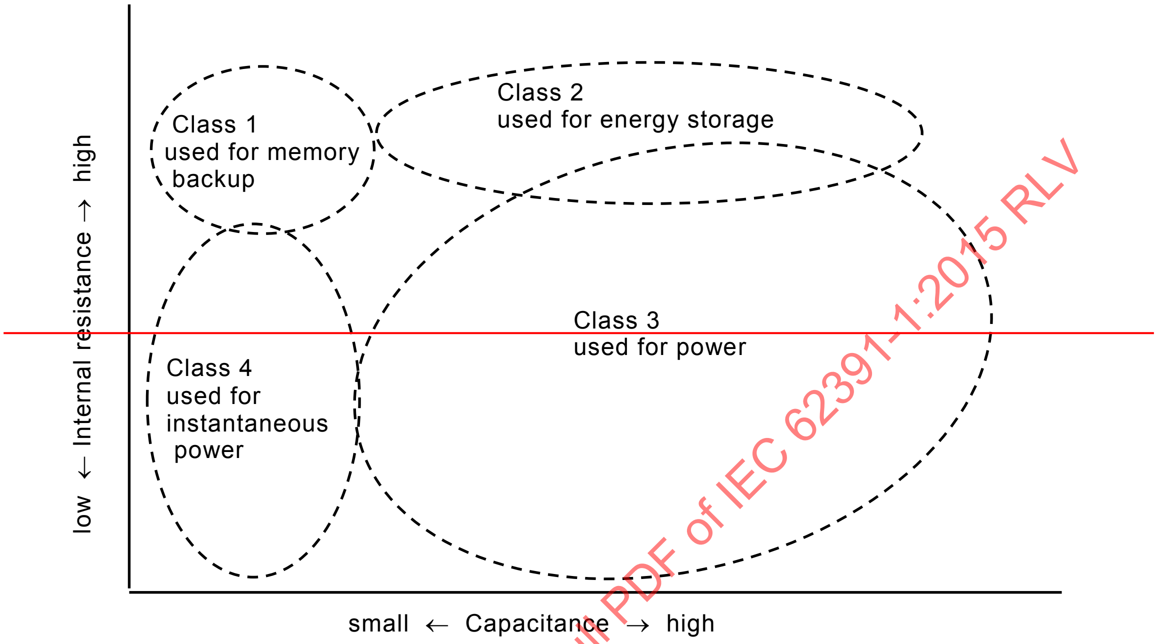
This class is suitable for those capacitors which are mainly used for driving motors, requiring power with magnitude of discharge current from mA to A. The characteristics of the capacitors for this application have relatively high capacitance and low internal resistance.

Class 4 (instantaneous power)

This class is suitable for the application that requires instantaneous power (relatively large current) even with a short operating time. The capacitors for this application have low capacitance and low internal resistance in characteristics.

Class 5 (high power)

This class is suitable for the application (i.e. automotive and railway) that requires high power (relatively large current) with heavy duty charge/discharge cycles. The capacitors for this application have higher capacitance value and lower internal resistance value compared to Class 3.



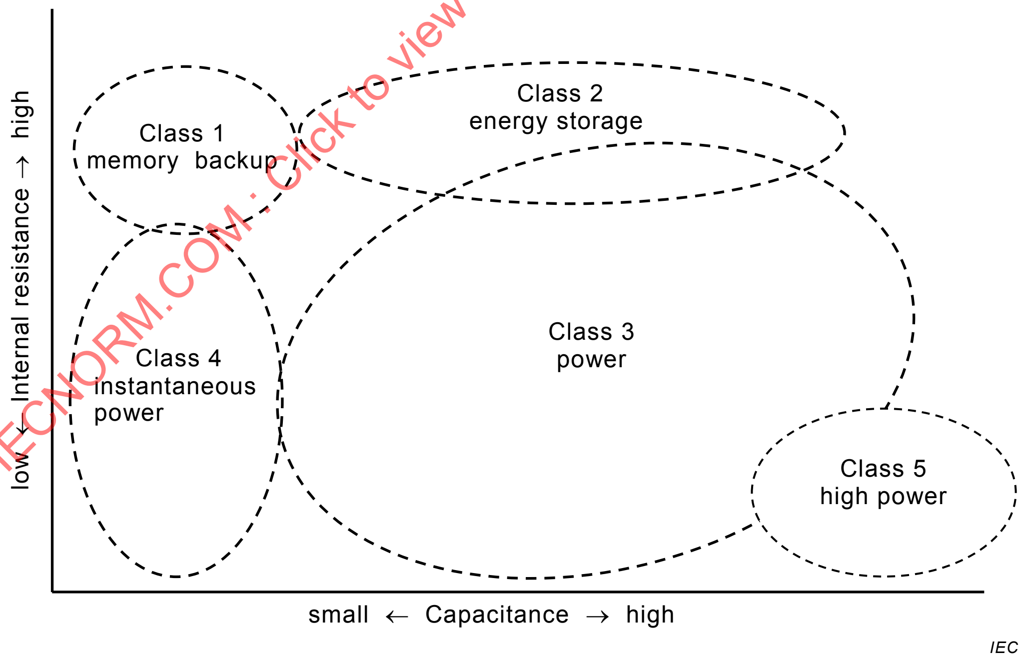


Figure A.1 – Conceptual rendering orientated by characteristics in each classification

~~Unless otherwise specified in the individual standards, it is recommended that the measurement items for electric performance by the above class classification shall be selected from those classes shown in Table A.1 according to the usage.~~

Unless otherwise specified in the detail specifications, electrical performance and measuring methods should be selected according to Table A.1, by the above mentioned class related to the application.

Table A.1 – ~~Measurement items for Electric performance~~ Electrical performance and measuring method by class

Measurement items		Sub clause No.	~~Selection~~ Class classification				
			Class 1	Class 2	Class 3	Class 4	Class 5
Capacitan-ce	Constant current discharge method	~~4.5.1~~ 5.5	A	A	A	A	A
	Constant resistance charging method	~~4.5.2~~ 5.6.1	B	B	B	B	C
Internal resistan-ce	AC resistance method	~~4.6.1~~ 5.6.2	A	B	B	B	C
	DC resistance method	~~4.6.2~~ 5.5	C	A	A	A	A
Leakage current		~~4.7~~ 4.7	C	C	C	C	C
~~Self discharge~~ Maintain voltage		~~4.8~~ 5.8	A	C	C	C	C

~~NOTE~~ Selection classification

A: use as a standard,

B: use as a ~~shortcut~~ simplified method,

C: use when necessary.

Selection classification shall be specified in the ~~individual standards~~ detail specification. For capacitance,see Annex B.

Annex B
(informative)

Measuring method of capacitance and low resistance by low frequency a.c. method (reference)

~~B.0 Introduction~~

B.1 General

This method is suitable for capacitors with relatively low internal resistance, and can be used as a shortcut method to reduce the measuring time.

B.2 Measuring system

The measuring system includes the components in Figure B.1. The system that replaces this method for measuring capacitance at low frequency may be used, as follows:

a) generate a sinusoidal voltage at the specified frequency with a frequency response analyzer and apply the voltage to a capacitor via a potentiostat;

b) detect the current that flows through the capacitor with a potentiostat (a device to automatically keep the electrode potential constant), and convert it into a voltage value to return it to the frequency analyser;

c) obtain the impedance $|Z|$ and phase angle φ from the voltage and current of the capacitor to be measured.

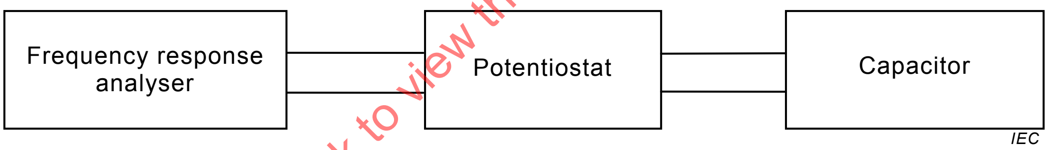


Figure B.1 – Capacitance measuring system by the low frequency a.c. method

B.3 Calculation of capacitance

The calculation of capacitance shall be as follows.

a) Calculate the reactance X by the following formula:

$$X = |Z| \times \sin \varphi$$

where

X is the reactance (Ω);

$|Z|$ is the impedance (Ω);

φ is the phase angle.

b) Use the calculated reactance to calculate the capacitance C of the capacitor by the following formula:

$$C = \frac{X}{2\pi f}$$

where

C is the capacitance (F);

π is the circle ratio;

f is the measuring frequency (Hz).

B.4 Measuring conditions

The measuring conditions shall be as follows:

a) Use ~~any~~ either of the measuring frequencies ~~from~~ of 0,05 Hz, 0,1 Hz, 1 Hz, 10 Hz or 100 Hz;

b) the measuring voltage shall be 3 % or less of the rated voltage;

c) the bias voltage shall be 50 % to 95 % of the rated voltage; if no doubt arises ~~on~~ with respect to judgment, the bias voltage may be omitted.

Annex C
(informative)

Thermal equilibrium time of capacitors

C.1 General

This annex describes the thermal equilibrium time of capacitors, as a reference in determining the soaking time for pre-treatment.

C.2 Thermal equilibrium time of capacitors

Presuming that the thermal equilibrium time, which is the time required for the central portion of a capacitor to reach the temperature difference from the external temperature within 1 °C, is dependent on the external dimensions of the capacitor, the temperature changes in the central portions of capacitors was verified.

The resultant data were obtained by verifying the thermal equilibrium time of the central portions of capacitors that were subjected to a certain environmental temperature. As a result, it was observed that the equilibrium time was proportional to the magnitudes of the external dimensions such as diameter for cylindrical capacitors and thickness (thinnest side) for cubic capacitors. Figure C.1 shows the thermal equilibrium times of the capacitors when soaked to normal room temperature from a high temperature. Figure C.2 shows the thermal equilibrium time of the capacitors when soaked to normal room temperature from a low temperature. In these figures, the dotted straight lines indicate the presumed longest thermal equilibrium time. It is advisable to use these dotted straight lines as soaking time for pre-conditioning. Figure C.3 shows the actual measured temperature changes in the capacitors' central portions.

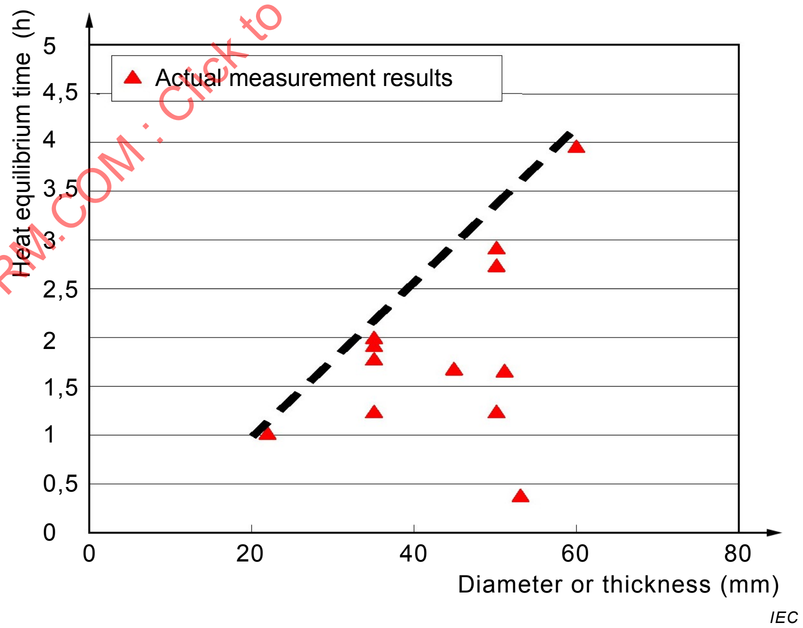


Figure C.1 – Thermal equilibrium times of capacitors (from 85 °C to 25 °C)

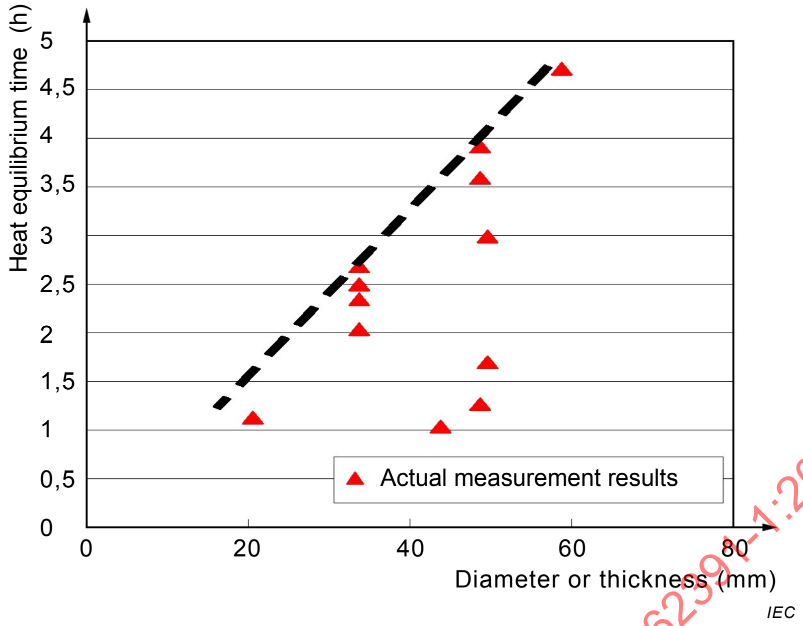
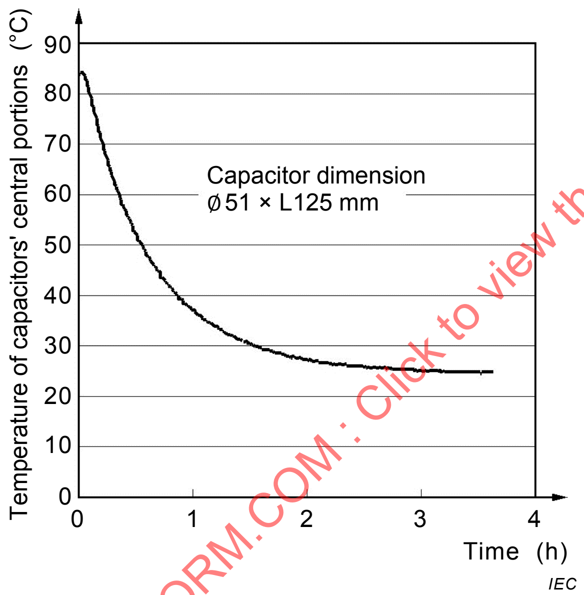
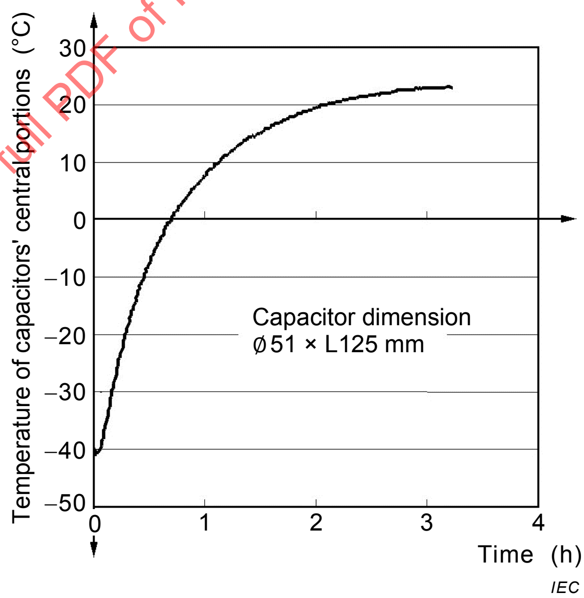


Figure C.2 – Thermal equilibrium times of capacitors (from −40 °C to 25 °C)



a) From 85 °C to 25 °C



b) From −40 °C to 25 °C

Figure C.3 – Capacitor core temperature change with respect to time

Annex D
(informative)

Charging/discharging efficiency and measurement current

D.1 General

This annex describes the general concept regarding the charging and discharging efficiency and measured current, which are provided in 5.5.3.

D.2 Charging efficiency, discharging efficiency, and current

Charge Q after charging or discharging for time t at a constant current I, stored energy W, and energy L lost by resistance R are given by Formulas (D.1), (D.2), and (D.3), respectively.

$$Q = It \tag{D.1}$$

$$W = \frac{Q^2}{2C} \tag{D.2}$$

$$L = I^2 Rt = \frac{RQ^2}{t} \tag{D.3}$$

When a capacitor is charged or discharged to its full capacity at a constant current according to Formula (D.2) or (D.3), respectively, the energy efficiency P_c for charging or P_d for discharging is given by Formula (D.4) or (D.5), respectively, where R is the internal resistance and C is the capacitance of the capacitor.

$$P_c = \frac{W}{W+L} = \frac{t}{t+2RC} \tag{D.4}$$

$$P_d = \frac{W-L}{W} = I - \frac{2RC}{t} \tag{D.5}$$

In this document, the efficiency for charging or discharging is proposed as 95 % after considering exothermal effect and time consumption for the measurement. The time t required for charging at 95 % efficiency is given by Formula (D.6) derived from Formula (D.4).

$$t = 38RC \tag{D.6}$$

Charge Q stored in a capacitor is given as a product of capacity C and charging voltage U, thus leading to Formula (D.7). Current I_c for 95 % charging is given by Formula (D.8) derived from Formulas (D.1), (D.6), and (D.7).

$$Q = CU \tag{D.7}$$

$$I_c = \frac{U}{38R} \tag{D.8}$$

Similarly, the time t needed for 95 % discharging is given by Formula (D.9) derived from Formula (C.5), and the current I_d needed for 95 % discharging is given by Formula (D.10).

$$t = 40RC \tag{D.9}$$

$$I_d = \frac{U}{40R} \tag{D.10}$$

Formulas (D.8) and (D.10) are suggested for determining the value of the current for the charging or discharging test. Once the value of the charging/discharging current is determined, the maximum output at the target efficiency can be calculated.

Annex E
(informative)

Procedures for setting the measurement current of capacitor with uncertain nominal internal resistance

E.1 General

This annex describes the current setting procedures provided in 5.5.3.

E.2 Current setting procedures for measurement of capacitor

When the nominal value of internal resistance of a capacitor is uncertain, the current for the measurement of the capacitor with 95 % charging efficiency and 95 % discharging efficiency can be set according to the following procedures.

a) Using the estimated value of the internal resistance, measure the time characteristic of the voltage between the capacitor terminals according to the procedure described in 5.5.3 and then calculate the internal resistance according to the description in 5.5.5.
b) When the internal resistance is unpredictable, it is recommended to temporarily set the charging and discharging currents as 30 A.
c) Using the internal resistance value calculated by step a) above, measure the time characteristic of the voltage between the capacitor terminals according to the procedure described in 5.5.3 and calculate the internal resistance according to the description in 5.5.5.
d) Repeat the above procedures until the difference between the calculated internal resistance value and the previous value becomes less than 10 % of the previous value.

However, when ΔU_3 becomes greater than 0,1U_R, follow procedures a) to c) with a smaller current and then perform the measurements. When the calculated internal resistance is a negative value, follow procedures a) to c) with a larger current and then perform the measurements.

E.3 Example of setting current for determining capacitor characteristics

Table E.1 shows examples of setting the measurement current. The setting was performed in the order of setting conditions shown in Table E.1.

Table E.1 – Example of setting current for measurement of capacitor

Setting condition	Internal resistance value used for setting mΩ	Charging current A	Discharging current A	Calculated capacitance F	Calculated internal resistance mΩ
1	1,5 (Estimated)	47,4	45,0	1 297	4,6
2	4,6 (Calculated with the result of No 1)	15,4	14,7	1 351	5,0
3	5,0 (Calculated with the result of No. 2)	14,2	13,5	1 351	5,0

Annex F
(informative)

Policy on uncertainty of measurement and inset limits

F.1 Objective

Specifications for electronic components give the parametric limits that define the acceptability of the component. These limits do not take into account the uncertainty of measurement caused by test and measuring equipment inaccuracies, test methods, environmental conditions and, sometimes, operator participation.

The purpose of this annex is to define policy on the calculation of measurement uncertainty and insetting limits to ensure uniform implementation. The special case of outsetting limits is also covered.

F.2 Terms and definitions

For the purposes of this annex the following terms and definitions apply.

F.2.1
uncertainty of measurement
statement of the limits of the range within which the true value of the measurement is expected to lie in relation to the recorded result with a defined confidence level

F.2.2
measuring equipment
all of the instruments which are necessary in order to carry out a measurement

Note 1 to entry: The definition makes it clear that items such as cables, connectors, handlers, handler cards or other fixtures used in conjunction with a measurement indicating instrument are subject to the requirements of this policy.

F.2.3
inset limits
tightened limits resulting from an allowance applied to the specified limits of a parameter to take into account all influence quantities on the indication of a measuring instrument so as to ensure that out of limit devices are not accepted due to measurement errors

F.2.4
outset limits
relaxed limits resulting from an allowance applied to the specified limits of a parameter to take into account all influence quantities on the indication of a measuring instrument so as to ensure that in limit devices are not rejected due to measurement errors

F.3 Calculation of measurement uncertainty

The assessment of uncertainty of measurement of a performance requirement can be broken down into three stages:

a) identification of possible error contributions;

b) quantifying the size of each listed contribution;

c) calculating the total uncertainty of measurement.

F.4 Policy

F.4.1 A measurement uncertainty value shall be calculated for each performance requirement which is related to qualification approval, capability approval, technology approval, process approval, screening, lot-by-lot and periodic tests as defined by the specifications.

F.4.2 Each measurement uncertainty value shall be used to apply an inset, of at least this value, to the relevant specification limits as defined in F.4.1.

F.4.3 This inset shall be applied in accordance with F.5.2 for qualification approval, capability approval, technology approval and process approval and F.5.3 for product audit testing.

F.4.4 Test reports and test records, compiled to show compliance with qualification approval, capability approval, screening, lot-by-lot and periodic tests as defined by the applicable specifications, shall list the uncertainty value for each performance requirement.

F.5 Calculation of inset and outset limits

F.5.1 The fundamental principle is that the limits should be inset from the specified values by the corresponding uncertainty of measurement. This increases the probability that measurement results which fall within the tightened limits, including marginal values, are genuinely within specification limits such that only truly conforming devices are accepted.

The exception to insetting limits occurs when product audit tests are conducted. In this situation, to ensure that, as far as possible, uncertainty of measurement does not cause good products to fail, an audit test outsets the limits. This increases the possibility that measurement results that fall outside the relaxed limits, including marginal values, are genuinely outside specification limits such that only truly nonconforming devices are rejected.

F.5.2 For a component manufacturer the upper specified value of a parameter being ‘x’, the lower specified value of the parameter being ‘y’ and the uncertainty of measurement being ‘a’, the “inset limits” for the parameter are (x-a) and (y+a).

F.5.3 For an audit test the upper specified value of a parameter being ‘x’, the lower specified value of the parameter being ‘y’ and the uncertainty of measurement being ‘b’, the “outset limits” for the parameter are (x+b) and (y-b).

The smaller the uncertainty of measurement, the lower the values of ‘a’ and ‘b’ become and the closer the manufacturer’s and the audit test’s inset/outset limits approach the specification limits.

F.6 Examples

F.6.1 General

Setting “inset limits” and “outset limits”.

F.6.2 Example 1: Resistor measurement

Specified resistance value:	100 Ω ± 10 % = 90 Ω to 110 Ω
Uncertainty of measurement calculated to be:	±1,2 % = ±1,08 Ω and ±1,32 Ω
Inset limits:	91,08 Ω to 108,68 Ω
Outset limits:	88,92 Ω to 111,32 Ω

F.6.3 Example 2: Resistor measurement

Initial measurement	105,00 Ω
Specified resistance value	<0,5 % = ±0,53 Ω
	= 104,47 Ω to 105,53 Ω
Uncertainty of measurement calculated to be	±0,1 % = ±0,10 Ω and ±0,11 Ω
Inset limits:	104,57 Ω to 105,42 Ω
Outset limits	104,37 Ω to 105,64 Ω

F.6.4 Example 3: Transistor measurement (gain)

Specified limits:	$60 \leq h_{21E} \leq 80$
Uncertainty of measurement calculated to be:	5
Inset limits:	65 to 75
Outset limits:	55 to 85

F.6.5 Example 4: Comparison between initial and final measurement results

Initial measurement:	102,05 µF
Specified tolerance:	Variation at 1 %
Uncertainty of measurement calculated to be	0,1 %
Inset limits:	101,13 µF to 102,97 µF
Outset limits	100,93 µF to 103,17 µF

Annex G
(informative)

Reference to IEC 62391-1:2006

The drafting of this standard has resulted in a new structure. The following table indicates the new clause and subclause numbers with respect to the IEC 62391-1:2006 (first edition).

IEC 62391-1:2006 first edition Clause/Subclause	**IEC 62391-1:2015** this edition Clause/Subclause	**Notes**
1	1	Gerneral and scope are merged into one
1.1		
1.2	2	In accordance with the ISO/IEC Directives, Part 2
2.1	4.1	
2.2	3	In accordance with ISO/IEC Directives, Part 2
2.3	4.2	
2.4	4.3	
3	4.4	
4	5	
4.1	5.1	In accordance with the change of clause numbers
4.2	5.2	
4.3	5.3	
4.4	5.4	
4.5	5.5, 5.6	Divide the measuring method into two
4.6	5.5, 5.6	Divide the measuring method into two
4.7	5.7	In accordance with the change of clause numbers
4.8	5.8	
4.9	5.9	
4.10	5.10	
4.11	5.11	
4.12	5.12	
4.13	5.13	
4.14	5.14	
4.15	5.15	
4.16	5.16	
4.17	5.17	
4.18	5.18	
4.19	5.19	
4.20	5.20	
4.21	5.21	

Annex Q
(normative)

Quality assessment procedures

Q.1 General

Q.1.1 Overview

When this standard, and any related standards are used for the purpose of a full quality assessment system compliance with Clauses Q.5, Q.6 or Q.14 is required.

When such standards are used outside quality assessment systems for purposes such as design proving or type testing, the procedures and requirements of Q.5.1 and Q.5.3 b) may be used, but, if used, the tests and parts of tests shall be applied in the order given in the test schedules.

Before components can be qualified according to the procedures of this annex, the manufacturer shall obtain the approval of his organization in accordance with the provisions of the specified quality assessment system (if any).

The methods that are available for the approval of components of assessed quality and which are covered by the following subclauses, are:

– qualification approval;
– capability approval;
– technology approval.

For a given subfamily of components, separate sectional specifications for qualification approval and capability approval are necessary and capability approval is therefore available only when a relevant sectional specification has been published.

Q.1.2 Applicability of qualification approval

Qualification approval is appropriate for a standard range of components manufactured to similar design and production processes and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and performance levels applies directly to the component range to be qualified, as prescribed in Clause Q.5 and the relevant sectional specification.

Q.1.3 Applicability of capability approval

Q.1.3.1 General

Capability approval is appropriate when components based on common design rules are fabricated by a group of common processes. It is particularly appropriate when components are manufactured to a user's specific requirements.

Under capability approval, detail specifications fall into the following three categories.

Q.1.3.2 Capability qualifying components (CQCs), including process validation test vehicles

A detail specification shall be prepared for each CQC. It shall identify the purpose of the CQC and include all relevant test severities and limits.

Q.1.3.3 Standard catalogue components

When the manufacturer requires a component approved under the capability approval procedure, a capability approval detail specification complying with the blank detail specification (if any) shall be written.

Q.1.3.4 Customer specific components

The content of the detail specification (often known as a customer detail specification (CDS)) shall be by agreement according to the specified quality assessment system (if any).

Further information on these detail specifications is given in the relevant sectional specification.

Approval is given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures and the results of tests on capability qualifying components, including any process validation test vehicles. See Clause Q.6 and the relevant sectional specification for further information.

Q.1.4 Applicability of technology approval

Technology approval is appropriate when the complete technological process (design, process realization, product manufacture, test and shipment) covers the qualification aspects common to all components determined by the technology.

Q.2 Primary stage of manufacture

The primary stage of manufacture shall be specified in the sectional specification.

Q.3 Subcontracting

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed it shall be in accordance with the specified quality assessment system (if any).

The generic or sectional specification may

– either forbid this subcontracting on technical grounds, or
– where it is considered necessary, include any special requirements, for example for specified successive stages to be performed by the same manufacturer, or
– permit the subcontracting unreservedly.

Q.4 Structurally similar components

The grouping of structurally similar components for qualification approval testing or for quality conformance testing under qualification approval, capability approval or technology approval shall be prescribed in the relevant sectional specification.

Q.5 Qualification approval procedures

Q.5.1 Eligibility for qualification approval

Qualification approval may be granted only to a manufacturer who has been granted manufacturer's approval and, additionally, the requirements of this annex. These approvals may be carried out in parallel, although qualification approval shall not be granted in advance of manufacturer's approval.

Q.5.2 Application for qualification approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.5.3 Test procedure for qualification approval

One of the following procedures shall be used.

a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible, and on one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

b) Samples shall be taken from the lots in accordance with IEC 61193-2. Normal inspection shall be used, but if the sample size gives acceptance on zero non-conformances, additional specimens shall be taken to meet the sample size requirements to give acceptance on one non-conforming item.

c) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the sectional specification.

d) The specimens taken to form the sample shall be selected at random from current production or as agreed.

e) For the two procedures, the sample sizes and the number of permissible non-conformances shall be of comparable order. The test conditions and requirements shall be the same.

Q.5.4 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completed satisfactorily.

Q.5.5 Maintenance of qualification approval

Qualification approval shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see Q.5.6).

Q.5.6 Quality conformance inspection

The blank detail specification(s) associated with the sectional specification shall prescribe the test schedule for quality conformance inspection. This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection.

Operation of the switching rule for reduced inspection in Group C is permitted in all subgroups except endurance.

Sampling plans and inspection levels shall be selected from those given in IEC 61193-2.

If required, more than one schedule may be specified.

Q.6 Capability approval procedures

Q.6.1 General

Capability approval covers

– the complete design, material preparation and manufacturing techniques, including control procedures and tests;

– the performance limits claimed for the processes and products, that is, those specified for the capability qualifying components (CQCs) and process control parameters (PCPs);

– the range of mechanical structures for which approval is granted.

For a general overview of capability approval, see Figure Q.1.

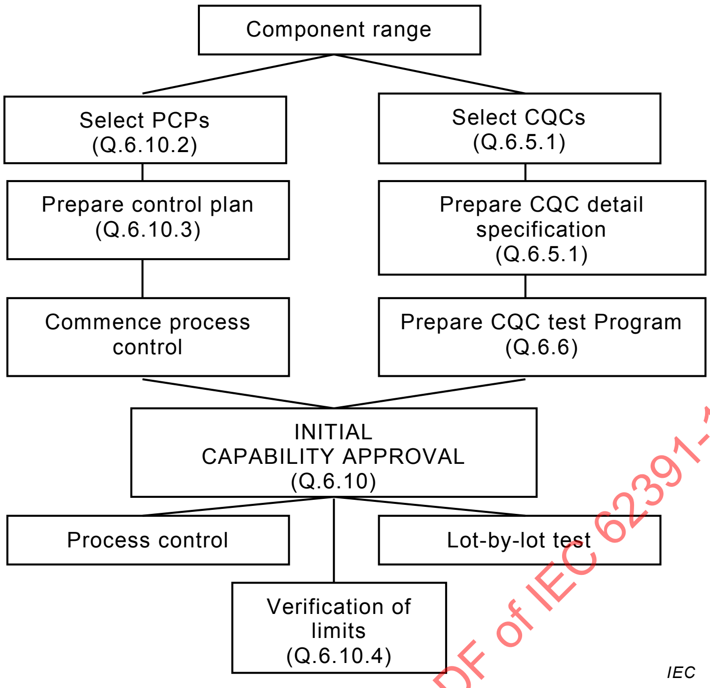


Figure Q.1 – General scheme for capability approval

Q.6.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any).

Q.6.3 Application for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any), and with the requirements of the relevant sectional specification.

Q.6.4 Description of capability

The capability shall be described in a capability manual in accordance with the specified quality assessment system (if any), and the requirements of the relevant sectional specification. The manual shall include or make reference to the following as a minimum:

– a general introduction and description of the technologies involved;
– aspects of customer liaison including provisions of design rules (if appropriate) and assistance to customers in the formulation of their requirements;
– a detailed description of the design rules to be used;
– the procedure for checking that the design rules are complied with for the relevant component technology manufactured to a detail specification;
– a list of all materials used, with reference to the corresponding purchasing specifications and goods inward inspection specifications;
– a flow chart for the total process, showing quality control points and permitted rework loops and containing references to all process and quality control procedures;
– a declaration of processes for which approval has been sought in accordance with the requirements of the relevant sectional specification;

– a declaration of limits for which approval has been sought in accordance with the requirements of the relevant sectional specification;
– a list of CQCs used to assess the capability, with a general description of each, supported by a detailed table showing where the declared limits of capability are demonstrated by a particular CQC design;
– detail specification for each CQC;
– a detailed control plan including PCPs used to control processes, with a general description of each PCP and showing the relation between a given PCP and the related properties and performance of the finished component;
– guidance on the application of structural similarity in sampling for quality conformance testing.

Q.6.5 Demonstration and verification of capability

Q.6.5.1 General

The manufacturer shall demonstrate and verify the capability in accordance with the specified quality assessment system (if any), and the requirements of the relevant sectional specification with the following details:

Q.6.5.2 CQCs for demonstrating capability

The manufacturer shall agree with the CB on the process qualifying parameters and the range of capability qualifying components which are necessary to demonstrate the capability range specified in the capability manual.

The demonstration shall be made by testing the agreed range of CQCs, which shall be designed, manufactured and the process parameters controlled in accordance with the capability manual. The CQCs shall comply with the following requirements:

a) The range of CQCs used shall represent all the limits of the declared capability. The CQCs shall be chosen to demonstrate mutually attainable combinations of limits.
b) The CQCs shall be one of the following:
   – components specially designed to demonstrate a combination of limits of capability, or
   – components of designs used in general production, or
   – a combination of both of these, provided the requirements of a) are met.

When CQCs are designed and produced solely for capability approval, the manufacturer shall use the same design rules, materials and manufacturing processes as those applied to released products.

A detail specification shall be prepared for each CQC and shall have a specific front page format. The detail specification shall identify the purpose of the CQC and shall include all relevant stress levels and test limits. It may refer to internal control documentation which specifies production testing and recording in order to demonstrate control and maintenance of processes and limits of capability.

Q.6.5.3 Limits of capability

The limits of capability shall be described in the relevant sectional specification.

Q.6.6 Programme for capability approval

In accordance with the specified quality assessment system (if any), the manufacturer shall prepare a programme for the assessment of the declared capability. This programme shall be so designed that each declared limit of capability is verified by an appropriate CQC.

The programme shall include the following:

– a bar chart or other means of showing the proposed timetable for the approval exercise;
– details of all the CQCs to be used with references to their detail specifications;
– a chart showing the features to be demonstrated by each CQC;
– reference to the control plans to be used for process control.

Q.6.7 Capability approval test report

In accordance with the specified quality assessment system (if any), a capability approval test report shall be issued. The report shall meet the specific requirements for the capability approval test report and shall contain the following information:

– the issue number and date of the capability manual;
– the programme for capability approval in accordance with Q.6.6;
– all the test results obtained during the performance of the programme;
– the test methods used;
– reports on actions taken in the event of failure (see Q.6.10.2).

The report shall be signed by the designated management representative (DMR) as a true statement of the results obtained and submitted to the body, designated in the national rules, which is responsible for the granting of capability approval.

Q.6.8 Abstract of description of capability

The abstract is intended for formal publication after capability approval has been granted.

The abstract shall include a concise description of the manufacturer's capability and give sufficient information on the technology, methods of construction and range of products for which the manufacturer has been approved.

Q.6.9 Modifications likely to affect the capability approval

Any modifications likely to affect the capability approval shall satisfy the requirements of the specified quality assessment system (if any).

Q.6.10 Initial capability approval

Q.6.10.1 General

The approval is granted when

– the selected range of CQCs has collectively satisfied the assessment requirements of the CQC detail specifications, with no nonconforming item allowed;
– the control plan has been fully implemented in the process control system.

Q.6.10.2 Procedure in the event of failure

See the specified quality assessment system (if any), with the following details.

In the event of the failure of the specimens to meet the test requirements, the manufacturer shall state his/her intention to follow one of the actions described in a) and b) below:

a) to modify the proposed scope of the capability;
b) to conduct an investigation to establish the cause of failure as being either
   – failure of the test itself, for example, test equipment failure or operator error,
     or

– design or process failure.

If the cause of failure is established as a failure of the test itself, then either the specimen which apparently failed or a new one, if appropriate, shall be returned to the test schedule after the necessary corrective action has been taken. If a new specimen is to be used, it shall be subjected to all of the tests in the given sequence of the test schedule(s) appropriate to the apparently failed specimen.

If the cause of failure is established as a design or process failure, a test programme shall be carried out to demonstrate that the cause of failure has been eradicated and that all corrective measures, including documentation, have been carried out. When this has been accomplished, the test sequences in which the failure has occurred shall be repeated in full using new CQCs.

After the action is complete the manufacturer shall send a report, and shall include a copy in the capability approval test report (see Q.6.7).

Q.6.10.3 General plan for the selection of PCPs and CQCs

Each manufacturer shall prepare a process flow chart, based on the example given in the relevant sectional specification. For all the process steps included in this flow chart, the manufacturer shall include the corresponding process controls.

Controls shall be denoted by the manufacturer as shown in the example in the relevant sectional specification.

Q.6.10.4 Process control test plans

The test plans shall form part of the process control system used by the manufacturer. When statistical process control (SPC) is used, implementation shall be in accordance with SPC basic requirements. The SPC plans represent mandatory controls at process nodes.

For each process step where production equipment is employed, the manufacturer shall monitor the process parameters at regular intervals and compare the readings to the control and action limits which he/she will establish.

Q.6.10.5 Test plans for CQCs demonstrating limits of capability

Test plans for CQCs for the demonstration of limits of capability shall be prescribed in the relevant sectional specification.

Q.6.11 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with the specified quality assessment system (if any), have been completed satisfactorily and the requirements of the relevant sectional specification have been met.

Q.6.12 Maintenance of capability approval

Capability approval shall be maintained by complying with the requirements of the specified quality assessment system (if any), and with the requirements declared in the capability manual following the schedule of maintenance given in the relevant sectional specification.

Additionally, the following details apply.

a) Capability approval remains valid without retesting for two years.
b) The programme for the retesting of CQCs shall be defined by the manufacturer. For process control, the manufacturer shall establish a control system. An example of a control programme chart may be given in the sectional specification. For verifying limits of

capability, the manufacturer shall ensure that all the test plans of Q.6.10.5 which are relevant to his capability approval are repeated at least every two years.

c) Quality conformance inspection of components for delivery may be used to support the maintenance of capability approval where relevant. In particular, where the manufacturer holds qualification approval for a range of components which are manufactured by the same processes and which also fall within the limits of capability for which he holds capability approval, process control test results and periodic quality conformance test results arising from the qualification approval may be used to support the maintenance of capability approval.

d) The manufacturer shall ensure that the range of CQCs remains representative of the products released and in accordance with the requirements of the relevant sectional specification.

e) The manufacturer shall maintain production, so that
   – the processes specified in the capability manual, with the exception of any agreed additions or deletions following the procedure of Q.6.9, remain unchanged,
   – no change has occurred in the place of manufacture, and final test,
   – no break exceeding six months has occurred in the manufacturer's production under capability approval.

f) The manufacturer shall maintain a record of the progress of the maintenance of capability programme so that at any time the limits of capability which have been verified and those which are awaiting verification in the specified period can be established.

Q.6.13 Extension of capability approval

The manufacturer may extend the limits of his capability approval by carrying out the test plan from Q.6.10.5, which relates to the type of limit to be extended. If the proposed extension refers to a different type of limit from those described in Q.6.10.5, the manufacturer shall propose the sampling and tests to be used and these shall be approved. The manufacturer shall also establish process control over any new processes needed for manufacture to the new limits.

An application for an extension of capability shall be made in the same way as for the original approval.

Q.6.14 Quality conformance inspection

The quality conformance test requirements are given in the detail specification and shall be carried out in accordance with the specified quality assessment system (if any).

Q.7 Rework and repair

Q.7.1 Rework

Rework as defined in the specified quality assessment system (if any), shall not be carried out if prohibited by the relevant sectional specification. The relevant sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection in accordance with the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the DMR. Rework shall not be subcontracted.

Q.7.2 Repair

Components which have been repaired as defined in the specified quality assessment system (if any), shall not be released.

Q.8 Release for delivery

Q.8.1 General

Components shall be released for delivery according to Q.5.6 and the specified quality assessment system (if any), after the quality conformance inspection prescribed in the detail specification has been carried out.

Q.8.2 Release for delivery under qualification approval before the completion of Group B tests

When the conditions of IEC 61193-2:2007 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

Q.9 Certified test records of released lots

When certified test records are requested by a purchaser, they shall be specified in the detail specification.

NOTE For capability approval, the certified test records refer only to tests carried out on capability qualifying components.

Q.10 Delayed delivery

Components held for a period exceeding two years (unless otherwise specified in the sectional specification) following the release of the lot shall, before delivery, be re-examined for solderability and electrical characteristics as specified in the detail specification.

The re-examination procedure adopted by the manufacturer's DMR shall be approved.

Once a lot has been satisfactorily re-inspected, its quality is reassured for the specified period.

Q.11 Alternative test methods

See the specified quality assessment system (if any), with the following details.

In case of dispute, for referee and reference purposes, only the specified methods shall be used.

Q.12 Manufacture outside the geographical limits of IECQ CBs

See the requirements of the specified quality assessment system (if any).

Q.13 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing shall be assumed to be within the specified limits. It cannot be assumed that any unspecified parameter will remain unchanged from one component to another. If it is necessary, for any reason, to control one or more additional parameters, then a new, more extensive specification shall be used.

The additional test method(s) shall be fully described and appropriate limits, sampling plans and inspection levels specified.

Q.14 Technology approval procedures

Q.14.1 General

Technology approval of components covers the complete technological process. It extends the existing concepts – qualification and capability approval – by adding as mandatory:

a) the use of in-process control methods, for example, SPC;
b) continuous quality improvement strategy;
c) monitoring the overall technologies and operations;
d) procedural flexibility due to the quality assurance management system and market sector requirements;
e) the acceptance of a manufacturer's operational documentation to provide means for rapid approval or extension of approval.

Q.14.2 Eligibility for technology approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.14.3 Application of technology approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.14.4 Description of technology

The technology shall be described in a Technology Approval Declaration Document (TADD) and a Technology Approval Schedule (TAS) in accordance with the specified quality assessment system (if any).

Q.14.5 Demonstration and verification of the technology

The manufacturer shall demonstrate and verify the technology in accordance with the specified quality assessment system (if any).

Q.14.6 Granting of technology approval

Technology approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completely satisfied.

Q.14.7 Maintenance of technology approval

Technology approval shall be maintained by complying with the requirements of the specified quality assessment system (if any).

Q.14.8 Quality conformance inspection

The quality conformance test and requirements shall be carried out in accordance with the detail specification and technology approval schedules.

Q.14.9 Failure rate level determination

The determination of failure rate level and certification shall be described in the detail specification.

Q.14.10 Outgoing quality level

The definition shall be agreed between customer and manufacturer.

Bibliography

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

IEC 61881-3:2012, *Railway applications – Rolling stock equipment – Capacitors for power electronics – Part 3: Electric double-layer capacitors*

IEC 62391-1:2006, *Fixed electric double-layer capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 62391-2:2006, *Fixed electric double-layer capacitors for use in electronic equipment – Part 2: Sectional specification – Electric double-layer capacitors for power application*

IEC 62391-2-1:2006, *Fixed electric double-layer capacitors for use in electronic equipment – Part 2-1: Blank detail specification – Electric double-layer capacitors for power application. Assessment level EZ*

IEC 62576:2009, *Electric double-layer capacitors for use in hybrid electric vehicles – Test methods for electrical characteristics*

ISO 80000-1:2009, *Quantities and units – Part 1: General*

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INTERNATIONAL STANDARD

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colour inside

Fixed electric double-layer capacitors for use in electric and electronic equipment –
Part 1: Generic specification

Condensateurs électriques fixes à double couche utilisés dans les équipements électriques et électroniques –
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FIXED ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN ELECTRIC AND ELECTRONIC EQUIPMENT –

Part 1: Generic specification

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62391-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This bilingual version (2017-12) corresponds to the monolingual English version, published in 2015-10.

This second edition cancels and replaces the first edition published in 2006 and constitutes a technical revision.

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

a) enhancement of the scope to include electric (high power) application;
b) implementation of Annex Q, replacing Clause 3 in the first edition;

c) in addition, minor revisions related to tables, figures and references.

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

FDIS	Report on voting
40/2393/FDIS	40/2415/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.

The French version of this standard has not been voted upon.

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

A list of all parts of IEC 62391 under the general title *Fixed electric double-layer capacitors for use in electric and electronic equipment* can be found in the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

The contents of the corrigenda of December 2016 and June 2019 have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

FIXED ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN ELECTRIC AND ELECTRONIC EQUIPMENT –

Part 1: Generic specification

1 Scope

This part of IEC 62391 applies to fixed electric double-layer capacitors (hereafter referred to as capacitor(s)) mainly used in d.c. circuits of electric and electronic equipment.

This part of IEC 62391 establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications of electronic components for quality assessment or any other purpose.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050 (all parts), *International Electrotechnical Vocabulary*

IEC 60062, *Marking codes for resistors and capacitors*

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

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

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Tests B: Dry Heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-20:2008, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices of with leads*

IEC 60068-2-21:2006, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-45:1980, *Environmental testing – Part 2-45: Tests – Test XA and guidance: Immersion in cleaning solvents*
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IEC 60294:2012, *Measurement of the dimensions of a cylindrical component with axial terminations*

IEC 60617 (all parts), *Graphical symbols for diagrams*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60717:2012, *Method for the determination of the space required by capacitors and resistors with unidirectional terminations*

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

3 Terms and definitions

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

3.1
type
group of components having similar design features and manufacturing techniques, enabling them to be considered together, either for qualification approval or for quality conformance inspection

Note 1 to entry: In some cases, components described in several detail specifications may be considered as belonging to the same type.

[SOURCE: IEC 60384-1:2008, 2.2.39 – modified, the remark on "single detail specification" was deleted from the definition and the Note was rephrased.]

3.2
style
subdivision of a type, generally based on dimensional factors

Note 1 to entry: A style may include several variants, generally of a mechanical order.

3.3
class
classification of the capacitor by the capacitance value and the internal resistance value depending upon the application

3.4
family
<electronic components> group of components which predominantly displays a particular physical attribute and/or fulfils a defined function

3.5
subfamily
<electronic components> group of components within a family manufactured by similar technological methods

3.6
d.c. capacitor
capacitor designed essentially for application with direct voltage

Note 1 to entry: A d.c. capacitor may not be suitable for use on a.c. supplies.

3.7
nominal capacitance
C_N
designated capacitance value usually indicated on the capacitor

3.8
category temperature range
range of ambient temperatures for which the capacitor has been designed to operate continuously

Note 1 to entry: This is given by the lower and upper category temperature.

3.9
lower category temperature
minimum ambient temperature for which a capacitor has been designed to operate continuously

3.10
upper category temperature
highest ambient temperature including internal heating in which a capacitor is designed to operate continuously

[SOURCE: IEC 61881-3:2012, 3.17, modified – The note to entry has been deleted.]

3.11
rated temperature
maximum ambient temperature at which the rated voltage may be continuously applied

3.12
rated voltage
U_R
maximum d.c. voltage or peak value of pulse voltage which may be applied continuously or repetitively to a capacitor at any temperature between the lower category temperature and the rated temperature

3.13
category voltage
U_C
maximum voltage which may be applied continuously to a capacitor at its upper category temperature

3.14
temperature derated voltage
maximum voltage that may be applied continuously to a capacitor when it is at any temperature between the rated temperature and the upper category temperature

Note 1 to entry: Information on the voltage/temperature dependence at temperatures between the rated temperature and the upper category temperature is given in the detail specification.

3.15
surge voltage ratio
quotient of the maximum instantaneous voltage which may be applied to the terminations of the capacitor for a specified time at any temperature within the category temperature range and the rated voltage or the temperature derated voltage, as appropriate

Note 1 to entry: The number of times per hour that this voltage may be applied is specified in the detail specification.

3.16
rated ripple voltage
r.m.s. value of the maximum allowable alternating voltage at a specified frequency superimposed on the d.c. voltage at which the capacitor may be operated continuously at a specified temperature

Note 1 to entry: The sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor does not exceed the rated voltage or temperature derated voltage, as applicable.

3.17
reverse voltage
<polar capacitors> voltage applied to the capacitor terminations in the reverse polarity direction

3.18
rated ripple current
r.m.s. value of the maximum allowable alternating current of a specified frequency, at which the capacitor may be operated continuously at a specified temperature

3.19
time constant
product of the internal resistance (including circuit resistance) and the capacitance

Note 1 to entry: The time constant is normally expressed in seconds.

3.20
internal resistance
resistance component in an equivalent series circuit of capacitance and resistance of a capacitor

Note 1 to entry: The internal resistance is given in ohms (Ω).

3.21
IR drop
voltage drop between the capacitor terminals that is generated at the start of discharge and quantified by the product of the discharge current and the internal resistance of the capacitor

3.22
maximum temperature of a capacitor
temperature at the hottest point of its external surface

Note 1 to entry: The terminations are considered as a part of the external surface.

3.23
minimum temperature of a capacitor
temperature at the coldest point of the external surface

Note 1 to entry: The terminations are considered to be part of the external surface.

3.24
minimum storage temperature
minimum ambient temperature which the capacitor should withstand in the non-operating condition without damage

3.25
maximum storage temperature
maximum ambient temperature which the capacitor withstands in the non-operating condition without damage

[SOURCE: IEC 60384-1:2008, 2.2.11]

3.26
temperature characteristic of capacitance
maximum reversible variation of capacitance produced over a given temperature range within the category temperature range

Note 1 to entry: The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

Note 2 to entry: The temperature characteristic of capacitance is normally expressed as a percentage of the capacitance related to a reference temperature of 20 °C.

3.27
visible damage
visible damage which reduces the usability of the capacitor for its intended purpose

3.28
leakage current
value of the current that flows through a capacitor after a charge for a fixed period of time

Note 1 to entry: Leakage current is given in amperes (A).

3.29
maintain voltage
self discharge
voltage held while being left for a fixed period of time under no load after a charge for a fixed period of time

3.30
temperature rise
<capacitor> increase of temperature of the capacitor relative to the ambient temperature resulting from the losses in the capacitor due to operation under charge and/or discharge conditions

3.31
insulated capacitor
capacitor in which all terminations of a section may be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

3.32
uninsulated capacitor
capacitor in which one or more of the terminations of a section cannot be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

3.33
surface mount capacitor
fixed capacitor whose small dimensions and nature or shape of terminations make it suitable for use in hybrid circuits and on printed boards

3.34
passive flammability
flammability caused by external heating of the component

Note 1 to entry: Passive flammability can be caused by flames for example.

3.35
active flammability
flammability (self-ignition) caused by internal heating of the component

Note 1 to entry: Active flammability can be caused by sparking due to insufficient internal contact for example.

3.36
category of passive flammability
category given by the maximum burning time after a specified time of flame application

3.37
mass
mass of the capacitor with all fixed parts

3.38
volume
volume of the capacitor body excluding terminations

4 General items

4.1 Unit and symbols

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following documents:

– IEC 60027;
– IEC 60050;
– IEC 60617;
– ISO 80000-1.

When further items are required they should be derived in accordance with the principles of the publications listed above.

4.2 Preferred values and class

4.2.1 General

The preferred values appropriate to the subfamily shall be prescribed in the sectional specification.

NOTE It is not possible to specify the preferred values of rated voltage due to the nature of the capacitor.

4.2.2 Preferred values of nominal capacitance

The preferred values of nominal capacitance shall be taken from the R series specified in IEC 60063.

4.2.3 Class

The class of the capacitor shall be classified according to capacitance and internal resistance (application). See Annex A for details.

4.3 Marking

4.3.1 General

The identification criteria and other information to be marked on the capacitor and/or packaging shall be indicated in the sectional specification.

The order of marking priority for small size capacitors shall be specified in the detail specification.

4.3.2 Coding

When coding is used for capacitance value, tolerance or date of manufacture, the method shall be selected from those given in IEC 60062.

4.4 Quality assessment procedures

See Annex Q.

5 Tests and measurement

5.1 General

The sectional and/or blank detail specification shall indicate the tests to be made, which measurements are to be made before and after each test or subgroup of tests, and the sequence in which they shall be made. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any quality assessment system include methods other than those specified in the above specifications, they shall be fully described.

Limits given in all specifications are absolute limits. The principle to take measurement uncertainty into account is given in Annex F.

5.2 Test and measurement requirements

5.2.1 Test conditions

Unless otherwise specified, all tests shall be made under standard atmospheric conditions for testing as given in IEC 60068-1:2013, 4.3.

– temperature : 15 °C to 35 °C;
– relative humidity : 25 % to 75 %;
– air pressure : 86 kPa to 106 kPa.

5.2.2 Measurement conditions

Unless otherwise specified, all measurements shall be made under standard atmospheric conditions for testing as given in IEC 60068-1:2013, 4.3 with following exception:

– temperature: 20 °C ± 2 °C.

All measurements shall be made after thermal equilibrium is accomplished, see 5.2.4.

5.2.3 Voltage treatment

The capacitor shall be charged up to U_R and be held for 30 min by means of a d.c. source. The capacitor shall be discharged through a suitable discharge device.

5.2.4 Thermal treatment

The capacitors shall be stored at the temperature specified in 5.2.2 for a time sufficient to allow the entire capacitor to reach this temperature (thermal equilibrium, see Annex C).

5.3 Drying

Unless otherwise specified in the detail specification, the capacitor shall be conditioned for 96 h ± 4 h by heating in a circulating air oven at a temperature of 55 °C ± 2 °C and a relative humidity not exceeding 20 %.

The capacitor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

5.4 Visual examination and check of dimensions

5.4.1 Visual examination

The condition, workmanship and finish shall be satisfactory, as checked by visual examination.

Marking shall be legible, as checked by visual examination and shall conform to the requirements of the detail specification.

5.4.2 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, and shall comply with the values prescribed.

When applicable, measurements shall be made in accordance with IEC 60294 or IEC 60717.

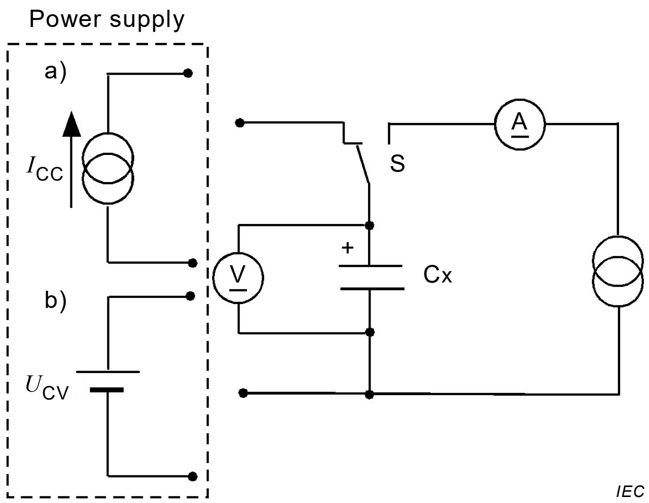
5.4.3 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

5.5 Measurement method 1 for capacitance and internal resistance (constant current discharge)

5.5.1 Basic circuit for measuring

The capacitance and the internal resistance shall be measured by using the constant current charging and discharging methods. The basic circuit for measurement is given in Figure 1.



Key

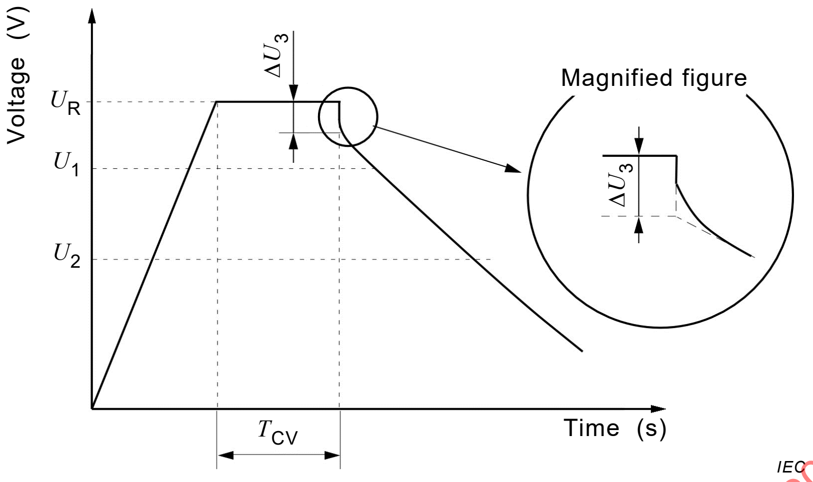
I_{CC}	constant-current
U_{CV}	constant-voltage
Ⓐ	d.c. ammeter
Ⓥ	d.c. voltage recorder
S	changeover switch
Cx	capacitor under test
	constant current discharger
a)	power supply for constant current charging-
b)	power supply for constant voltage charging-

Figure 1 – Basic circuit for measuring

5.5.2 Measuring equipment

The measuring equipment shall be capable of constant current charging, constant voltage charging, constant current discharging, and continuous measurement monitoring of the current and the voltage between the capacitor terminals as a function of discharging time as shown in Figure 2. The measuring equipment shall be able to set and measure the current and the voltage with the accuracy equal to ±1 % or less.

The power supply shall provide constant charge current for the capacitor charge with 95 % efficiency, and setting function of the constant voltage charge duration. The constant current discharger shall provide constant discharging current as specified in Table 1 or Table 2, respectively. The d.c. voltage recorder shall be capable of conducting measurements, and it shall record with a 5 mV resolution and sampling rate of 100 ms or less.



Key

U_R	rated voltage (V)
U_1	calculation start voltage (V)
U_2	calculation end voltage (V)
ΔU_3	voltage drop (V)
T_{CV}	constant voltage charging duration (min)

Figure 2 – Voltage–time characteristics between capacitor terminals in capacitance and internal resistance measurement

5.5.3 Measuring procedure

5.5.3.1 General

The measurement shall be carried out by analysing voltage-time characteristics between capacitor terminals.

The measuring method shall be either in accordance with 5.5.3.2 or 5.5.3.3 corresponding to the class (refer to Annex A) and shall be specified in the detail specification.

Preconditioning of voltage treatment as in 5.2.3 and thermal treatment as in 5.2.4 shall be carried out, and, if specified in the detail specification, drying as in 5.3 may be carried out before measurement.

The voltage between capacitor terminals shall be measured and recorded as a function of time throughout the measuring procedure.

5.5.3.2 Measuring method 1A (class 1, 2, 3 and 4)

Unless otherwise specified in the detail specification, the measuring conditions shall be as shown in Table 1. The constant charging current (I_{cc}) shall be able to charge the capacitor with 95 % charging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_N) by I_{cc} (= U_R /38 R_N). The constant discharge currents are set for capacitance measurement and internal resistance respectively, corresponding to the nominal capacitance of the capacitor.

The measuring procedure shall be as follows:

a) the capacitor shall be charged with the constant charging current;

b) when the output voltage of the power supply reaches the specified value, the charging of the capacitor shall be continued with the constant voltage;

c) then the capacitor shall be discharged through the constant current discharger;

d) then the time shall be measured from the start of discharge to the point at which the voltage between the capacitor terminals becomes U_1 and U_2, respectively (see Figure 2).

Table 1 – Measuring conditions for measuring method 1A

Measuring conditions	**Class** Application			
	Class 1 Memory backup	**Class 2** Energy storage	**Class 3** Power	**Class 4** Instantaneous power
Constant current charging mA	95 % charging efficiency [a]			
Constant voltage charging time min	30			
Constant discharge current for capacitance measurement [b] mA	$1 \times C_N$	$0,4 \times C_N U_R$	$4 \times C_N U_R$	$40 \times C_N U_R$
Constant discharge current for internal resistance measurement [c] mA	$10 \times C_N$	$4 \times C_N U_R$	$40 \times C_N U_R$	$400 \times C_N U_R$
U_1	$0,8 \times U_R$			
U_2	$0,4 \times U_R$			

For class 3 and class 4, measuring method 1B may be used.

The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.

The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.

NOTE C_N is the nominal capacitance in farad (F) and U_R is the rated voltage in volt (V).

[a] For the general concept of charging/discharging efficiency, see Annex D.

[b] If ΔU_3 exceeds 5 % of the charging voltage ($0,05 \times U_R$) in the initial characteristics, discharge current value may be reduced by one half, one fifth or one tenth.

[c] If ΔU_3 exceeds 20 % of the charging voltage ($0,2 \times U_R$) in the initial characteristics, discharge current value may be reduced by one half, one fifth or one tenth.

5.5.3.3 Measuring method 1B (class 3, 4 and 5)

Unless otherwise specified in the detail specification, the measuring conditions shall be as shown in Table 2. The constant charging current (I_{cc}) shall be able to charge the capacitor with 95 % charging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_N) by I_{cc} (= U_R /38 R_N). The constant discharge current (I_d) shall be able to discharge the capacitor with 95 % discharging efficiency and is set using the rated voltage (U_R) and the nominal internal resistance (R_n) by I_d (= U_R /40R_n).

The measuring procedure shall be as follows:

a) the capacitor shall be charged with the constant charging current;

b) when the output voltage of the power supply reaches the specified value, the charging of the capacitor shall be continued with the constant voltage;

c) then the capacitor shall be discharged through the constant current discharger;

d) then the time shall be measured from the start of discharge to the point at which the voltage between the capacitor terminals becomes U_1 and U_2, respectively (see Figure 2).

Table 2 – Measuring conditions for measuring method 1B

Measuring conditions	Class Application		
	Class 3 Power	**Class 4** Instantaneous power	**Class 5** High power
Constant current charging mA	95 % charging efficiency [a]		
Constant voltage charging time min	5		
Constant current discharging	95 % discharging efficiency [a]		
U_1	$0{,}8 \times U_R$		
U_2	$0{,}4 \times U_R$		

For class 3 and class 4, measuring method 1A may be used.

The number of significant figures for the discharge current value of 10 A or less shall be one digit; the second digit of the calculated value should be rounded down.

The number of significant figures for the discharge current value exceeding 10 A shall be two digits; the third digit of the calculated value should be rounded down.

[a] For the general concept of charging/discharging efficiency, see Annex D.

5.5.4 Calculation methods for capacitance

5.5.4.1 General

The capacitance shall be calculated by the straight line approximation method or the energy conversion method.

5.5.4.2 Straight line approximation method (measuring method 1A)

The capacitance C of a capacitor shall be calculated by the following formula:

$$C = \frac{I_d \times (t_2 - t_1)}{U_1 - U_2}$$

where

C is the capacitance of capacitor (F);

I_d is the discharge current (A);

U_1 is the measuring start voltage (V);

U_2 is the measuring end voltage (V);

t_1 is the time at which the terminal voltage of the capacitor reaches the value U_1 from the start of the discharge;

t_2 is the time at which the terminal voltage of the capacitor reaches the value U_2 from the start of the discharge.

5.5.4.3 Energy conversion method (measuring method 1B)

The capacitance C of a capacitor shall be calculated by the following formula:

$$C = \frac{2W}{U_1^2 - U_2^2}$$

where

C is the capacitance of the capacitor (F);

W is the measured discharged energy (J), from start voltage U_1 to end voltage U_2;

U_1 is the measured start voltage;

U_2 is the measured end voltage.

5.5.5 Calculation methods for internal resistance

5.5.5.1 General

The internal resistance shall be calculated by the least square internal resistance calculation method or the intersection line internal resistance calculation method.

5.5.5.2 Intersection line internal resistance calculation method (measuring method 1A)

The internal resistance R of a capacitor shall be calculated by the following formula:

$$R = \frac{\Delta U_3}{I_d}$$

where

R is the internal resistance of the capacitor (Ω);

I_d is the discharge current (A);

ΔU_3 is the voltage drop (V).

NOTE The voltage drop is read by drawing an auxiliary line while extending the straight part of the time-varying voltages between the capacitor terminals obtained from the voltage recorder shown in Figure 2.

5.5.5.3 Least square internal resistance calculation method (measuring method 1B)

The internal resistance R of a capacitor shall be calculated by the following formula:

$$R = \frac{\Delta U_3}{I_d}$$

where

R is the internal resistance of the capacitor (Ω);

I_d is the discharge current (A);

ΔU_3 is the voltage drop (V).

Apply the straight-line approximation to the voltage drop characteristics from the calculation start voltage (U_1) to the calculation end voltage (U_2) by using the least squares method. Obtain the intercept (voltage value) of the straight line at the discharge start time. ΔU_3 is the difference of voltages (V) between the intercept voltage value and the set value of constant voltage charging (V).

5.5.6 Conditions to be prescribed in the detail specification

The detail specification shall prescribe:

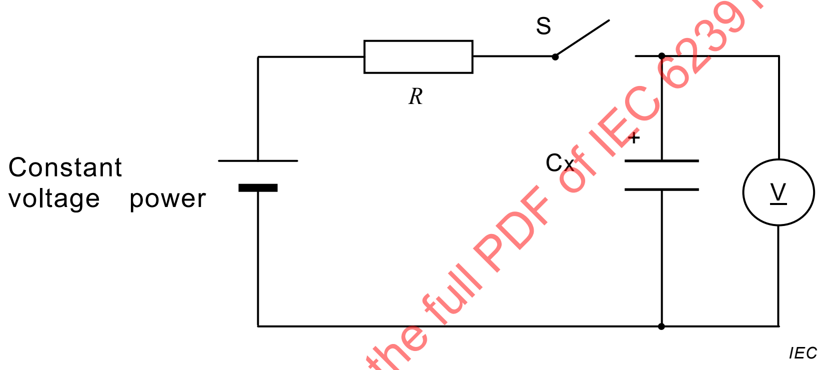
a) the classification of method;
b) the applied voltage other than the rated voltage;
c) charging time other than 30 min (see Table 2) or 5 min (see Table 3);
d) constant current discharge value other than that in Table 2 or Table 3;
e) U_1 and U_2 at the time of discharge voltage drop other than those in Table 2 or Table 3.

5.6 Measurement method 2 for capacitance and internal resistance

5.6.1 Constant resistance charging method for capacitance measurement

5.6.1.1 Measuring circuit

Measurements shall be carried out using the measuring circuit shown in Figure 3.



Key

R	series resistance
S	switch
V	d.c. voltmeter
Cx	capacitor under test

Figure 3 – Circuit for constant resistance charging method

5.6.1.2 Measuring method

The measuring procedure shall be as follows:

a) prior to measurement, short-circuit between capacitor terminals for 30 min or more to ensure discharge sufficiently;
b) set the value of R in such a way that the time constant τ settles at 60 s to 120 s;
c) measure the time constant τ when d.c. voltage U_R is applied, and calculate the capacitance value by the following formula:

$$C = \frac{\tau}{R}$$

where

C is the capacitance (F);

τ is the time constant: charging time up to 0,632 × U_R (s);

R is the series resistance (Ω).

5.6.1.3 Conditions to be prescribed in the detail specification

The detail specification shall prescribe:

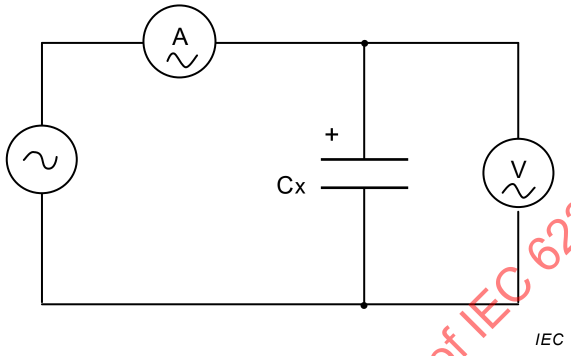
a) the applied voltage other than the rated voltage;

b) the series resistance R when the time constant is other than 60 s to 120 s.

5.6.2 AC internal resistance measuring method

5.6.2.1 Measuring circuit

Measurements shall be carried out using the measuring circuit shown in Figure 4.



Key

 oscillator

 a.c. ammeter

 a.c. voltmeter

Cx capacitor under test

Figure 4 – Circuit for a.c. resistance method

5.6.2.2 Measuring method

The measuring procedure shall be as follows:

a) the measuring frequency shall be 1 kHz;

b) the a.c. current shall be from 1 mA to 10 mA;

c) the internal resistance R_a of a capacitor shall be calculated by the following formula:

$$R_a = \frac{U}{I}$$

where

R_a is the a.c. internal resistance (Ω);

U is the root-mean-square value of a.c. voltage (V);

I is the root-mean-square value of a.c. current (A).

5.7 Leakage current

5.7.1 Measuring method

The measuring procedure shall be as follows.

a) Before this measurement is carried out, the capacitors shall be fully discharged. The discharge procedure shall take 1 h to 24 h and shall be specified in the detail specification.

b) The leakage current shall be measured, unless otherwise prescribed in the detail specification, using the direct voltage (U_R) appropriate to the test temperature. The electrification period after maximum 30 min charge-up time to reach 95 % of the applied voltage shall be selected from 30 min, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h or 48 h and shall be specified in the detail specification.

c) A steady source of power such as a regulated power supply shall be used.

d) Unless otherwise specified in the detail specification, apply the voltage to a capacitor through a protective resistor of 1 000 Ω or less.

5.7.2 Items to be specified in the detail specification

The detail specification shall specify the following items:

a) the leakage current limit at a reference temperature of 20 °C, and at other specified temperatures;

b) when necessary, the correction factor: if the measurements are made at a temperature other than 20 °C, but within the range of temperatures covered by the standard atmospheric conditions for testing;

c) the electrification time;

d) the resistance value of protective resistors other than 1 000 Ω.

5.8 Maintain voltage

5.8.1 Measuring method

The measuring method shall be as follows (see Figure 5).

a) Before this measurement is carried out, the capacitors shall be fully discharged. The discharge procedure shall take 1 h to 24 h and shall be specified in the detail specification.

b) Apply the rated voltage U_R directly to the capacitor terminals, without using a protective resistor. Unless otherwise specified by the detail specifications, the charging time shall be 8 h, including maximum 30 min charge-up time to reach 95 % of the applied voltage.

c) Disconnect the capacitor terminals from the voltage source. Unless otherwise specified in the detail specification, the capacitor shall be kept under standard conditions for 16 h, 24 h, 48 h or 96 h.

d) The internal resistance of the d.c. voltmeter used shall be 1 MΩ or higher.

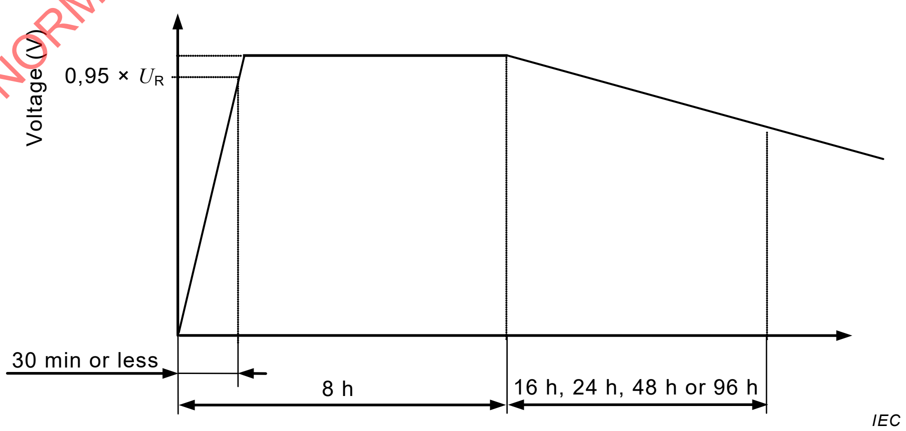


Figure 5 – Maintain voltage test diagram

5.8.2 Calculation of voltage maintenance rate

The voltage maintenance rate A shall be calculated by the following formula:

$$A = \frac{U_{\text{end}}}{U_{\text{R}}} \times 100$$

where

A is the voltage maintenance rate (%);

U_{end} is the voltage between open capacitor terminals after 72 h (T_{OC1}) have elapsed (V);

U_{R} is the rated voltage (V).

5.8.3 Conditions to be prescribed in the detail specification

The detail specification shall prescribe:

a) the discharge duration;

b) an applied voltage other than the rated voltage;

c) a charging time other than 8 h;

d) the time period between disconnecting the capacitor from the charging voltage and the measurement.

5.9 Robustness of terminations

5.9.1 Test Ua1 – Tensile

The capacitors shall be subjected to IEC 60068-2-21, Test Ua1, as applicable.

The force applied shall be:

– for terminations other than wire terminations: 20 N;

– for wire terminations: see Table 3.

Table 3 – Tensile force

Nominal cross-sectional area (S) [a] mm^2	Corresponding diameter (d) for circular section wires mm	Force with tolerance of ±10 % N
$S \leq 0,05$	$d \leq 0,25$	1
$0,05 < S \leq 0,1$	$0,25 < d \leq 0,35$	2,5
$0,1 < S \leq 0,2$	$0,35 < d \leq 0,5$	5
$0,2 < S \leq 0,5$	$0,5 < d \leq 0,8$	10
$0,5 < S \leq 1,2$	$0,8 < d \leq 1,25$	20
$1,2 < S$	$1,25 < d$	40

[a] For circular-section wires, strips or pins, the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the detail specification. For stranded wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the detail specification.

5.9.2 Test Ub – Bending (half of the sample)

The capacitors shall be subjected to IEC 60068-2-21, Test Ub, as applicable.

Method 1: Two consecutive bends shall be applied in each direction. This test shall not apply if, in the detail specification, the terminations are described as rigid.

5.9.3 Test Uc – Torsion (remaining sample)

The capacitors shall be subjected to IEC 60068-2-21, Test Uc, as applicable.

Method A, severity 2 (two successive rotations of 180°) shall be used.

This test shall not apply if in the detail specification the terminations are described as rigid and to components with unidirectional terminations designed for printed wiring applications.

5.9.4 Test Ud – Torque (for terminations with threaded studs or screws and for integral mounting devices)

The capacitors shall be subjected to IEC 60068-2-21, Test Ud, as applicable.

The degree of severity to be used shall be specified in the detail specification (see Table 4).

Table 4 – Torque

Nominal thread diameter mm		2,6	3	3,5	4	5	6	8
Torque Nm	Severity 1	0,4	0,5	0,8	1,2	2,0	2,5	5
	Severity 2	0,2	0,25	0,4	0,6	1,0	1,25	2,5

5.9.5 Visual examination

After each of these tests, the capacitors shall be visually examined. There shall be no visible damage.

5.10 Resistance to soldering heat

5.10.1 Preconditioning and initial measurement

When prescribed by the detail specification the capacitors shall be dried using the method of 5.3.

The capacitors shall be measured as prescribed in the detail specification.

5.10.2 Test

Unless otherwise stated in the detail specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the detail specification.

a) For all capacitors except those of item b) and c) below: IEC 60068-2-20, Test Tb, method 1 (solder bath).

b) For capacitors not designed for use in printed boards, but with connections intended for soldering as indicated by the detail specification:

   1) IEC 60068-2-20, Test Tb, method 1 (solder bath);

   2) IEC 60068-2-20, Test Tb, method 2 (soldering iron).

c) For surface mount capacitors, IEC 60068-2-58, reflow or solder bath method.

5.10.3 Recovery

The period of recovery shall, unless otherwise specified by the detail specification, be not less than 1 h or more than 2 h, except for surface mount capacitors, for which the period of recovery shall be 24 h ± 2 h be carried out by 5.3.

5.10.4 Final inspection, measurements and requirements

For all capacitors, except surface mount capacitors, the following shall apply:

– when the test has been carried out, the capacitors shall be visually examined;
– there shall be no visible damage and the marking shall be legible;
– the capacitors shall then be measured as prescribed in the detail specification.

Surface mount capacitors shall be visually examined and measured and shall meet the requirements as prescribed in the detail specification.

5.11 Solderability

5.11.1 General

This test shall not be applicable to those terminations which the detail specification describes as not designed for soldering.

5.11.2 Preconditioning

The detail specification shall prescribe whether ageing is to be applied. If accelerated ageing is required, one of the ageing procedures given in IEC 60068-2-20 shall be applied.

Unless otherwise stated in the detail specification, the test shall be carried out with non-activated flux.

5.11.3 Capacitors with leads

5.11.3.1 General

Capacitors shall be subjected to Test Ta of IEC 60068-2-20 either using the solder bath method (method 1), or the soldering iron method (method 2) as prescribed by the detail specification.

When the solder bath method (method 1) is specified, the following requirements apply.

5.11.3.2 Test conditions

Unless otherwise stated in the detail specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the detail specification.

a) For all capacitors except those of item b) and c) below:
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath)
      Depth of immersion (from the seating plane or component body): $2\,^{0}_{-0{,}5}$ mm, using a thermal insulating screen of 1,5 mm ± 0,5 mm thickness;
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron);
   3) IEC 60068-2-54.
b) For capacitors not designed for use in printed boards, but with connections intended for soldering as indicated by the detail specification:
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath);
      Depth of immersion (from the seating plane or component body): $3{,}5\,^{0}_{-0{,}5}$ mm;
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron).

c) For surface mount capacitors:
   1) IEC 60068-2-58, reflow or solder bath method;
   2) IEC 60068-2-69, solder bath or solder globule method.

When the solder bath method is not applicable, the detail specification shall define the test method, test conditions and the requirements.

5.11.3.3 Final inspection, measurements and requirements

The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

5.11.4 Surface mount capacitors

5.11.4.1 General

Capacitors shall be tested in accordance with Test Td of IEC 60068-2-58. The detail specification shall prescribe the severity and attitude to be used for wetting, dewetting or resistance to dissolution of metallization.

The detail specification shall also indicate the specific areas of the specimen to be examined after wetting.

5.11.4.2 Final inspection, measurements and requirements

The surface mount capacitors shall meet the requirements as prescribed in the detail specification.

5.12 Rapid change of temperature

5.12.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

5.12.2 Test

The capacitors shall be subjected to Test Na of IEC 60068-2-14, using the degree of severity as prescribed in the detail specification.

5.12.3 Final inspection, measurements and requirements

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

5.13 Vibration

5.13.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

5.13.2 Test

The capacitors shall be subjected to Test Fc of IEC 60068-2-6, using the mounting method and the degree of severity prescribed in the detail specification.

When specified in the detail specification, during the last 30 min of the vibration test an electrical measurement shall be made in each direction of movement to check intermittent contact, or open- or short-circuit.

The method of measurement shall be prescribed in the detail specification.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

5.13.3 Final measurement and requirements

After the test, the capacitors shall be visually examined. There shall be no visible damage. When capacitors are tested as specified in 5.17.4, the requirements shall be stated in the detail specification.

The measurements prescribed in the detail specification shall then be made.

5.14 Damp heat, steady state

5.14.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

5.14.2 Test

The capacitors shall be subjected to Test Cab of IEC 60068-2-78, using the degree of severity corresponding to the detail specification.

5.14.3 Final measurement

The measurements prescribed in the detail specification shall then be made.

5.15 Endurance

5.15.1 Initial measurements

The measurements prescribed in the detail specification shall be made.

5.15.2 Test

5.15.2.1 General

IEC 60068-2-2:2007, Test Bb, shall be applied with the following exceptions:

– capacitors may be inserted in the test chamber at any temperature between room ambient temperature and the specified test temperature;

– a specified voltage shall be applied to the capacitor during the test, but the voltage shall not be applied to the capacitor before it has reached the chamber temperature.

The capacitors shall be placed in the test chamber in such way that no capacitor is located within 5 mm from any other capacitor.

5.15.2.2 Test conditions

The test conditions shall be as follows:

a) applied voltage : rated voltage;

b) test temperature : upper category temperature;

c) test duration : 1 000 h or as specified in the detail specification.

5.15.3 Final measurement, inspection and requirements

After the specified period, the capacitors shall be allowed to cool to standard atmospheric conditions for testing and where specified in the detail specification, the capacitors shall be subjected to recovery.

The capacitors shall then be visually examined.

The measurements prescribed in the detail specification shall then be carried out. A capacitor shall be considered to have failed when the requirements of the detail specification during or at the end of the test are not satisfied.

5.16 Storage

5.16.1 Storage at high temperature

5.16.1.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

5.16.1.2 Test conditions

The capacitors shall be subjected to IEC 60068-2-2:2007, Test Bb, using the following severities:

– test temperature : upper category temperature;

– test duration : 96 h ± 4 h.

5.16.1.3 Final measurement

After recovery for at least 16 h, the measurements prescribed in the detail specification shall be made.

5.16.2 Storage at low temperature

5.16.2.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

5.16.2.2 Test conditions

The capacitors shall be subjected to IEC 60068-2-1:2007, Test Ab. The capacitors shall be stored at –40 °C for either a period of 4 h after thermal stability has been reached, or for 16 h, whichever is the shorter period.

5.16.2.3 Final measurement

After recovery for at least 16 h, the measurements prescribed in the detail specification shall be made.

5.17 Characteristics at high and low temperature

5.17.1 General

The capacitors shall be subjected to the procedures of the dry heat and cold test (5.17.3 and 5.17.4 respectively) with the following details.

5.17.2 Test procedure

The degree of severity for these tests shall be the same as for the dry heat and cold tests. Tests at intermediate temperatures may be prescribed by the detail specification.

The measurements prescribed in the detail specification shall be made.

5.17.3 Dry heat

The capacitors shall be subjected to IEC 60068-2-2:2007, Test Bb, for 16 h, using the degree of severity of the upper category temperature, as prescribed in the detail specification.

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the detail specification shall be made.

5.17.4 Cold

The capacitors shall be subjected to IEC 60068-2-1:2007, Test Ab, for 2 h, using the degree of severity of the lower category temperature, as prescribed in the detail specification.

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the detail specification shall be made.

5.17.5 Final measurement and requirements

The capacitors shall not exceed the limits prescribed in the detail specification.

5.18 Component solvent resistance

5.18.1 Initial measurements

The measurements prescribed in the detail specification shall be made.

5.18.2 Test

The components shall be subjected to IEC 60068-2-45:1980, Test XA, with the following details:

a) solvent to be used : 2-propanol;

b) solvent temperature : 23 °C ± 5 °C, unless otherwise specified in the detail specification;

c) conditioning : Method 2 (without rubbing);

d) recovery time : 2 h or more (see Annex C), unless otherwise stated in the detail specification.

5.18.3 Requirements

The measurements prescribed in the detail specification shall then be carried out and the specified requirements shall be met.

5.19 Solvent resistance of marking

5.19.1 Test

The components shall be subjected to IEC 60068-2-45:1980, Test XA, with the following details:

a) solvent to be used : 2-propanol;

b) solvent temperature : 23 °C ± 5 °C;

c) conditioning : method 1 (with rubbing);

d) rubbing material : cotton wool;

e) recovery time : not applicable, unless otherwise stated in the detail specification.

5.19.2 Requirements

After the test, the marking shall be legible.

5.20 Passive flammability

5.20.1 Test procedure

The capacitors shall be tested according to the following procedure.

a) The test shall be carried out according to IEC 60695-11-5.

b) The capacitor under test shall be held in the flame in the position which best promotes burning (if this position is not given in the detail specification, it shall be evaluated by pre-testing). Each specimen shall only be exposed once to the flame.

c) The smallest, a medium (in the case of more than four case sizes), and the biggest case size shall be tested. Of each case size, three specimens of the maximum and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

For the time of exposure to flame and burning time, see Table 5. If applicable, the detail specification shall specify the category of passive flammability.

5.20.2 Requirements

The burning time of any specimen shall not exceed the time specified in Table 5.

Burning droplets or glowing parts falling down shall not ignite the tissue paper.

Table 5 – Severities and requirements

Category of flamma-bility	Severities Flame exposure time, in seconds, for capacitor volume ranges [a] mm³				Maximum burning time s
	volume ≤ 250	250 < volume ≤ 500	500 < volume ≤ 1 750	1 750 < volume ≤ 12 000	
A	15	30	60	120	3
B	10	20	30	60	10
C	5	10	20	30	30

[a] Test severities for capacitor volumes above 12 000 mm^3 are under consideration.

5.21 Pressure relief (if applicable)

5.21.1 Test

Unless otherwise specified in the detail specification, d.c. voltage of an amplitude necessary to produce a current of 10 mA/F or more shall be applied to the capacitor in the forward direction.

5.21.2 Requirements

The pressure relief device shall open in such a way as to avoid any danger of explosion or fire.

Annex A
(normative)

Classification according to capacitance and internal resistance

A.1 General

This annex describes classification of the capacitor, according to the capacitance value and internal resistance value depending upon the application.

A.2 Classification by capacitance and internal resistance

Measurements of capacitance and internal resistance by the constant current discharge method and the d.c. resistance method, respectively require much (long) measuring time depending on the product ratings provided that the measuring conditions are standardized with the specificity of these measuring methods. Therefore, it is necessary to select efficient measuring conditions. For this reason, the following application classification has been considered, classifying into four measuring conditions (see Figure A.1).

In the meantime, it has been suggested that the same discharge current condition may be appropriate for capacitance and internal resistance for every application of the five classes. However, classification was made in terms of accuracy in measurement. Note that the same measuring conditions may be used for capacitance and internal resistance within the scope of the capacitors that can obviously achieve accurate measurements.

Class 1 (memory backup)

This class is suitable for those capacitors which are mainly used for RAM memory backup with magnitude of discharge current from nA to μA. The characteristics of the capacitors for this application have relatively low capacitance and high internal resistance.

Class 2 (energy storage)

This class is suitable for those energy storage capacitors which mainly require a long time operation with magnitude of discharge current from mA to A. The capacitors for this application have high capacitance in characteristics without any consideration of internal resistance. This class handles higher internal resistance compared with the power application in Class 3.

Class 3 (power)

This class is suitable for those capacitors which are mainly used for driving motors, requiring power with magnitude of discharge current from mA to A. The characteristics of the capacitors for this application have relatively high capacitance and low internal resistance.

Class 4 (instantaneous power)

This class is suitable for the application that requires instantaneous power (relatively large current) even with a short operating time. The capacitors for this application have low capacitance and low internal resistance in characteristics.

Class 5 (high power)

This class is suitable for the application (i.e. automotive and railway) that requires high power (relatively large current) with heavy duty charge/discharge cycles. The capacitors for this application have higher capacitance value and lower internal resistance value compared to Class 3.

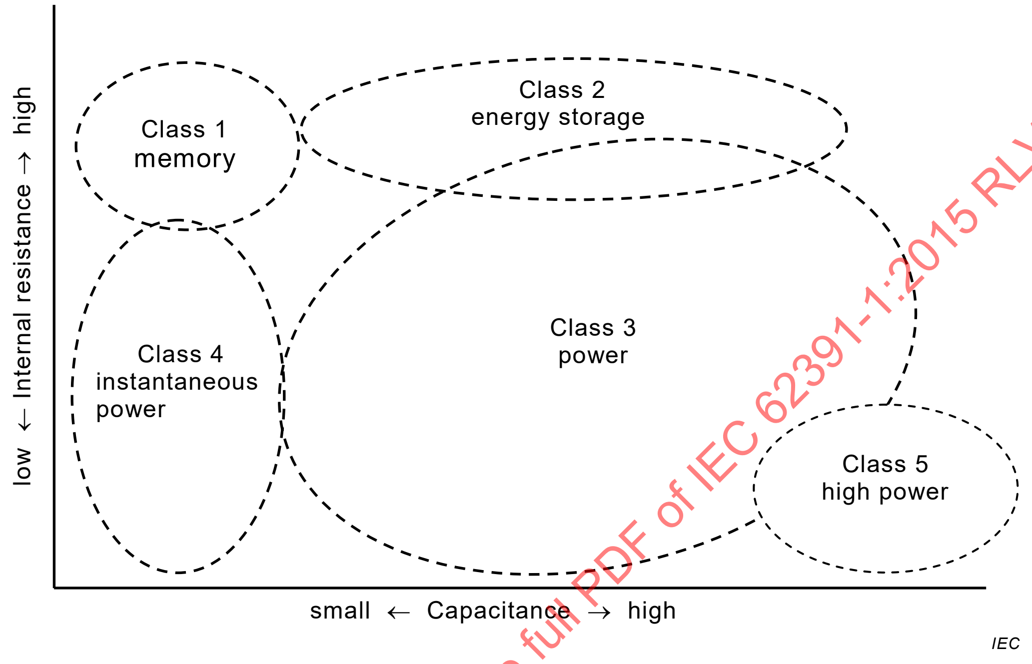


Figure A.1 – Conceptual rendering orientated by characteristics in each classification

Unless otherwise specified in the detail specifications, electrical performance and measuring methods should be selected according to Table A.1, by the above mentioned class related to the application.

Table A.1 – Electrical performance and measuring method by class

Measurement items		Sub clause No.	Class				
			Class 1	Class 2	Class 3	Class 4	Class 5
Capacitance	Constant current discharge method	5.5	A	A	A	A	A
	Constant resistance charging method	5.6.1	B	B	B	B	C
Internal resistance	AC resistance method	5.6.2	A	B	B	B	C
	DC resistance method	5.5	C	A	A	A	A
Leakage current		5.7	C	C	C	C	C
Maintain voltage		5.8	A	C	C	C	C

Selection classification A: use as a standard;
B: use as a simplified method;
C: use when necessary.
Selection classification shall be specified in the detail specification. For capacitance, see Annex B.

Annex B
(informative)

Measuring method of capacitance and low resistance by low frequency a.c. method (reference)

B.1 General

This method is suitable for capacitors with relatively low internal resistance, and can be used as a shortcut method to reduce the measuring time.

B.2 Measuring system

The measuring system includes the components in Figure B.1. The system that replaces this method for measuring capacitance at low frequency may be used, as follows:

a) generate a sinusoidal voltage at the specified frequency with a frequency response analyzer and apply the voltage to a capacitor via a potentiostat;

b) detect the current that flows through the capacitor with a potentiostat (a device to automatically keep the electrode potential constant), and convert it into a voltage value to return it to the frequency analyser;

c) obtain the impedance $|Z|$ and phase angle φ from the voltage and current of the capacitor to be measured.

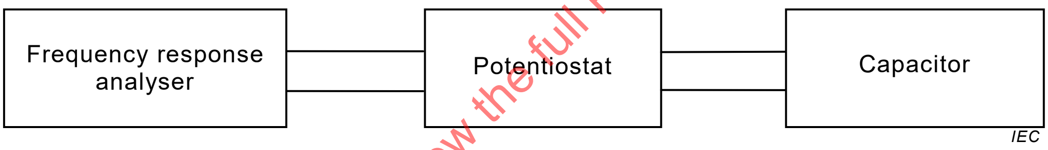


Figure B.1 – Capacitance measuring system by the low frequency a.c. method

B.3 Calculation of capacitance

The calculation of capacitance shall be as follows.

a) Calculate the reactance X by the following formula:

$$X = |Z| \times \sin \varphi$$

where

X is the reactance (Ω);

$|Z|$ is the impedance (Ω);

φ is the phase angle.

b) Use the calculated reactance to calculate the capacitance C of the capacitor by the following formula:

$$C = \frac{X}{2\pi f}$$

where

C is the capacitance (F);

π is the circle ratio;

f is the measuring frequency (Hz).

B.4 Measuring conditions

The measuring conditions shall be as follows:

a) use either of the measuring frequencies of 0,05 Hz, 0,1 Hz, 1 Hz, 10 Hz or 100 Hz;

b) the measuring voltage shall be 3 % or less of the rated voltage;

c) the bias voltage shall be 50 % to 95 % of the rated voltage; if no doubt arises with respect to judgment, the bias voltage may be omitted.

Annex C
(informative)

Thermal equilibrium time of capacitors

C.1 General

This annex describes the thermal equilibrium time of capacitors, as a reference in determining the soaking time for pre-treatment.

C.2 Thermal equilibrium time of capacitors

Presuming that the thermal equilibrium time, which is the time required for the central portion of a capacitor to reach the temperature difference from the external temperature within 1 °C, is dependent on the external dimensions of the capacitor, the temperature changes in the central portions of capacitors was verified.

The resultant data were obtained by verifying the thermal equilibrium time of the central portions of capacitors that were subjected to a certain environmental temperature. As a result, it was observed that the equilibrium time was proportional to the magnitudes of the external dimensions such as diameter for cylindrical capacitors and thickness (thinnest side) for cubic capacitors. Figure C.1 shows the thermal equilibrium times of the capacitors when soaked to normal room temperature from a high temperature. Figure C.2 shows the thermal equilibrium time of the capacitors when soaked to normal room temperature from a low temperature. In these figures, the dotted straight lines indicate the presumed longest thermal equilibrium time. It is advisable to use these dotted straight lines as soaking time for pre-conditioning. Figure C.3 shows the actual measured temperature changes in the capacitors' central portions.

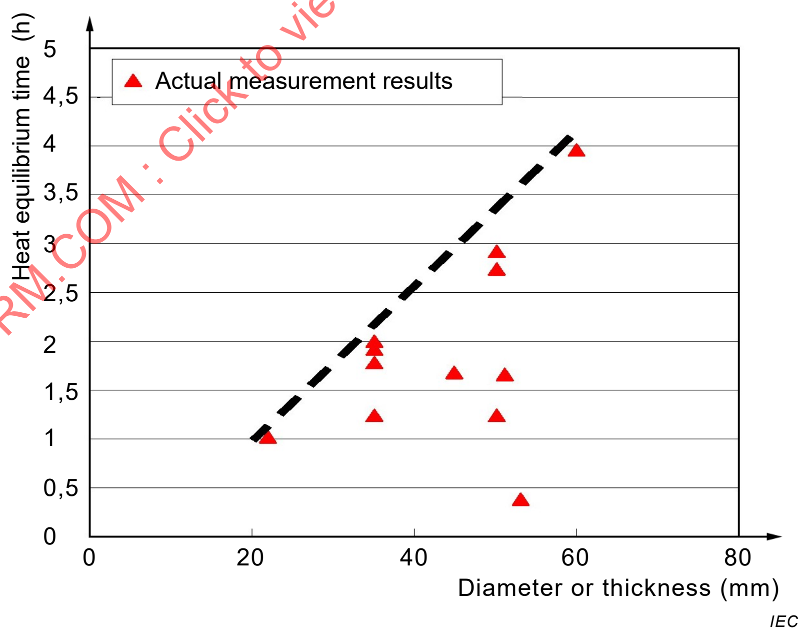


Figure C.1 – Thermal equilibrium times of capacitors (from 85 °C to 25 °C)

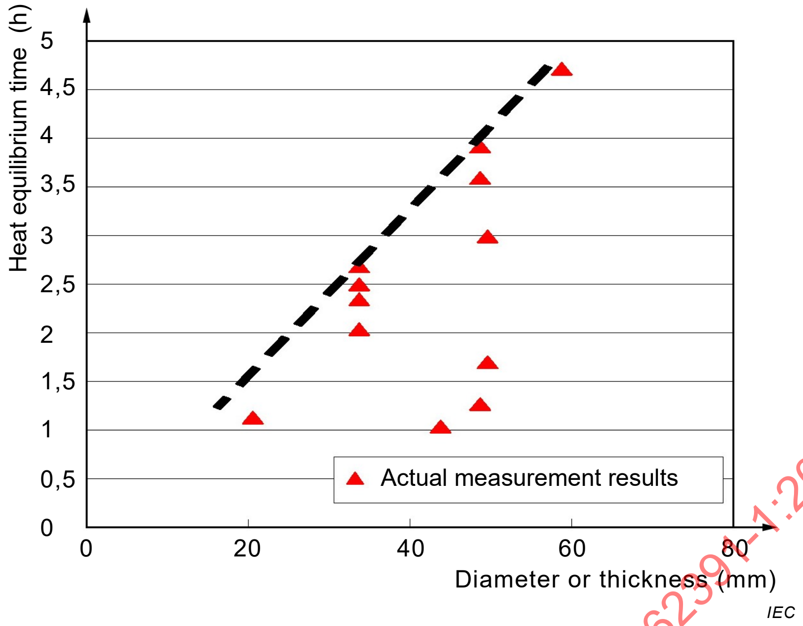
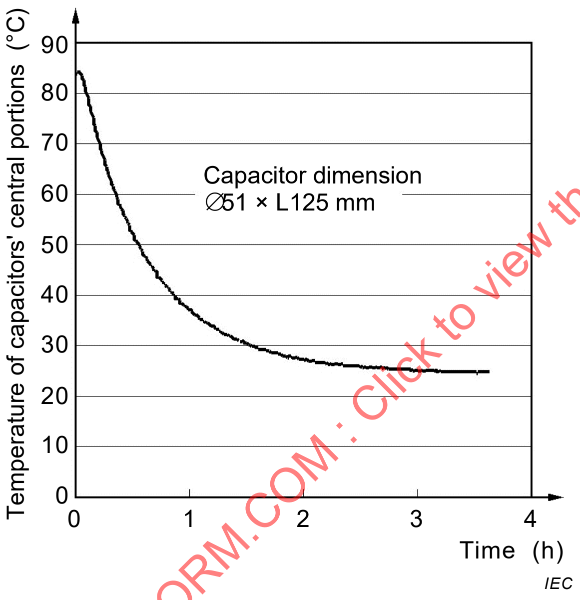
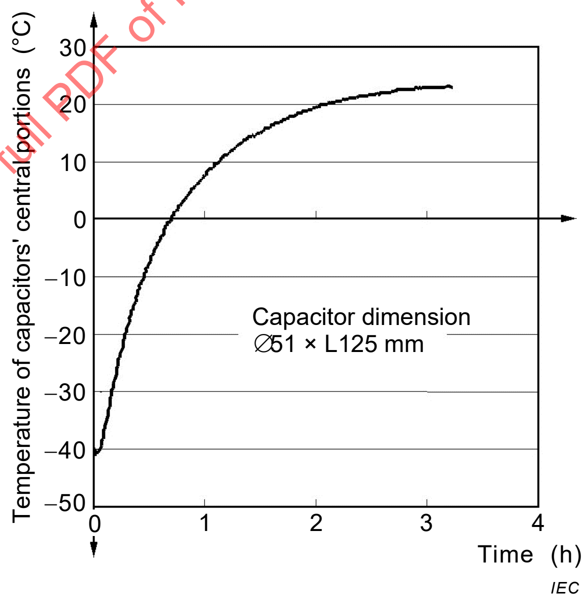


Figure C.2 – Thermal equilibrium times of capacitors (from −40 °C to 25 °C)



a) From 85 °C to 25 °C



b) From −40 °C to 25 °C

Figure C.3 – Capacitor core temperature change with respect to time

Annex D
(informative)

Charging/discharging efficiency and measurement current

D.1 General

This annex describes the general concept regarding the charging and discharging efficiency and measured current, which are provided in 5.5.3.

D.2 Charging efficiency, discharging efficiency, and current

Charge Q after charging or discharging for time t at a constant current I, stored energy W, and energy L lost by resistance R are given by Formulas (D.1), (D.2), and (D.3), respectively.

$$Q = It \tag{D.1}$$

$$W = \frac{Q^2}{2C} \tag{D.2}$$

$$L = I^2 Rt = \frac{RQ^2}{t} \tag{D.3}$$

When a capacitor is charged or discharged to its full capacity at a constant current according to Formula (D.2) or (D.3), respectively, the energy efficiency P_c for charging or P_d for discharging is given by Formula (D.4) or (D.5), respectively, where R is the internal resistance and C is the capacitance of the capacitor.

$$P_c = \frac{W}{W+L} = \frac{t}{t+2RC} \tag{D.4}$$

$$P_d = \frac{W-L}{W} = I - \frac{2RC}{t} \tag{D.5}$$

In this document, the efficiency for charging or discharging is proposed as 95 % after considering exothermal effect and time consumption for the measurement. The time t required for charging at 95 % efficiency is given by Formula (D.6) derived from Formula (D.4).

$$t = 38RC \tag{D.6}$$

Charge Q stored in a capacitor is given as a product of capacity C and charging voltage U, thus leading to Formula (D.7). Current I_c for 95 % charging is given by Formula (D.8) derived from Formulas (D.1), (D.6), and (D.7).

$$Q = CU \tag{D.7}$$

$$I_c = \frac{U}{38R} \tag{D.8}$$

Similarly, the time t needed for 95 % discharging is given by Formula (D.9) derived from Formula (C.5), and the current I_d needed for 95 % discharging is given by Formula (D.10).

$$t = 40RC \tag{D.9}$$

$$I_d = \frac{U}{40R} \tag{D.10}$$

Formulas (D.8) and (D.10) are suggested for determining the value of the current for the charging or discharging test. Once the value of the charging/discharging current is determined, the maximum output at the target efficiency can be calculated.

Annex E
(informative)

Procedures for setting the measurement current of capacitor with uncertain nominal internal resistance

E.1 General

This annex describes the current setting procedures provided in 5.5.3.

E.2 Current setting procedures for measurement of capacitor

When the nominal value of internal resistance of a capacitor is uncertain, the current for the measurement of the capacitor with 95 % charging efficiency and 95 % discharging efficiency can be set according to the following procedures.

a) Using the estimated value of the internal resistance, measure the time characteristic of the voltage between the capacitor terminals according to the procedure described in 5.5.3 and then calculate the internal resistance according to the description in 5.5.5.

b) When the internal resistance is unpredictable, it is recommended to temporarily set the charging and discharging currents as 30 A.

c) Using the internal resistance value calculated by step a) above, measure the time characteristic of the voltage between the capacitor terminals according to the procedure described in 5.5.3 and calculate the internal resistance according to the description in 5.5.5.

d) Repeat the above procedures until the difference between the calculated internal resistance value and the previous value becomes less than 10 % of the previous value.

However, when ΔU_3 becomes greater than $0{,}1U_R$, follow procedures a) to c) with a smaller current and then perform the measurements. When the calculated internal resistance is a negative value, follow procedures a) to c) with a larger current and then perform the measurements.

E.3 Example of setting current for determining capacitor characteristics

Table E.1 shows examples of setting the measurement current. The setting was performed in the order of setting conditions shown in Table E.1.

Table E.1 – Example of setting current for measurement of capacitor

Setting condition	Internal resistance value used for setting mΩ	Charging current A	Discharging current A	Calculated capacitance F	Calculated internal resistance mΩ
1	1,5 (Estimated)	47,4	45,0	1 297	4,6
2	4,6 (Calculated with the result of No 1)	15,4	14,7	1 351	5,0
3	5,0 (Calculated with the result of No. 2)	14,2	13,5	1 351	5,0

Annex F
(informative)

Policy on uncertainty of measurement and inset limits

F.1 Objective

Specifications for electronic components give the parametric limits that define the acceptability of the component. These limits do not take into account the uncertainty of measurement caused by test and measuring equipment inaccuracies, test methods, environmental conditions and, sometimes, operator participation.

The purpose of this annex is to define policy on the calculation of measurement uncertainty and insetting limits to ensure uniform implementation. The special case of outsetting limits is also covered.

F.2 Terms and definitions

For the purposes of this annex the following terms and definitions apply.

F.2.1
uncertainty of measurement
statement of the limits of the range within which the true value of the measurement is expected to lie in relation to the recorded result with a defined confidence level

F.2.2
measuring equipment
all of the instruments which are necessary in order to carry out a measurement

Note 1 to entry: The definition makes it clear that items such as cables, connectors, handlers, handler cards or other fixtures used in conjunction with a measurement indicating instrument are subject to the requirements of this policy.

F.2.3
inset limits
tightened limits resulting from an allowance applied to the specified limits of a parameter to take into account all influence quantities on the indication of a measuring instrument so as to ensure that out of limit devices are not accepted due to measurement errors

F.2.4
outset limits
relaxed limits resulting from an allowance applied to the specified limits of a parameter to take into account all influence quantities on the indication of a measuring instrument so as to ensure that in limit devices are not rejected due to measurement errors

F.3 Calculation of measurement uncertainty

The assessment of uncertainty of measurement of a performance requirement can be broken down into three stages:

a) identification of possible error contributions;
b) quantifying the size of each listed contribution;
c) calculating the total uncertainty of measurement.

F.4 Policy

F.4.1 A measurement uncertainty value shall be calculated for each performance requirement which is related to qualification approval, capability approval, technology approval, process approval, screening, lot-by-lot and periodic tests as defined by the specifications.

F.4.2 Each measurement uncertainty value shall be used to apply an inset, of at least this value, to the relevant specification limits as defined in F.4.1.

F.4.3 This inset shall be applied in accordance with F.5.2 for qualification approval, capability approval, technology approval and process approval and F.5.3 for product audit testing.

F.4.4 Test reports and test records, compiled to show compliance with qualification approval, capability approval, screening, lot-by-lot and periodic tests as defined by the applicable specifications, shall list the uncertainty value for each performance requirement.

F.5 Calculation of inset and outset limits

F.5.1 The fundamental principle is that the limits should be inset from the specified values by the corresponding uncertainty of measurement. This increases the probability that measurement results which fall within the tightened limits, including marginal values, are genuinely within specification limits such that only truly conforming devices are accepted.

The exception to insetting limits occurs when product audit tests are conducted. In this situation, to ensure that, as far as possible, uncertainty of measurement does not cause good products to fail, an audit test outsets the limits. This increases the possibility that measurement results that fall outside the relaxed limits, including marginal values, are genuinely outside specification limits such that only truly nonconforming devices are rejected.

F.5.2 For a component manufacturer the upper specified value of a parameter being ‘x’, the lower specified value of the parameter being ‘y’ and the uncertainty of measurement being ‘a’, the “inset limits” for the parameter are (x-a) and (y+a).

F.5.3 For an audit test the upper specified value of a parameter being ‘x’, the lower specified value of the parameter being ‘y’ and the uncertainty of measurement being ‘b’, the “outset limits” for the parameter are (x+b) and (y-b).

The smaller the uncertainty of measurement, the lower the values of ‘a’ and ‘b’ become and the closer the manufacturer’s and the audit test’s inset/outset limits approach the specification limits.

F.6 Examples

F.6.1 General

Setting “inset limits” and “outset limits”.

F.6.2 Example 1: Resistor measurement

Specified resistance value:	100 Ω ± 10 % = 90 Ω to 110 Ω
Uncertainty of measurement calculated to be:	±1,2 % = ±1,08 Ω and ±1,32 Ω
Inset limits:	91,08 Ω to 108,68 Ω
Outset limits:	88,92 Ω to 111,32 Ω

F.6.3 Example 2: Resistor measurement

Initial measurement	105,00 Ω
Specified resistance value	<0,5 % = ±0,53 Ω
	= 104,47 Ω to 105,53 Ω
Uncertainty of measurement calculated to be	±0,1 % = ±0,10 Ω and ±0,11 Ω
Inset limits:	104,57 Ω to 105,42 Ω
Outset limits	104,37 Ω to 105,64 Ω

F.6.4 Example 3: Transistor measurement (gain)

Specified limits:	$60 \leq h_{21E} \leq 80$
Uncertainty of measurement calculated to be:	5
Inset limits:	65 to 75
Outset limits:	55 to 85

F.6.5 Example 4: Comparison between initial and final measurement results

Initial measurement:	102,05 μF
Specified tolerance:	Variation at 1 %
Uncertainty of measurement calculated to be	0,1 %
Inset limits:	101,13 μF to 102,97 μF
Outset limits	100,93 μF to 103,17 μF

Annex G
(informative)

Reference to IEC 62391-1:2006

The drafting of this standard has resulted in a new structure. The following table indicates the new clause and subclause numbers with respect to the IEC 62391-1:2006 (first edition).

IEC 62391-1:2006 first edition Clause/Subclause	IEC 62391-1:2015 this edition Clause/Subclause	Notes
1	1	General and scope are merged into one
1.1		
1.2	2	In accordance with the ISO/IEC Directives, Part 2
2.1	4.1	
2.2	3	In accordance with ISO/IEC Directives, Part 2
2.3	4.2	
2.4	4.3	
3	4.4	
4	5	
4.1	5.1	In accordance with the change of clause numbers
4.2	5.2	
4.3	5.3	
4.4	5.4	
4.5	5.5, 5.6	Divide the measuring method into two
4.6	5.5, 5.6	Divide the measuring method into two
4.7	5.7	In accordance with the change of clause numbers
4.8	5.8	
4.9	5.9	
4.10	5.10	
4.11	5.11	
4.12	5.12	
4.13	5.13	
4.14	5.14	
4.15	5.15	
4.16	5.16	
4.17	5.17	
4.18	5.18	
4.19	5.19	
4.20	5.20	
4.21	5.21	

Annex Q
(normative)

Quality assessment procedures

Q.1 General

Q.1.1 Overview

When this standard, and any related standards are used for the purpose of a full quality assessment system compliance with Clauses Q.5, Q.6 or Q.14 is required.

When such standards are used outside quality assessment systems for purposes such as design proving or type testing, the procedures and requirements of Q.5.1 and Q.5.3 b) may be used, but, if used, the tests and parts of tests shall be applied in the order given in the test schedules.

Before components can be qualified according to the procedures of this annex, the manufacturer shall obtain the approval of his organization in accordance with the provisions of the specified quality assessment system (if any).

The methods that are available for the approval of components of assessed quality and which are covered by the following subclauses, are:

– qualification approval;
– capability approval;
– technology approval.

For a given subfamily of components, separate sectional specifications for qualification approval and capability approval are necessary and capability approval is therefore available only when a relevant sectional specification has been published.

Q.1.2 Applicability of qualification approval

Qualification approval is appropriate for a standard range of components manufactured to similar design and production processes and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and performance levels applies directly to the component range to be qualified, as prescribed in Clause Q.5 and the relevant sectional specification.

Q.1.3 Applicability of capability approval

Q.1.3.1 General

Capability approval is appropriate when components based on common design rules are fabricated by a group of common processes. It is particularly appropriate when components are manufactured to a user's specific requirements.

Under capability approval, detail specifications fall into the following three categories.

Q.1.3.2 Capability qualifying components (CQCs), including process validation test vehicles

A detail specification shall be prepared for each CQC. It shall identify the purpose of the CQC and include all relevant test severities and limits.

Q.1.3.3 Standard catalogue components

When the manufacturer requires a component approved under the capability approval procedure, a capability approval detail specification complying with the blank detail specification (if any) shall be written.

Q.1.3.4 Customer specific components

The content of the detail specification (often known as a customer detail specification (CDS)) shall be by agreement according to the specified quality assessment system (if any).

Further information on these detail specifications is given in the relevant sectional specification.

Approval is given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures and the results of tests on capability qualifying components, including any process validation test vehicles. See Clause Q.6 and the relevant sectional specification for further information.

Q.1.4 Applicability of technology approval

Technology approval is appropriate when the complete technological process (design, process realization, product manufacture, test and shipment) covers the qualification aspects common to all components determined by the technology.

Q.2 Primary stage of manufacture

The primary stage of manufacture shall be specified in the sectional specification.

Q.3 Subcontracting

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed it shall be in accordance with the specified quality assessment system (if any).

The generic or sectional specification may

– either forbid this subcontracting on technical grounds, or
– where it is considered necessary, include any special requirements, for example for specified successive stages to be performed by the same manufacturer, or
– permit the subcontracting unreservedly.

Q.4 Structurally similar components

The grouping of structurally similar components for qualification approval testing or for quality conformance testing under qualification approval, capability approval or technology approval shall be prescribed in the relevant sectional specification.

Q.5 Qualification approval procedures

Q.5.1 Eligibility for qualification approval

Qualification approval may be granted only to a manufacturer who has been granted manufacturer's approval and, additionally, the requirements of this annex. These approvals may be carried out in parallel, although qualification approval shall not be granted in advance of manufacturer's approval.

Q.5.2 Application for qualification approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.5.3 Test procedure for qualification approval

One of the following procedures shall be used.

a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible, and on one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.
b) Samples shall be taken from the lots in accordance with IEC 61193-2. Normal inspection shall be used, but if the sample size gives acceptance on zero non-conformances, additional specimens shall be taken to meet the sample size requirements to give acceptance on one non-conforming item.
c) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the sectional specification.
d) The specimens taken to form the sample shall be selected at random from current production or as agreed.
e) For the two procedures, the sample sizes and the number of permissible non-conformances shall be of comparable order. The test conditions and requirements shall be the same.

Q.5.4 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completed satisfactorily.

Q.5.5 Maintenance of qualification approval

Qualification approval shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see Q.5.6).

Q.5.6 Quality conformance inspection

The blank detail specification(s) associated with the sectional specification shall prescribe the test schedule for quality conformance inspection. This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection.

Operation of the switching rule for reduced inspection in Group C is permitted in all subgroups except endurance.

Sampling plans and inspection levels shall be selected from those given in IEC 61193-2.

If required, more than one schedule may be specified.

Q.6 Capability approval procedures

Q.6.1 General

Capability approval covers

– the complete design, material preparation and manufacturing techniques, including control procedures and tests;
– the performance limits claimed for the processes and products, that is, those specified for the capability qualifying components (CQCs) and process control parameters (PCPs);

– the range of mechanical structures for which approval is granted.

For a general overview of capability approval, see Figure Q.1.

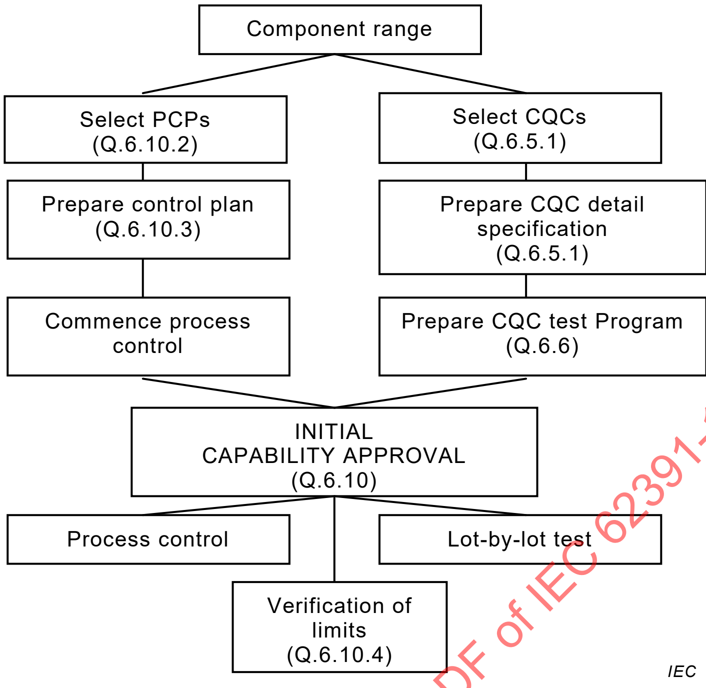


Figure Q.1 – General scheme for capability approval

Q.6.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any).

Q.6.3 Application for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any), and with the requirements of the relevant sectional specification.

Q.6.4 Description of capability

The capability shall be described in a capability manual in accordance with the specified quality assessment system (if any), and the requirements of the relevant sectional specification. The manual shall include or make reference to the following as a minimum:

– a general introduction and description of the technologies involved;
– aspects of customer liaison including provisions of design rules (if appropriate) and assistance to customers in the formulation of their requirements;
– a detailed description of the design rules to be used;
– the procedure for checking that the design rules are complied with for the relevant component technology manufactured to a detail specification;
– a list of all materials used, with reference to the corresponding purchasing specifications and goods inward inspection specifications;
– a flow chart for the total process, showing quality control points and permitted rework loops and containing references to all process and quality control procedures;
– a declaration of processes for which approval has been sought in accordance with the requirements of the relevant sectional specification;

- a declaration of limits for which approval has been sought in accordance with the requirements of the relevant sectional specification;
- a list of CQCs used to assess the capability, with a general description of each, supported by a detailed table showing where the declared limits of capability are demonstrated by a particular CQC design;
- detail specification for each CQC;
- a detailed control plan including PCPs used to control processes, with a general description of each PCP and showing the relation between a given PCP and the related properties and performance of the finished component;
- guidance on the application of structural similarity in sampling for quality conformance testing.

Q.6.5 Demonstration and verification of capability

Q.6.5.1 General

The manufacturer shall demonstrate and verify the capability in accordance with the specified quality assessment system (if any), and the requirements of the relevant sectional specification with the following details:

Q.6.5.2 CQCs for demonstrating capability

The manufacturer shall agree with the CB on the process qualifying parameters and the range of capability qualifying components which are necessary to demonstrate the capability range specified in the capability manual.

The demonstration shall be made by testing the agreed range of CQCs, which shall be designed, manufactured and the process parameters controlled in accordance with the capability manual. The CQCs shall comply with the following requirements:

a) The range of CQCs used shall represent all the limits of the declared capability. The CQCs shall be chosen to demonstrate mutually attainable combinations of limits.
b) The CQCs shall be one of the following:
   - components specially designed to demonstrate a combination of limits of capability, or
   - components of designs used in general production, or
   - a combination of both of these, provided the requirements of a) are met.

When CQCs are designed and produced solely for capability approval, the manufacturer shall use the same design rules, materials and manufacturing processes as those applied to released products.

A detail specification shall be prepared for each CQC and shall have a specific front page format. The detail specification shall identify the purpose of the CQC and shall include all relevant stress levels and test limits. It may refer to internal control documentation which specifies production testing and recording in order to demonstrate control and maintenance of processes and limits of capability.

Q.6.5.3 Limits of capability

The limits of capability shall be described in the relevant sectional specification.

Q.6.6 Programme for capability approval

In accordance with the specified quality assessment system (if any), the manufacturer shall prepare a programme for the assessment of the declared capability. This programme shall be so designed that each declared limit of capability is verified by an appropriate CQC.

The programme shall include the following:

– a bar chart or other means of showing the proposed timetable for the approval exercise;
– details of all the CQCs to be used with references to their detail specifications;
– a chart showing the features to be demonstrated by each CQC;
– reference to the control plans to be used for process control.

Q.6.7 Capability approval test report

In accordance with the specified quality assessment system (if any), a capability approval test report shall be issued. The report shall meet the specific requirements for the capability approval test report and shall contain the following information:

– the issue number and date of the capability manual;
– the programme for capability approval in accordance with Q.6.6;
– all the test results obtained during the performance of the programme;
– the test methods used;
– reports on actions taken in the event of failure (see Q.6.10.2).

The report shall be signed by the designated management representative (DMR) as a true statement of the results obtained and submitted to the body, designated in the national rules, which is responsible for the granting of capability approval.

Q.6.8 Abstract of description of capability

The abstract is intended for formal publication after capability approval has been granted.

The abstract shall include a concise description of the manufacturer's capability and give sufficient information on the technology, methods of construction and range of products for which the manufacturer has been approved.

Q.6.9 Modifications likely to affect the capability approval

Any modifications likely to affect the capability approval shall satisfy the requirements of the specified quality assessment system (if any).

Q.6.10 Initial capability approval

Q.6.10.1 General

The approval is granted when

– the selected range of CQCs has collectively satisfied the assessment requirements of the CQC detail specifications, with no nonconforming item allowed;
– the control plan has been fully implemented in the process control system.

Q.6.10.2 Procedure in the event of failure

See the specified quality assessment system (if any), with the following details.

In the event of the failure of the specimens to meet the test requirements, the manufacturer shall state his/her intention to follow one of the actions described in a) and b) below:

a) to modify the proposed scope of the capability;
b) to conduct an investigation to establish the cause of failure as being either
   – failure of the test itself, for example, test equipment failure or operator error,
     or

– design or process failure.

If the cause of failure is established as a failure of the test itself, then either the specimen which apparently failed or a new one, if appropriate, shall be returned to the test schedule after the necessary corrective action has been taken. If a new specimen is to be used, it shall be subjected to all of the tests in the given sequence of the test schedule(s) appropriate to the apparently failed specimen.

If the cause of failure is established as a design or process failure, a test programme shall be carried out to demonstrate that the cause of failure has been eradicated and that all corrective measures, including documentation, have been carried out. When this has been accomplished, the test sequences in which the failure has occurred shall be repeated in full using new CQCs.

After the action is complete the manufacturer shall send a report, and shall include a copy in the capability approval test report (see Q.6.7).

Q.6.10.3 General plan for the selection of PCPs and CQCs

Each manufacturer shall prepare a process flow chart, based on the example given in the relevant sectional specification. For all the process steps included in this flow chart, the manufacturer shall include the corresponding process controls.

Controls shall be denoted by the manufacturer as shown in the example in the relevant sectional specification.

Q.6.10.4 Process control test plans

The test plans shall form part of the process control system used by the manufacturer. When statistical process control (SPC) is used, implementation shall be in accordance with SPC basic requirements. The SPC plans represent mandatory controls at process nodes.

For each process step where production equipment is employed, the manufacturer shall monitor the process parameters at regular intervals and compare the readings to the control and action limits which he/she will establish.

Q.6.10.5 Test plans for CQCs demonstrating limits of capability

Test plans for CQCs for the demonstration of limits of capability shall be prescribed in the relevant sectional specification.

Q.6.11 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with the specified quality assessment system (if any), have been completed satisfactorily and the requirements of the relevant sectional specification have been met.

Q.6.12 Maintenance of capability approval

Capability approval shall be maintained by complying with the requirements of the specified quality assessment system (if any), and with the requirements declared in the capability manual following the schedule of maintenance given in the relevant sectional specification.

Additionally, the following details apply.

a) Capability approval remains valid without retesting for two years.
b) The programme for the retesting of CQCs shall be defined by the manufacturer. For process control, the manufacturer shall establish a control system. An example of a control programme chart may be given in the sectional specification. For verifying limits of

capability, the manufacturer shall ensure that all the test plans of Q.6.10.5 which are relevant to his capability approval are repeated at least every two years.

c) Quality conformance inspection of components for delivery may be used to support the maintenance of capability approval where relevant. In particular, where the manufacturer holds qualification approval for a range of components which are manufactured by the same processes and which also fall within the limits of capability for which he holds capability approval, process control test results and periodic quality conformance test results arising from the qualification approval may be used to support the maintenance of capability approval.

d) The manufacturer shall ensure that the range of CQCs remains representative of the products released and in accordance with the requirements of the relevant sectional specification.

e) The manufacturer shall maintain production, so that
   – the processes specified in the capability manual, with the exception of any agreed additions or deletions following the procedure of Q.6.9, remain unchanged,
   – no change has occurred in the place of manufacture, and final test,
   – no break exceeding six months has occurred in the manufacturer's production under capability approval.

f) The manufacturer shall maintain a record of the progress of the maintenance of capability programme so that at any time the limits of capability which have been verified and those which are awaiting verification in the specified period can be established.

Q.6.13 Extension of capability approval

The manufacturer may extend the limits of his capability approval by carrying out the test plan from Q.6.10.5, which relates to the type of limit to be extended. If the proposed extension refers to a different type of limit from those described in Q.6.10.5, the manufacturer shall propose the sampling and tests to be used and these shall be approved. The manufacturer shall also establish process control over any new processes needed for manufacture to the new limits.

An application for an extension of capability shall be made in the same way as for the original approval.

Q.6.14 Quality conformance inspection

The quality conformance test requirements are given in the detail specification and shall be carried out in accordance with the specified quality assessment system (if any).

Q.7 Rework and repair

Q.7.1 Rework

Rework as defined in the specified quality assessment system (if any), shall not be carried out if prohibited by the relevant sectional specification. The relevant sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection in accordance with the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the DMR. Rework shall not be subcontracted.

Q.7.2 Repair

Components which have been repaired as defined in the specified quality assessment system (if any), shall not be released.

Q.8 Release for delivery

Q.8.1 General

Components shall be released for delivery according to Q.5.6 and the specified quality assessment system (if any), after the quality conformance inspection prescribed in the detail specification has been carried out.

Q.8.2 Release for delivery under qualification approval before the completion of Group B tests

When the conditions of IEC 61193-2:2007 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

Q.9 Certified test records of released lots

When certified test records are requested by a purchaser, they shall be specified in the detail specification.

NOTE For capability approval, the certified test records refer only to tests carried out on capability qualifying components.

Q.10 Delayed delivery

Components held for a period exceeding two years (unless otherwise specified in the sectional specification) following the release of the lot shall, before delivery, be re-examined for solderability and electrical characteristics as specified in the detail specification.

The re-examination procedure adopted by the manufacturer's DMR shall be approved.

Once a lot has been satisfactorily re-inspected, its quality is reassured for the specified period.

Q.11 Alternative test methods

See the specified quality assessment system (if any), with the following details.

In case of dispute, for referee and reference purposes, only the specified methods shall be used.

Q.12 Manufacture outside the geographical limits of IECQ CBs

See the requirements of the specified quality assessment system (if any).

Q.13 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing shall be assumed to be within the specified limits. It cannot be assumed that any unspecified parameter will remain unchanged from one component to another. If it is necessary, for any reason, to control one or more additional parameters, then a new, more extensive specification shall be used.

The additional test method(s) shall be fully described and appropriate limits, sampling plans and inspection levels specified.

Q.14 Technology approval procedures

Q.14.1 General

Technology approval of components covers the complete technological process. It extends the existing concepts – qualification and capability approval – by adding as mandatory:

a) the use of in-process control methods, for example, SPC;
b) continuous quality improvement strategy;
c) monitoring the overall technologies and operations;
d) procedural flexibility due to the quality assurance management system and market sector requirements;
e) the acceptance of a manufacturer's operational documentation to provide means for rapid approval or extension of approval.

Q.14.2 Eligibility for technology approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.14.3 Application of technology approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.14.4 Description of technology

The technology shall be described in a Technology Approval Declaration Document (TADD) and a Technology Approval Schedule (TAS) in accordance with the specified quality assessment system (if any).

Q.14.5 Demonstration and verification of the technology

The manufacturer shall demonstrate and verify the technology in accordance with the specified quality assessment system (if any).

Q.14.6 Granting of technology approval

Technology approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completely satisfied.

Q.14.7 Maintenance of technology approval

Technology approval shall be maintained by complying with the requirements of the specified quality assessment system (if any).

Q.14.8 Quality conformance inspection

The quality conformance test and requirements shall be carried out in accordance with the detail specification and technology approval schedules.

Q.14.9 Failure rate level determination

The determination of failure rate level and certification shall be described in the detail specification.

Q.14.10 Outgoing quality level

The definition shall be agreed between customer and manufacturer.

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

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CONDENSATEURS ÉLECTRIQUES FIXES À DOUBLE COUCHE UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRIQUES ET ÉLECTRONIQUES –

Partie 1: Spécification générique

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La Norme internationale IEC 62391-1 a été établie par le comité d'études 40 de l'IEC: Condensateurs et résistances pour équipements électroniques.

La présente version bilingue (2017-12) correspond à la version anglaise monolingue publiée en 2015-10.

Cette deuxième édition annule et remplace la première édition parue en 2006 dont elle constitue une révision technique.

La présente édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) renforcement du domaine d'application pour inclure des applications électriques (haute puissance);

b) mise en œuvre de l'Annexe Q qui remplace l'Article 3 de la première édition;

c) en plus, des révisions mineures des tableaux, valeurs et références.

Le texte anglais de cette norme est issu des documents 40/2393/FDIS et 40/2415/RVD.

Le rapport de vote 40/2415/RVD donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série de normes IEC 62391, publiées sous le titre général *Condensateurs fixes à double couche utilisés dans les équipements électriques et électroniques*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

Le contenu des corrigenda de décembre 2016 et juin 2019 a été inclus dans cette copie.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

CONDENSATEURS ÉLECTRIQUES FIXES À DOUBLE COUCHE UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRIQUES ET ÉLECTRONIQUES –

Partie 1: Spécification générique

1 Domaine d'application

La présente partie de l'IEC 62391 s'applique aux condensateurs électriques fixes à double couche (appelés ci-après condensateurs) principalement utilisés dans des circuits à courant continu d'équipements électriques et électroniques.

La présente partie de l'IEC 62391 définit les termes normalisés, les procédures de contrôle et les méthodes d'essai utilisés dans les spécifications intermédiaires et particulières des composants électroniques dans le cadre de l'assurance de la qualité, ainsi qu'à d'autres fins.

2 Références normatives

Les documents ci-après, dans leur intégralité ou non, sont des références normatives indispensables à l'application du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60027 (toutes les parties), *Symboles littéraux à utiliser en électrotechnique*

IEC 60050 (toutes les parties), *Vocabulaire Electrotechnique International*

IEC 60062, *Codes de marquage des résistances et des condensateurs*

IEC 60063, *Séries de valeurs normales pour résistances et condensateurs*

IEC 60068-1:2013, *Essais d'environnement – Partie 1: Généralités et lignes directrices*

IEC 60068-2-1:2007, *Essais d'environnement – Partie 2-1: Essais – Essai A: Froid*

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IEC 60068-2-78:2012, *Essais d'environnement – Partie 2-78: Essais – Essai Cab: Chaleur humide, essai continu*

IEC 60294:2012, *Mesure des dimensions d'un composant cylindrique à deux sorties axiales*

IEC 60617 (toutes les parties), *Symboles graphiques pour schémas*

IEC 60695-11-5, *Essais relatifs aux risques du feu – Partie 11-5: Flammes d'essai – Méthode d'essai au brûleur-aiguille – Appareillage, dispositif d'essai de vérification et lignes directrices*

IEC 60717:2012, *Méthode pour la détermination de l'encombrement des condensateurs et résistances à sorties unilatérales*

IEC 61193-2, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

3.1
type
ensemble de composants de conception et de techniques de fabrication identiques, permettant de les prendre en compte soit en vue de procéder à une homologation, soit dans le cadre d'un contrôle de conformité de la qualité

Note 1 à l'article: Dans certains cas, des composants décrits dans plusieurs spécifications particulières peuvent être considérés comme appartenant à un même type.

[SOURCE: IEC 60384-1:2008, 2.2.39 – modifiée, la remarque sur la "seule spécification particulière" a été supprimée de la définition et la note reformulée.]

3.2
modèle
subdivision d'un type, généralement fondée sur des facteurs dimensionnels

Note 1 à l'article: Un modèle peut inclure plusieurs variantes, généralement d'ordre mécanique.

3.3
classe
classification du condensateur selon la valeur de la capacité et la valeur de la résistance interne en fonction de l'application

3.4
famille
<composants électroniques> groupe de composants qui présentent principalement un attribut physique particulier et/ou réalisent une fonction définie

3.5
sous-famille
<composants électroniques> groupe de composants d'une famille, fabriqués par des méthodes technologiques similaires

3.6
condensateur pour courant continu
condensateur conçu essentiellement pour fonctionner sous des tensions continues

Note 1 à l'article: Un condensateur pour courant continu peut ne pas convenir pour l'utilisation sur des sources de courant alternatif.

3.7
capacité nominale
C_N
valeur de capacité pour laquelle a été conçu le condensateur et qui est habituellement marquée sur celui-ci

3.8
plage de températures de catégorie
plage des températures ambiantes pour laquelle le condensateur a été conçu pour fonctionner de façon continue

Note 1 à l'article: Cette plage est donnée par la température de catégorie inférieure et la température de catégorie supérieure.

3.9
température de catégorie inférieure
température ambiante minimale à laquelle un condensateur est conçu pour fonctionner de façon continue

3.10
température de catégorie supérieure
température ambiante maximale, incluant le chauffage intérieur, à laquelle un condensateur est conçu pour fonctionner de façon continue

[SOURCE: IEC 61881-3:2012, 3.17, modifiée – La note à l'article a été supprimée.]

3.11
température assignée
température ambiante maximale à laquelle la tension assignée peut être appliquée de manière continue

3.12
tension assignée
U_R
tension continue maximale ou valeur de crête d'une tension d'impulsion qui peut être appliquée de manière continue ou répétée à un condensateur à n'importe quelle température entre la température de catégorie inférieure et la température assignée

3.13
tension de catégorie
U_C
tension maximale pouvant être appliquée de manière continue à un condensateur utilisé à sa température de catégorie supérieure

3.14
tension corrigée en fonction de la température
tension maximale pouvant être appliquée de façon permanente aux bornes d'un condensateur à toute température comprise entre la température assignée et la température de catégorie supérieure

Note 1 à l'article: La dépendance entre la tension et la température à des températures comprises entre la température assignée et la température de catégorie supérieure est donnée dans la spécification particulière.

3.15
rapport de surtension
quotient de la tension instantanée maximale qui peut être appliquée aux sorties du condensateur, pour une durée spécifiée, à toute température à l'intérieur de la plage des températures de catégorie par, selon le cas, la tension assignée ou la tension corrigée en fonction de la température

Note 1 à l'article: Le nombre de fois par heure que cette tension peut être appliquée est indiqué dans la spécification particulière.

3.16
tension ondulée assignée
valeur efficace de la tension alternative maximale admissible d'une fréquence spécifiée superposée à la tension continue à laquelle le condensateur peut fonctionner de façon permanente à une température spécifiée

Note 1 à l'article: La somme de la tension continue et de la valeur de crête de la tension alternative appliquée au condensateur ne dépasse pas la tension assignée ou, selon le cas, la tension corrigée en fonction de la température.

3.17
tension inverse
<condensateurs polarisés> tension appliquée aux sorties du condensateur dans le sens inverse de la polarité

3.18
courant ondulé assigné
valeur efficace du courant alternatif maximal admissible d'une fréquence spécifiée, sous lequel le condensateur peut fonctionner de façon permanente à une température spécifiée

3.19
constante de temps
produit de la résistance interne (incluant la résistance du circuit) par la capacité

Note 1 à l'article: La constante de temps s'exprime normalement en secondes.

3.20
résistance interne
composante de la résistance dans un circuit équivalent série de la capacité et de la résistance d'un condensateur

Note 1 à l'article: La résistance interne s'exprime en ohms (Ω).

3.21
chute IR
chute de tension entre les bornes d'un condensateur générée au début d'une décharge et quantifiée par le produit du courant de décharge et par la résistance interne du condensateur

3.22
température maximale d'un condensateur
température du point le plus chaud de la surface externe

Note 1 à l'article: Les sorties sont considérées comme faisant partie de la surface externe.

3.23
température minimale d'un condensateur
température du point le plus froid de la surface externe

Note 1 à l'article: Les sorties sont considérées comme faisant partie de la surface externe.

3.24
température minimale de stockage
température ambiante minimale qu'il convient que le condensateur supporte sans dommage en conditions de non-fonctionnement

3.25
température maximale de stockage
température ambiante maximale que le condensateur supporte sans dommage en conditions de non-fonctionnement

[SOURCE: IEC 60384-1:2008, 2.2.11]

3.26
caractéristique de température de condensateur
variation réversible maximale de capacité qui se produit sur une plage donnée de températures à l'intérieur de la plage des températures de catégorie

Note 1 à l'article: Cette caractéristique s'applique principalement aux condensateurs dont les variations de capacité en fonction de la température, variations linéaires ou non linéaires, ne peuvent pas être exprimées avec précision et certitude.

Note 2 à l'article: La caractéristique de température de condensateur s'exprime normalement en pourcentage de la valeur de capacité par rapport à la température de référence de 20 °C.

3.27
dommage visible
dommage visible susceptible de réduire l'aptitude du condensateur à l'emploi pour lequel il a été prévu

3.28
courant de fuite
valeur du courant qui traverse un condensateur après une charge pendant une durée fixe

Note 1 à l'article: Le courant de fuite s'exprime en ampères (A).

3.29
tension de maintien
autodécharge
tension restant lorsqu'aucune charge n'est appliquée pendant une durée fixe après l'application d'une charge pendant une durée fixe

3.30
échauffement
<condensateur> augmentation de la température du condensateur par rapport à la température ambiante résultant des pertes dans le condensateur dues au fonctionnement dans des conditions de charge et/ou de décharge

3.31
condensateur isolé
condensateur dont toutes les sorties d'une section peuvent être portées à un potentiel différent (sans être inférieur à la tension assignée) de celui de toute surface conductrice avec laquelle le boîtier est susceptible d'entrer en contact en utilisation normale

3.32
condensateur non isolé
condensateur dont au moins une des sorties d'une section ne peut pas être portée à un potentiel différent (sans être inférieur à la tension assignée) de celui de toute surface conductrice avec laquelle le boîtier est susceptible d'entrer en contact en utilisation normale

3.33
condensateur pour montage en surface
condensateur fixe dont les petites dimensions et la nature ou la forme des sorties rendent approprié son montage dans des circuits hybrides et en surface des cartes imprimées

3.34
inflammabilité passive
inflammabilité causée par un chauffage externe du composant

Note 1 à l'article: Par exemple, l'inflammabilité passive peut être causée par des flammes.

3.35
inflammabilité active
inflammabilité (auto-allumage) causée par un réchauffement interne du composant

Note 1 à l'article: Par exemple, l'inflammabilité active peut être causée par des étincelles dues à un défaut de contact interne.

3.36
catégorie d'inflammabilité passive
catégorie donnée par la durée maximale d'inflammation après une durée d'application de flamme spécifiée

3.37
masse
masse du condensateur avec tous les éléments fixés

3.38
volume
volume du corps du condensateur sans les sorties

4 Eléments généraux

4.1 Unités et symboles

Les unités, les symboles graphiques, les symboles littéraux et la terminologie doivent, dans la mesure du possible, être tirés des documents suivants:

– IEC 60027;
– IEC 60050;
– IEC 60617;
– ISO 80000-1.

Si d'autres éléments sont exigés, il convient qu'ils soient établis conformément aux principes énoncés dans les publications référencées ci-dessus.

4.2 Classe et valeurs préférentielles

4.2.1 Généralités

Les valeurs préférentielles appropriées à la sous-famille doivent être prescrites dans la spécification intermédiaire.

NOTE Il n'est pas possible de spécifier les valeurs préférentielles de la tension assignée en raison de la nature du condensateur.

4.2.2 Valeurs préférentielles de la capacité nominale

Les valeurs préférentielles de la capacité nominale doivent être prises dans les séries R spécifiées dans l'IEC 60063.

4.2.3 Classe

La classe du condensateur doit être déterminée en fonction de la capacité et de la résistance interne (application). Les détails sont présentés à l'Annexe A.

4.3 Marquage

4.3.1 Généralités

Les critères d'identification et les autres informations devant être marquées sur le condensateur et/ou l'emballage doivent être indiqués dans la spécification intermédiaire.

L'ordre de priorité du marquage des petits condensateurs doit être indiqué dans la spécification particulière.

4.3.2 Codage

Lorsqu'un code est utilisé pour le marquage de la valeur de la capacité, de la tolérance ou de la date de fabrication, la méthode doit être choisie parmi celles données dans l'IEC 60062.

4.4 Procédures d'assurance de la qualité

Se reporter à l'Annexe Q.

5 Essais et mesures

5.1 Généralités

La spécification intermédiaire et/ou la spécification particulière-cadre doivent indiquer les essais à effectuer, les mesures à faire avant et après chaque essai ou chaque sous-groupe d'essais et l'ordre dans lequel ces essais doivent être effectués. Les essais doivent être effectués dans l'ordre indiqué. Les conditions de mesure doivent être les mêmes pour les mesures initiales et finales.

Si les spécifications nationales d'un système d'évaluation de la qualité incluent des méthodes différentes de celles spécifiées dans les spécifications ci-dessus, elles doivent être décrites de façon détaillée.

Les limites données dans toutes les spécifications sont des limites absolues. Le principe de prise en compte de l'incertitude de mesure est présenté à l'Annexe F.

5.2 Exigences sur les essais et les mesures

5.2.1 Conditions d'essai

Sauf spécification contraire, tous les essais doivent être effectués dans les conditions atmosphériques normalisées d'essai indiquées dans l'IEC 60068-1,2013, 4.3.

– température : 15 °C à 35 °C;
– humidité relative : 25 % à 75 %;
– pression atmosphérique : 86 kPa à 106 kPa.

5.2.2 Conditions de mesure

Sauf spécification contraire, toutes les mesures doivent être effectuées dans les conditions atmosphériques normalisées d'essai indiquées dans l'IEC 60068-1,2013, 4.3, avec l'exception suivante:

– température: 20 °C ± 2 °C.

Toutes les mesures doivent être effectuées lorsque l'équilibre thermique est atteint, voir 5.2.4.

5.2.3 Traitement de la tension

Le condensateur doit être chargé à la tension U_R et maintenu à cette tension pendant 30 min au moyen d'une source de tension continue. Le condensateur doit être déchargé à l'aide d'un dispositif de décharge approprié.

5.2.4 Traitement thermique

Les condensateurs doivent être stockés à la température spécifiée en 5.2.2 pendant un temps suffisant pour permettre à l'ensemble du condensateur d'atteindre cette température (équilibre thermique, voir l'Annexe C).

5.3 Séchage

Sauf indication contraire dans la spécification particulière, le condensateur doit être conditionné pendant 96 h ± 4 h par un chauffage dans un four à circulation d'air porté à une température de 55 °C ± 2 °C et dont l'humidité relative ne dépasse pas 20 %.

Le condensateur doit ensuite être mis à refroidir dans un dessiccateur contenant un déshydratant approprié, tel que de l'alumine activée ou du gel de silice, et doit y être maintenu depuis la sortie du four jusqu'au début des essais spécifiés.

5.4 Examen visuel et contrôle des dimensions

5.4.1 Examen visuel

Un examen visuel du composant doit montrer que l'état, la qualité et la finition sont satisfaisants.

Le marquage doit être lisible à l'examen visuel et doit être conforme aux exigences de la spécification particulière.

5.4.2 Dimensions (calibrage)

Les dimensions indiquées dans la spécification particulière, appropriées au calibrage, doivent être vérifiées, et elles doivent être conformes aux valeurs prescrites.

Lorsque cela est applicable, les mesures doivent être effectuées conformément à l'IEC 60294 ou à l'IEC 60717.

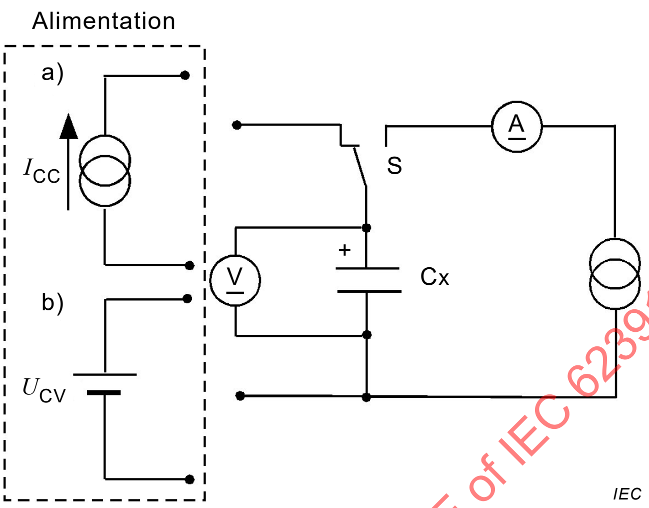
5.4.3 Dimensions (détail)

Toutes les dimensions prescrites dans la spécification particulière doivent être vérifiées et doivent être conformes aux valeurs prescrites.

5.5 Méthode de mesure 1 pour la capacité et la résistance interne (décharge à courant constant)

5.5.1 Circuit de base pour la mesure

La capacité et la résistance interne doivent être mesurées en utilisant les méthodes de charge et de décharge à courant constant. Le circuit de base pour la mesure est présenté à la Figure 1.



Légende

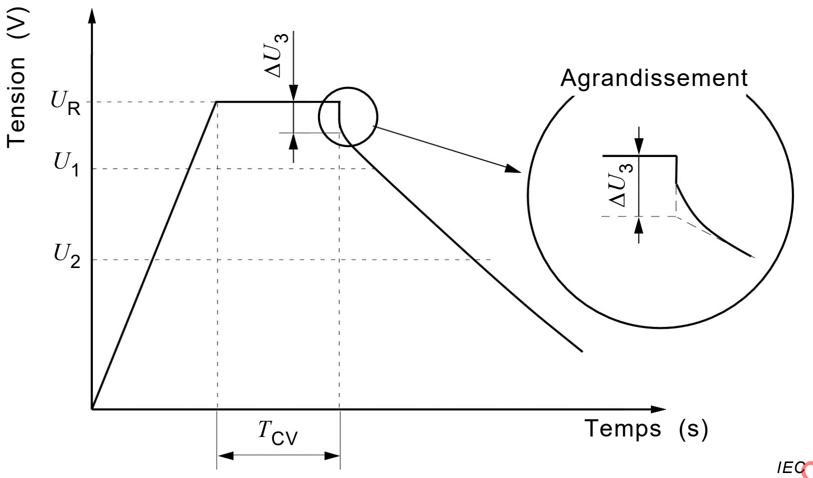
I_{CC}	courant constant
U_{CV}	tension constante
Ⓐ	ampèremètre pour courant continu
Ⓥ	enregistreur de tension continue
S	commutateur
Cx	condensateur en essai
	déchargeur à courant constant
a)	alimentation pour charge à courant constant
b)	alimentation pour charge à tension constante

Figure 1 – Circuit de base pour la mesure

5.5.2 Appareil de mesure

L'appareil de mesure doit être capable de réaliser une charge à courant constant, une charge à tension constante, une décharge à courant constant et de contrôler en permanence les mesures du courant et de la tension entre les bornes d'un condensateur en fonction du temps de décharge comme cela est représenté à la Figure 2. L'appareil de mesure doit être capable de régler et de mesurer le courant et la tension avec une précision de ± 1 % ou moins.

L'alimentation doit délivrer un courant de charge constant au condensateur avec une efficacité de 95 % et disposer d'une fonction de réglage de la durée de la charge à tension constante. Le déchargeur à courant constant doit délivrer un courant de décharge constant comme spécifié dans le Tableau 1 ou dans le Tableau 2, respectivement. L'enregistreur de tension continue doit être capable de réaliser des mesures et doit enregistrer avec une résolution de 5 mV et une cadence d'échantillonnage de 100 ms ou moins.



Légende

U_R tension assignée (V)

U_1 tension au début du calcul (V)

U_2 tension à la fin du calcul (V)

ΔU_3 chute de tension (V)

T_{CV} durée de la charge à tension constante (min)

Figure 2 – Caractéristique de la tension en fonction du temps entre les bornes d'un condensateur dans la mesure de la capacité et de la résistance interne

5.5.3 Procédure de mesure

5.5.3.1 Généralités

La mesure doit être effectuée en analysant la caractéristique de la tension en fonction du temps entre les bornes du condensateur.

La méthode de mesure doit être conforme soit à 5.5.3.2 soit à 5.5.3.3 selon la classe (se reporter à l'Annexe A) et doit être indiquée dans la spécification particulière.

Un préconditionnement du traitement de la tension selon 5.2.3 et du traitement thermique selon 5.2.4 doit être réalisé, et, si la spécification particulière l'indique, un séchage selon 5.3 peut être réalisé avant la mesure.

La tension entre les bornes du condensateur doit être mesurée et enregistrée en fonction du temps tout au long de la procédure de mesure.

5.5.3.2 Méthode de mesure 1A (classe 1, 2, 3 et 4)

Sauf indication contraire dans la spécification particulière, les conditions de mesure doivent être celles qui figurent dans le Tableau 1. Le courant de charge constant (I_{cc}) doit être capable de charger le condensateur avec une efficacité de charge de 95 %. Sa valeur est définie par I_{cc} (=U_R /38 R_N), où (U_R) est la tension assignée et (R_N) est la résistance interne nominale. Les courants de décharge constants sont réglés pour la mesure de la capacité et la résistance interne respectivement, correspondant à la capacité nominale du condensateur.

La procédure de mesure doit être la suivante:

a) le condensateur doit être chargé avec un courant de charge constant;

b) lorsque la tension de sortie de l'alimentation atteint la valeur spécifiée, la charge du condensateur doit continuer avec la tension constante;

c) le condensateur doit ensuite être déchargé dans le déchargeur à courant constant;

d) puis le temps entre le début de la décharge et l'instant où la tension aux bornes du condensateur devient U_1 et U_2 respectivement doit être mesuré (voir Figure 2).

Tableau 1 – Conditions de mesure pour la méthode de mesure 1A

Conditions de mesure	**Classe** Application			
	Classe 1 (sauvegarde en mémoire)	**Classe 2** (stockage d'énergie)	**Classe 3** (puissance)	**Classe 4** (puissance instantanée)
Charge à courant constant mA	Efficacité de charge de 95 % [a]			
Temps de charge à tension constante min	30			
Courant de décharge constant pour la mesure de la capacité [b] mA	$1 \times C_N$	$0{,}4 \times C_N U_R$	$4 \times C_N U_R$	$40 \times C_N U_R$
Courant de décharge constant pour la mesure de la résistance interne [c] mA	$10 \times C_N$	$4 \times C_N U_R$	$40 \times C_N U_R$	$400 \times C_N U_R$
U_1	$0{,}8 \times U_R$			
U_2	$0{,}4 \times U_R$			

Pour la classe 3 et la classe 4, la méthode de mesure 1B peut être utilisée.

Un courant de décharge inférieur ou égal à 10 A doit être indiqué avec un chiffre significatif. Il convient d'arrondir le deuxième chiffre de la valeur calculée.

Un courant de décharge supérieur à 10 A doit être indiqué avec deux chiffres significatifs. Il convient d'arrondir le troisième chiffre de la valeur calculée.

NOTE C_N est la capacité nominale en farad (F), et U_R est la tension assignée en volt (V).

[a] L'Annexe D présente le concept général de l'efficacité de charge et de décharge.

[b] Si ΔU_3 dépasse 5 % de la tension de charge ($0{,}05 \times U_R$) dans les caractéristiques initiales, la valeur du courant de décharge peut être réduite de 50 %, 20 % ou 10 %.

[c] Si ΔU_3 dépasse 20 % de la tension de charge ($0{,}2 \times U_R$) dans les caractéristiques initiales, la valeur du courant de décharge peut être réduite de 50 %, 20 % ou 10 %.

5.5.3.3 Méthode de mesure 1B (classe 3, 4 et 5)

Sauf indication contraire dans la spécification particulière, les conditions de mesure doivent être celles qui figurent dans le Tableau 2. Le courant de charge constant (I_{cc}) doit être capable de charger le condensateur avec une efficacité de charge de 95 %. Sa valeur est définie par I_{cc} (= U_R/38 R_N), où (U_R) est la tension assignée et (R_N) est la résistance interne nominale. Le courant de décharge constant (I_d) doit être capable de décharger le condensateur avec une efficacité de décharge de 95 %. Sa valeur est définie par I_d (= U_R/40 R_n), où (U_R) est la tension assignée et (R_n) est la résistance interne nominale.

La procédure de mesure doit être la suivante:

a) le condensateur doit être chargé avec un courant de charge constant;

b) lorsque la tension de sortie de l'alimentation atteint la valeur spécifiée, la charge du condensateur doit continuer avec la tension constante;

c) le condensateur doit alors être déchargé dans le déchargeur à courant constant;

d) puis le temps entre le début de la décharge et l'instant où la tension aux bornes du condensateur devient U_1 et U_2 respectivement doit être mesuré (voir Figure 2).

Tableau 2 – Conditions de mesure pour la méthode de mesure 1B

<table>
<tr><th rowspan="2">Conditions de mesure</th><th colspan="3">Classe
Application</th></tr>
<tr><th>Classe 3
(puissance)</th><th>Classe 4
(puissance instantanée)</th><th>Classe 5
(haute puissance)</th></tr>
<tr><td>Charge à courant constant
mA</td><td colspan="3">Efficacité de charge de 95 % [a]</td></tr>
<tr><td>Temps de charge à tension constante
min</td><td colspan="3">5</td></tr>
<tr><td>Décharge à courant constant</td><td colspan="3">Efficacité de décharge de 95 % [a]</td></tr>
<tr><td>U_1</td><td colspan="3">$0,8 \times U_R$</td></tr>
<tr><td>U_2</td><td colspan="3">$0,4 \times U_R$</td></tr>
<tr><td colspan="4">Pour la classe 3 et la classe 4, la méthode de mesure 1A peut être utilisée.
Un courant de décharge inférieur ou égal à 10 A doit être indiqué avec un chiffre significatif. Il convient d'arrondir le deuxième chiffre de la valeur calculée.
Un courant de décharge supérieur à 10 A doit être indiqué avec deux chiffres significatifs. Il convient d'arrondir le troisième chiffre de la valeur calculée.</td></tr>
<tr><td colspan="4">[a] L'Annexe D présente le concept général de l'efficacité de charge et de décharge.</td></tr>
</table>

5.5.4 Méthodes de calcul de la capacité

5.5.4.1 Généralités

La capacité doit être calculée par la méthode d'approximation de la ligne droite ou par la méthode de conversion de l'énergie.

5.5.4.2 Méthode d'approximation de la ligne droite (méthode de mesure 1A)

La capacité C d'un condensateur doit être calculée par la formule suivante:

$$C = \frac{I_d \times (t_2 - t_1)}{U_1 - U_2}$$

où

C est la capacité du condensateur (F);

I_d est le courant de décharge (A);

U_1 est la tension au début de la mesure (V);

U_2 est la tension à la fin de la mesure (V);

t_1 est l'instant auquel la tension aux bornes du condensateur atteint la valeur U_1 à partir du début de la décharge;

t_2 est l'instant auquel la tension aux bornes du condensateur atteint la valeur U_2 à partir du début de la décharge.

5.5.4.3 Méthode de conversion de l'énergie (méthode de mesure 1B)

La capacité C d'un condensateur doit être calculée par la formule suivante:

$$C = \frac{2W}{{U_1}^2 - {U_2}^2}$$

où

C est la capacité du condensateur (F);

W est l'énergie déchargée mesurée (J), de la tension de début U_1 à la tension de fin U_2;

U_1 est la tension de début mesurée;

U_2 est la tension de fin mesurée.

5.5.5 Méthodes de calcul de la résistance interne

5.5.5.1 Généralités

La résistance interne doit être calculée par la méthode des moindres carrés ou par la méthode des intersections de droites.

5.5.5.2 Calcul de la résistance interne par la méthode des intersections de droite (méthode de mesure 1A)

La résistance interne R d'un condensateur doit être calculée par la formule suivante:

$$R = \frac{\Delta U_3}{I_d}$$

où

R est la résistance interne du condensateur (Ω);

I_d est le courant de décharge (A);

ΔU_3 est la chute de tension (V).

NOTE La chute de tension est lue en traçant une ligne secondaire tout en prolongeant la partie droite des tensions variant dans le temps aux bornes du condensateur obtenue à l'aide de l'enregistreur de tension, comme cela est représenté à la Figure 2.

5.5.5.3 Calcul de la résistance interne par la méthode des moindres carrés (méthode de mesure 1B)

La résistance interne R d'un condensateur doit être calculée par la formule suivante:

$$R = \frac{\Delta U_3}{I_d}$$

où

R est la résistance interne du condensateur (Ω);

I_d est le courant de décharge (A);

ΔU_3 est la chute de tension (V).

Appliquer l'approximation de droites à la caractéristique de la chute de tension entre la tension au début du calcul (U_1) et la tension à la fin du calcul (U_2) en utilisant la méthode des moindres carrés. Déterminer le point d'interception (valeur de la tension) de la droite à l'instant du début de la décharge. ΔU_3 est la différence des tensions (V) entre la valeur de la tension d'interception et la valeur définie de la charge à tension constante (V).

5.5.6 Conditions devant être prescrites dans la spécification particulière

La spécification particulière doit prescrire:

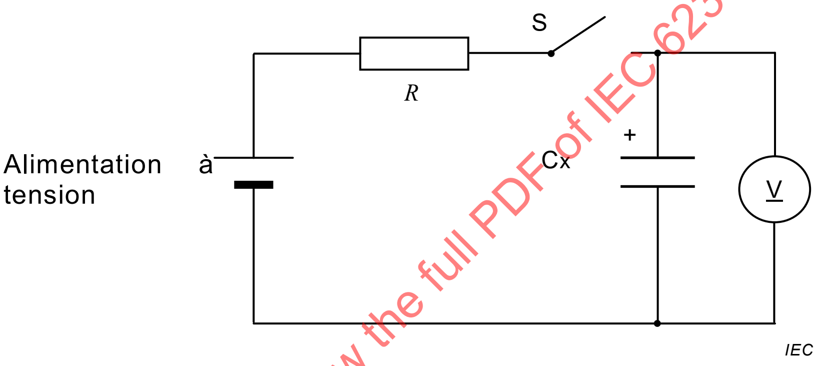
a) la classification des méthodes;
b) la tension appliquée différente de la tension assignée;
c) un temps de charge différent de 30 min (voir Tableau 2) ou 5 min (voir Tableau 3);
d) une valeur de décharge à courant constant autre que celle du Tableau 2 ou du Tableau 3;
e) les tensions U_1 et U_2 au moment de la chute de tension de décharge différentes des tensions du Tableau 2 ou du Tableau 3.

5.6 Méthode de mesure 2 pour la capacité et la résistance interne

5.6.1 Méthode de charge à résistance constante pour la mesure de la capacité

5.6.1.1 Circuit de mesure

Les mesures doivent être réalisées à l'aide du circuit de mesure représenté à la Figure 3.



Légende

R résistance série

S interrupteur

voltmètre pour courant continu

Cx condensateur en essai

Figure 3 – Circuit pour la méthode de charge à résistance constante

5.6.1.2 Méthode de mesure

La procédure de mesure doit être la suivante:

a) avant d'effectuer la mesure, court-circuiter les bornes du condensateur pendant au moins 30 min pour s'assurer que le condensateur se décharge suffisamment;
b) régler la valeur de R de telle sorte que la constante de temps τ se stabilise entre 60 s et 120 s;
c) mesurer la constante de temps τ lorsque la tension continue U_R est appliquée et calculer la valeur de la capacité à l'aide de la formule suivante:

$$C = \frac{\tau}{R}$$

où

C est la capacité (F);

τ est la constante de temps: temps de charge jusqu'à 0,632 × U_R (s);

R est la résistance série (Ω).

5.6.1.3 Conditions devant être prescrites dans la spécification particulière

La spécification particulière doit prescrire:

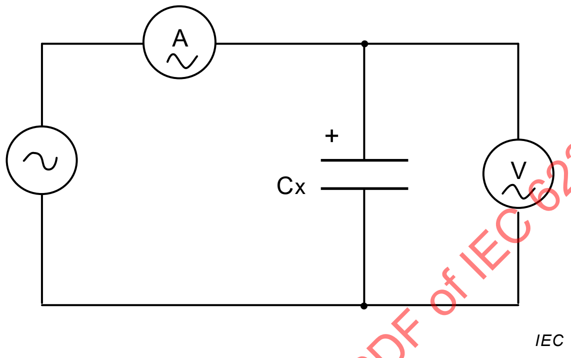
a) la tension appliquée différente de la tension assignée;

b) la résistance série R lorsque la constante de temps est différente de 60 s à 120 s.

5.6.2 Méthode de mesure de la résistance à courant alternatif interne

5.6.2.1 Circuit de mesure

Les mesures doivent être réalisées à l'aide du circuit de mesure représenté à la Figure 4.



Légende

	oscillateur
	ampèremètre à courant alternatif
	voltmètre à courant alternatif
Cx	condensateur en essai

Figure 4 − Circuit pour la méthode de la résistance à courant alternatif

5.6.2.2 Méthode de mesure

La procédure de mesure doit être la suivante:

a) la fréquence de mesure doit être 1 kHz;

b) le courant alternatif doit être compris entre 1 mA et 10 mA;

c) la résistance interne R_a d'un condensateur doit être calculée par la formule suivante:

$$R_a = \frac{U}{I}$$

où

R_a est la résistance à courant alternatif interne (Ω);

U est la valeur efficace de la tension alternative (V);

I est la valeur efficace du courant alternatif (A).

5.7 Courant de fuite

5.7.1 Méthode de mesure

La procédure de mesure doit être la suivante.

a) Avant d'effectuer cette mesure, les condensateurs doivent être complètement déchargés. La procédure de décharge doit durer entre 1 h et 24 h et doit être indiquée dans la spécification particulière.

b) Le courant de fuite doit être mesuré, sauf indication contraire dans la spécification particulière, sous la tension continue (U_R) appropriée à la température de l'essai. La durée d'électrisation après un temps de charge maximal de 30 min nécessaire pour atteindre 95 % de la tension appliquée doit être sélectionnée parmi 30 min, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h ou 48 h et doit être indiquée dans la spécification particulière.

c) Une source d'alimentation stable telle qu'une alimentation stabilisée doit être utilisée.

d) Sauf indication contraire dans la spécification particulière, appliquer la tension à un condensateur par une résistance de protection de 1 000 Ω ou moins.

5.7.2 Eléments à indiquer dans la spécification particulière

La spécification particulière doit indiquer les éléments suivants:

a) la limite du courant de fuite à la température de référence de 20 °C, et à d'autres températures spécifiées;

b) si nécessaire, le facteur de correction: si les mesures sont effectuées à une température différente de 20°C, mais située dans la plage des températures correspondant aux conditions atmosphériques normalisées d'essai;

c) la durée d'électrisation;

d) la valeur des résistances de protection différente de 1 000 Ω.

5.8 Tension de maintien

5.8.1 Méthode de mesure

La méthode de mesure doit être la suivante (voir Figure 5).

a) Avant d'effectuer cette mesure, les condensateurs doivent être complètement déchargés. La procédure de décharge doit durer entre 1 h et 24 h et doit être indiquée dans la spécification particulière.

b) Appliquer la tension assignée U_R directement aux bornes du condensateur, sans résistance de protection. Sauf indication contraire dans les spécifications particulières, la durée de charge doit être 8 h. Cette durée inclut un temps de charge maximal de 30 min nécessaire pour atteindre 95 % de la tension appliquée.

c) Déconnecter les bornes du condensateur de la source de tension. Sauf indication contraire dans la spécification particulière, le condensateur doit rester dans des conditions normalisées pendant 16 h, 24 h, 48 h ou 96 h.

d) La résistance interne du voltmètre pour courant continu utilisé doit être de 1 MΩ ou plus.