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INTERNATIONAL STANDARD

QC 300000

Fixed capacitors for use in electronic equipment –
Part 1: Generic specification

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

FOREWORD

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International Standard IEC 60384-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment

This fourth edition cancels and replaces the third edition issued in 1999 and constitutes a technical revision, including minor revisions related to tables, figures and references.

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

- implementation of Annex Q which replaces Clause 3.

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

FDIS	Report on voting
40/1915/FDIS	40/1924/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 QC number that appears on the front cover of this publication is the specification number in the IECQ Quality Assessment System for Electronic Componenets (IECQ).

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

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

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- withdrawn,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

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

The contents of the corrigendum of November 2008 have been included in this copy.

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

1 General

1.1 Scope

This part of IEC 60384 is a generic specification and is applicable to fixed capacitors for use in electronic equipment.

It 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.

1.2 Normative references

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

IEC 60027, *Letter symbols to be used in electrical technology*

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

IEC 60062, *Marking codes for resistors and capacitors*

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

IEC 60068-1:1988, *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: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-13:1983, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-17:1994, *Environmental testing – Part 2-17: Tests – Test Q: Sealing*

IEC 60068-2-20:1979, *Environmental testing – Part 2-20: Tests – Test T: Soldering*

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

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing – Part 2-29: Tests – Test Eb and guidance: Bump*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

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

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

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

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

IEC 60294, *Measurement of the dimensions of a cylindrical component having two axial terminations*

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

IEC 60617, *Graphical symbols for diagrams*

IEC 60695-11-5:2004, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60717, *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 packaging*[1]

IEC 61249-2-7:2002, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC QC 001002-3, *Rules of Procedure – Part 3: Approval procedures*

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

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

ISO 9000, *Quality management systems – Fundamentals and vocabulary*

2 Technical data

2.1 Units and symbols

Units, graphical symbols and letter symbols should, whenever possible, be taken from the following publications:

[1] To be published.

– IEC 60027;
– IEC 60050 (series);
– IEC 60617;
– ISO 1000.

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

2.2 Terms and definitions

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

2.2.1
a.c. capacitor
capacitor designed essentially for application with alternating voltages

2.2.2
bipolar capacitor (for electrolytic capacitors)
electrolytic capacitor designed to withstand an alternating voltage and/or reversal of the applied direct voltage

2.2.3
category of passive flammability
category of passive flammability is given by the maximum burning time after a specified time of flame application

2.2.4
category temperature range
range of ambient temperatures for which the capacitor has been designed to operate continuously; this is given by the lower and upper category temperature

2.2.5
category voltage (U_C)
maximum voltage which may be applied continuously to a capacitor at its upper category temperature

2.2.6
d.c. capacitor
capacitor designed essentially for application with direct voltage

NOTE A d.c. capacitor may not be suitable for use on a.c. supplies.

2.2.7
family (of electronic components)
group of components which predominantly displays a particular physical attribute and/or fulfils a defined function

2.2.8
grade
term to indicate an additional general characteristic concerning the intended application of the component

2.2.9
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

2.2.10
lower category temperature
minimum ambient temperature for which a capacitor has been designed to operate continuously

2.2.11
maximum storage temperature
maximum ambient temperature which the capacitor withstands in the non-operating condition without damage

2.2.12
maximum temperature of a capacitor
temperature at the hottest point of its external surface

NOTE The terminations are considered to be part of the external surface.

2.2.13
minimum storage temperature
minimum ambient temperature which the capacitor withstands in the non-operating condition without damage

2.2.14
minimum temperature of a capacitor
temperature at the coldest point of the external surface

NOTE The terminations are considered to be part of the external surface.

2.2.15
nominal capacitance (C_N)
designated capacitance value usually indicated on the capacitor

2.2.16
passive flammability
ability of a capacitor to burn with a flame as a consequence of the application of an external source of heat

2.2.17
polar capacitor (for electrolytic capacitors)
capacitor intended for use with a unidirectional voltage connected according to the polarity indication

2.2.18
pulse capacitor
capacitor for use with pulses of current or voltage

NOTE The definitions of IEC 60469-1 and IEC 60469-2 apply.

2.2.19
pulse equivalent circuit of a capacitor
equivalent circuit consisting of an ideal capacitor in series with its residual inductance and the equivalent series resistance (ESR)

NOTE For pulse operation the equivalent series resistance will be similar to, but not identical with, the ESR measured with a sinusoïdal voltage. The pulse ESR should take into account the series of harmonics in the pulse and the variation of the losses with frequency.

2.2.20
rated a.c. load
maximum sinusoidal a.c. load which may be applied continuously to the terminations of a capacitor at any temperature between the lower category temperature and the rated temperature (see 2.2.24); it may be expressed:

a) at low frequencies as a rated a.c. voltage;

b) at high frequencies as a rated a.c. current;

c) at intermediate frequencies as a rated reactive power (var).

This is shown in Figure 1.

NOTE 1 For a particular type of capacitor, it may be necessary to specify one or more of the above characteristics.

NOTE 2 Capacitors within the scope of this specification are normally less than 500 var at 50 Hz to 60 Hz. Low frequencies may be 50 Hz to 60 Hz, 100 Hz to 120 Hz, or 400 Hz. Voltages may be up to 600 V r.m.s. at 50 Hz to 60 Hz. However, capacitors for filters, transmitter or converter circuits may be required to operate under power over a wide range of frequencies and up to 10 kvar at the higher frequencies with voltages up to 1 000 V r.m.s.

Figure 1 – Reactive power against frequency

2.2.21
rated pulse load
maximum pulse load which may be applied at a certain pulse repetition frequency to the terminations of a capacitor at any temperature between the lower category temperature and the rated temperature (see 2.2.24); it may be expressed as a) and b) and any of the remaining items:

a) peak current per µF or du/dt (V/µs);

b) relative duration of charge and discharge periods;

c) current;

d) peak voltage;

e) peak reverse voltage;

f) pulse repetition frequency (see note 1);

g) maximum active power.

These parameters are fixed for periodic pulses.

NOTE 1 In the case of intermittent pulses, the duty cycle should be specified. In the case of random pulses, the total number expected over a given time period should be stated.

NOTE 2 The r.m.s. pulse current should be calculated in accordance with IEC 60469-1, 2.5.2.4. In the case of intermittent or random pulses, the time interval should be chosen to correspond with the maximum temperature rise.

2.2.22
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

NOTE As the ripple current will generate a ripple voltage across the capacitor, the sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor should not exceed the rated voltage or temperature derated voltage as applicable.

2.2.23
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 The sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor should not exceed the rated voltage or temperature derated voltage, as applicable.

2.2.24
rated temperature
maximum ambient temperature at which the rated voltage may be continuously applied

2.2.25
rated voltage (U_R)

2.2.25.1
rated d.c. voltage
maximum d.c. voltage which may be applied continuously to a capacitor at the rated temperature

NOTE Maximum d.c. voltage is the sum of the d.c. voltage and peak a.c. voltage or peak pulse voltage applied to the capacitor.

2.2.25.2
rated a.c. voltage
maximum r.m.s. alternating voltage which may be applied continuously to a capacitor at the rated temperature and at a given frequency

2.2.25.3
rated pulse voltage
peak value of the pulse voltage within a given pulse wave form which may be applied continuously to a capacitor at the rated temperature

2.2.26
reverse voltage (for polar capacitors only)
voltage applied to the capacitor terminations in the reverse polarity direction

2.2.27
self-healing
process by which the electrical properties of the capacitor, after a local breakdown of the dielectric, are rapidly and essentially restored to the values before the breakdown

2.2.28
style
subdivision of a type, generally based on dimensional factors, which may include several variants, generally of a mechanical order

2.2.29
subfamily (of electronic components)
group of components within a family manufactured by similar technological methods

2.2.30
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

2.2.31
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 The number of times per hour that this voltage may be applied should be specified.

2.2.32
tangent of loss angle (tan δ**)**
power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage at a specified frequency

2.2.33
temperature characteristics of capacitance
maximum variation of capacitance produced over a given temperature range within the category temperature range, normally expressed as a percentage of the capacitance related to a reference temperature of 20 °C

NOTE 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.

2.2.34
temperature coefficient of capacitance (α**)**
rate of change of capacitance with temperature measured over a specified range of temperature, normally expressed in parts per million per kelvin (10^{-6}/K)

NOTE The term characterizing this property applies to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

2.2.35
temperature cyclic drift of capacitance
maximum irreversible variation of capacitance observed at room temperature during or after the completion of a number of specified temperature cycles; it is expressed normally as a percentage of the capacitance related to a reference temperature, usually 20 °C

NOTE 1 The term characterizing this property applies to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

NOTE 2 The conditions of measurement, during or after temperature cycling, a description of the temperature cycle and the number of cycles, should be stated.

2.2.36
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 (see Figure 2)

NOTE Information on the voltage/temperature dependence at temperatures between the rated temperature and the upper category temperature should, if applicable, be given in the relevant specification.

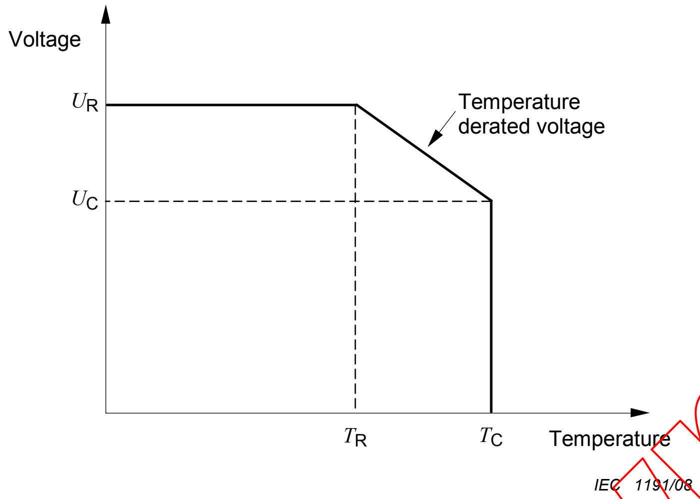

Figure 2 – Relation between category temperature range and applied voltage

2.2.37
temperature rise
temperature rise of the capacitor relative to the ambient temperature resulting from the losses in the capacitor due to operation under a.c., pulse or charge/discharge conditions

2.2.38
time constant
product of the insulation resistance and the capacitance, normally expressed in seconds

2.2.39
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; they are generally covered by a single detail specification

NOTE Components described in several detail specifications, may, in some cases, be considered as belonging to the same type.

2.2.40
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

2.2.41
upper category temperature
maximum ambient temperature for which a capacitor has been designed to operate continuously

2.2.42
variation of capacitance with temperature
variation of capacitance with temperature expressed either as the temperature characteristics of capacitance or as the temperature coefficient of capacitance

2.2.43
visible damage
visible damage which reduces the usability of the capacitor for its intended purpose

2.3 Preferred values

2.3.1 General

Each sectional specification shall prescribe the preferred values appropriate to the subfamily; for nominal capacitance see also 2.3.2.

2.3.2 Preferred values of nominal capacitance

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

2.3.3 Preferred values of rated voltage

The preferred values of the rated voltage are the values of the R10 series of ISO 3: 1,0 – 1,25 – 1,6 – 2,0 – 2,5 – 3,15 – 4,0 – 5,0 – 6,3 – 8,0 and their decimal multiples ($\times 10^n$, n: integer).

2.4 Marking

2.4.1 General

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

The order of priority for marking small capacitors shall be specified.

2.4.2 Coding

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

3 Quality assessment procedures

When this standard and related standards are used for the purpose of a full quality assessment system such as IEC Quality Assessment System for Electronic Components (IECQ), the relevant clauses of Annex Q apply.

NOTE Clause 3 has been moved to Annex Q. To maintain reference to previous editions of this standard, the clause numbers of Clause 3 have been converted into the clause numbers of Annex Q as shown by the following examples:

Clause 3.1 → Clause Q.1
Clause 3.1.2 → Clause Q.1.2

4 Tests and measurement procedures

General information on test and measurement procedures	Subcl.
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Pressure relief (for aluminium electrolytic capacitors)	4.28
Passive flammability	4.38

4.1 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 IEC QC 001002-3, Annex C to Clause 2).

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing as given in IEC 60068-1, 5.3:

- 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 IEC 60068-1, 5.4.1 shall be used.

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

The definition of recovery is as given in IEC 60068-1, 4.1.3, being further restricted for capacitors as follows:

When a recovery period is specified as, for example, 1 h to 2 h, this means that measurement (or other subsequent action) on a batch of capacitors may start after 1 h and shall be completed before 2 h from the beginning of the recovery period.

The preferred method of specifying a recovery period is in the form "x h to y h".

4.2.3 Referee conditions

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

Table 1 – Referee 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 IEC 60068-1, 5.1 apply:

– temperature: 20 °C;

– air pressure: 101,3 kPa.

4.3 Drying

Unless otherwise specified in the relevant 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.

4.4 Visual examination and check of dimensions

4.4.1 Visual examination

The condition, workmanship and finish shall be satisfactory, as checked by visual examination (see 2.2.43).

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

4.4.2 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.

4.4.3 Dimensions (detail)

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

4.5 Insulation resistance

4.5.1 Preconditioning

Before this measurement is made, the capacitors shall be fully discharged.

4.5.2 Measuring conditions

Unless otherwise specified in the relevant specification, the insulation resistance shall be measured at the voltage specified in Table 2.

The insulation resistance shall be measured after the voltage has been applied for 60 s ± 5 s, unless otherwise prescribed in the detail specification.

Table 2 – Measurement of insulation resistance

Voltage rating of capacitor V	Measuring voltage V
U_R or U_c <10	U_R or U_c ± 10 %
10 ≤ U_R or U_c <100	10 ± 1*
100 ≤ U_R or U_c <500	100 ± 15
500 ≤ U_R or U_c	500 ± 50

* When it can be demonstrated that the voltage has no influence on the measuring result, or that a known relationship exists, measurements can be performed at voltages up to the rated or category voltage. In case of dispute, 10 V shall be used, unless otherwise specified by the sectional specification.

U_R is the rated voltage for use in defining the measuring voltage to be used under standard atmospheric conditions for testing.

U_C is the category voltage for use in defining the measuring voltage to be used at the upper category temperature.

4.5.3 Test points

The insulation resistance shall be measured between the measuring points defined in Table 3, specified in the relevant specification.

Test A, between terminations, applies to all capacitors, whether insulated or not.

Test B, internal insulation, applies to insulated capacitors in uninsulated metal cases and to insulated and uninsulated multiple section capacitors.

Test C, external insulation, applies to insulated capacitors in non-metallic cases or in insulated metal cases. For this test, the measuring voltage shall be applied using one of the three following methods as specified in the relevant specification:

4.5.4 Test methods

4.5.4.1 Foil method

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm can be maintained between the foil and the terminations. If this minimum distance cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm.

For capacitors with unidirectional terminations, a minimum distance of 1 mm shall be maintained between the edge of the foil and each termination.

4.5.4.2 Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 12,7 mm in all directions beyond the mounting face of the capacitor.

4.5.4.3 V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned in accordance with the following:

a) for cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block;
b) for rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the terminations at their emergence from the capacitor body shall be ignored.

4.5.5 Temperature compensation

When prescribed by the detail specification the temperature at which the measurement is made shall be noted. If this temperature differs from 20 °C, a correction shall be made to the measured value by multiplying the value by the appropriate correction factor prescribed in the sectional specification.

4.5.6 Conditions to be prescribed the relevant specification

The relevant specification shall prescribe:

a) the measuring points and the measuring voltage corresponding to each of these test points;
b) the method of applying the voltage (one of the methods described in 4.5.4);
c) time of electrification if other than 1 min;
d) any special precautions to be taken during measurements;
e) any correction factors required for measurement over the range of temperatures covered by the standard atmospheric conditions for testing;
f) the temperature of measurement if other than the standard atmospheric conditions for testing;
g) the minimum value of insulation resistance for the various measuring points (see Table 3).

Table 3 – Measuring points

Test	Applicable to:	1: Single-section capacitors	2: Multiple-section capacitors having common termination for all sections	3: Multiple-section capacitors having no common termination
A. Between terminations (see note)	All capacitors	1a: Between terminations	2a: Between each of the terminations and the common termination	3a: Between terminations of each section
B. Internal insulation	Insulated single- and multiple-section capacitors in uninsulated metal cases (1b, 2b, 3b)	1b: Between terminations connected together and the case	2b: Between all terminations connected together and the case	3b: Between all terminations connected together and the case
	Insulated and uninsulated multiple-section capacitors (2c and 3c)		2c: Between the non-common termination of each section and all the other terminations connected together	3c: Between the terminations of separate sections, the two terminations of each section being connected together
C. External insulation	Insulated capacitors in non-metallic cases or in insulated metal cases	1c: Between the two terminations connected together and, as appropriate, the metal foil, the metal plate or the metal V-block	2d:	3d:
			Between all terminations connected together and, as appropriate: the metal foil, the metal plate or the metal V-block	

NOTE Where a capacitor has more than two terminations, the measuring points are the two terminations which are insulated from one another by the capacitor's element dielectric. For example, for a coaxial lead-through capacitor, the measuring points should be one of the terminations connected to the central conductor and the coaxial metal case or mounting face.

4.6 Voltage proof

The test prescribed below is a d.c. test. When the relevant specification prescribes an a.c. test, the test circuit shall be prescribed by that specification.

4.6.1 Test circuit (for the test between terminations)

The test circuit elements shall be selected in such a way as to ensure that the conditions relating to the charging and discharging currents and the time constant for charging, prescribed in the relevant specification, are maintained.

Figure 3 specifies the characteristics of a suitable test circuit.

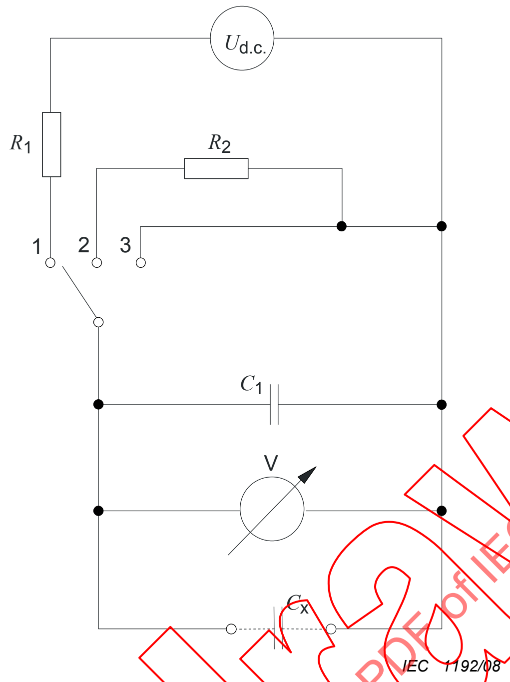
The resistance of the voltmeter shall be not less than 10 000 Ω/V.

The resistor R_1 includes the internal resistance of the voltage source.

The resistors R_1 and R_2 shall have a value sufficient to limit the charging and discharging current to the value prescribed in the relevant specification.

The capacitance of capacitor C_1 shall be not less than 10 times the capacitance of the capacitor under test.

If applicable, the time constant $R_1 \times (C_X + C_1)$ shall be less than, or equal to, the value prescribed in the relevant specification.



NOTE The capacitor C_1 may be omitted for the testing of certain types of capacitors. This should be stated in the sectional specification.

Figure 3 – Voltage-proof test circuit

4.6.2 Test

Depending on the case, the test comprises one or more parts in accordance with Table 3 and the requirements of the relevant specification.

Repeated application of the voltage proof test may cause permanent damage to the capacitor and should be avoided as far as possible.

4.6.2.1 Test A – Between terminations

4.6.2.1.1 Test points

The test voltage is applied to 1a, 2a, 3a of Table 3 in accordance with the requirements of the relevant specification.

4.6.2.1.2 Procedure

With the switch in position 2, connect the two terminals in Figure 3 to a variable d.c. supply of sufficient power adjusted to the required test voltage.

Connect the capacitor to be tested (C_X) to the test circuit as indicated in Figure 3.

Move the switch to position 1 so as to charge capacitors C_1 and C_X via R_1.

The switch remains in this position for the time specified after the test voltage has been reached.

Discharge the capacitors C_1 and C_X through R_2 by moving the switch to position 2. As soon as the voltmeter reading has fallen to zero, short-circuit the capacitors by moving the switch to position 3 and disconnect the capacitor C_X.

4.6.2.2 Test B – Internal insulation

4.6.2.2.1 Test points

The test voltage is applied to 1b, 2b, 2c, 3b, 3c of Table 3 in accordance with the requirements of the relevant specification.

4.6.2.2.2 Procedure

The specified test voltage is applied instantaneously via the internal resistance of the power supply for the time specified in the relevant specification. For point 2c use the test circuit and the procedure indicated for the test between terminations (4.6.1 and 4.6.2.1).

4.6.2.3 Test C – External insulation (applicable only to insulated capacitors in non-metallic case or in insulated metal case)

4.6.2.3.1 Test points

The test voltage is applied to 1c, 2d or 3d, using one of the three following methods for the application of the voltage in accordance with the requirements of the relevant specification.

4.6.2.3.2 Foil method

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm/kV can be maintained between the foil and the terminations. If this minimum cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm/kV of test voltage.

For capacitors with unidirectional terminations, a minimum distance of 1 mm/kV shall be maintained between the edge of the foil and each termination.

In no case shall the distance between the foil and the terminations be less than 1 mm.

4.6.2.3.3 Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate which extends by not less than 12,7 mm in all directions beyond the mounting face of the capacitor.

4.6.2.3.4 V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such a size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned as follows:

a) for cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block;
b) for rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the termination at its emergence from the capacitor body shall be ignored.

4.6.2.3.5 Procedure

The specified test voltage is applied instantaneously through the internal resistance of the power source for the time specified in the relevant specification.

4.6.3 Requirements

For each of the specified test points there shall be no sign of breakdown or flashover during the test period.

4.6.4 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the test points (see Table 3) and the test voltage corresponding to each of these points;
b) for the external insulation test (test C), the method of applying the test voltage (one of the methods described in 4.6.2.3);
c) the time for which the voltage is applied;
d) the maximum charging and discharging currents;
e) when applicable, the maximum value of the time constant for charging ($R_1 \times (C_1 + C_X)$).

4.7 Capacitance

4.7.1 Measuring frequency and measuring voltage

The capacitance shall be measured at one of the following frequencies, unless otherwise prescribed by the relevant specification:

– electrolytic capacitors:		100 Hz to 120 Hz
– other capacitors:	$C_R \leq 1$ nF:	100 kHz, 1 MHz or 10 MHz (1 MHz shall be reference)
	1 nF < $C_R \leq 10$ µF:	1 kHz or 10 kHz (1 kHz shall be reference)
	$C_R > 10$ µF:	50 Hz (60 Hz) or 100 Hz (120 Hz)

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

The measuring voltage shall not exceed 3 % of U_R or 5 V, whichever is the smaller, unless otherwise prescribed in the relevant specification.

4.7.2 Measuring equipment

The accuracy of the measuring equipment shall be such that the error does not exceed:

a) for absolute capacitance measurements: 10 % of the capacitance tolerance or 2 % absolute, whichever is the smaller;
b) for measurement of variation of capacitance: 10 % of the specified maximum change of capacitance.

In neither case a) nor case b) need the accuracy be better than the minimum absolute measurement error (for example 0,5 pF) prescribed in the relevant specification.

4.7.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the temperature for measurement if other than the standard atmospheric conditions for testing;

b) the frequencies for measurement and the capacitance range over which they apply, if different from those specified in 4.7.1;

c) the absolute measurement error, when applicable (for example 0,5 pF);

d) measuring voltage if different from those specified in 4.7.1;

e) the applied polarizing voltage, when applicable.

4.8 Tangent of loss angle and equivalent series resistance (ESR)

4.8.1 Tangent of loss angle

4.8.1.1 Measuring frequency

The tangent of loss angle shall be measured under the same conditions as those given for the measurement of capacitance at one or more frequencies taken from the list in 4.7.1, as prescribed in the relevant specification.

4.8.1.2 Measuring accuracy

Unless otherwise specified in the sectional specification, the measuring method shall be such that the error does not exceed 10 % of the specified value or 0,000 3, whichever is the greater.

4.8.2 Equivalent series resistance (ESR)

4.8.2.1 Measuring frequency

The ESR shall be measured at one of the following frequencies, unless otherwise prescribed by the relevant specification:

50 Hz, 60 Hz, 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 10 MHz.

4.8.2.2 Measuring accuracy

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

4.8.2.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe

a) the frequency of measurement;

b) the absolute error measurement;

c) the measuring voltage, if different from that specified in 4.7.1;

d) the applied polarizing voltage, where applicable;

e) the temperature at which measurements shall be made, if other than the standard atmospheric conditions for testing.

4.9 Leakage current

4.9.1 Preconditioning

Before this measurement is made, the capacitors shall be fully discharged.

4.9.2 Test method

The leakage current shall be measured, unless otherwise prescribed in the relevant specification, using the direct voltage (U_R or U_C) appropriate to the test temperature, after a maximum electrification period of 5 min. The full 5 min electrification need not be applied if the specified leakage current limit is reached in a shorter time.

4.9.3 Power source

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

4.9.4 Measuring accuracy

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

4.9.5 Test circuit

When prescribed in the relevant specification, a 1 000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current.

4.9.6 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe

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, if different from 5 min;

d) whether or not a 1 000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current as defined in 4.9.5.

4.10 Impedance

Impedance shall be measured by the voltmeter-ammeter method according to the circuit of Figure 4, or equivalent.

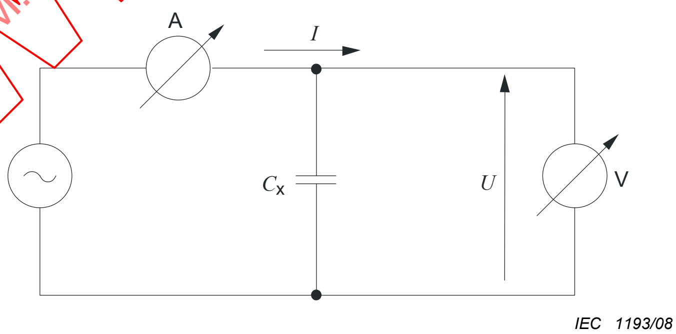


Figure 4 – Schematic diagram of the impedance measuring circuit

The impedance Z_X of the capacitor C_X is given by $Z_X = \frac{U}{I}$

The frequency of the measuring voltage shall, preferably, be chosen from the following values:

50 Hz, 60 Hz, 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 10 MHz.

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

NOTE At frequencies above 120 Hz, precautions are necessary to avoid errors arising from stray currents. The current flowing through the capacitor should be limited so that the measuring result is not significantly affected by the rise of the temperature of the capacitor.

The relevant specification shall prescribe

a) the frequency of measurement;
b) the temperature(s) at which measurements shall be made;
c) the limits of impedance, or ratio of impedances measured at different temperatures.

4.11 Self-resonant frequency and inductance

4.11.1 Self-resonant frequency (f_r)

For this measurement three methods are described. The first method is for general application; the other methods may be particularly suitable for measuring certain types of capacitors having low capacitance.

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

4.11.1.1 Method 1

Using the impedance measuring method of 4.10 and a variable frequency source, the lowest frequency shall be determined at which the impedance passes through a minimum. This is the self-resonant frequency.

NOTE When it is difficult to determine precisely the frequency at which the impedance is at a minimum, then use may be made of a phase-meter to compare the phase of the voltage across the capacitor with the phase of the voltage across a low-inductance resistor connected in series with the capacitor. The resonant frequency is then the frequency when there is no phase difference. A Q-meter may be used for this purpose.

4.11.1.2 Method 2

For this measuring method, use shall be made of an absorption oscillator-wavemeter (grid dip meter).

4.11.1.2.1 Mounting of capacitors with terminations for general use

Four capacitors of nearly equal value and configuration shall be soldered in series at right angles to form a closed loop. The wires shall be of the specified length and no additional wiring or connections shall be employed (see Figure 5). This loop shall be coupled as loosely as possible to an absorption oscillator-wavemeter and the resonant frequency shall then be determined.

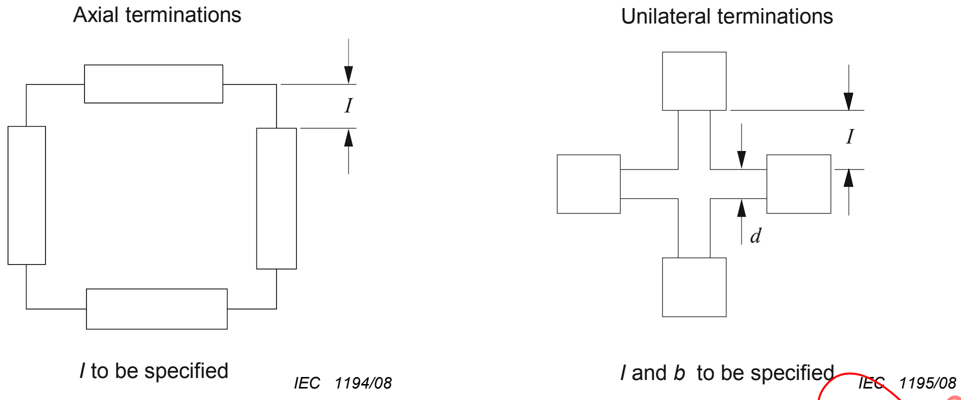


Figure 5 – Capacitor mounting arrangement

4.11.1.2.2 Mounting of capacitors with terminations for printed circuit use

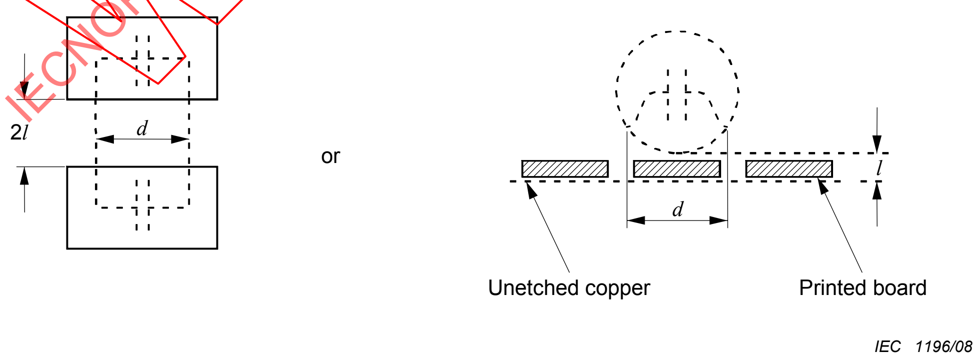
To determine the resonant frequency under the conditions of the capacitor being mounted on a printed circuit board and where the configuration of the case and/or the terminations does not permit a four capacitor loop to be formed correctly, the loop shall be by formed by two (nearly) identical capacitors with straight terminations of specified length (see Figure 6).

The second capacitor may be substituted by its mirror image on a conductive plane in the following way.

A copper-clad, unetched sheet of printed circuit base material, the edges of which are at least three times as long as the maximum dimension of the capacitor is drilled in its centre to accommodate the capacitor in its normal way.

The relevant specification shall prescribe the details of mounting. The capacitor is soldered in place with the capacitor being short-circuited by the copper laminate. Then the capacitor is coupled to the search coil and measured as in 4.11.1.2.4.

NOTE Metal-cased capacitors may necessitate special arrangements for coupling, which should be prescribed in the relevant specification.



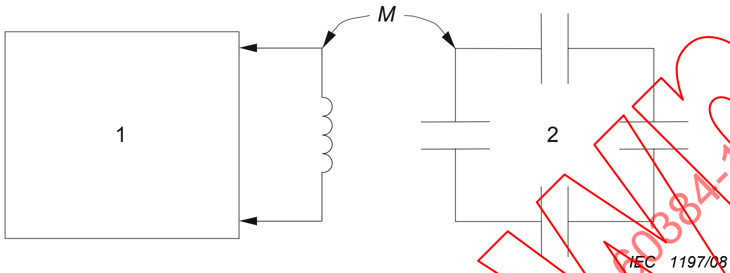
l and *d* to be specified, where *l* is to be measured from the seating plane

Figure 6 – Capacitor mounting arrangement

4.11.1.2.3 Description of the method

The absorption oscillator-wavemeter is a variable frequency L-C oscillator with the inductor formed as an external search coil. When the search coil is coupled into another resonant circuit, power is absorbed causing a change in the mean grid (gate on FETs) voltage. This is monitored and hence "dips" at the resonant frequency of the coupled circuit. This coupled circuit consists of four capacitors mounted as described in 4.11.1.2.1 and connected in series to minimize the mutual inductance.

A typical diagram showing the use of an absorption oscillator-wavemeter is given in Figure 7.



1 absorption oscillator-wavemeter (grid-dip meter)
2 coupled resonant circuit
M coupling factor

Figure 7 – Typical diagram of an absorption oscillator-wavemeter

4.11.1.2.4 Use of the absorption oscillator-wavemeter

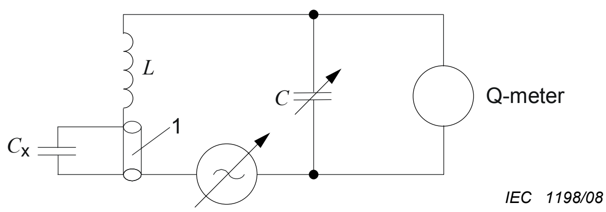
With the search coil of the wavemeter close to the capacitors under investigation, the resonant frequency is approached from a lower frequency. Dips should be checked by moving the wavemeter away from the capacitors (reducing the absorbed power) to make sure the dip is not due to internal effects of the wavemeter. The resonant frequency should be measured with as loose a coupling as is practical to avoid pulling the oscillator.

4.11.1.2.5 Requirements

The resonant frequency shall not exceed the limits prescribed by the relevant specification.

4.11.1.3 Method 3

This method is particularly suitable for capacitors of low capacitance and with a self-resonant frequency within Q-meter operating range. Using a Q-meter and the circuit shown in Figure 8, the lowest frequency shall be determined at which the same resonant frequency is obtained, whether the capacitor shorting strap is in place or not. This frequency can be shown equal to the self-resonant frequency of the capacitor.



1 shorting strap

Figure 8 – Schematic diagram of the measuring circuit

4.11.2 Inductance

The series inductance L_X of a capacitor is calculated from the measured self-resonant frequency f_r of the capacitor using the formula given below:

$$L_X = \frac{1}{4\pi^2 \times f_r^2 \times C_X}$$

where C_X is the capacitance of the capacitor measured in accordance with 4.7 and the requirements of the relevant sectional specification.

4.11.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe

a) which test method is preferred;

b) the lead length of the capacitor to be employed in the measurement;

c) any special mounting arrangement;

d) the limits of series inductance or self-resonant frequency.

4.12 Outer foil termination

The correct indication of the termination which is connected to the outside metal foil shall be checked in such a way that the capacitor is not damaged.

A suitable method is given in Figure 9.

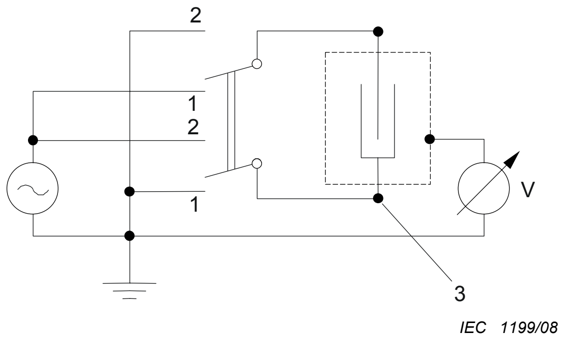
The frequency of the generator may be from 50 Hz to a few thousand Hertz and shall be so chosen as to give a clear result of measurement, the most appropriate value being dependent on the type of capacitor under test.

The voltage shall be of the order of 10 V.

The voltmeter shall have an input impedance of not less than 1 MΩ.

The stray capacitance of the wiring shall be kept low.

With the switch in position 1, the deflection of the voltmeter shall be markedly less than with the switch in position 2.



Three outer foil terminations

Figure 9 – Test circuit

4.13 Robustness of terminations

The capacitors shall be subjected to Tests IEC 60068-2-21, Ua_1, Ub, Uc, and Ud, as applicable.

4.13.1 Test Ua_1 – Tensile

The force applied shall be:

– for terminations other than wire terminations: 20 N;

– for wire terminations: see Table 4.

Table 4 – Tensile force

Nominal cross-sectional area (S) (see note) 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 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 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 specification.		

4.13.2 Test Ub – Bending (half of the sample)

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.

4.13.3 Test Uc – Torsion (remaining sample)

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.

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

Table 5 – Torque

Nominal thread diameter mm		2,6	3	3,5	4	5	6	8	10	12
Torque Nm	Severity 1	0,4	0,5	0,8	1,2	2,0	2,5	5	7	12
	Severity 2	0,2	0,25	0,4	0,6	1,0	1,25	2,5	3,5	6

4.13.5 Visual examination

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

4.14 Resistance to soldering heat

4.14.1 Preconditioning

When prescribed by the relevant specification the capacitors shall be dried using the method of 4.3.

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

4.14.2 Test procedure

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

The test conditions shall be defined in the relevant 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 mounting capacitors
IEC 60068-2-58, reflow or solder bath method

4.14.3 Recovery

The period of recovery shall, unless otherwise specified by the detail specification, be not less than 1 h nor more than 2 h, except for surface mount capacitors, for which the period of recovery shall be 24 h ± 2 h.

4.14.4 Final inspection, measurement 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 specification.

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

4.15 Solderability

NOTE Not applicable to those terminations which the detail specification describes as not designed for soldering.

4.15.1 Preconditioning

The relevant 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 relevant specification, the test shall be carried out with non-activated flux.

4.15.2 Test procedure

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

The test conditions shall be defined in the relevant 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 mm $^{0}_{-0,5}$ 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, solder bath wetting balance method.

NOTE IEC 60068-2-54 is applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.

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 mm $^{0}_{-0,5}$ mm.

   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron).

c) For surface mounting capacitors

   1) IEC 60068-2-58, reflow or solder bath method
   2) IEC 60068-2-69, solder bath wetting balance or solder globule wetting balance method.

NOTE IEC 60068-2-69 is applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.

4.15.3 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.

The capacitors shall meet the requirements as prescribed in the relevant specification.

4.16 Rapid change of temperature

4.16.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.16.2 Test procedure

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

4.16.3 Final inspection, measurements and requirements

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

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

4.17 Vibration

4.17.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.17.2 Test procedure

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

4.17.3 Electrical test

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 contacts, or open or short circuits.

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.

4.17.4 Final inspection, measurements and requirements

After the test the capacitors shall be visually examined. There shall be no visible damage. When capacitors are tested as specified in 4.17.3, the requirements shall be stated in the detail specification.

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

4.18 Bump

4.18.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.18.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-29, test Eb, using the mounting method and the degree of severity prescribed in the relevant specification.

4.18.3 Final inspection, measurements and requirements

After the test, the capacitors shall be visually examined. There shall be no visible damage.

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

4.19 Shock

4.19.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.19.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-27, test Ea, using the mounting method and the severity prescribed in the relevant specification.

4.19.3 Final inspection, measurements and requirements

After the test the capacitors shall be visually examined. There shall be no visible damage.

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

4.20 Container sealing

The capacitors shall be subjected to the procedure of the appropriate method of test Q of IEC 60068-2-17 as prescribed in the relevant specification.

4.21 Climatic sequence

In the climatic sequence, an interval of a maximum of three days is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period for the first cycle of the damp heat, cyclic, IEC 60068-2-30, test Db.

4.21.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.21.2 Dry heat

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

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the upper category temperature

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the relevant 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.

4.21.3 Damp heat, cyclic, test Db, first cycle

The capacitors shall be subjected to IEC 60068-2-30, test Db, for one cycle of 24 h, using a temperature of 55 °C (severity b).

Unless otherwise specified in the relevant specification, variant 2 shall be used.

After recovery the capacitors shall be subjected immediately to the cold test.

4.21.4 Cold

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

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the lower category temperature

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the relevant 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.

4.21.5 Low air pressure

The capacitors shall be subjected to IEC 60068-2-13, test M, using the appropriate degree of severity prescribed in the relevant specification. The duration of the test shall be 10 min, unless otherwise stated in the relevant specification.

The relevant specification shall prescribe

a) duration of test; if other than 10 min;

b) temperature;

c) degree of severity.

While at the specified low pressure, the rated voltage shall be applied for the last 1 min of the test period, unless otherwise prescribed in the relevant specification.

During and after the test, there shall be no evidence of permanent breakdown, flashover, harmful deformation of the case, or seepage of impregnant.

4.21.6 Damp heat, cyclic, test Db, remaining cycles

The capacitors shall be subjected to IEC 60068-2-30, test Db, for the following number of cycles of 24 h as indicated in Table 6, under the same conditions as used for the first cycle.

Table 6 – Number of cycles

Climatic categories	Number of cycles
-/-/56	5
-/-/21	1
-/-/10	1
-/-/04	None

4.21.7 Final measurements

After the prescribed recovery, the measurements prescribed in the relevant specification shall be made.

4.22 Damp heat, steady state

4.22.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.22.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-78, test Cab, using the degree of severity corresponding to the climatic category of the capacitor as indicated in the detail specification.

When specified in the blank detail specification, the detail specification may specify the application of a polarizing voltage during the whole period of damp heat conditioning. For metallized film capacitors this test should be carried out in accordance with Annex G.

With the exception of electrolytic capacitors, within 15 min after removal from the test chamber, the voltage proof test of 4.6 shall be carried out at test point A only, using the rated voltage, unless otherwise specified in the detail specification.

4.22.3 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined. There shall be no visible damage. The measurements prescribed in the relevant specification shall then be made.

In case of testing metallized film capacitors, when specified in the blank detail specification, the permissible deviation of the average C-value of test group with and the test group without DC-voltage shall be described in the relevant detail specification.

4.23 Endurance

4.23.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.23.2 Test procedure

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

a) d.c. tests – test Bb;

b) a.c. tests – test Bb or Bd as applicable;

c) pulse tests – test Bb or Bd as applicable.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the upper category temperature but the voltage shall not be applied to the capacitor before it has reached the chamber temperature.

4.23.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) duration of the test (for example, hours or number of pulses);

b) test temperature (for example, room, rated or upper category temperature);

c) voltage and/or current to be applied (see also 4.23.4).

When capacitors have to meet additional requirements for electric shock hazard protection, additional test conditions for endurance testing (for example, pulse voltage application) shall be prescribed in the relevant specification.

4.23.4 Test voltage

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

a) 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.

b) a.c. tests (sinusoïdal voltage)

The test shall be made at 50 Hz to 60 Hz and at a multiplying factor times the rated voltage (a.c.) (see 2.2.20 a)) at temperatures up to the rated temperature, or at the upper category temperature with a derating factor for the voltage. The test temperature and the value of the multiplying factor/derating factor for the voltage shall be specified in the relevant specification.

c) a.c. tests (sinusoïdal current)

This test shall be made with a current applied in accordance with 2.2.20 b). The test temperature, the value of current and frequency shall be specified in the relevant specification.

NOTE 1 To facilitate testing, the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

d) Sinusoïdal a.c. tests (reactive power)

This test shall be made with reactive power in accordance with 2.2.20 c). The test temperature, the value of the reactive power, and the frequency shall be specified in the relevant specification.

NOTE 2 To facilitate testing, the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

A thermal stability test (see 4.30) may constitute an alternative to this test. The test to be carried out shall be specified in the detail specification.

e) Pulse tests

This test shall be made with pulses applied in accordance with 2.2.21 and as specified in the relevant specification. Guidance for pulse tests is given in Annex E.

f) Sinusoïdal a.c. or pulse tests with superimposed d.c.

Tests b) to e) may be carried out with superimposed d.c. as required by the relevant specification (see also 2.2.23).

An example of a test circuit suitable for electrolytic capacitors is given in Figure 10.

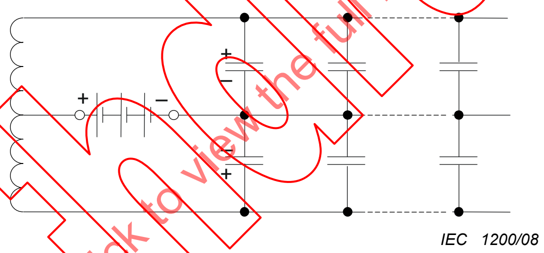


Figure 10 – Test circuit for electrolytic capacitors

4.23.5 Placement in the test chamber

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.

4.23.6 Recovery

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

4.23.7 Final inspection, measurements and requirements

The capacitors shall then be visually examined.

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

4.24 Variation of capacitance with temperature

4.24.1 Static method

4.24.1.1 Initial measurement

Measurements of capacitance shall be made under the conditions prescribed in the relevant specification.

4.24.1.2 Test procedure

The capacitor shall be maintained at each of the following temperatures in turn:

a) 20 °C ± 2 °C;

b) lower category temperature ± 3 °C;

c) intermediate temperatures, if required by the detail specification;

d) 20 °C ± 2 °C;

e) intermediate temperatures, if required by the detail specification;

f) upper category temperature ± 2 °C;

g) 20 °C ± 2 °C.

If required for a particular type of capacitor, the relevant specification shall prescribe whether thermal shock is to be avoided or whether a maximum rate of change of temperature shall be specified.

4.24.1.3 Measuring method

Capacitance measurements shall be made at each of the temperatures specified above, after the capacitor has reached thermal stability.

The condition of thermal stability is judged as having been reached when two readings of capacitance taken at 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 measurement of the actual temperature shall be made with a precision compatible with the requirements of the detail specification.

Care must be taken during measurements to avoid condensation or frost on the surface of the capacitors.

4.24.1.4 Reduced procedure

For the lot-by-lot quality conformance testing, the detail specification may prescribe a reduced procedure, for example, measurements d), f) and g) (in 4.24.1.2) covering the temperature range from 20 °C to the upper category temperature.

4.24.2 Dynamic method

As an alternative to the static method of 4.24.1, a dynamic plotting method may be employed. The capacitors shall be subjected to a slowly varying temperature.

A temperature-sensing device shall be embedded in a dummy capacitor to be included with the capacitor under test in a manner that will ensure that the measured temperature is the same as that occurring in the capacitor under test. The capacitance shall be measured using a self-balancing bridge or comparator.

The output of the bridge or comparator shall be coupled to the "Y" axis of a plotting table.

The output of the temperature sensing device shall be coupled to the "X" axis of a plotting table.

The temperature shall be varied slowly enough to produce a uniform curve with no loop at the lower or upper category temperature. The temperature shall be varied subsequently from 20 °C to the lower category temperature, then to the upper category temperature and back to 20 °C. Two cycles shall be carried out.

This method may be employed only when it can be demonstrated that the results are the same as for the method employing stabilized temperatures.

In case of dispute, the static method shall be used.

4.24.3 Methods of calculation

The following applies:

C_0 is the capacitance measured at point d) of 4.24.1.2;

T_0 is the temperature measured at point d) of 4.24.1.2;

C_i is the capacitance measured at the test temperature, other than at points a), d) and g) of 4.24.1.2;

T_i is the temperature measured on test.

4.24.3.1 Temperature characteristics of capacitance

The variation of capacitance as a function of temperature shall be calculated for all the values of C_i as follows:

$$\frac{\Delta C}{C_0} = \frac{C_i - C_0}{C_0}$$

The variation of capacitance is normally expressed in per cent.

4.24.3.2 Temperature coefficient of capacitance and temperature cyclic drift of capacitance

a) **Temperature coefficient of capacitance (α)**

Temperature coefficient of capacitance (α) shall be calculated for all the values of C_i as follows:

$$\alpha_i = \frac{C_i - C_0}{C_0 (T_i - T_0)} \times 10^6$$

The temperature coefficient is normally expressed in parts per million per kelvin (10^{-6}/K).

b) **Temperature cyclic drift of capacitance**

The temperature cyclic drift of capacitance shall be calculated for the points of measurement of 4.24.1.2 a), d) and g) in the following manner:

$$\delta_{da} = \frac{C_0 - C_a}{C_0}$$

$$\delta_{gd} = \frac{C_g - C_0}{C_0}$$

$$\delta_{ga} = \frac{C_g - C_a}{C_0}$$

as required by the relevant specification. The largest of these values is the "temperature cyclic drift of capacitance".

The capacitance drift is normally expressed in per cent.

4.25 Storage

4.25.1 Storage at high temperature

4.25.1.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.25.1.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-2, test Bb, using the following severities:

– temperature: upper category temperature;

– duration: 96 h ± 4 h.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the upper category temperature.

4.25.1.3 Final inspection, measurements and requirements

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

4.25.2 Storage at low temperature

4.25.2.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.25.2.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-1, 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.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to –40 °C.

4.25.2.3 Final inspection, measurements and requirements

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

4.26 Surge

4.26.1 Initial measurement

The measurements specified in the relevant specification shall be made.

4.26.2 Test procedure

Suitable test circuits are shown in Figures 11 and 12.

NOTE The thyristor circuit has the advantage of high repetition rates and is free from troubles associated with dirty contacts and contact bounce.

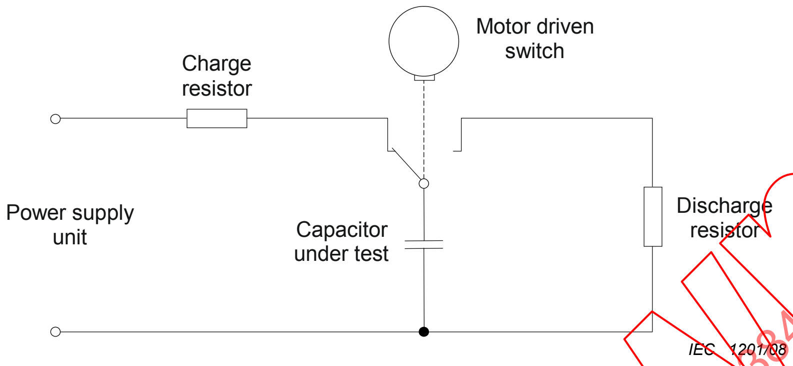


Figure 11 – Relay circuit

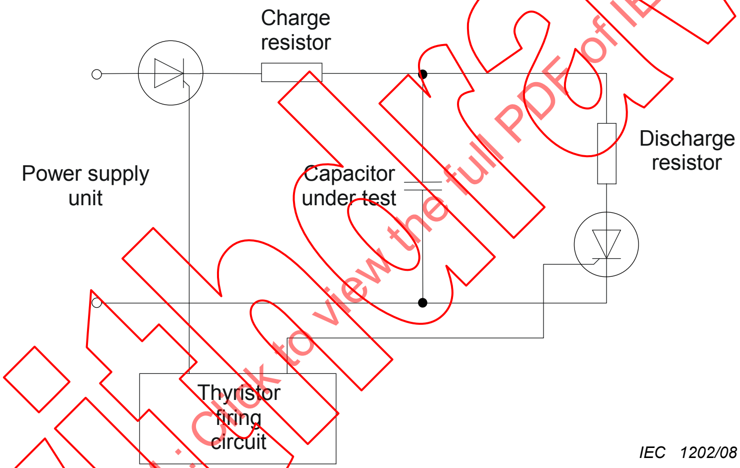


Figure 12 – Thyristor circuit

The voltage waveform across the capacitor under test shall be approximately as shown in Figure 13.

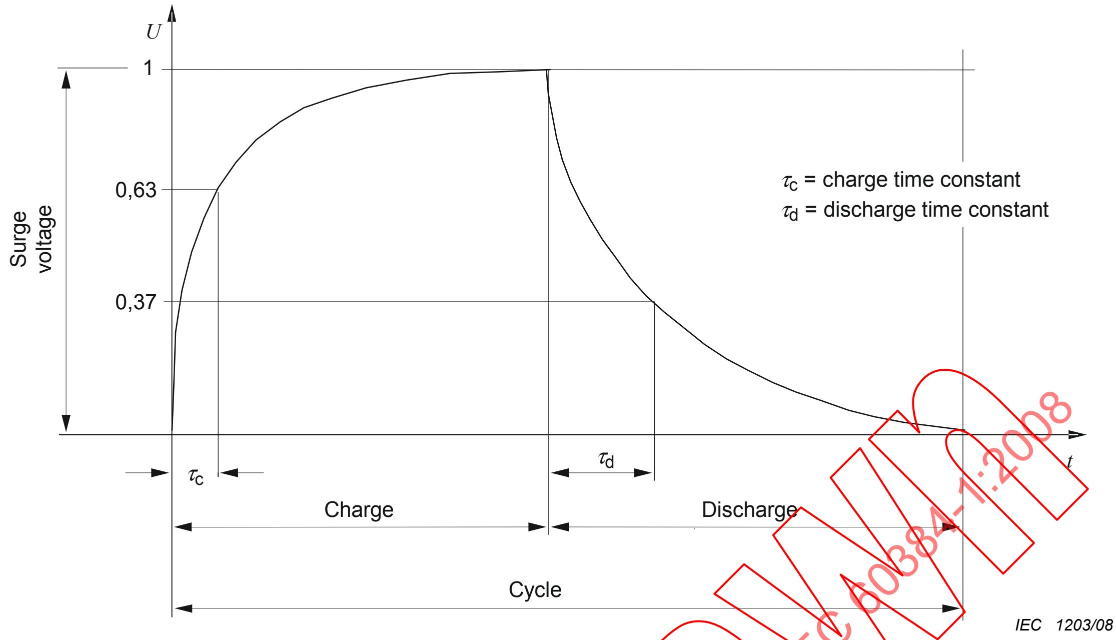


Figure 13 – Voltage waveform across capacitor

4.26.3 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.26.4 Information to be given in the relevant detail specification

The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitance of the capacitor under test;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitor under test;

c) the ratio of the surge voltage to rated or category voltage (as appropriate);

d) the number of cycles of test;

e) the duration of the charge period;

f) the duration of the discharge period;

g) the repetition rate (cycles per second);

h) temperature, if different from standard atmospheric conditions for testing.

4.27 Charge and discharge tests and inrush current test

4.27.1 Initial measurement

The measurements specified in the relevant specification shall be made.

4.27.2 Test procedure

Suitable test circuits are given in 4.26.2, Figures 11 and 12.

The voltage and current waveforms across and through the capacitor under test are approximately as shown in Figure 14.

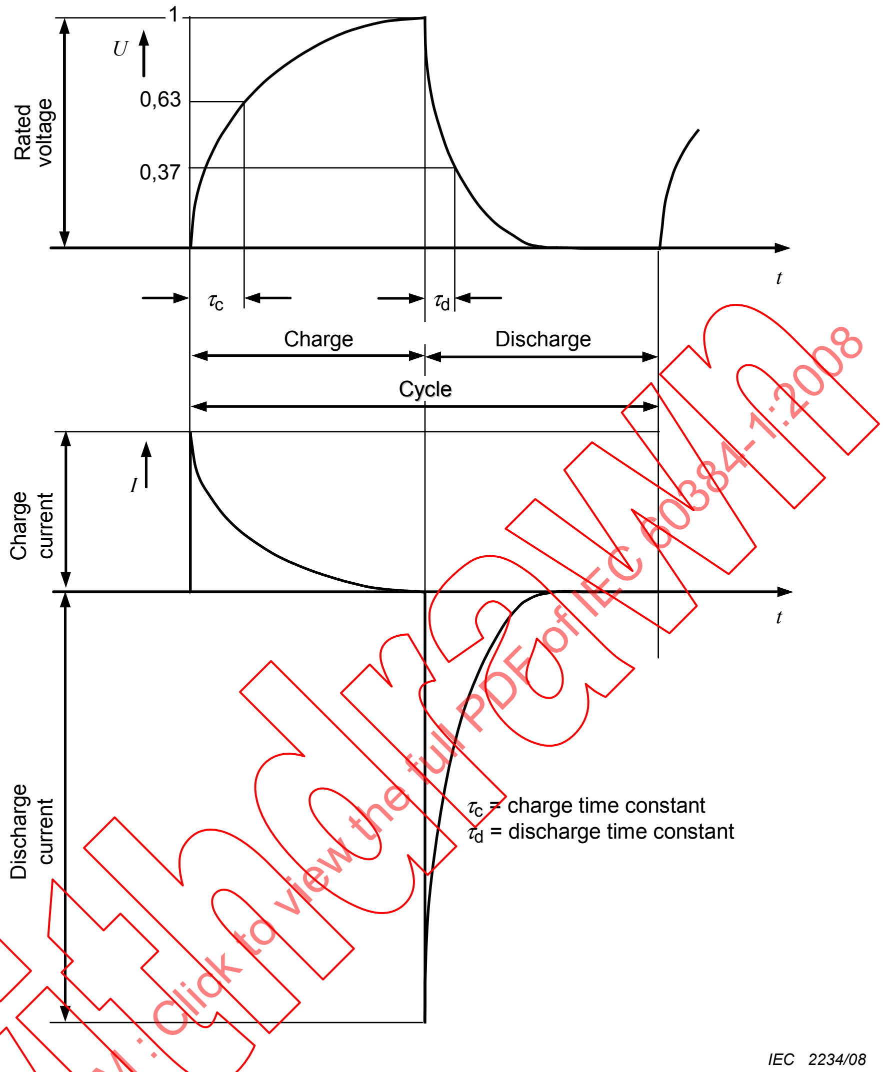


Figure 14 – Voltage and current waveform

4.27.3 Charge and discharge

The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of power supply and the resistance of the charge circuit and the capacitance of the capacitor under test;
b) the discharge time constant arising from the resistance of the discharge circuit and the capacitance of the capacitor under test;
c) the voltage to be applied during the charge period, if different from the rated voltage;
d) the number of cycles of test;
e) the duration of the charge period;
f) the duration of the discharge period;
g) the repetition rate (cycles per second);
h) temperature, if different from standard atmospheric conditions for testing.

4.27.4 Inrush current

The following information shall be given in the relevant specification:

a) the peak charge current;
b) the voltage to be applied during the charge period if different from the rated voltage;
c) the number of cycles of test;
d) the duration of the charge period in milliseconds;
e) the duration of the discharge period;
f) the repetition rate;
g) the temperature if different from standard atmospheric conditions for testing.

4.27.5 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.28 Pressure relief (for aluminium electrolytic capacitors)

Unless otherwise specified in the relevant specification, one of the following tests shall be used to test the pressure relief device of the capacitors.

4.28.1 a.c. test

Applied voltage: alternating voltage with r.m.s. value not exceeding 0,7 times the rated direct voltage.

Frequency of the applied voltage: 50 Hz or 60 Hz.

Series resistor: R = 0,5 times the impedance of the capacitor at the test frequency.

4.28.2 d.c. test

Applied voltage: direct voltage applied in the reverse direction, of an amplitude necessary to produce a current of 1 A to 10 A.

4.28.3 Pneumatic test

Applied pneumatic pressure: gas pressure introduced from outside shall be increased at a rate of 20 kPa/s continuously.

4.28.4 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.29 Characteristics at high and low temperature

4.29.1 Test procedure

The capacitors shall be subjected to the procedures of the dry heat and cold test (4.21.2 and 4.21.4, respectively) with the following details.

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 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.

4.29.2 Requirements

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

4.30 Thermal stability test

A thermal stability test may constitute an alternative to the endurance test in accordance with 4.23.4 d). The test to be carried out shall be specified in the detail specification.

The capacitor shall be loaded with a specified factor times the rated reactive power dissipation at the rated temperature and duration as specified in the relevant specification.

A test for thermal stability shall be made by measuring the temperature rise as a function of time over the last part of the specified duration. The temperature rise shall be within specified limits.

The measurement of the temperature rise may be made by the use of a thermocouple, thermistor, infra-red thermometer, infra-red photography, etc. Care should be taken to ensure that the error of measurement does not exceed ±1 °C and that errors due to heat conduction along measuring connections are kept to a minimum.

The relevant specification shall specify the point at which the measurements shall be made and the method of mounting (see IEC 60068-2-2, 6.4).

4.31 Component solvent resistance

4.31.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.31.2 Test procedure

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

a) solvent to be used: IPA (IEC 60068-2-45, 3.1.2);

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

c) conditioning: method 2, (without rubbing);

d) recovery time: 48 h, unless otherwise stated in the detail specification.

4.31.3 Final inspection, measurements and requirements

The measurements prescribed in the relevant specification shall then be made and the specified requirements be met.

4.32 Solvent resistance of marking

4.32.1 Test procedure

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

a) solvent to be used: IPA (IEC 60068-2-45, 3.1.2);

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.

4.32.2 Final inspection, measurements and requirements

After the test the marking shall be legible.

4.33 Mounting (for surface mount capacitors only)

4.33.1 Substrate

Surface mount capacitors shall be mounted on a suitable substrate, the method of mounting dependent on the capacitor construction. The substrate material shall normally be an epoxide woven glass fabric laminated printed board (as defined in IEC 61249-2-7) with a thickness of 1,6 mm ± 0,20 mm or 0,8 mm ± 0,10 mm, or a 90 % to 98 % alumina substrate having a thickness of 0,635 mm ± 0,05 mm or more, and shall not affect the result of any test or measurement. The detail specification shall indicate which material is to be used for the electrical measurements.

The substrate shall have metallized land areas of proper spacing to permit mounting of surface mount capacitors and shall provide electrical connection to the surface mount capacitor terminals. The details shall be specified in the detail specification.

Examples of test substrates for mechanical and electrical tests are shown in Figures 15 and 16, respectively.

If another method of mounting applies, the method should be clearly described in the detail specification.

4.33.1.1 Wave soldering

When the detail specification specifies wave soldering, suitable glue, details of which may be specified in the detail specification, shall be used to fasten the component to the substrate before soldering is performed.

Small dots of the glue shall be applied between the conductors of the substrate by means of a suitable device securing repeatable results.

The surface mount capacitors shall be placed on the dots using tweezers. To ensure that no glue is applied to the conductors, the surface mount capacitors shall not be moved about.

The substrate with the surface mount capacitors shall be heat-treated in an oven at 100 °C for 15 min.

The substrate shall be soldered in a wave soldering apparatus. The apparatus shall be adjusted to have a pre-heating temperature of 80 °C to 100 °C, a solder bath at 260 °C ± 5 °C and a soldering time of 5 s ± 0,5 s.

The substrate shall be cleaned for 3 min in a suitable solvent (see IEC 60068-2-45, 3.1.2).

4.33.1.2 Reflow soldering

When the detail specification specifies reflow soldering, the following mounting procedure applies.

a) The solder used in preform or paste form shall be silver- bearing (2 % minimum) eutectic Sn/Pb solder together with a flux as stated in IEC 60068-2-20. Alternative solders such as 60/40 or 63/37 may be used on chips whose construction includes solder leach barriers. Pb-free solder used in preform or paste form shall be Sn96,5Ag3,0Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58, or as defined in the relevant specification.

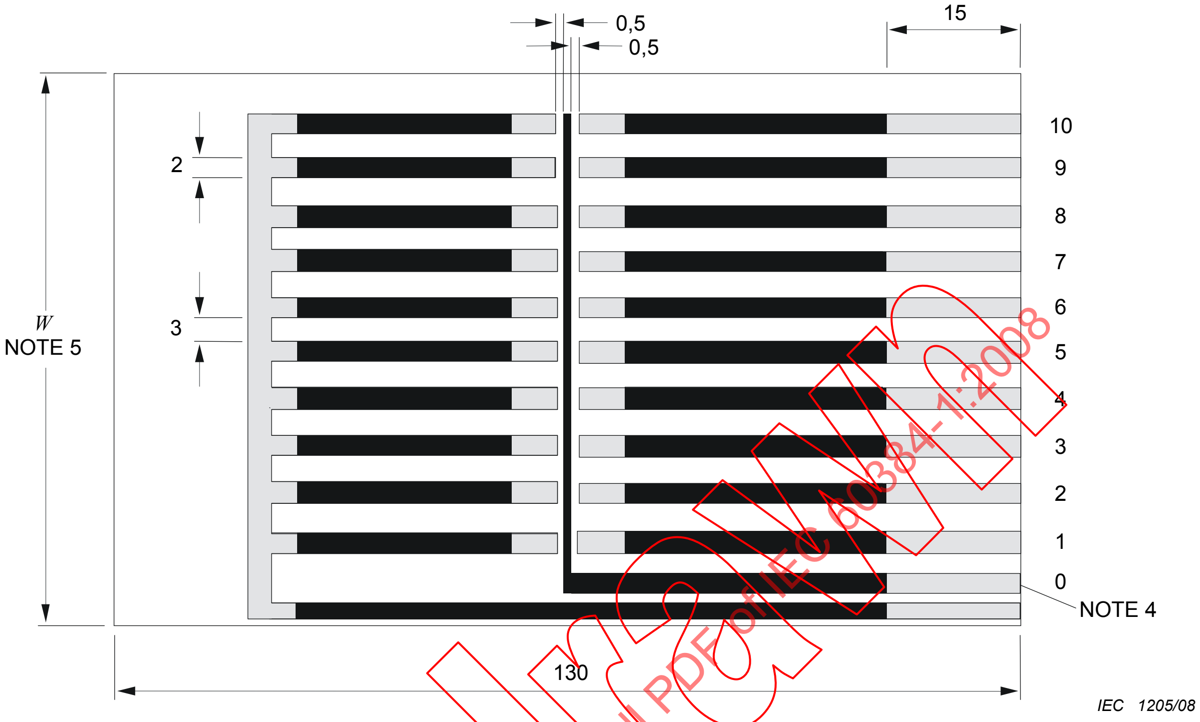
b) The surface mount capacitor shall then be placed across the metallized land areas of the test substrate so as to make contact between surface mount and substrate land areas.

c) The substrate shall then be placed in or on a suitable heating system (molten solder, hot plate, tunnel oven, etc.). The temperature of the unit shall be maintained between 215 °C and 260 °C, until the solder melts and reflows forming a homogeneous solder bond, but for not longer than 10 s.

NOTE 1 Flux should be removed by a suitable solvent (see IEC 60068-2-45, 3.1.2). All subsequent handling should be such as to avoid contamination. Care should be taken to maintain cleanliness in test chambers and during post test measurements.

NOTE 2 The detail specification may require a more restricted temperature range.

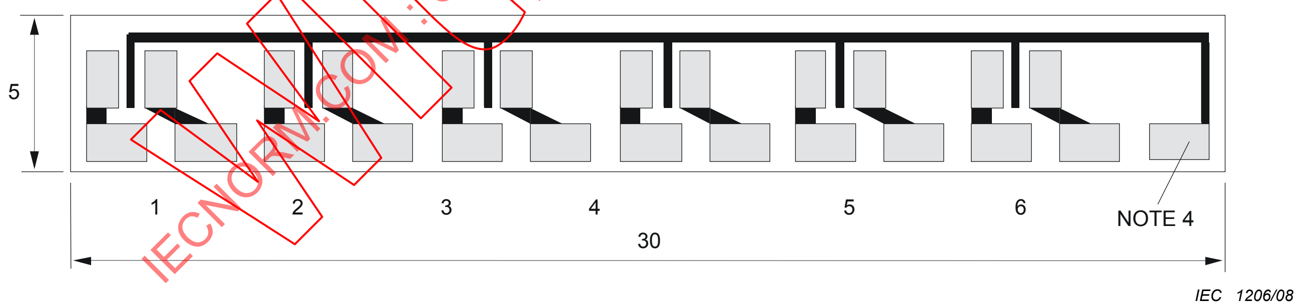
NOTE 3 If vapour phase soldering is applied, the same method may be used with the temperatures adapted.



Material: epoxide woven glass

Thickness: 1,6 mm ± 0,20 mm, or 0,8 mm ± 0,10 mm

Figure 15 – Suitable substrate for mechanical tests (may not be suitable for impedance measurements)



Material: 90 % to 98 % alumina substrate

Thickness: 0,635 mm ± 0,05 mm, or more

Figure 16 – Suitable substrate for electrical tests

Notes to Figures 15 and 16:

NOTE 1 [light grey box] Solderable areas
[black box] Non-solderable areas (covered with non-solderable lacquer)

NOTE 2 All dimensions are in millimetres. Tolerances: medium.

NOTE 3 Dimensions not given should be chosen according to the design and size of the specimens to be tested.

NOTE 4 This conductor may be omitted or used as a guard electrode.

NOTE 5 Dimension W is dependent on the design of the test equipment.

4.34 Shear test

4.34.1 Test procedure

The surface mount capacitors shall be mounted as described in IEC 60068-2-21, test U.

The capacitors shall be subjected to IEC 60068-2-21, Test Ue3, under the following condition.

A force shall be applied to the surface mount capacitor body progressively, without shock, and shall be maintained for a period of 10 s ± 1 s. Unless otherwise specified in the relevant specification, a force shall be selected from 1 N, 2 N, 5 N or 10 N.

4.34.2 Final inspection, measurements and requirements

The surface mount capacitors shall be visually examined in the mounted state. There shall be no visible damage.

4.35 Substrate bending test

4.35.1 Test procedure

The surface mount capacitor shall be mounted on a epoxide woven glass printed board as described in 4.33.

a) The capacitance of the surface mount capacitor shall be measured as specified in 4.7 and in the relevant sectional specification.

b) The capacitor shall be subjected to IEC 60068-2-21, test Ue, using the conditions as prescribed in the relevant specification for the deflection D and the number of bends.

c) The capacitance of the surface mount capacitors shall be measured as specified in a) with the board in the bent position. The change of capacitance shall not exceed the limits prescribed by the relevant specification.

4.35.2 Recovery

The printed board shall be allowed to recover from the bent position and then removed from the test jig.

4.35.3 Final inspection and requirements

The surface mount capacitors shall be visually examined and there shall be no visible damage.

4.36 Dielectric absorption

4.36.1 Test procedure

The capacitor under test shall be placed in a screened enclosure to reduce the effect of electric fields.

For the measurement of the voltage an electrometer or other suitable instrument having an input resistance of minimum 10 000 MΩ shall be used.

The resistance of any jigs, switches etc. used shall not affect the input resistance of the measuring system.

The capacitor shall then be charged at the d.c. voltage rating for 60 min ± 1 min. The initial surge current shall not exceed 50 mA.

At the end of this period the capacitor shall be disconnected from the power source and shall be discharged through a 5 Ω ± 5 % resistor for 10 s ± 1 s, unless the specified d*u*/d*t* value is exceeded.

The discharge resistor shall be disconnected from the capacitor at the end of the 10 s discharge period. The voltage remaining or regained on the capacitor (recovery voltage) shall be measured.

NOTE The recovery voltage is the maximum voltage occurring across the capacitor terminations within a 15 min period.

The dielectric absorption shall be calculated from the following formula:

$$d = \frac{U_1}{U_2} \times 100 \times \frac{C_X + C_0}{C_X}$$

where

d is the per cent dielectric absorption;

U_1 is the recovery voltage;

U_2 is the charging voltage;

C_X is the capacitance of capacitor under test;

C_0 is the input capacitance of measuring system.

If C_0 is less than 10 % of C_X, the above formula can be simplified to:

$$d = \frac{U_1}{U_2} \times 100$$

4.36.2 Requirement

The dielectric absorption calculated shall not exceed the limit specified in the detail specification.

4.37 Accelerated damp heat, steady state (for multilayer ceramic capacitors only)

4.37.1 Mounting of capacitors

The capacitors shall be mounted so that each capacitor is connected in series with a resistor. Half of the capacitors shall be connected in series with resistors of 100 kΩ ± 10 % and half in series with resistors of 6,8 kΩ ± 10 %.

4.37.2 Initial measurement

The capacitors, mounted as in 4.37.1, shall be measured for insulation resistance with a voltage of 1,5 V ± 0,1 V applied across the capacitor and resistor in series.

The insulation resistance shall meet the requirements given in the relevant specification.

4.37.3 Test procedure

The capacitors with associated resistors shall be subjected to conditioning at (85 ± 2) °C, (85 ± 3) % RH for a duration to be specified in the relevant specification. Those capacitors connected to 100 kΩ resistors shall have a voltage of (1,5 ± 0,1) V applied, and those connected to 6,8 kΩ resistors shall have (50 ± 0,1) V or U_R, whichever is the lower, applied. In both cases the voltage shall be applied across the capacitor/resistor combination.

Care shall be taken to avoid condensation of water on to the capacitors or substrates. Condensation may happen if the door is opened during the test before the humidity is lowered.

4.37.4 Recovery

The applied voltage shall be disconnected and the capacitors and resistors shall be removed from the test chamber and allowed to recover for 4 h to 24 h in standard atmospheric conditions for testing.

4.37.5 Final inspection, measurements and requirements

The capacitors, mounted as in 4.37.1, shall be measured for insulation resistance as in 4.37.2 above.

The insulation resistance shall be greater than 0,1 times the initial limit.

4.38 Passive flammability

4.38.1 Test procedure

The test shall be made according to IEC 60695-11-5.

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 be exposed only once to the flame.

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 time of exposure to flame and burning time, see Table 7. If applicable, the detail specification shall specify the category of passive flammability.

4.38.2 Final inspection, measurements and requirements

The burning time of any specimen shall not exceed the time specified in Table 7.

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

Table 7 – Severities and requirements

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

4.39 High surge current test

4.39.1 Initial measurements

Not required.

4.39.2 Test procedure

The test shall be carried out at a temperature of (23 ± 3) °C.

The test circuit is shown in Figure 17. The switch may be mechanical or electronic but is preferably electronic. With the switch in position A, the capacitor under test is charged for 1 s from a low-impedance electrolytic capacitor of capacitance at least 20 000 µF to the rated voltage of the capacitor under test (U_R ± 2 %) from a regulated power supply capable of delivering 10 A. The impedance of the circuit through which the capacitor under test is charged shall meet the requirements of 4.39.3. After the 1 s charging time the capacitor under test shall be discharged for 1 s with the switch in position B through a circuit whose resistance is greater than 0,05 Ω but less than 0,2 Ω.

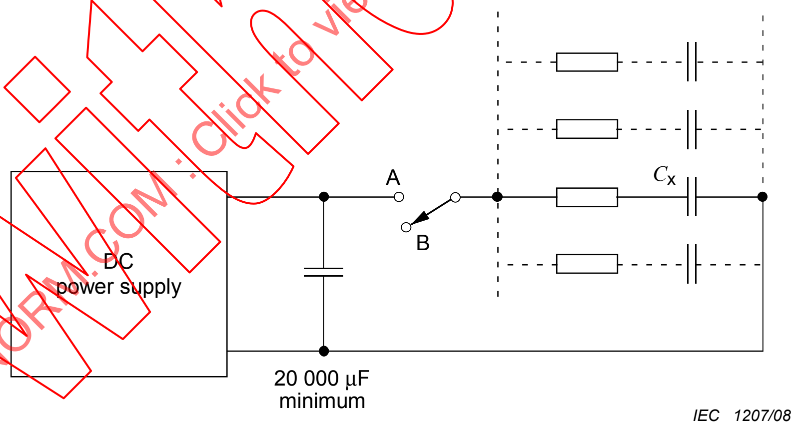
The voltage across the capacitor under test shall be monitored. Four further chargings and dischargings of the capacitor under test shall be carried out under the same conditions.

Capacitors may be tested in parallel provided that

a) their total capacitance is less than 2 % of the capacitance of the reservoir capacitor, and

b) all the conditions specified above are met for each capacitor under test.

The fuse may be a wire fuse designed to blow between 0,5 A and 2,0 A or an electronic circuit designed to trip in the same current range.



C_x = capacitor under test

Figure 17 – High surge current test

4.39.3 Requirements for the charging circuit

The test procedure of 4.39.2 shall be carried out with a capacitor of 47 µF ± 10 %, 35 V in the test position, or in every one of the test positions if provision is made for testing capacitors in parallel. The monitoring of the voltage across the capacitor under test shall demonstrate that the peak voltage across the capacitor during charging is $U_R\,{}^{+5}_{-2}$ %, and that 90 % of the measured peak voltage is achieved within 60 µs from the time of closure of the switch and without unwanted transients due to switch bounce or circuit inductance. Where there is provision for testing capacitors in parallel, this requirement shall be verified for each capacitor under test.

NOTE It is unlikely that this requirement will be met unless the d.c. resistance of the charging circuit including wiring, fuse, fixtures, and the series resistance of the tank capacitor is less than 0,5 Ω.

4.39.4 Nonconforming items

A capacitor shall be considered a nonconforming item if the fuse blows or the electronic circuit trips at any single charging or discharging of the capacitor.

4.40 Voltage transient overload (for aluminium electrolytic capacitors with non-solid electrolyte)

4.40.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

4.40.2 Test procedure

The capacitor(s) shall then be conditioned at the test temperature by having U_R ± 1 % applied from a regulated power supply. At the end of this period, the test may commence but not later than 48 h after conditioning.

An example of a test circuit is shown in Figure 18.

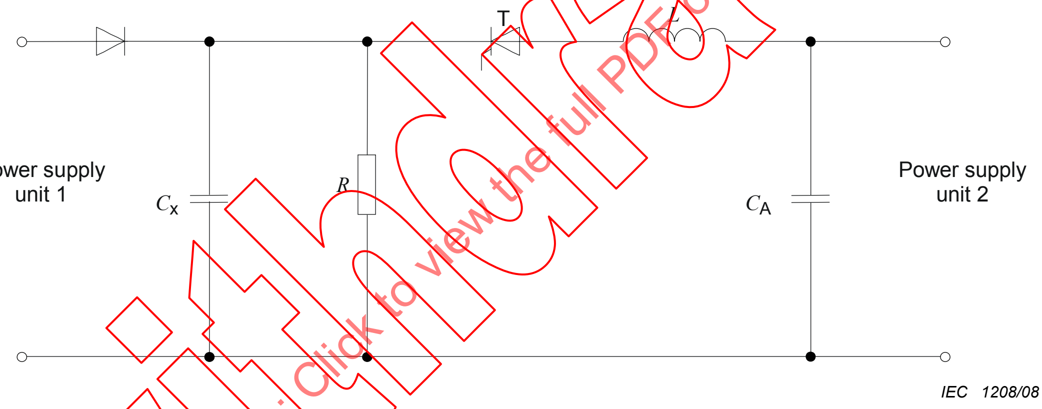


Figure 18 – Voltage transient overload test circuit

The capacitor under test C_X is charged from the power supply unit 1, and the auxiliary capacitor bank C_A is charged to a voltage higher than the test voltage U_P from the power supply unit 2. On triggering the thyristor T, the capacitor bank C_A is discharged through the inductor L charging the test capacitor C_X to U_P. On turning the thyristor off, the test capacitor C_X is discharged through the resistor R from U_P down to U_R.

The voltage waveform across the capacitor under test shall be approximately as shown in Figure 19.

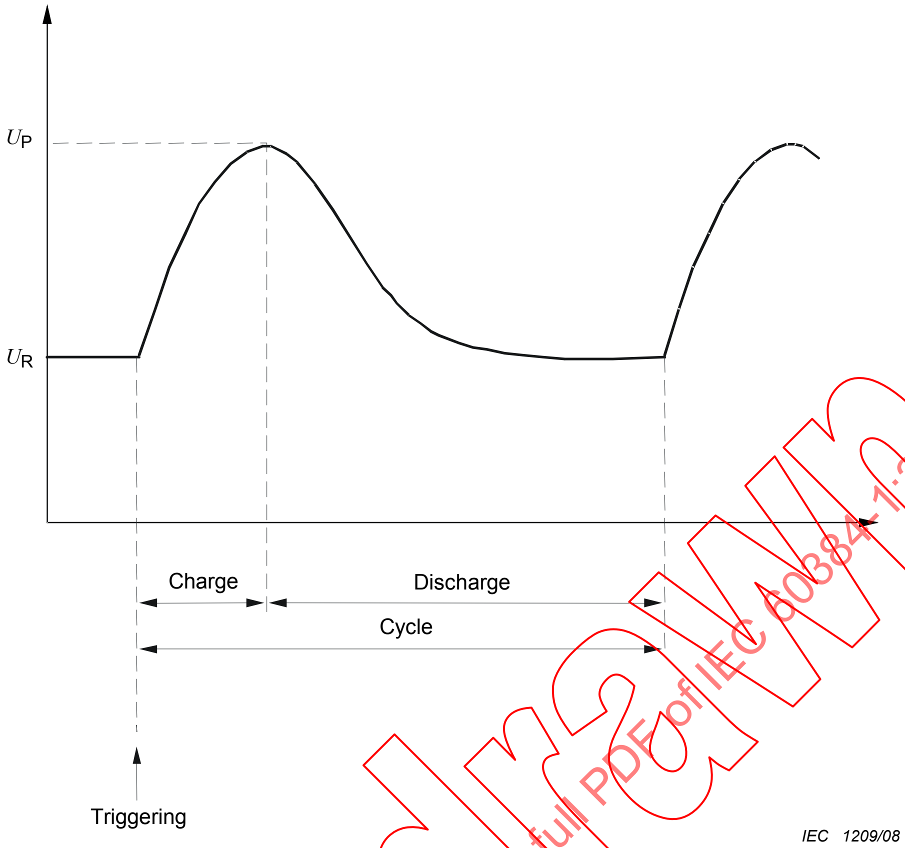


Figure 19 – Voltage waveform

4.40.3 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.40.4 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe

a) the duration of the conditioning period;
b) the value of the transient peak voltage U_P;
c) the value of C_A, L and R to give a maximum charge time of 15 ms;
d) the duration of each test cycle;
e) the number of test cycles;
f) the temperature if different from standard atmospheric conditions of testing.

Annex A
(normative)

Interpretation of sampling plans and procedures as described in IEC 60410 for use within the IECQ system

When using IEC 60410 for inspection by attributes, the interpretations of the clauses and subclauses of IEC 60410, as indicated below, apply for the purpose of this standard.

1 The responsible authority is the national authorized institution implementing the basic rules and rules of procedure.

1.5 The unit of product is the electronic component defined in a detail specification.

2 Only the following definitions from this clause are required:

- a "defect" is any nonconformance of the unit of product to specified requirements;
- a "defective" is a unit of product which contains one or more nonconformances.

3.1 The extent of nonconformance of a product shall be expressed in terms of per cent defective.

3.3 Not applicable.

4.5 The responsible authority is the IEC technical committee drafting the blank detail specification which forms part of the generic or sectional specification.

5.4 The responsible authority is the designated management representative (DMR), acting in accordance with the procedures prescribed in the document describing the inspection department of the approved manufacturer, and approved by the national supervising inspectorate.

6.2 The responsible authority is the DMR.

6.3 Not applicable.

6.4 The responsible authority is the DMR.

8.1 Normal inspection shall always be used at the start of inspection.

8.3.3d) The responsible authority is the DMR.

8.4 The responsible authority is the national supervising inspectorate.

9.2 The responsible authority is the IEC technical committee drafting the blank detail specification which forms part of the generic or sectional specification.

9.4 (Fourth sentence only) Not applicable.
(Fifth sentence only) The responsible authority is the DMR.

10.2 Not applicable.

Annex B
(normative)

Rules for the preparation of detail specifications for capacitors and resistors for electronic equipment for use within the IECQ system

B.1 The drafting of a complete detail specification by IEC technical committee 40, if required, shall begin only when all the following conditions have been met.

a) The generic specification has been approved.

b) The sectional specification, when appropriate, has been circulated for approval as an FDIS.

c) The associated blank detail specification has been circulated for approval as an FDIS.

d) There is evidence that at least three national committees have formally approved, as their own national standard, specifications covering a component of closely similar performance.

When a national committee formally asserts that substantial or significant use is made within its country of a part described by some other national standard, this assertion may count towards the foregoing requirement.

B.2 Detail specifications prepared under the responsibility of technical committee 40 shall use the standard of preferred values, ratings and characteristics and severities for environmental tests, etc., which are given in the appropriate generic or sectional specifications.

An exception to this rule may only be granted for a specified detail specification, when agreed by technical committee 40.

B.3 The detail specification should not be circulated as an FDIS until the sectional and blank detail specifications have been approved for publication.

Annex C
(normative)

Layout of the first page of a PCP/CQC specification

Manufacturer's name

Location

Capability approval number PCP/CQC specification number

Issue

Capability manual reference number Date

Description of PCP/CQC

Purpose of PCP/CQC

Drawing reference

Part identity

Annex D
(normative)

Requirements for capability approval test report

D.1 Introduction

The test report shall be dated and shall include the information given in Clauses D.2, D.3 and D.4.

D.2 General

- manufacturer's name and address;
- place of manufacture, if different from above;
- generic and sectional specification number, issue and amendment date;
- the issue number and date of the description of capability;
- reference to PCP/CQC specification;
- reference to the test programme for capability approval, as applicable;
- a list of test equipment used together with appropriate uncertainties of measurement.

D.3 Summary of test information (for each CQC)

- tests;
- number of specimens tested;
- number of nonconforming items allowed;
- number of nonconforming items found.

D.4 Measurement record

A record of the results of the measurements is taken before and after the various mechanical, environmental, and endurance tests for which post-test limits or final measurements are specified.

Annex E
(informative)

Guide for pulse testing of capacitors

E.1 Introduction

Existing testing methods covered by this standard are suitable for capacitors operating in circuits where the applied voltage is predominantly direct voltage. There are now an increasing number of applications in which the applied voltage is in the form of pulse with or without a reversal of polarity. These pulses may be continuous, intermittent, or random in occurrence.

This annex specifies the factors affecting pulse ratings and the way in which these ratings may be checked by appropriate endurance tests. The parameters of a pulse are defined. Different combinations of these parameters can give rise to different causes of failure as follows.

Type	Cause of failure	Test
Electrolytic	Surge voltage exceeded	Surge voltage
	Reverse voltage exceeded	Reverse voltage
	Overheating (I^2R)	Pulse or a.c.
Metallized types	Peak current	Charge/discharge (intermittent)
	du/dt	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Ionization	a.c.
All other	du/dt	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Excess peak voltage	Surge
	Ionization	a.c.

E.2 Typical capacitor pulse conditions

The figures listed below for typical applications show that test specifications requiring 100 000 or 1 million pulses correspond to operations of only 5 s to 50 s.

It is not possible to produce one circuit which will reproduce all of the required conditions.

It is likely, however, that circuits can be produced which will reproduce various groups of conditions. It does not appear possible at the present time to specify accelerated test conditions to simulate, for example, a five-year operation.

E.2.1 Examples for TV applications

E.2.1.1 S-correction

Typical peak voltage:	25 V, 50 V, 180 V
Typical peak currents:	5 A – 15 A
d*u*/d*t*:	about 5 V/µs
Frequency:	15 kHz to 20 kHz
Reactive power:	up to 250 var

E.2.1.2 Line tuning

Typical peak voltage:	up to 1 500 V
Typical peak current:	5 A
d*u*/d*t*:	180 V/µs

E.2.1.3 Multiplier capacitors

Typical peak voltage:	10 kV d.c. with ripple
Typical peak current:	0,1 A
d*u*/d*t*:	up to 1 000 V/µs

E.2.2 Examples for power electronics

Typical peak voltages:	60 V – 100 V
Typical peak currents:	40 A – 100 A
d*u*/d*t*:	1 V/µs – 20 V/µs
Frequencies :	50 Hz to 20 kHz
Reactive power:	up to 500 var

E.2.3 Example for d.c.-d.c. convertors

Typical peak voltage:	30 V
Typical peak current:	6 A
d*u*/d*t*:	600 V/µs
Frequency:	up to 20 kHz

E.2.4 Examples for switch-mode power supplies

Typical peak voltages:	15 V – 400 V
Typical peak currents:	2 A – 10 A
Frequencies:	100 Hz to 40 kHz

E.2.5 Examples for lasers and pulse light sources

Typical peak voltages:	1 kV – 3 kV
Typical peak current:	1 000 A
d*u*/d*t*:	about 500 V/µs
Frequencies:	1 kHz to 5 kHz

E.3 Effect of inductance on pulse testing

Proposed pulse test methods are likely to consist of test circuits involving repetitive charge and discharge of capacitors in resistive circuits. This will result in conventional exponential current and voltage characteristics.

In many applications, however, inductive effects are of considerable importance and have a major influence on the suitability of the capacitor for the application.

These are particularly important at high values of d*u*/d*t*. If the conditions for critical damping exist ($R^2 = 4 \times L/C$), the effect is a minor modification of the shape of the charge or discharge curve which will have little effect on the severity of the test.