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Fixed inductors for electromagnetic interference suppression –

Part 2: Sectional specification

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60938-2 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This consolidated version of IEC 60938-2 is based on the second edition (1999) [documents 40/1111/FDIS and 40/1137/RVD] and its amendment 1 (2006) [documents 40/1603/CDV and 40/1700A/RVC].

It bears the edition number 2.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

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

Annexes A, B, C, D and E form an integral part of this standard.

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

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- withdrawn,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

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

FIXED INDUCTORS FOR ELECTROMAGNETIC INTERFERENCE SUPPRESSION – Part 2: Sectional specification

1 General

1.1 Scope

This International Standard applies to fixed inductors designed for electromagnetic interference suppression and which fall within the scope of the generic specification, IEC 60938-1. It is restricted to fixed inductors for which safety tests are appropriate. This implies that inductors specified according to this specification will either be connected to mains supplies, when compliance with the mandatory tests of table 1 is necessary, or used in other circuit positions where the equipment specification prescribes that some or all of these safety tests are required.

This standard applies to fixed inductors which will be connected to an a.c. mains or other supply with a nominal voltage not exceeding 1 000 V a.c. (r.m.s.) or d.c. between conductors and with a nominal frequency not exceeding 400 Hz.

1.2 Object

The object of this standard is to prescribe standard requirements for safety tests and standard ratings and characteristics, to select from IEC 60938-1 the appropriate methods of test and to give general performance requirements for suppression inductors. Test severities and performance requirements prescribed in detail specifications referring to this sectional specification shall be of equal or higher performance level. In addition, the minimum requirements for safety tests specified herein always apply.

1.3 Normative references

Les documents de référence suivants sont indispensables pour l'application du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60063:1963, *Preferred number series for resistors and capacitors*
Amendment 1 (1967)
Amendment 2 (1977)

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

IEC 60279:1969, *Measurement of the winding resistance of an a.c. machine during operation at alternative voltage*

IEC 60938-1:1999, *Fixed inductors for electromagnetic interference suppression – Part 1: Generic specification*

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

CISPR 16-1-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

1.4 Information to be given in a detail specification

1.4.1 General

Detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic or sectional specification. When more severe requirements are included they shall be listed in 1.8 of the detail specification and indicated in the test schedules, for example by an asterisk.

NOTE The information given in 1.4.2 may, for convenience, be presented in tabular form.

The information given in 1.4.2 to 1.4.5 shall be given in each detail specification and the values quoted shall preferably be selected from those given in the appropriate clause of this sectional specification.

1.4.2 Outline drawing and dimensions

There shall be an illustration of the inductor as an aid to easy recognition and for comparison of the inductor with others. Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be indicated upon the drawing. All dimensions shall be stated in millimetres.

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

When the configuration is other than described above, the detail specification shall state such dimensional information as will adequately describe the inductor. When the inductor is not designed for use on printed boards, this shall be clearly stated in the detail specification.

1.4.3 Mounting

The detail specification shall specify the method of mounting to be recommended for normal use and the method which is mandatory for the application of the vibration, bump and shock tests. The design of the inductor may be such that special mounting fixtures are required in its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used in the application of the bump, shock and vibration tests. The specified heat sink shall be used in the application of the endurance test.

1.4.4 Ratings and characteristics

The ratings and characteristics shall be in accordance with the relevant clauses of this specification.

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

1.4.5 Marking

Deviations from 1.6 of this sectional specification, shall be specifically stated in the detail specification.

1.5 Definitions

For the purpose of this International Standard, the definitions in IEC 60938-1 apply.

1.6 Marking

1.6.1 The information given in the marking is normally selected from the following list; the relative importance of each item is indicated by its position in the list:

a) manufacturer's name (or trade mark);

b) manufacturer's type designation;

c) recognized approval mark;

d) rated inductance and tolerance;

e) rated voltage;

f) rated current;

g) identification of terminations or circuit diagram;

h) rated temperature;

i) climatic category;

j) year and month (or week) of manufacture (this may be in code form);

k) reference to the detail specification.

1.6.2 Marking of the inductor may be omitted when the manufacturer considers that there is insufficient space, and this fact is recorded in the detail specification. When present, the marking shall be sufficient to provide a clear identification of the inductor. Any duplication of information in the marking on the inductor should be avoided.

1.6.3 The packaging containing the inductor(s) shall be clearly marked with all the information listed in 1.6.1, except g).

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

2 Preferred ratings and characteristics

2.1 Climatic categories

Electromagnetic interference suppression inductors covered by this specification are classified into climatic categories according to the general rules given in IEC 60068-1. The lower and upper category temperatures and the duration of the damp heat, steady state test shall be selected from the following:

Lower category temperature: –65 °C, –55 °C, –40 °C, –25 °C and –10 °C.

Upper category temperature: +85 °C, +100 °C, +125 °C and +155 °C.

Duration of the damp heat, steady state test: 21 and 56 days.

The severities for the cold and dry heat tests are the lower and upper category temperatures respectively.

2.2 Values of ratings

2.2.1 Rated inductance and tolerance

Preferred values of rated inductance are values chosen from the E 6 series of preferred values given in IEC 60063.

The preferred tolerances on rated inductance are as follows:

±30 %; –30 %/+50 %.

2.2.2 Rated voltage (U_R)

Preferred values for rated voltages are:

AC inductors: 50 V, 125 V, 250 V, 400 V, 440 V, 480 V and 760 V.

DC inductors: 50 V, 160 V, 250 V and 500 V.

NOTE Electromagnetic interference suppression inductors are normally chosen to have their rated voltage equal to or greater than the nominal voltage of the supply system to which they are to be connected. It should, however, be borne in mind that the voltage of the system may rise up to 10 % above the nominal voltage.

2.2.3 Category voltage (U_C)

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

2.2.4 Rated temperature

The rated temperature shall not be lower than +40 °C.

2.2.5 Rated current

The preferred values of rated current are selected from the R10 series of ISO 3.

2.2.6 Passive flammability

When specified, the minimum category of passive flammability permitted is category C.

3 Quality assessment procedures

3.1 Primary stage of manufacture

See 3.2 of IEC 60938-1.

3.2 Structurally similar inductors

Inductors are structurally similar when for their range of inductance values they have the following common characteristics:

a) essentially the same materials;

b) similar design features and manufacturing techniques;

c) same rated voltage.

3.3 Certified records of released lots

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

3.4 Qualification approval

The procedures for qualification approval testing for structurally similar inductors are given in 3.4 of IEC 60938-1.

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

3.4.1.1 Sampling

This standard covers procedures for qualification approval tests only. Two alternative test procedures are given, namely the full test procedure covering both safety tests and performance requirements, and a restricted test procedure covering safety tests.

Table 1 and annex A form the schedule limited to tests for safety tests only approval. Prior to the approval testing for safety tests only it is necessary to submit to the certification body a declaration of design (annex D) registering essential data and basic design details of the inductors for which approval is sought.

Table 2 and annex B form the full schedule for safety tests and performance approval.

Each rated voltage shall be separately qualified. The total number of inductors of each rated voltage to be tested in each group is given in table 1 or 2. For each rated voltage the sample shall contain equal numbers of specimens of the highest and lowest inductance and the highest and lowest rated current in the range to be qualified. Where only one inductance value or rated current value is involved, the total number of inductors as stated in table 1 or 2 shall be tested.

Spare specimens are permitted as follows:

a) one per inductance/rated current combination which may be used to replace the permitted non-conforming items in group 0;

b) one per inductance/rated current combination which may be used as replacements for specimens lost due to incidents not attributable to the manufacturer or the test sequence;

c) the remainder of the spares may be required if it is necessary to repeat any test according to the provisions of note 1 to table 1 or 2;

d) spares may be kept at the premises of the manufacturer instead of being sent to the testing station.

The number of samples given in group 0 assume that all groups are applicable. If this is not so the numbers may be reduced accordingly.

When additional groups are introduced into the qualification approval test schedule, the number of specimens required for group 0 shall be increased by the same number as that required for the additional groups.

3.4.1.2 Tests

The complete series of tests specified in either table 1 or 2 is required for the approval of a series of structurally similar inductors of one rated voltage. The tests of each group shall be carried out in the order given.

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

Non-conforming items found during the tests of group 0 shall not be used for the other groups.

"One non-conforming item" is counted when an inductor has not satisfied the whole or part of the tests of a group.

The approval is granted when the number of non-conformances does not exceed the specified number of permissible non-conforming items for each group or subgroup and the total number of permissible non-conformances indicated in table 1 or 2.

NOTE Table 1 and annex A or table 2 and annex B together form the fixed sample size test schedule, for which table 1 or 2 includes the details for the sampling and permissible non-conforming items for the different tests or groups of tests, whereas annexes A or B together with the details of test contained in clause 4 give a complete summary of test conditions and performance requirements and indicate where, for example for the test method or conditions of test, a choice has to be made in the detail specification. The conditions of test and performance requirements for the fixed sample size test schedule shall be identical to those prescribed in the detail specification.

Table 1 – Sampling plan for safety tests only

Group	Test	Subclause of this publication	Number of specimens tested per rated voltage and for each mass group (2)	Number of permissible non-conforming items per rated voltage	
				Per group	Total
			n	c	c
0	Visual examinations Line resistance Inductance Voltage proof Insulation resistance Spares	4.1 4.5 4.4 4.2 4.3	40/22/10/5 4/2/2/1	1	
1A	Dimensions (detail) Creepage distances and clearances Robustness of terminations Resistance to soldering heat (1) Component solvent resistance (if applicable) (5)	4.1.2 4.1.2 4.6 4.7 4.20	10/6/2/1	0	
2	Damp heat, steady state	4.15	18/10/4/2	0	0
3A 3B	Temperature rise (3) or Endurance current (4) Impulse voltage (7)(8) Endurance voltage between line terminations (7)	4.16 or 4.18 4.17 4.18	12/6/4/2	0	
4	Passive flammability (5)	4.19	see 4.19	0	

NOTES to tables 1 and 2:

NOTE 1 If applicable.

NOTE 2 The number of specimens indicated relate to the mass limits as follows:

≤5 g

>5 g and ≤250 g

>250 g and ≤1 500 g

>1 500 g respectively.

Where a range is qualified which contains inductors within more than one of the mass classifications listed above, the number of specimens selected shall be that for the classification in which the majority of the values in the range fall.

The numbers in group 0 exclude the numbers of specimens required for group 4.

NOTE 3 For inductors with a weight >5 g only.

NOTE 4 For inductors with a weight ≤5 g only.

NOTE 5 If required in the detail specification.

NOTE 6 Whichever is required in the detail specification.

NOTE 7 Applicable to inductors with more than one winding of different polarity.

NOTE 8 Applicable to inductors with earthed metal case, not connected to one of the line terminations.

NOTE 9 If one non-conforming item is obtained, all tests of the group shall be repeated on a new sample and then no further non-conforming items are permitted. The non-conforming item obtained in the first sample shall be counted for the total non-conforming items permitted in the sixth column. Repetition of tests is permitted in one group only.

Table 2 – Sampling plan for safety tests and performance tests, assessment level D

Group	Test	Subclause of this publication	Number of specimens tested per qualification (2)	Number of permissible non-conforming items per qualification (2)	
				Per group	Total
			n	c	c
0	Dimensions (gauging)	4.1			
	Visual examinations	4.1			
	DC line resistance	4.5			
	Inductance	4.4	76/48/28/16	2/1/1/1	
	Voltage proof	4.2			
	Insulation resistance	4.3			
	Spares		24/15/10/5		
1A	Dimensions (detail)	4.1.2			
	Creepage distances and clearances	4.1.2			
	Robustness of terminations	4.6			
	Resistance to soldering heat (1)	4.7	10/6/2/1	0 (9)	
	Component solvent resistance (5)	4.20			
	Solderability (1)	4.8			
	Solvent resistance of marking (5)	4.21			
1B	Rapid change of temperature	4.9	18/12/6/3	0 (9)	1/1/1/0
	Vibration	4.10			
	Bump or shock (6)	4.11 or 4.12			
1	Container sealing (5)	4.13	28/18/8/4	0 (9)	
	Climatic sequence	4.14			
2	Damp heat, steady state	4.15	16/10/8/4	0 (9)	
3A	Temperature rise (3) or Endurance current (4)	4.16 or 4.18	12/8/4/4	0 (9)	
3B	Impulse voltage (7)(8)	4.17			
	Endurance voltage between line terminations (7)	4.18	20/12/8/4	0	
4	Passive flammability (5)	4.19	See 4.19	0	
See notes to tables 1 and 2 at the bottom of table 1.					

3.5 Quality conformance inspection

3.5.1 Formation of inspection lots

a) Groups A and B inspection

These tests shall be carried out on a lot-by-lot basis using sampling plans appropriate to the given assessment level specified in the relevant blank detail specification.

Manufactured lots of separately identified inductors may be aggregated into inspection lots formed for such tests as are relevant to structural similarities between those manufactured lots.

b) Group C inspection

– Safety tests only approval

Re-qualification tests according to annex A may be required by the certification body when a change of the design as given in annex D is intended.

The certification body will be informed about the intended change(s) and decide whether re-qualification tests have to be performed.

– Full safety tests and performance approval

Periodic tests according to annex B shall be carried out at the periodicities and on the numbers of specimens appropriate to the given assessment level specified in the relevant blank detail specification. In order to reduce the number of specimens required to carry out any single complete periodic test, the manufacturer may elect to have the tests of more than one subgroup carried out sequentially on the same specimens.

The specimens shall be representative of the inductors manufactured during each period. In subsequent periods other inductors in the approved range in production shall be tested with the aim of covering the whole range of the approval.

3.5.2 Test schedule

– Safety tests only approval

The test schedule for the lot-by-lot and periodic tests or criteria for re-qualification is given in table 4 of the relevant blank detail specification, IEC 60938-2-2.

– Full safety tests and performance approval

The test schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in table 4 of the relevant blank detail specification, IEC 60938-2-1.

3.5.3 Delayed delivery

When according to the procedures in 3.5.2 of IEC 60938-1, re-inspection has to be made, insulation resistance shall be checked as specified in group A inspection and solderability shall be checked according to group B inspection.

4 Test and measurement procedures

4.1 Visual examination and check of dimensions

Visual examination and check of dimensions shall be in accordance with 4.4 of IEC 60938-1.

4.1.1 **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, checks shall be made in accordance with IEC 60294.

4.1.2 **Dimensions** (detail)

Creepage distances and clearances shall comply with the values prescribed in table 2 of IEC 60938-1. All other dimensions shall comply with the values prescribed in the detail specification.

4.2 Voltage proof

See 4.6 of IEC 60938-1 with the following details:

a) the test voltage to be applied to mains inductors is given in table 3:

Table 3 – Measuring points

Inductors for	**Test A between terminations***	**Test B – Internal insulation) Test C – External insulation Test D** – Between windings and core**
Alternating current	4,3 U_R (d.c.)	2 U_R + 1 500 V (a.c.) with a minimum of 2 000 V (a.c.)
Direct current	3 U_R (d.c.)	2 U_R + 1 500 V (d.c.)
* Applies only to inductors with more than one winding. ** Test not required for insulated or non-insulated and self-supporting mountable inductors.		

b) the method of applying the test voltage for test C shall be given in the detail specification. For qualification testing the foil method of 4.6.2.3 of IEC 60938-1, shall be used;

c) for qualification approval and periodic testing the full test voltage shall be applied for 1 min. For quality conformance tests the detail specification may specify a shorter time;

d) for d.c. tests the charge and discharge current shall not exceed 0,05 A;

e) for d.c. tests the time constant $R_1 \times C_S$ shall not exceed 1 s;

f) for qualification approval a.c. tests, the voltage shall be supplied from a transformer.

The voltage shall be raised from near zero to the test voltage at a rate not faster than 150 V/s. The test time shall begin at the moment the test voltage is reached. For quality conformance tests, the detail specification may require the full test voltage to be applied directly.

NOTE Attention is drawn to the fact that repetition of the voltage proof test may damage the inductor.

4.3 Insulation resistance

See 4.5 of IEC 60938-1 with the following details:

a) the measuring voltage shall be as prescribed in 4.5.2 of IEC 60938-1;

b) the method of applying the test voltage for test C may be any of the methods specified in 4.5.2.1, 4.5.2.2 and 4.5.2.3 of IEC 60938-1. For qualification testing the foil method of 4.5.2.1 shall be used;

c) the minimum value of insulation resistance with tests A, B and C shall be 6 000 MΩ.

4.4 Inductance

Unless otherwise stated in the detail specification, the following measuring conditions apply:

a) the measuring frequency shall be chosen from the following:

1 MHz ± 20 %	for	$L \leq 10\ \mu H$
100 kHz ± 20 %	for	$10\ \mu H < L \leq 1$ mH
10 kHz ± 20 %	for	1 mH $< L \leq 50$ mH
50 Hz to 120 Hz	for	$L > 50$ mH

b) the measuring current shall be 0,1 mA ± 10 %. For some inductance values it may be desirable to use other currents or frequencies. The values of the current or frequency shall be given in the detail specification.

4.5 DC line resistance

Using a d.c. measuring method with an applied voltage of less than 10 V, the resistance between any input terminal and the corresponding output terminal shall be measured and shall not exceed the limit prescribed in the detail specification. The detail specification may specify precise points of connection between the terminals and the measuring instrument.

4.6 Robustness of terminations

See 4.9 of IEC 60938-1.

4.7 Resistance to soldering heat

See 4.10 of IEC 60938-1 with the following details:

Not applicable to inductors having leads with insulation length greater than 10 mm or with snap-on terminations.

4.7.1 Conditions

No pre-drying.

4.7.2 Final inspection, measurements and requirements

The inductors shall be visually examined and measured and shall meet the requirements in annex A or B.

4.8 Solderability

See 4.11 of IEC 60938-1 with the following details:

4.8.1 When the solder globule method is used the soldering time shall be less than 3 s.

4.8.2 The requirements are given in annex B.

4.9 Rapid change of temperature

See 4.12 of IEC 60938-1 with the following details:

4.9.1 Number of cycles: 5.

Duration of exposure at the temperature limits:

– 1 h for mass group <250 g;
– 3 h for mass group ≥250 g.

4.10 Vibration

See 4.13 of IEC 60938-1 with the following details:

4.10.1 One of the following severities of test Fc, as specified in the detail specification:

Displacement or acceleration, whichever is the lower acceleration as specified in table 4.

Table 4 – Acceleration

Mass group	Amplitude or acceleration (whichever is the lower acceleration)
>5 g	0,35 mm or 49 m/s^2 (5 *g*)
≤5 g	0,75 mm or 98 m/s^2 (10 *g*)

Over one of the following frequency ranges: 10 Hz to 55 Hz, 10 Hz to 500 Hz, 10 Hz to 2 000 Hz.

The total number of sweep cycles to be applied in relation to the frequency ranges are as specified in table 5.

Table 5 – Sweep cycles

Frequency Hz	Total number of sweep cycles
10 to 55	3 × 24
10 to 500	3 × 10
10 to 2 000	3 × 8

The detail specification shall specify the frequency range and shall also prescribe the mounting method to be used.

4.10.2 Final inspection and requirements

The inductors shall be visually examined and shall meet the requirements in annex B.

4.11 Bump

See 4.14 of IEC 60938-1 with the following details:

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

One of the following severities shall be specified in the detail specification:

Total number of bumps: 1 000 or 4 000

Acceleration: 390 m/s^2 (40 *g*) or 98 m/s^2 (10 *g*)

Pulse duration: 6 ms 16 ms

The detail specification shall also prescribe the mounting method to be used.

4.11.2 Final inspection and requirements

The inductors shall be visually examined and meet the requirements in annex B.

4.12 Shock

See 4.15 of IEC 60938-1 with the following details:

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

4.12.2 The detail specification shall state which of the preferred severities in table 6 applies. Pulse shape: half-sine.

Table 6 – Preferred severities

Peak acceleration m/s^2 (*g*)	**Corresponding duration of the pulse** ms
294 (30)	18
490 (50)	11
981 (100)	6

The detail specification shall also prescribe the mounting method to be used.

4.12.3 Final inspection, measurements and requirements

The inductors shall be visually examined and measured and shall meet the requirements in annex B.

4.13 Container sealing

See 4.16 of IEC 60938-1.

4.14 Climatic sequence

See 4.17 of IEC 60938-1 with the following details:

4.14.1 Initial measurements

Not required.

4.14.2 Dry heat

No measurements are required at the upper category temperature.

4.14.3 Damp heat, cyclic, test Db, first cycle

See 4.17.3 of IEC 60938-1.

4.14.4 Cold

No measurements are required at the lower category temperature.

4.14.5 Low air pressure

See 4.17.5 of IEC 60938-1 with the following details:

If required in the detail specification, the test shall be made at a room temperature of 15 °C to 35 °C and a pressure of 8,0 kPa, unless otherwise stated in the detail specification. The duration of the tests shall be 1 h.

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

4.14.6 Damp heat, cyclic, test Db, remaining cycles

See 4.17.6 of IEC 60938-1.

4.14.7 Final inspection, measurements and requirements

After recovery the inductors shall be visually examined and measured and shall meet the requirements given in annex B.

4.15 Damp heat, steady state

See 4.18 of IEC 60938-1 with the following details:

4.15.1 Final inspection, measurements and requirements

After recovery the inductors shall be visually examined and measured and shall meet the requirements of annex A or B.

4.16 Temperature rise (applies only to inductors with a mass >5 g)

The purpose of the test is to show that when the relevant temperature rise is added to the rated temperature the maximum working temperature of the internal insulation (according to the requirements of IEC 60085), or of the inductive element(s) is not exceeded.

See 4.19 of IEC 60938-1 with the following details:

4.16.1 Test method

The inductor shall be placed in a chamber maintained at an ambient temperature as close as possible to the rated temperature. The rated a.c. current or a d.c. current equal to the r.m.s. value of the rated a.c. current shall be applied.

After thermal equilibrium has been reached the internal temperature of the inductor shall be determined by evaluating the change of resistance of the inductor series resistance.

The internal temperature T_2 at thermal equilibrium shall be calculated from the measured resistance R_2 between the input and the output terminals at the temperature T_2 and its measured resistance R_1 at the test chamber temperature at the start of the test T_1 using the formula:

$$T_2 = \frac{R_2}{R_1}(235 + T_1) - (T_3 - T_1) - 235 \text{ (for copper)}$$

$$T_2 = \frac{R_2}{R_1}(225 + T_1) - (T_3 - T_1) - 225 \text{ (for aluminium)}$$

where T_3 is the temperature of the test chamber at the end of the test and T_1, T_2 and T_3 are expressed in degrees Celsius.

Where other metals are used for the inductor windings the appropriate formula shall be stated in the detail specification.

The resistance R_2 is measured either after switching off the supply, or without interruption of the supply by means of the superposition method, which consists of injecting into the winding a d.c. current of low value superposed on the load current. (The use of superposed d.c. current for the measurement of the resistances of a.c. machines is described in IEC 60279.)

NOTE As T_2 is intended to be the internal temperature when the inductor is operating in an ambient of the rated temperature T_1, the factor (T_3 – T_1) is introduced to correct for any change of temperature of the ambient temperature which may occur during the course of the test.

4.16.2 Requirements

The internal temperature T_2 shall not exceed the temperature specified in the detail specification. The detail specification may not specify a temperature higher than specified in IEC 60085 for the lowest class of insulation contained within the inductor.

4.17 Impulse voltage (applies to inductors with more than one winding)

This test is to be carried out as a sequence with the endurance test described in 4.18.2 according to clause 18 of IEC 60060-1.

Test conditions

Inductors shall be submitted to an impulse voltage test with a full 1,2/50 μs wave according to IEC 60060-1. Three pulses of the same polarity shall be applied to each inductor. The time between impulses shall not be less than 10 s. The impulses shall be applied across the same terminals as the subsequent endurance test voltage prescribed in 4.18. The crest voltage shall be 4 kV between terminations of different polarity and 5 kV between terminations and case.

4.17.1 Initial measurements

Initial measurements have been made in group 0 of annexes A and B.

4.17.2 Requirements

There shall be no permanent breakdown or flashover.

4.18 Endurance

This test shall be carried out within one week of the completion of the impulse voltage test.

See 4.20 of IEC 60938-1, with the following details:

4.18.1 Test conditions – Endurance current test

This test is not applicable to inductors of mass greater than 5 g. See table 2, notes 4, 5 and 6.

The inductors shall be mounted in the test chamber using such heat-sinking arrangements specified by the detail specification as appropriate for normal use with the inductor at the current and temperature specified in the test.

After the chamber has been stabilized at the rated temperature, the test current of 1,1 times rated current shall be passed through the inductors. The frequency of the test current shall be 50 Hz unless the detail specification specifies that the rated frequency shall be used.

NOTE A fuse or other suitable device may be connected in the circuit of each inductor to indicate if failure occurs.

After 1 000 h the inductors shall be allowed to recover for 1 h to 26 h and shall then meet the requirements of 4.18.3.

4.18.2 Test conditions – Endurance voltage test between terminations
(applies to inductors with more than one winding)

The inductors shall be submitted to an endurance test of 1 000 h at the upper category temperature. The voltage applied shall be 1,25 U_R at rated frequency, except that once every hour the voltage shall be increased to 1 000 V r.m.s. 50 Hz (or rated frequency if this is specified in the detail specification) for 0,1 s. Each of these voltages shall be applied to each inductor, individually across the terminals designed to be connected to the mains supply through a resistor of 47 Ω ± 5 %. For frequencies of test voltages above 100 Hz a resistor of lower value than 47 Ω may be prescribed by the detail specification. A suitable circuit is shown in annex C.

The test circuit should be designed so that voltage transients and current surges are avoided during switching. This may be achieved by discharging the capacitance of the inductor before switching to the new voltage provided that the total time taken to change over to 1 000 V and back does not exceed 30 s.

NOTE A fuse or other suitable device may be connected in the circuit of each inductor to indicate if failure occurs.

After 1 000 h the inductors shall be allowed to recover for 1 h to 26 h and shall then meet the requirements of 4.18.3.

4.18.3 Final inspection, measurements and requirements

The inductors shall be visually examined according to 4.1. There shall be no visible damage and any marking shall be legible.

The voltage proof test according to 4.2 shall be carried out with 66 % of the voltage as specified in table 5. There shall be no permanent breakdown or flashover.

The insulation resistance shall be measured according to 4.3.

The value shall exceed 3 000 MΩ.

The d.c. line resistance shall be measured according to 4.5.

The value shall be within the original limit prescribed in the detail specification.

4.19 Passive flammability (if applicable)

See 4.21 of IEC 60938-1.

The requirements are those given in IEC 60938-1 for the category of flammability prescribed in the detail specification.

4.20 Component solvent resistance (if applicable)

See 4.24 of IEC 60938-1.

The initial and final measurements shall be prescribed in the detail specification.

4.21 Solvent resistance of marking (if applicable)

See 4.23 of IEC 60938-1.

The requirements are as in 4.23 of IEC 60938-1.

Annex A
(normative)

Test schedule for safety tests only approval

Subclause number and test (see Note 1)	D or ND (see Note 2)	Conditions of test (see Note 1)	Number of specimens (n) and number of non-conforming items (c)	Performance requirements (see Note 1)
Group 0	ND		See tables 1 or 2	
4.1.1 Dimensions (gauging)				See detail specification
4.1 Visual examination				No visible damage Legible marking
4.5 DC line resistance				See detail specification
4.4 Inductance				Within specified tolerance
4.2 Voltage proof		See Table 3 See detail specification for the method Foil method duration: 1 min		No breakdown or flashover
4.3 Insulation resistance		See detail specification for the method		As in 4.3

Subclause number and test (see Note 1)	**D or ND** (see Note 2)	**Conditions of test** (see Note 1)	**Number of specimens (*n*) and number of non-conforming items (*c*)**	**Performance requirements** (see Note 1)
Group 1A	D		See Tables 1 or 2	
4.1.2 Dimensions (detail)				See detail specification and 4.1.2
Creepage distances and clearances		For method and severity: see detail specification		
4.6 Robustness of terminations		See detail specification for the method (1A or 1B)		No visible damage
4.7 Resistance to soldering heat (if applicable)		For method 1A: Immersion time: 10 s, unless otherwise specified in the detail specification		
4.20 Component solvent resistance (if applicable)				
4.7.2 Final measurements		DC line resistance		As in group 0
		Voltage proof at 66 % of value in table 3		No breakdown or flashover
		Visual examination		No visible damage
Group 2	D		See Tables 1 or 2	
4.15 Damp heat, steady state		Recovery: 1 h to 26 h		
4.15.1 Final measurement		Visual examination		No visible damage Legible marking
		DC line resistance		As in group 0
		Inductance	See Tables 1 or 2	Within ± 30 % of value measured in group 0
		Voltage proof Voltage: 66 % of voltage applied in group 0		No breakdown or flashover
		A polarizing voltage shall be applied if specified in the detail specification		
		Insulation resistance		≥50 % of value in 4.3

Subclause number and test (see Note 1)	**D or ND** (see Note 2)	**Conditions of test** (see Note 1)	**Number of specimens (*n*) and number of non-conforming items (*c*)**	**Performance requirements** (see Note 1)
Group 3A	D		See Tables 1 or 2 ↓	
4.16 Temperature rise (inductors with mass >5 g only)		Duration: until thermal equilibrium has been reached		
4.16.1 Test conditions		Current: rated current Ambient temperature: rated temperature		
4.16.2 Final measurements				
4.18.1 Endurance, current (inductors with mass ≤5 g only)		Internal temperature Duration: 1 000 h Current: 1,1 × rated current Recovery: 1 h to 26 h		As in 4.16.2
Group 3B (inductors with more than one winding only)	D		See Tables 1 or 2 ↓	
4.17 Impulse voltage		3 impulses, full wave Crest voltage: see 4.17.1		No breakdown or flashover
4.18.2 Endurance, voltage between line terminations		Duration: 1 000 h Voltage and temperature, see 4.18.2		
Group 3			See Tables 1 or 2 ↓	
4.18.3 Final measurements		Recovery: 1 h to 26 h	2	
		Visual examination		No visible damage Legible marking
		DC line resistance		As for group 0
		Voltage proof Voltage: 66 % of voltage applied in group 0		No breakdown or flashover
		Insulation resistance		≥50 % of values in 4.3
Group 4	D		See Tables 1 or 2 ↓	
4.19 Passive flammability (if required in the detail specification)				As in 4.19

NOTE 1 Subclause numbers of test and performance requirements refer to Clause 4 .

NOTE 2 In this table, D = destructive, ND = non-destructive.

Annex B
(normative)

Test schedule for safety tests and performance tests for qualification approval, assessment level D

Subclause number and test (see Note 1)	D or ND (see Note 2)	Conditions of test (see Note 1)	Number of specimens (n) and number of non-conforming items (c)	Performance requirements (see Note 1)
Group 0	ND		See Tables 1 or 2	
4.1.1 Dimensions (gauging)				See detail specification
4.1 Visual examination				No visible damage Legible marking
4.5 DC line resistance				See detail specification
4.4 Inductance				Within specified tolerance
4.2 Voltage proof		See table 3 See detail specification for the method Foil method duration: 1 min		No breakdown or flashover
4.3 Insulation resistance		See detail specification for the method		As in 4.3
Group 1A	D		See Tables 1 or 2	
4.1.2 Dimensions (detail)				See detail specification and 4.1.2
4.6 Robustness of terminations		For method and severity: see detail specification		No visible damage
4.7 Resistance to soldering heat (if applicable)		See detail specification for the method (1A or 1B) For method 1A: Immersion time: 10 s, unless otherwise specified in the detail specification		
4.20 Component solvent resistance (if applicable)				
4.7.2 Final measurements		Visual examination		No visible damage
		DC line resistance		As in group 0

Subclause number and test (see Note 1)	D or ND (see Note 2)	Conditions of test (see Note 1)	Number of specimens (*n*) and number of non-conforming items (*c*)	Performance requirements (see Note 1)
Group 1B			See Tables 1 or 2	
4.8 Solderability (if applicable)		See detail specification for the method		Good tinning as evidenced by free flowing of the solder with wetting of the terminations, or solder shall flow within 3 s, as applicable
4.21 Solvent resistance of the marking (if applicable)				
4.9 Rapid change of temperature		θ_A = Lower category temperature θ_B = Upper category temperature Five cycles Duration *t* =... h, see 4.9.1		
		Visual examination		No visible damage
4.10 Vibration		For mounting method see detail specification Frequency range: from... Hz to... Hz		
		Total number of sweep cycles:...		
		Visual examination		No visible damage
4.10.2 Intermediate inspection				
4.11 Bump, (or shock, see 4.12)		For mounting method see detail specification Number of bumps:... Acceleration:... m/s^2 Duration of pulse:... ms		
		Visual examination		No visible damage
4.12 Shock, (or bump, see 4.11)		For mounting method see detail specification Acceleration:... m/s^2 Duration of pulse:... ms		
4.11.2 or 4.12.3 Final measurements		Visual examination		No visible damage
		DC line resistance		As in group 0

Subclause number and test (see Note 1)	**D or ND** (see Note 2)	**Conditions of test** (see Note 1)	**Number of specimens (*n*) and number of non-conforming items (*c*)**	**Performance requirements** (see Note 1)
Group 1	D		See Tables 1 or 2	
4.13 Container sealing (if required in the detail specification)		Test Qc or Qd as prescribed in the detail specification		No leakage
4.14 Climatic sequence				
4.14.2 Dry heat		Temperature: upper category temperature Duration: 16 h		
4.14.3 Damp heat, cyclic, test Db, first cycle				
4.14.4 Cold		Temperature: lower category temperature Duration: 2 h		
4.14.5 Low air pressure (if required in the detail specification)		Air pressure 8,0 kPa unless otherwise stated in the detail specification Duration: 1 h		
		Visual examination		No permanent breakdown, flashover, harmful deformation of the case
4.14.6 Damp heat, cyclic, test Db, remaining cycles		Recovery: 1 h to 26 h		
4.14.7 Final measurement		Visual examination		No visible damage Legible marking
		DC line resistance		As in group 0
		Inductance		Within ± 30 % of value measured in group 0
		Voltage proof Voltage: 66 % of voltage applied in group 0		No breakdown or flashover
		Insulation resistance		≥50 % of values in 4.3

Subclause number and test (see Note 1)	D or ND (see Note 2)	Conditions of test (see Note 1)	Number of specimens (*n*) and number of non-conforming items (*c*)	Performance requirements (see Note 1)
Group 2	D		See Tables 1 or 2	
4.15 Damp heat, steady state		Recovery: 1 h to 26 h		
4.15.1 Final measurements		Visual examination		No visible damage Legible marking
		DC line resistance		As in group 0
		Inductance		Within +/- 30 % of value measured in group 0
		Voltage proof Voltage: 66 % of voltage applied in group 0 A polarizing voltage shall be applied if specified in the detail specification		No breakdown or flashover
		Insulation resistance		≥50 % of value in 4.3
Group 3A	D		See Tables 1 or 2	
4.16 Temperature rise (inductors with mass >5 g only)		Duration: until thermal equilibrium has been reached		
			See Tables 1 or 2	
4.16.1 Test conditions		Current: rated current Ambient temperature: rated temperature		
4.16.2 Final measurements		Internal temperature		As in 4.16.2
4.18.1 Endurance, current (inductors with mass ≤5 g only)		Duration: 1 000 h Current: 1,1 × rated current Recovery: 1 h to 26 h		
Group 3B (inductors with more than one winding only)	D		See Tables 1 or 2	
4.17 Impulse voltage		3 impulses, full wave Crest voltage: see 4.17.1		No breakdown or flashover
4.18.2 Endurance, voltage between line terminations		Duration: 1 000 h Voltage and temperature, see 4.18.2		

Subclause number and test (see Note 1)	**D or ND** (see Note 2)	**Conditions of test** (see Note 1)	**Number of specimens (*n*) and number of non-conforming items (*c*)**	**Performance requirements** (see Note 1)
Group 3			See Tables 1 or 2	
4.18.3 Final measurements		Recovery: 1 h to 26 h		
		Visual examination		No visible damage Legible marking
		DC line resistance		As for group 0
		Voltage proof Voltage: 66 % of voltage applied in group 0		No breakdown or flashover
		Insulation resistance		See 4.18.3
		Inductance		Within +/- 30 % of value measured in group 0
Group 4	D		See Tables 1 or 2	
4.19 Passive flammability (if required in the detail specification)				As in 4.19

NOTE 1 Subclause numbers of test and performance requirements refer to Clause 4.

NOTE 2 In this table, D = destructive, ND = non-destructive.

Annex C
(normative)

Example of a suitable circuit for the endurance test voltage

The test prescribed in 4.18.2 may be carried out with the following circuit:

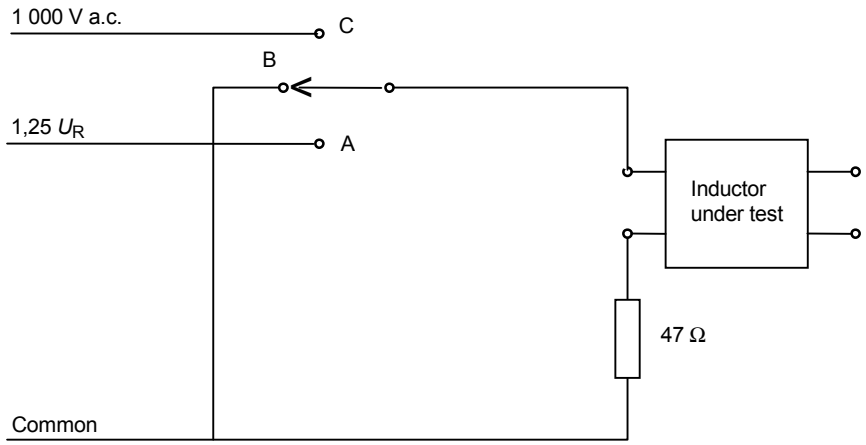


Figure C.1 – Endurance test circuit

The part of the circuit for discharging the inductor may be omitted if the switching between the two supplies is arranged to take place at the zero voltage point on the sinusoidal wave.

When the discharging circuit is used the switching shall be arranged in the following sequence for each occasion when the 1 000 V is applied.

1) Switch from position A to position B. Time for switching and remaining on position B is t_1.
2) Switch from position B to position C. Time for switching and remaining on position C is t_2. Time on position C is 0,1 s.
3) Switch from position C to position B. Time for switching and remaining on position B is t_3.
4) Switch from position B to position A. Time for switching is t_4.

For any inductor under test the following condition must be fulfilled:

$t_1 + t_2 + t_3 + t_4 < 30$ s.

Annex D
(normative)

Declaration of design
(confidential to the manufacturer and the certification body)

The purpose of this description is to register essential data and the basic design of the inductors for which approval is sought. The completed form shall be submitted to the relevant certification body prior to any approval testings; its circulation to the other parties is left to the decision of the manufacturer.

Changes of the declared design are permitted only after notifying the certification body in writing.

In this case, the certification body will decide on necessary steps to be taken. As a maximum, a complete re-qualification may be required.

Registration number: (to be allocated by the certification body)

1 Applicant:

2 Manufacturer:

3 Manufacturing site:

4 Type designation:

5 Circuit diagram:

6 Identification of materials

6.1 Encapsulation (if applicable)

6.2 Insulation sleeve (if applicable)

6.3 Core

6.4 Wire

6.5 Others

7 Constructional details:

_____ _____

Location Date Signature

Annex E
(normative)

Test methods for thyristor electromagnetic interference suppression inductors

E.1 Inductance

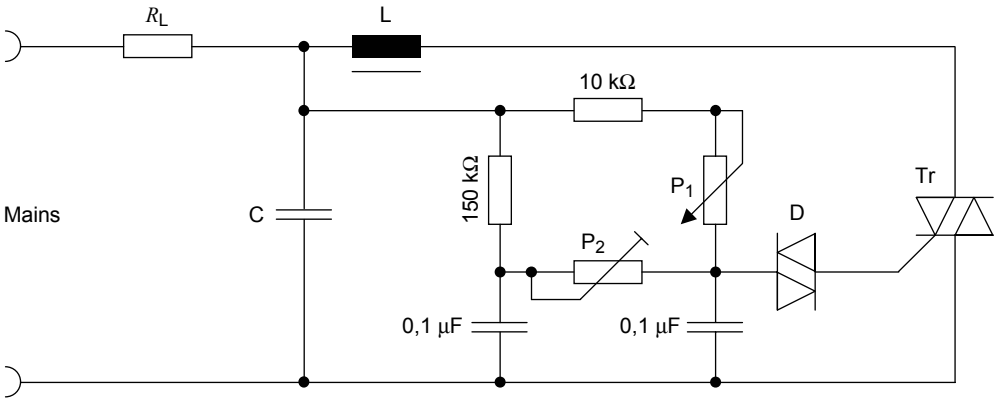
The inductance of thyristor electromagnetic interference suppression inductors shall be measured at a frequency of 100 kHz ± 20 kHz, unless otherwise specified in the detail specification.

E.2 Temperature rise

The temperature rise of thyristor electromagnetic interference suppression inductors shall be measured under the following conditions, using the phase control circuit of Figure E.1.

a) At a gating angle of 0° (thyristor short circuit), adjust R_L to achieve the rated current.

b) Adjust the gating angle until the highest temperature rise is reached.



Key

R_L rated load (ohm resistive load)

L thyristor electromagnetic interference suppression inductor (DUT)

C interference suppression capacitor

D bidirectional trigger diode (ignition-voltage approx, 32 V)

Tr bi-polar thyristor (triac)

P_1 500 kΩ potentiometer for setting the gating angle

P_2 100 kΩ variable resistor for adjusting the smallest angle

Figure E.1 – Test circuit for temperature rise

E.3 Voltage attenuation

E.3.1 Definition of the interference voltage attenuation a_{ws}

The effective interference voltage attenuation a_{ws} is the attenuation of the thyristor electromagnetic interference suppression inductor together with one capacitor for interference suppression inserted in a defined phase controlled modulator circuit.

E.3.2 Measurement of a_{ws}

The effective interference voltage attenuation a_{ws} shall be measured as the ratio (in dB) between the interference voltage U_{st} with and without EMI suppression components L and C, using the test circuit of Figure E. 2 and a quasi-peak measuring receiver according to CISPR 16-1-1:2003.

a) At a gating angle of 0° (thyristor short circuit) and with L replaced by a short circuit and C by an open circuit, adjust R_L to achieve the rated current.

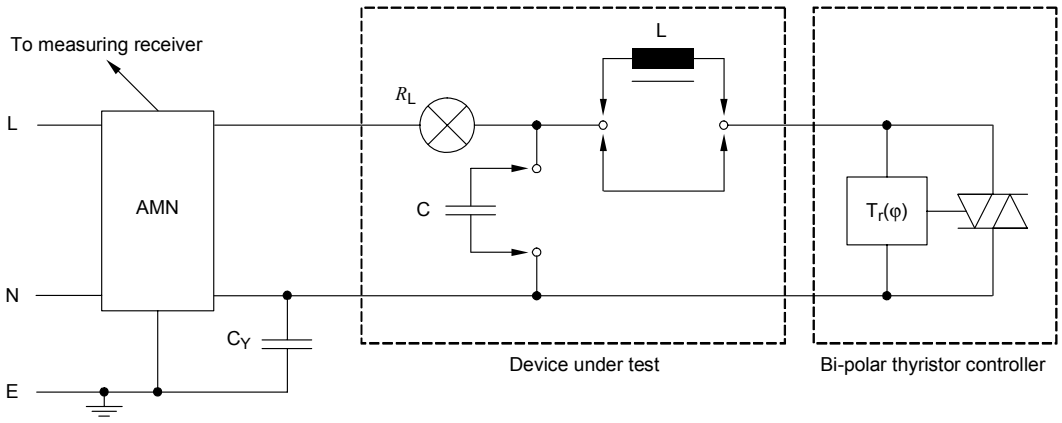
b) At a measurement frequency of 160 kHz, adjust the gating angle until the highest disturbance voltage (U_{st1}) is achieved.

c) Insert the inductor under test (L) and the capacitor (C). Record the value selected for C.

d) Without changing the gating angle or measurement frequency, measure the disturbance voltage (U_{st2}), and calculate a_{ws} (= 20*log10(U_{st1}/U_{st2}) dB)

NOTE 1 The capacitor (C) will normally be in the range 0,1 µF to 0,22 µF.

NOTE 2 If, in place of the bi-polar thyristor (triac), a unipolar thyristor is used, different values are obtained. This special case should be indicated. In worst cases, the test results are dependent on the thyristor characteristic; in critical cases, the manufacturer should indicate the quenching time and the maximum permitted return current.



Key

L	thyristor electromagnetic interference suppression inductor
C	interference suppression capacitor
AMN	artificial V-mains network 50 Ω / 50 µH + 5 Ω (if not otherwise specified) according to IEC/CISPR 16-1-2: 2003
T_r (φ)	phase controlled modulator
R_L	rated load (resistive, for example, a light bulb)
C_Y	capacitor(s) ≥ 0,22 µF of capacitor class Y according to IEC 60384-14

Caution: High leakage current! Ensure that the circuit is properly earthed before power is applied.

Figure E. 2 – Test circuit for interference voltage attenuation

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