BS EN 62674-1:2012

BSI Standards Publication

High Frequency Inductive Components — Fixed surface mount inductors for use in electronic and telecommunication equipment

National foreword

This British Standard is the UK implementation of EN 62674-1:2012. It is identical to IEC 62674-1:2012.

The UK participation in its preparation was entrusted to Technical Committee EPL/51, Transformers, inductors, magnetic components and ferrite materials.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English version

High frequency inductive components - Part 1: Fixed surface mount inductors for use in electronic and telecommunication equipment (IEC 62674-1:2012)

Composants inductifs à haute fréquence - Partie 1: Inductances fixes pour montage en surface utilisées dans les matériels électroniques et les équipements de télécommunications (CEI 62674-1:2012)

Induktive Hochfrequenzbauelemente - Teil 1: Oberflächenmontierbare Festinduktivität für den Einsatz in Elektronik und Telekommunikationsgeräten (IEC 62674-1:2012)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 51/1006/FDIS, future edition 1 of IEC 62674-1, prepared by IEC TC 51, "Magnetic components and ferrite materials" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62674-1:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-08-16
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-11-16

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The text of the International Standard IEC 62674-1:2012 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-1 + corr. October	1988 1988	Environmental testing - Part 1: General and guidance	EN 60068-1 [1)]	1994
IEC 60068-2-1	2007	Environmental testing - Part 2-1: Tests - Test A: Cold	EN 60068-2-1	2007
IEC 60068-2-2	2007	Environmental testing - Part 2-2: Tests - Test B: Dry heat	EN 60068-2-2	2007
IEC 60068-2-14	2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	2009
IEC 60068-2-45	-	Environmental testing - Part 2: Tests - Test Xa and guidance: Immersion in cleaning solvents	EN 60068-2-45	-
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)	EN 60068-2-58 + corr. December	2004 2004
IEC 60068-2-78	-	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	-
IEC 61605	2005	Fixed inductors for use in electronic and telecommunication equipment - Marking codes	EN 61605	2005
IEC 62024-1 + corr. July	2008 2008	High frequency inductive components - Electrical characteristics and measuring methods - Part 1: Nanohenry range chip inductor	EN 62024-1	2008
IEC 62024-2	2008	High frequency inductive components - Electrical characteristics and measuring methods - Part 2: Rated current of inductors for DC to DC converters	EN 62024-2	2009
IEC 62025-2	2005	High frequency inductive components - Non-electrical characteristics and measuring methods - Part 2: Test methods for non-electrical characteristics	EN 62025-2	2005
IEC 62211	2003	Inductive components - Reliability management	EN 62211	2004
ISO 3	-	Preferred numbers - Series of preferred numbers	-	-

[1)] EN 60068-1 includes A1 to IEC 60068-1+ corr. October .

Publication	Year	Title	EN/HD	Year
ISO 3599	-	Vernier callipers reading to 0,1 and 0,05 mm	-	-
ISO 3611	-	Geometrical product specifications (GPS) - Dimensional measuring equipment: Micrometers for external measurements - Design and metrological characteristics	EN ISO 3611	-
ISO 6906	-	Vernier callipers reading to 0,02 mm	-	-

CONTENTS

HIGH FREQUENCY INDUCTIVE COMPONENTS –

Part 1: Fixed surface mount inductors for use in electronic and telecommunication equipment

1 Scope

This part of IEC 62674 applies to fixed surface mount inductors and ferrite beads.

The object of this standard is to define the terms necessary to describe the inductors covered by this standard, provide recommendations for preferred characteristics, recommended performance, test methods and general guidance.

2 Normative references

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

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

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

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

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

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

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

IEC 61605:2005, *Fixed inductors for use in electronic and telecommunication equipment – Marking codes*

IEC 62024-1:2008, *High frequency inductive components – Electrical characteristics and measuring methods – Part 1: Nanohenry range chip inductor*

IEC 62024-2:2008, *High frequency inductive components – Electrical characteristics and measuring methods – Part 2: Rated current of inductors for DC to DC converters*

IEC 62025-2:2005, *High frequency inductive components – Non-electrical characteristics and measuring methods – Part 2: Test methods for non-electrical characteristics*

IEC 62211:2003, *Inductive components – Reliability management*

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

ISO 3599, *Vernier callipers reading to 0,1 and 0,05 mm*

ISO 3611, *Geometrical product specifications (GPS) – Dimensional measuring equipment: Micrometers for external measurements – Design and metrological characteristics*

ISO 6906, *Vernier callipers reading to 0,02 mm*

3 Terms and definitions

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

3.1
rated current
maximum current which may be loaded continuously by inductors at the rated temperature

Note 1 to entry: A DC saturation limited current value or a temperature rise limited current value, whichever is less, has been adopted as the rated current (see IEC 62024-2:2008, Clause 7).

3.2
operating temperature range
category temperature range
range of ambient temperatures for which the inductor has been designed to operate continuously

Note 1 to entry: Unless otherwise specified in the detail specification, the operating temperature is ambient temperature plus temperature rise of components.

4 Designation

It is recommended to express the designation of the fixed surface mount inductors by the following 12 digits format. In the case of another format, designation shall be specified in the detail specifications.

The designation of ferrite beads shall be specified in the detail specifications.

□□□	□□□□	□	□□□	□
a)	b)	c)	d)	e)

a) Identification of the type of inductor

Fixed surface mount inductors shall be identified by the three alphabetic characters ‘LCL’.

b) Indication of outline dimensions

The outline dimensions of the surface mount inductor shall be indicated by a four-digit number based on two significant figures for each dimension of L and W (or H). As for the dimensions of shape D, the first two digits indicate the longer side dimension L, and the last two digits indicate the shorter side dimension W, as shown in Figure 1. As for the dimensions of shape K, the first two digits indicate the outline dimension L, and the last two digits indicate the height dimension H.

c) Indication of shape

A single alphabetic character as given in Figure 1 indicates the shape for fixed surface mount inductors.

The shape codes are classified by the base shape of inductors.

D: rectangular

K: square

d) Indication of nominal inductance

Three alphanumeric characters specified in IEC 61605:2005, Clause 4, indicate the nominal inductance value (see Table 1).

Table 1 – Letter code for inductance value

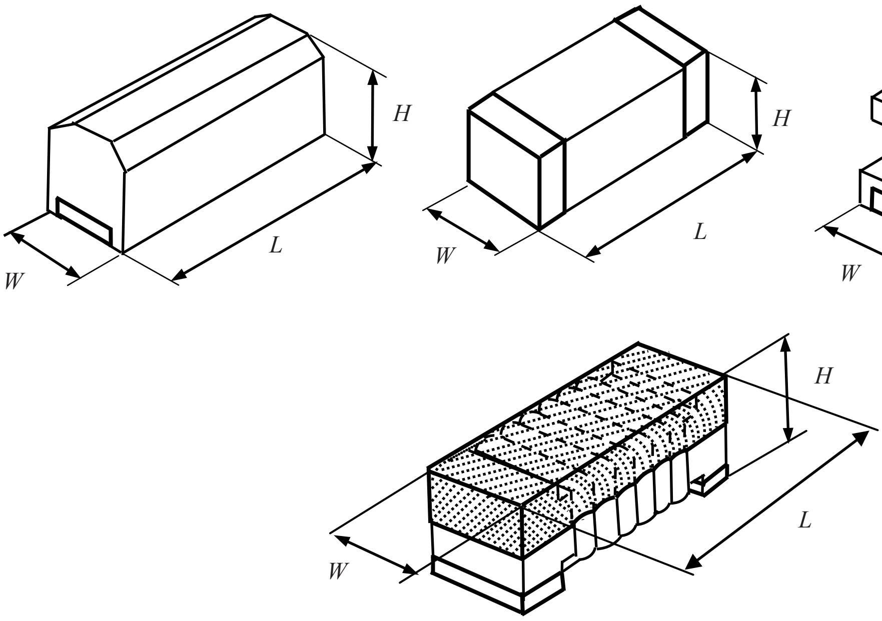
Inductance values	Digit and letter code
0,1 nH 0,47 nH	N10 N47
1 nH 4,7 nH	1N0 4N7
10 nH 47 nH	10N 47N
0,1 µH 0,47 µH	R10 R47
1 µH 4,7 µH	1R0 4R7
10 µH 47 µH	100 470
100 µH 470 µH	101 471
1 mH 4,7 mH	102 472
10 mH 47 mH	103 473
100 mH 470 mH	104 474
1 H 4,7 H	105 475
10 H 47 H	106 476

e) Indication of tolerance for inductance

Single alphabetic characters specified in Table 8 indicate the tolerance for the inductance value.

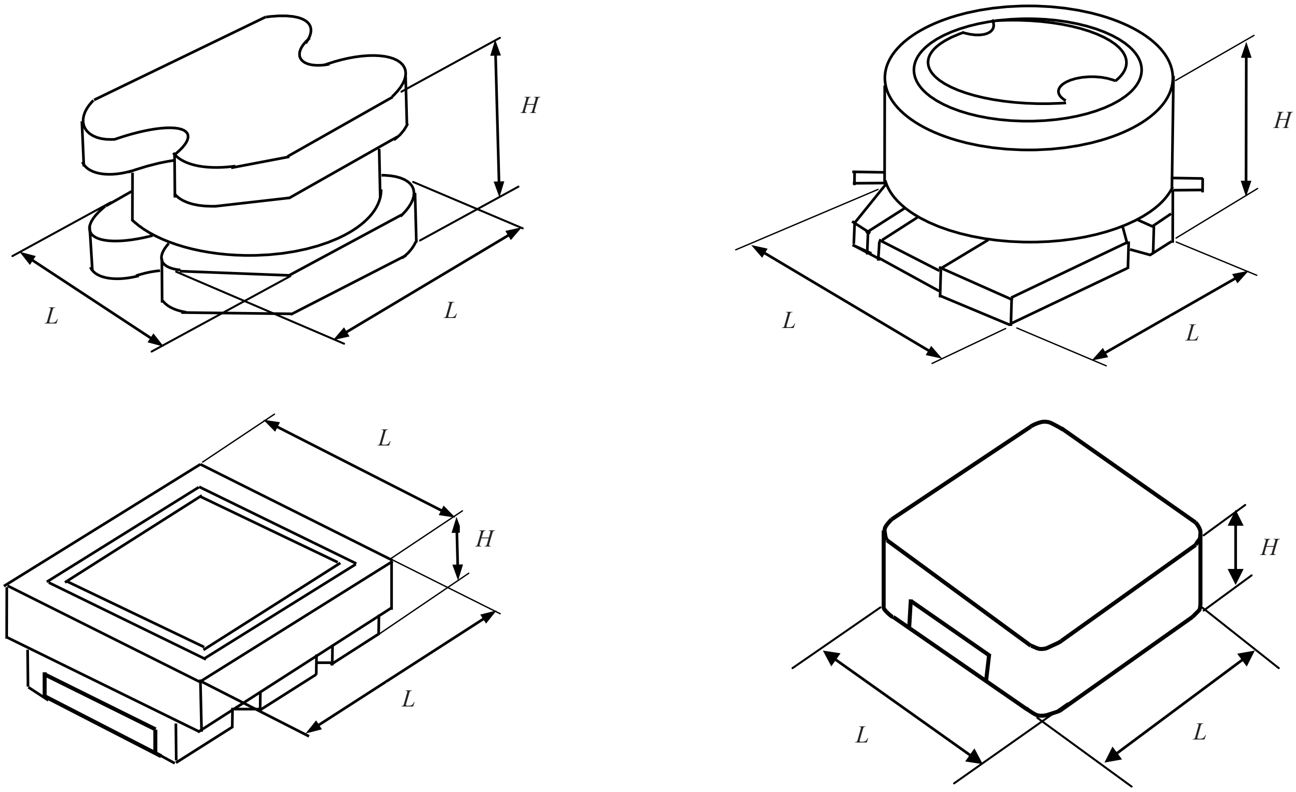
5 Shape

The shapes of fixed surface mount inductors and ferrite beads are classified as shown in Figure 1.



IEC 1855/12

Shape D



Shape K

IEC 1856/12

Figure 1 – Shapes of inductor and ferrite beads (examples)

6 Dimensions

6.1 Shape D

For the dimensions for shape D, see a) and b).

a) Outline dimensions *L* (long side) and *W* (short side) of shape D shall be chosen from the values marked with x in Table 2. These values have been selected from the R 20 series of ISO 3:1973, but the values 0,315, 0,56 and 3,15 have been rounded off to 0,3, 0,6 and 3,2 respectively. 1,25 may be rounded off to 1,2.

b) Dimensions of height greater than 1,00 mm shall be chosen from Table 3. These values are taken from the R 20 series of ISO 3:1973 where, however, the values 1,12, 2,24, 3,15 and 3,55 have been rounded off to 1,1, 1,2, 3,2 and 3,6 respectively. 1,25 may be rounded off to 1,2. Dimensions of height, less than 1,00 mm, shall be selected from Table 4.

Table 2 – Dimensions for shape D

L (long side) mm	*W* (short side) mm																
	0,2	0,3	0,4	0,5	0,8	1,0	1,25 (1,2)	1,6	1,8	2,0	2,5	3,2	4,0	5,0	5,6	6,3	7,1
0,4	X																
0,6		X															
0,8			X														
1,0				X													
1,2						X											
1,6					X	X											
2,0						X	X	X									
2,5									X	X							
3,2								X	X		X						
4,0																	
4,5								X			X	X					
5,0													X				
5,6														X			
6,3															X		
7,1																X	
8,0																	X

Table 3 – Dimensions of height for shape D (R 20 series)

Dimensions in millimetres

1,0	1,1	1,25 (1,2)	1,4	1,6	1,8	2,0	2,2	2,5	2,8	3,2
3,6	4,0	4,5	5,0	5,6	6,3	7,1	8,0	9,0	10,0	

Table 4 – Dimensions of height for shape D less than 1,00 mm

0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,85	0,9

6.2 Shape K

Outline dimensions L and H of shape K shall be chosen from the values marked with x in Table 5.These values are based on the R 20 series of ISO 3:1973.

Table 5 – Dimensions for shape K

L (length) mm	***H*** (height) mm																			
	0,6	0,8	0,9	1,0	1,1	1,2	1,4	1,6	1,8	2,0	2,2	2,5	3,2	4,0	4,5	5,0	6,3	7,1	8,0	9,0
2,5	X	X		X					X											
2,8	X	X	X	X	X															
3,2				X		X	X	X												
3,6										X										
4,0				X		X	X	X	X	X		X								
4,5													X							
5,0							X			X	X			X	X					
5,6									X							X				
6,3																	X			
7,1																		X		
8,0														X					X	
9,0																				X
10,0														X		X				
12,0																X				

6.3 Tolerance for outline dimensions

Tolerance for outline dimension and height shall be selected from Table 6.

Table 6 – Tolerance for outline dimension and height

Outline dimensions (X) mm	**Tolerances** mm	
	Standard	**Maximum**
× ≤ 0,6	± 0,05	± 0,10
0,6 < × ≤ 1,0	± 0,10	± 0,20
1,0 < × ≤ 1,6	± 0,15	± 0,30
1,6 < × ≤ 2,5	± 0,20	± 0,40
2,5 < × ≤ 4,0	± 0,30	± 0,60
4,0 < × ≤ 8,0	± 0,40	± 0,80
8,0 < × ≤ 10,0	± 0,50	± 1,00

7 Ratings and characteristics

7.1 Nominal inductance or impedance

The preferred values of nominal inductance or impedance shall be selected from the numeric values of the E 24 series in Table 7 and their decimal multiples or submultiples.

The detail specification sheet should clearly note whether the value given is inductance or impedance, as well as the units and measuring frequency. The choice of specifying either inductance or impedance depends on the intended application for the inductor.

Table 7 – E 24 series for nominal inductance or impedance

1,0	1,1	1,2	1,3	1,5	1,6	1,8	2,0	2,2	2,4	2,7	3,0
3,3	3,6	3,9	4,3	4,7	5,1	5,6	6,2	6,8	7,5	8,2	9,1

7.2 Tolerance for nominal inductance or impedance

The tolerance for nominal inductance or impedance shall be selected from Table 8 which includes the tolerances specified in IEC 61605:2005, 5.1.

Table 8 – Tolerance for nominal inductance or impedance

Tolerance	± 0,05 nH	± 0,1 nH	± 0,2 nH	± 0,3 nH	± 0,5 nH	± 1 %	± 2 %	± 3 %	± 5 %	± 10 %	± 15 %	± 20 %	± 25 %	± 30 %
Letter code	W	B	C	S	D	F	G	H	J	K	L	M	-	N

NOTE 1 nH should be applied to inductance only.

NOTE 2 ± 25 % should be applied to impedance only.

7.3 Operating temperature range

The operating temperature range shall be selected from a lower temperature and an upper temperature in Table 9. Examples of the application and operating temperature range (user reference) are shown in Table 10.

Table 9 – Temperatures to be selected for operating temperature ranges

Lower temperature °C	**Upper temperature** °C
– 55	+ 155
– 40	+ 150
– 25	+ 125
– 10	+ 105
	+ 100
	+ 85
	+ 70
	+ 40

NOTE Unless otherwise specified in the detail specification, the operating temperature is the ambient temperature plus the temperature rise of components.

Table 10 – User reference / Examples of application and operating temperature range

Category applies	Temperature range °C	Standard identification
Automobile and aerospace	–55 to +155	MIL-PRF-27, Class V
	–55 to +150	IEC 62211:2003, Level S
	–55 to +125	-
	–40 to +150	-
	–40 to +125	AEC Q200,Grade 1
		IEC 62211:2003,Level A
Telecommunication and power supply	–55 to +105	MIL-PRF-27, Class R
	–55 to +85	MIL-PRF-27, Class Q
	–40 to +125	IEC 62211:2003, Level B
	–40 to +105	AEC Q200, Grade 2
		IEC 62211:2003, Level B
	–40 to +85	AEC Q200, Grade 3
		IEC 62211:2003, Level B
Consumer and commercial electronics	–40 to +85	IEC 62211:2003, Level C
		AEC Q200, Grade 3
	–25 to +105	-
	–25 to +100	-
	–25 to +85	-
	–25 to +70	IEC 62211:2003, Level D
	0 to +70	AEC Q200, Grade 4
NOTE AEC Q200 and IEC 62211:2003 are component-level reliability specifications. A distinction exists between component-level and system-level specifications.		

8 Marking

The selection of type(s) of marking information is subject to agreement between supplier and user. In lieu of such an agreement, the marking information should be as published in the supplier's data sheet. One or more of the following types of marking information is recommended on the body or the packaging:

a) user part number;
b) serial number, lot code or date code;
c) characteristics as specified in IEC 61605:2005;
d) supplier part number and logo or mark;
e) quantity (packaging only).

9 Direction marking or shape of polarity

For the purpose of indicating the winding start location, or the first pin number, or first electrode, or winding orientation, either a mark or a shape should be used. A shape inductor is a corner cut, or small circle indent, or other molded feature, or terminal shape that indicates polarity on the inductor (if such an indication is necessary).

10 Tests and performance requirements

10.1 Standard atmospheric conditions for testing

10.1.1 Standard atmospheric conditions for measurements and tests

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions as given in IEC 60068-1:1988, 5.3.1:

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

In the event of a dispute, or if required, the measurements shall be repeated using one of the referee conditions as given in 10.1.2.

If it is difficult to carry out the measurement under the standard conditions, the tests and measurements may be carried out under conditions other than the standard ones if there is no dispute for referee.

10.1.2 Referee condition

The referee condition shall be one of the standard atmospheres for referee measurements and tests taken from IEC 60068-1:1988, 5.2, below:

– temperature: 18 °C to 22 °C;
– relative humidity: 60 % to 70 %;
– air pressure: 86 kPa to 106 kPa.

10.2 Visual examination and check of dimensions

10.2.1 Visual examination

10.2.1.1 Test methods

The inductors shall be visually examined.

If required, a visual examination may be carried out with suitable equipment with appropriate magnification agreed upon between manufacturer and user.

10.2.1.2 Requirements

There shall be no visible damage and, if applicable, the marking shall be legible.

10.2.2 Dimensions

10.2.2.1 Test methods

The test for dimensions shall be carried out using the vernier callipers of Class 2 or of a higher class, specified in ISO 3599 or ISO 6906, or the micrometer callipers for external measurement specified in ISO 3611.

However, other measuring instruments may be used, unless doubt arises for referee.

10.2.2.2 Requirements

The dimensions shall meet the requirements of 6.3 or the requirements specified in the detail specification.

10.3 Electrical performance tests

10.3.1 Inductance

10.3.1.1 Measuring methods

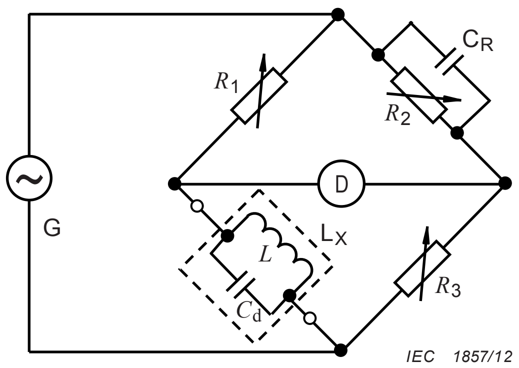
For inductors with 1 μH or more, the inductance shall be measured by the bridge method (10.3.1.1.1), the vector voltage/current method (10.3.1.1.2) or the automatic balancing bridge method (10.3.1.1.3). For inductors less than 1 μH, the inductance shall be measured by the vector voltage/current method prescribed in IEC 62024-1:2008, 3.1.

10.3.1.1.1 Bridge method

The bridge method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 2.



Key
Components

G	Signal generator
D	Detector
C_R	Standard capacitor
L_X	Inductor under test
L	Inductance of inductor under test
C_d	Distributed capacitance of inductor under test
R_1, R_2, R_3	Variable resistors

Figure 2 – Example of circuit for measurement by the bridge method

b) Measuring method and calculation formula

Using the circuit given in Figure 2, the frequency and output of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test shall be connected and R_1, R_2 and R_3 shall be adjusted so that the indication of the detector may become the minimum, and the resistances of R_1 and R_3 shall be read and the inductance L shall be calculated from the following formula:

$$L = C_R \times R_1 \times R_3$$

where

L is the inductance of the inductor under test;

C_R is the capacitance of the standard capacitor;

R_1, R_3 is the resistance of the variable resistors.

c) Precaution for measurement

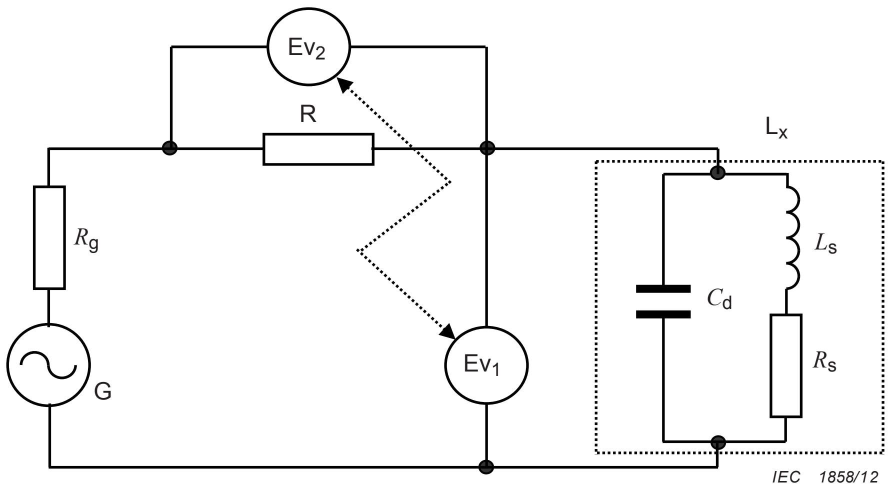
The specified value of the measuring frequency shall be selected in such a way, to minimize errors in the measurement, so that the reactance in the distributed capacitance of the inductor under test becomes large enough as compared with the reactance in the inductance of inductor under test.

10.3.1.1.2 Vector voltage/current method

The vector voltage/current method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 3.



Key

Components

R_g	Source resistance of signal generator (50 Ω)
R	Resistor
L_X	Inductor under test
L_s	Series inductance of inductor under test
C_d	Distributed capacitance of inductor under test
R_s	Series resistance of inductor under test
·······►	Phase reference signal
Ev_1, Ev_2	Vector voltmeter
G	Signal generator

Figure 3 – Example of circuit for measurement by the vector voltage/current method

b) Measuring method and calculation formula

Using the circuit given in Figure 3, the frequency and output of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test shall be connected and E_1 and E_2 shall be measured by the vector voltmeter and the inductance L shall be calculated from the following formula:

$$L = \frac{\text{Im}\left[R \times \frac{E_1}{E_2}\right]}{2\pi f}$$

where

L is the inductance of inductor under test;

Im is the imaginary part of the complex value;

R is the resistance of the resistor;

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2;

f is the frequency of signal generator.

c) Precaution for measurement

If required, open-short compensation shall be performed prior to measurements.

10.3.1.1.3 Automatic balancing bridge method

The automatic balancing bridge method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 4.

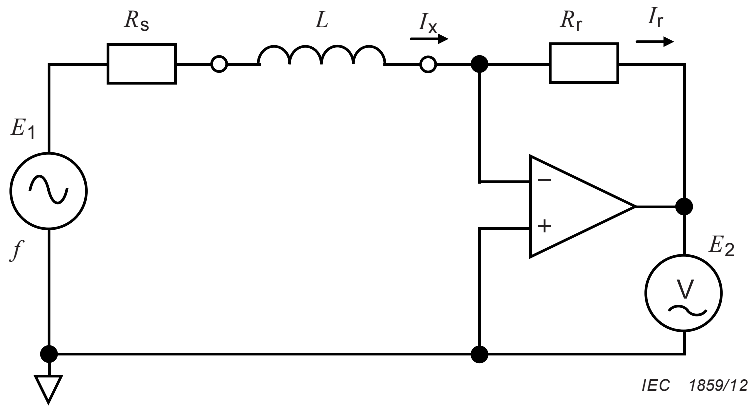


Figure 4 – Example of a circuit for measurement by the automatic balancing bridge method

b) Measuring method and calculation formula

Using the circuit given in Figure 4, the frequency f and output voltage E_1 of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test shall be connected and E_2 shall be measured by the vector voltmeter and the inductance L shall be calculated from the following formula:

$$Z_x = \frac{E_1}{I_x} = \frac{-E_1 R_x}{E_2}$$

$$Z_x = \frac{|E_1|}{|E_2|\angle -\theta} R_x = R_x + jX_x$$

$$L = \frac{X_x}{2\pi f}$$

where

Z_x is the impedance of inductor under test;

R_x is the real part of impedance;

X_x is the imaginary part of impedance;

R_s is the resistance of resistor R_s;

R_r is the resistance of resistor R_r;

θ is the phase angle.

c) Precaution for measurement

If required, open-short compensation shall be performed prior to measurements.

10.3.1.2 Requirements

The inductance shall meet the requirements of 7.1 and 7.2, or the requirements specified in the detail specification.

10.3.2 Q

10.3.2.1 Test methods

10.3.2.1.1 General

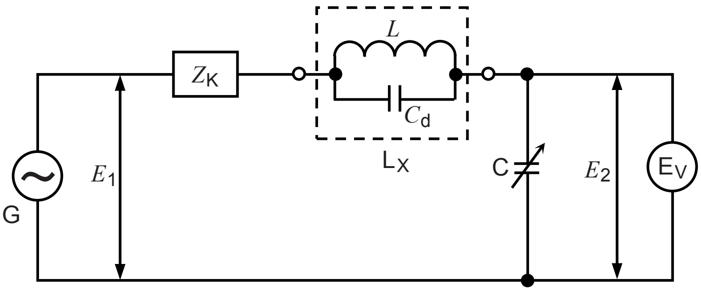
For inductors with 1 μH or more, Q shall be measured by the series resonance method (10.3.2.1.2), the parallel resonance method (10.3.2.1.3) or the automatic balancing bridge method (10.3.2.1.5). For inductors less than 1 μH, Q shall be measured by the vector voltage/current method (10.3.2.1.4) as prescribed in IEC 62024-1:2008, 3.2.

10.3.2.1.2 Series resonance method

The series resonance method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 5.



Key

Components

G	Signal generator
Z_K	Coupling impedance
C	Variable capacitor
L_X	Inductor under test
L	Inductance of inductor under test
C_d	Distributed capacitance of inductor under test
E_V	Electronic voltmeter

Figure 5 – Example of circuit for measurement by the series resonance method

b) Measuring method and calculation formula

Using the circuit given in Figure 5, the frequency and output of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test shall be connected and the variable capacitor shall be adjusted so that the voltage E_2 may become a maximum, and then the voltage E_2 shall be read and Q shall be calculated from one of the following formulas:

1) $$Q = \frac{E_2}{E_1}\left(1 + \frac{C_d}{C}\right)$$

2) $$Q = \frac{E_2}{E_1}$$ to be used when there is no doubt even if C_d is ignored.

where,

E_1 is the output voltage of signal generator;

E_2 is the indicated value of electronic voltmeter Ev;

C is the capacitance of variable capacitor;

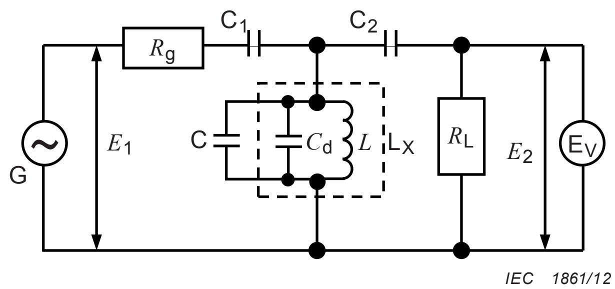
C_d is the distributed capacitance of inductor under test.

10.3.2.1.3 Parallel resonance method

The parallel resonance method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 6.



Key

Components

G	Signal generator
R_g	Source resistance of signal generator (50 Ω)
C_1, C_2	Coupling capacitors
C	Tuning capacitor
L_X	Inductor under test
L	Inductance of inductor under test
C_d	Distributed capacitance of inductor under test
E_V	Electronic voltmeter
R_L	Input resistor of electronic voltmeter

NOTE A suitably calibrated network analyser may be used in place of the signal generator and RF voltmeter.

Figure 6 – Example of a circuit for measurement by the parallel resonance method

b) Measuring method and calculation formula

Using the circuit given in Figure 6, the frequency and output of the signal generator shall be adjusted to the respective values specified in the detail specification.

The variable capacitor shall be adjusted so that the voltage E_2 may become a maximum. At that time, fine-tuning may be performed by tuning ~~of~~ the frequency of the signal generator.

Then f_1 and f_2, where E_2 is 3 dB less than $E_{2\ max}$ (see Figure 7), shall be read and Q shall be calculated from the following formula:

$$Q = \frac{f_1 + f_2}{2\left|f_1 - f_2\right|}$$

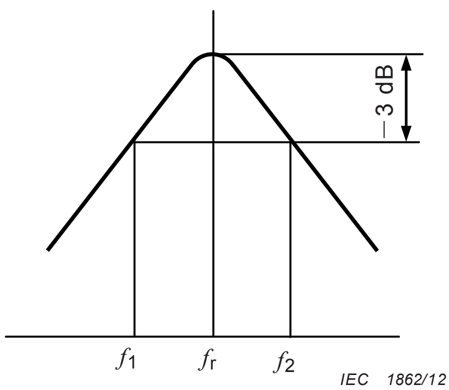


Figure 7 – Tuning characteristics of inductor

c) Precaution for measurement

The precautions for measurements are as follows:

1) The capacitance of coupling capacitors C_1 and C_2 shall be small enough as compared to the capacitance of the tuning capacitor C;
2) The output voltage E_1 of the signal generator shall be a value within the range where the inductor under test is not saturated, and where the value of E_2 also rises by 3 dB when the output voltage is raised by 3 dB.

10.3.2.1.4 Vector voltage/current method

The vector voltage/current method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 3.

b) Measuring method and calculation formula

Using the circuit given in Figure 3, the frequency and output of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test shall be connected and then the voltages E_1 and E_2 shall be measured by the vector voltmeter and Q shall be calculated from the following formula:

$$Q = \frac{\mathrm{Im}\left(\frac{E_1}{E_2}\right)}{\mathrm{Re}\left(\frac{E_1}{E_2}\right)}$$

where

- Q is Q of the inductor under test;
- Re is the real part of the complex value;
- Im is the imaginary part of the complex value;
- E_1 is the indicated value of vector voltmeter Ev_1;
- E_2 is the indicated value of vector voltmeter Ev_2.

10.3.2.1.5 Automatic balancing bridge method

The automatic balancing bridge method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 4.

b) Measuring method and calculation formula

Using the circuit given in Figure 4, the frequency f and output voltage E_1 of the signal generator shall be adjusted to the respective values specified in the detail specification.

The inductor under test L_x shall be connected and the voltage E_2 shall be measured and Q shall be calculated from the following formula:

$$Z_x = \frac{E_1}{I_r} = \frac{-E_1 R_r}{E_2}$$

$$Z_x = \frac{|E_1|}{|E_2|\angle - \theta} R_r = R_x + jX_x$$

$$Q = \frac{X_x}{R_x}$$

where

Z_x is the impedance of the inductor under test;

R_x is the real part of impedance;

X_x is the imaginary part of impedance;

R_s is the resistance of resistor R_s;

R_r is the resistance of resistor R_r;

θ is the phase angle.

10.3.2.2 Requirements

Q shall meet the requirements specified in the detail specification.

10.3.3 Impedance

10.3.3.1 Test methods

For inductors with 1 μH or more, the impedance shall be measured by the automatic balancing bridge method (10.3.1.1.3). For inductors less than 1 μH, the impedance shall be measured by the vector voltage/current method as prescribed in IEC 62024-1:2008, 3.3.

10.3.3.2 Requirements

The impedance shall meet the requirements specified in the detail specification.

10.3.4 Self-resonant frequency

10.3.4.1 Test methods

10.3.4.1.1 General

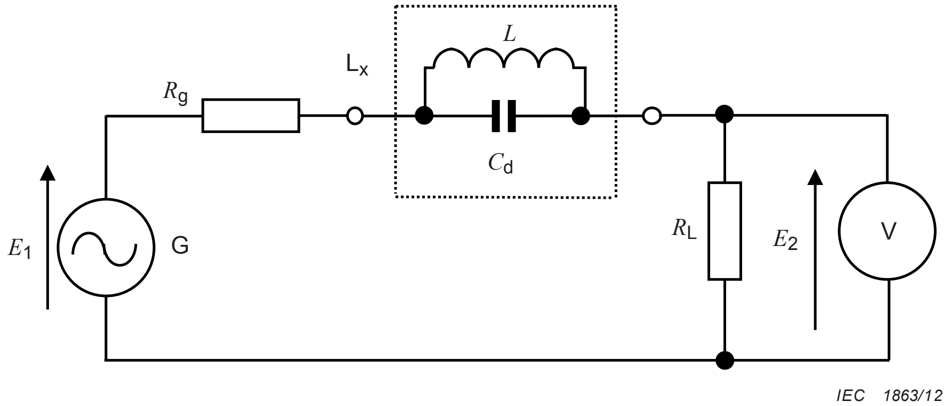
For inductors with 1 μH or more, the self-resonant frequency shall be measured by the minimum output method (10.3.4.1.2) or the maximum impedance measuring method (10.3.4.1.3). For inductors less than 1 μH, the self-resonant frequency shall be measured by one of the methods as prescribed in IEC 62024-1:2008, 4.2 (Minimum output method) or 4.3 (Reflection method).

10.3.4.1.2 Minimum output method

The minimum output method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figure 8.



Key

Components

G	Signal generator
R_g	Source resistance of the signal generator (50 Ω)
L_X	Inductor under test
C_d	Distributed capacitance of the inductor under test
L	Inductance of the inductor under test
V	RF voltmeter
R_L	Input resistance of the RF voltmeter

NOTE A suitably calibrated network analyser may be used in place of the signal generator and RF voltmeter.

Figure 8 – Example of circuit for measurement by the minimum output method

b) Measuring method

Using the circuit given in Figure 8, the output voltage E_1 of the signal generator shall be adjusted to the respective values specified in the detail specification.

Then the oscillating frequency of the signal generator shall be gradually increased until resonance is obtained as indicated by E_2 assuming its minimum value. This frequency is then taken as the self-resonant value.

10.3.4.1.3 Maximum impedance measuring method

The maximum impedance measuring method is as follows:

a) Measuring circuit

An example of a measuring circuit is shown in Figures 3 or 4.

b) Measuring method

Using the circuit given in Figures 3 or 4, the oscillating frequency of the signal generator shall be gradually increased until resonance is obtained as indicated by the impedance assuming its maximum value. This frequency is then taken as the self-resonant value.

10.3.4.2 Requirements

The self-resonant frequency shall meet the requirements specified in the detail specification.

10.3.5 DC resistance

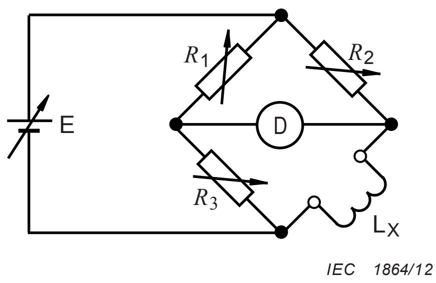
10.3.5.1 Measuring circuit

An example of a measuring circuit for DC resistance is shown in Figure 9.

10.3.5.2 Measuring method and calculation formula

Using the circuit as given in Figure 9, the bridge shall be balanced by adjusting the proportional arm resistors R_1 and R_2 and standard variable resistor R_3, and DC resistance R_x of the inductor shall be calculated from the following formula:

$$R_x = \frac{R_2}{R_1} \times R_3$$



Key

Components

R_1, R_2	Resistance of proportional arm resistors R_1 and R_2
R_3	Resistance of standard variable resistor R_3
L_X	Inductor under test
D	Detector
E	DC

Figure 9 – Example of measuring circuit for DC resistance

10.3.5.3 Precaution for measurement

The precautions for measurements are as follows:

a) Measurement of resistance shall be made by using a direct voltage of a small magnitude for as short a time as practicable, in order to avoid an appreciable rise in the temperature of the resistance element during measurement. The measuring voltage shall not exceed 0,5 V;

b) Care will be taken that the temperature of the inductor under test coincides with the ambient temperature;

c) The current passed through the inductors shall be kept within a range where the resistance of the inductor does not change much;

d) A double bridge may be used for measuring an especially low resistance.

10.3.5.4 Measuring temperature

The DC resistance shall meet the specified limits at a temperature of (20 ± 1) °C.

When the test is carried out at a temperature T_e other than 20 °C, the result shall be corrected to 20 °C by means of the following formula:

$$R_{20} = \frac{R_{\mathrm{Te}}}{0{,}92 + 0{,}004 T_{\mathrm{e}}}$$

where

T_{e} is the measuring temperature (°C);

R_{20} is the corrected resistance to 20 °C;

R_{Te} is the resistance at T_{e}.

10.3.6 Rated current

10.3.6.1 Test method

See IEC 62024-2:2008, Clause 5 to Clause 8.

10.3.6.2 Requirements

The inductors shall meet the performance specified in the detail specification.

10.4 Mechanical performance tests

10.4.1 Mounting to substrate

See IEC 62025-2:2005, Annex A.

10.4.2 Body strength test

10.4.2.1 Test methods

See IEC 62025-2:2005, 5.1

10.4.2.2 Requirements

There shall be no signs of damage such as cracks or flaws. If any electrical performance parameters are specified in the detail specification, the inductors shall meet the specification.

10.4.3 Robustness of terminations (electrodes)

10.4.3.1 Resistance to bending of printed circuit board

10.4.3.1.1 Test methods

See IEC 62025-2:2005, 5.2.1.

10.4.3.1.2 Requirements

There shall be no signs of damage such as cracks or flaws. In this case, the abnormalities at the solder joint, such as peel and crack, shall not be treated as the non-conformity of the inductor. If any electrical performance parameters are specified in the detail specification, the inductors shall meet the specification.

10.4.3.2 Share test (Adherence test)

10.4.3.2.1 Test methods

See IEC 62025-2:2005, 5.2.2.

10.4.3.2.2 Requirements

There shall be no signs of damage such as cracks or flaws. In this case, the abnormalities at the solder joint, such as peel and crack, shall not be treated as the non-conformity of the inductor. If any electrical performance parameters are specified in the detail specification, the inductors shall meet the specification.

10.4.4 Solderability

10.4.4.1 Test methods

See IEC 62025-2:2005, 5.3.

10.4.4.2 Requirements

The wetting shall be assessed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x.

90 % or over of the surface of terminations tested shall be covered with new solder. The scattered imperfections, such as pinholes or unwetted or de-wetted areas, shall not be concentrated in one area.

For solder alloy containing lead, the surface of terminations shall be covered with a smooth and bright solder coating. See IEC 60068-2-58:2004, 9.3.1 for details.

If any electrical performance parameters are specified in the detail specification, the inductors shall meet the specification.

10.4.5 Resistance to soldering heat

10.4.5.1 Test methods

See IEC 62025-2:2005, 5.4.

10.4.5.2 Requirements

There shall be no signs of damage such as cracks or flaws.

If specified in the detail specification to measure the electrical performances, the inductors shall meet the detail specification. The electrical performances that should be applied are in Table 11.

Table 11 – Electrical performance

Items	Performance requirements
Inductance change	≤ ±5 %
Q change	≤ ±20 %
NOTE For the inductor with the tolerance G or less, the inductance change complies with the agreements between manufacturer and user.	

10.4.6 Resistance to dissolution of metallization

10.4.6.1 Test methods

See IEC 62025-2:2005, 5.5.

10.4.6.2 Requirements

The resistance to dissolution of metallization shall be assessed visually under adequate light with a binocular microscope of magnification in the range between 10x and 25x, in accordance with IEC 60068-2-58:2004, 9.3.4. Then, if specified in the detail specification, the electrical performances shall be measured. The following criteria shall be applied. If these criteria cannot be applied, the criteria shall be prescribed in the detail specification.

a) Areas where metallization is lost during immersion shall not individually exceed 5 % of the total electrode area, and shall not collectively exceed 10 % of the total electrode area.
b) The functional connection of the electrode to the interior of the inductor under test shall not be exposed.
c) Where the metallization of the electrode extends over edges onto adjacent surfaces, loss of metallization on the edges shall not exceed 10 % of their total length.

10.4.7 Vibration

10.4.7.1 Test methods

See IEC 62025-2:2005, 5.6.

10.4.7.2 Requirements

There shall be no visible damage.

If specified in the detail specification to measure the electrical performances, the inductors shall meet the detail specification. The electrical performances that should be applied are in Table 11.

10.4.8 Resistance to shock

10.4.8.1 Test methods

See IEC 62025-2:2005, 5.7.

10.4.8.2 Requirements

There shall be no visible damage.

If specified in the detail specification to measure the electrical performances, the inductors shall meet the detail specification. The electrical performances that should be applied are in Table 11.

10.5 Environmental and climatic tests

10.5.1 Cold

10.5.1.1 Test methods

Unless otherwise specified in the detail specification, the inductors shall be subjected to test Ab of IEC 60068-2-1:2007 with the following details.

The inductors shall be measured for the electrical and/or mechanical performances in accordance with the detail specification, and then be placed in the test chamber. Unless otherwise specified, the temperature of chamber shall be decreased gradually to the specified test temperature. The inductors shall be left at that temperature for the specified period, and then returned gradually to the temperature of the standard conditions of 10.1.1 and then taken out from the test chamber.

The combination of the test temperature and duration shall be selected from Table 12.

Table 12 – Combined test conditions for cold

Test temperature °C	Duration h
–25 ± 3	96
–40 ± 3	96
–55 ± 3	96

10.5.1.2 Requirements

After the test, the drops of water, if any, shall be completely removed from the surface of the inductors under test. The inductors shall be left under the standard conditions of 10.1.1 for 1 h to 2 h, and then the electrical and/or mechanical performances shall be measured in accordance with the detail specification. The variation in the measured values on each performance taken before and after this test shall then be calculated. The inductors shall be visually examined.

There shall be no signs of damage such as cracks or flaws.

The inductors shall meet the electrical performances specified in the detail specification.

10.5.2 Dry heat

10.5.2.1 Test methods

Unless otherwise specified in the detail specification, the inductors shall be subjected to test Bb of IEC 60068-2-2:2007 with the following details.

The inductors shall be measured for the electrical and/or mechanical performances in accordance with the detail specification, and then be placed in the test chamber. Unless otherwise specified, the temperature of chamber shall be increased gradually to the specified test temperature. The inductors shall be left at that temperature for the specified period, and then returned gradually to the temperature of the standard conditions of 10.1.1 and then taken out from the test chamber.

The combination of the test temperature and duration shall be selected from Table 13.

Table 13 – Combined test conditions for dry heat

Test temperature °C	Duration h
+150 ± 2	1 000
+125 ± 2	1 000
+105 ± 2	1 000
+85 ± 2	1 000
+85 ± 2	500
+70 ± 2	96

10.5.2.2 Requirements

After the test, the inductors shall be left under the standard conditions of 10.1.1 for 1 h to 2 h, and then the electrical and/or mechanical performances shall be measured in accordance with the detail specification. The variation in the measured values on each performance taken before and after this test shall then be calculated. The inductors shall be visually examined.

There shall be no signs of damage such as cracks or flaws.

The inductors shall meet the electrical performances specified in the detail specification.

10.5.3 Change of temperature

10.5.3.1 Test methods

Unless otherwise specified in the detail specification, the inductors shall be subjected to test Na of IEC 60068-2-14:2009 with the following details.

The inductors shall be measured for the electrical and/or mechanical performances in accordance with the detail specification, and then be subjected to the change of temperature by the specified severities, and then taken out of the test chamber.

The severities of the test shall be selected from the test conditions as shown in Table 14 (see IEC 62211:2003, Table 3). The cycle number shall be either 100 cycles or 1 000 cycles.

Table 14 – Test conditions for change of temperature

High temperature °C	**Low temperature** °C	**Duration** min
+150 ± 2	–55 ± 3	30
+125 ± 2	–40 ± 3	30
+105 ± 2	–40 ± 3	30
+85 ± 2	–40 ± 3	30
+70 ± 2	–25 ± 3	30

10.5.3.2 Requirements

After the test, the inductors shall be left under the standard conditions of 10.1.1 for 1 h to 2 h, and then the electrical and/or mechanical performances shall be measured in accordance with the detail specification. The variation in the measured values on each performance taken before and after this test shall then be calculated. The inductors shall be visually examined.

There shall be no signs of damage such as cracks or flaws.

The inductors shall meet the electrical performances specified in the detail specification.

10.5.4 Damp heat (steady state)

10.5.4.1 Test methods

Unless otherwise specified in the detail specification, the inductors shall be subjected to IEC 60068-2-78 with the following details.

The inductors shall be measured for the electrical and/or mechanical performances in accordance with the detail specification, and then be placed in the test chamber of the specified severities and be exposed to the test atmosphere for the specified period.

In the above procedures, the sweating of the inductors shall be avoided immediately after placing in the test chamber and during testing.

Unless otherwise specified, the severities of test shall be selected from the test conditions as shown in Table 15 (see IEC 62211:2003, Table 3).

Table 15 – Test conditions for damp heat (steady state)

Temperature °C	**Relative humidity** %	**Duration** h
+85 ± 2	85 ± 3	1 000
+60 ± 2	93 ± 3	1 000
+40 ± 2	93 ± 3	1 000

10.5.4.2 Requirements

After the test, the inductors shall be left under the standard conditions of 10.1.1 for 1 h to 2 h, and then the electrical and/or mechanical performances shall be measured in accordance with the detail specification. The variation in the measured values on each performance taken before and after this test shall then be calculated. The inductors shall be visually examined.

There shall be no signs of damage such as cracks or flaws.

The inductors shall meet the electrical performances specified in the detail specification.

10.5.5 Component solvent resistance

10.5.5.1 Test methods

The inductors shall be subjected to test XA of IEC 60068-2-45:1980, which contains the following details:

a) Solvent to be used: IPA (IEC 60068-2-45:1980, 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.

10.5.5.2 Requirements

After the test, the inductor under test shall be visually examined.

There shall be no signs of damage such as cracks or flaws.

Bibliography

AEC-Q200, *Stress Test Qualification For Passive Components*

MIL-PRF-27, *General Specification for Transformers and Inductors (Audio, Power, and High-Power Pulse)*

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