IEC 62024-2

Edition 2.0 2020-03
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

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

IEC 62024-2:2020-03 RLV(en)

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.100.10 ISBN 978-2-8322-8136-9

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 2: Rated current of inductors for DC-to-DC converters

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 62024-2 has been prepared IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials.

This second edition cancels and replaces the first edition published in 2008. This edition constitutes a technical revision.

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

a) addition of Table 2 and Figure 2 b).

The text of this International Standard is based on the following documents:

CDV	Report on voting
51/1303/CDV	51/1325/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts of IEC 62024 series, published under the general title *High frequency inductive components – Electrical characteristics and measuring methods* can be found on the IEC website.

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

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- withdrawn,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

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 2: Rated current of inductors for DC-to-DC converters

1 Scope

This part of IEC 62024 specifies the measuring methods of the rated direct current limits for small inductors.

Standardized measuring methods for the determination of ratings enable users to accurately compare the current ratings given in various manufacturers' data books.

This document is applicable to leaded and surface mount inductors with dimensions according to IEC 62025-1 and generally with rated current less than 22 A, although inductors with rated current greater than 22 A are available that fall within the dimension restrictions of this document (no larger than a 12 mm × 12 mm footprint approximately). These inductors are typically used in DC-to-DC converters built on PCBs, for electric and telecommunication equipment, and small size switching power supply units.

The measuring methods are defined by the saturation and temperature rise limitations induced solely by direct current.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 62025-1, *High frequency inductive components – Non-electrical characteristics and measuring methods – Part 1: Fixed, surface mounted inductors for use in electronic and telecommunication equipment*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
DC saturation limited current
allowable value of DC current for which the decrease of the inductance is within the specified value

3.2
temperature rise limited current
allowable value of DC current for which the self-generation heat of the inductor results in temperature rise within the specified value

4 Standard atmospheric conditions

4.1 Standard atmospheric conditions for testing

Standard atmospheric conditions for testing shall be as follows (see ~~5.3.1 of~~ IEC 60068-1:2013, 4.3):

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

In the event of dispute or where required, the measurements shall be repeated using the referee temperatures and such other conditions as given in 4.2.

4.2 Reference conditions

For reference purposes, one of the standard atmospheric conditions for referee tests taken from ~~5.2 of~~ IEC 60068-1:2013, 4.2, shall be selected and shall be as follows:

- temperature: 20 °C ± 2 °C;
- relative humidity: 60 % to 70 %;
- air pressure: 86 kPa to 106 kPa.

5 Measuring method of DC saturation limited current

5.1 General

When alternating current in which DC current is superimposed is supplied to an inductor, the inductance of the inductor decreases according to the DC current value.

In a typical application, the saturation current results from the peak current of the superposition of AC on DC current. In this document, the saturation current is measured as DC current offsetting a small signal AC current.

NOTE It is not practical to set a standard for AC saturation limited current, because there is an unlimited number of different ways to apply AC current in an application. Therefore, manufacturers and users have generally defined DC saturation limited current as a common point of reference. This document does the same.

5.2 Test conditions

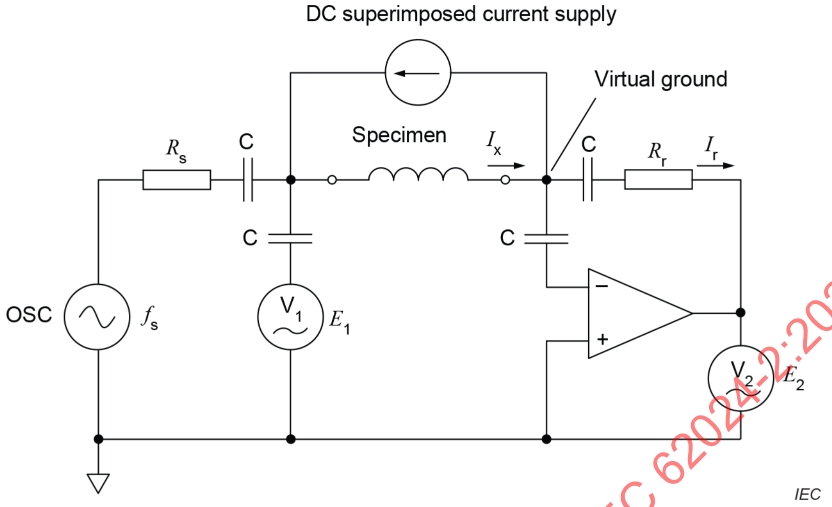
Unless otherwise specified in the detail specification, the test conditions shall be in accordance with Clause 4.

NOTE The variation of the value of DC saturation limited current, as a function of temperature, is dependent on the magnetic material and the structure of the magnetic core of the inductor. However, measurement of DC saturating currents at elevated temperatures is generally not practical for inspection purposes. Therefore, the measurement at room temperature as provided by this document is generally applied for specification purposes. De-rating curves indicating variation of DC saturation limited current as a function of maximum operating temperature of the inductor can be generated. These curves can be used to correlate the DC saturation limited current at room temperature to the DC saturation limited current at typical operating temperatures. In some cases, it will become necessary for the manufacturer and user to agree on an additional specification at a high temperature such as 85 °C, 105 °C or 125 °C.

5.3 ~~Measurement~~ Measuring circuit and calculation

5.3.1 Measuring circuit

The measuring circuit is as shown in Figure 1.



Components

R_s source resistor R = R_s

R_r range resistor R = R_r

V_1 voltmeter V_1 = E_1

V_2 voltmeter V_2 = E_2

C DC current blocking capacitor

Supplies

f_s frequency of source

I_r supplied current to range resistor

I_x supplied current to specimen

$I_x = I_r$

Figure 1 – Inductance ~~measurement~~ measuring circuit under application of DC saturation condition

5.3.2 Calculation

Voltages E_1 and E_2 shall be measured when frequency f_s and voltage E_s of the signal generator are supplied in accordance with the detail specification, and an initial value of the inductance shall be calculated by the following formulae.

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

$$Z_x = |Z_x| \cos\theta + j |Z_x| \sin\theta$$

$$Z_x = R_x + jX_x$$

$$L_x = \frac{X_x}{\omega} = \frac{X_x}{2\pi f_s}$$

where

R_x is the resistance of the specimen;

X_x is the reactance of the specimen;

Z_x is the impedance of the specimen;

L_x is the equivalent series inductance of the specimen;

E_1 is the applied voltage to the specimen;

E_2 is the applied voltage to the range resistor (= $I_r R_r$) (E_2 can be regarded as current);

θ is the phase angle difference between E_1 and E_2.

5.4 Attachment jig of inductor

The attachment jig of the specimen shall be specified in the detail specification.

5.5 Measuring method

a) A short compensation shall be done before measurement.

b) The specimen shall be connected to the circuit shown in Figure 1, by using the attachment jig specified in 5.4.

c) When the specimen is connected by soldering, it shall be left until it becomes cool enough.

d) Voltages E_1 and E_2 shall be measured when frequency f_s and voltage E_s of the signal generator are supplied in accordance with the detail specification, and an initial value of the inductance shall be calculated by the formulae of 5.3.2.

e) The value of the DC current that is superimposed on the specimen shall be modulated and the inductance value shall be measured.

f) The decrease from the initial value of the inductance shall be calculated. DC saturation limited current shall be determined by measuring the DC current when the decrease in inductance matches the specified value in the detail specification.

g) The decrease in inductance that is specified in the detail specification should be 10 % or 30 %.

NOTE 10 % is one of the design points typical for sharp-saturating inductors, and 30 % is one of the design points typical for soft-saturating inductors. See Annex A.

5.6 Quality conformance inspection

The DC current specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 5.3 to 5.5, and then inductance shall be measured. The decrease in inductance shall be within the specified value.

6 Measuring method of temperature rise limited current

6.1 General

When DC current is supplied to an inductor, the inductor generates heat by itself according to the supplied DC current value because of its DC current resistance.

NOTE 1 Temperature rise results from self-heating of the inductor. The sources of heating are DC copper losses, AC copper losses and AC core losses. This document defines the temperature rise induced only by DC currents. ~~In specific applications, it is necessary to consider~~ AC copper losses and AC core losses are considered for the temperature rise. AC losses are highly affected by waveform, amplitude and frequency.

NOTE 2 It is not practical to set a standard for AC temperature rise limited current, because there is an unlimited number of different ways to apply AC current in an application. ~~In DC to DC converters, often AC loss is far smaller than DC loss.~~ Therefore, manufacturers and users have generally defined DC temperature rise limited current as a common point of reference. This document does the same.

6.2 Test conditions

Unless otherwise specified in the detail specification, for example an elevated ambient temperature, the test conditions shall be in accordance with Clause 4.

Since the value of DC current resistance increases as a function of temperature, some applications require a high ambient temperature such as 85 °C, 105 °C or 125 °C for the temperature rise test.

NOTE 1 The overall power loss of an inductor is a combination of DC power loss due to DC current resistance, as well as AC power loss due to AC current in the windings, and losses due to the corresponding AC flux induced in the magnetic core. The value of AC and DC current resistance (the conductor resistance) increases with temperature, thus the power loss associated with conductor resistance increases with temperature. The loss associated with the magnetic core is all due to AC excitation. The core loss decreases with increasing temperature up to a temperature typically referred to as the core loss minima temperature, above which point this loss begins to increase. The minima temperature and magnitude of loss are dependent on the magnetic material type and grade. ~~Most~~ Some ferrites exhibit sharp minima temperatures~~, while powder alloys do not~~. These considerations ~~must be~~ are taken into account when applying temperature rise currents to applications with high operating temperatures and a non-trivial amount of AC power loss in addition to DC power loss. The overall total loss at any given temperature ~~may~~ can be dominated by DC loss or AC loss depending on the power loss distribution at room temperature as well as the variation of each of these power losses with temperature.

NOTE 2 Regarding DC temperature rise limited currents at high temperatures, the variation in DC temperature rise limited current with ambient temperature variation can be ~~predicted~~ modeled. ~~Moreover, measurement of DC temperature rise limited currents at elevated temperatures is generally not practical. Therefore, the measurement at room temperature as provided by this standard is generally applied.~~ Measurement at room temperature is commonly applied for detail specifications. In any event, the ambient temperature for the test is specified in the detail specification.

6.3 ~~Measurement~~ Measuring jig

6.3.1 General

The ~~measurement~~ measuring jig shall be either printed-wiring board method given in 6.3.2 or lead wire method given in 6.3.3, and shall be specified in the detail specification.

6.3.2 Printed-wiring board method

The printed-wiring board shall be made of epoxide woven glass (FR4). Unless otherwise specified in the detail specification, the dimensions shall be as shown in Table 1, Table 2 and Figure 2.

Table 1 – Width of circuits

Rated current class	Rated current of inductor I A	Pattern width~~[a]~~ W mm
$I_{class\ A}$	$I \leq 1$	1,0 ± 0,2
	$1 < I \leq 2$	2,0 ± 0,2
	$2 < I \leq 3$	3,0 ± 0,3
	$3 < I \leq 5$	5,0 ± 0,3
	$5 < I \leq 7$	7,0 ± 0,5
	$7 < I \leq 11$	11,0 ± 0,5
	$11 < I \leq 16$	16,0 ± 0,5
	$16 < I \leq 22$	22,0 ± 0,5
	$22 < I$	According to the detail specification

~~[a]~~ NOTE See Figure 2a).

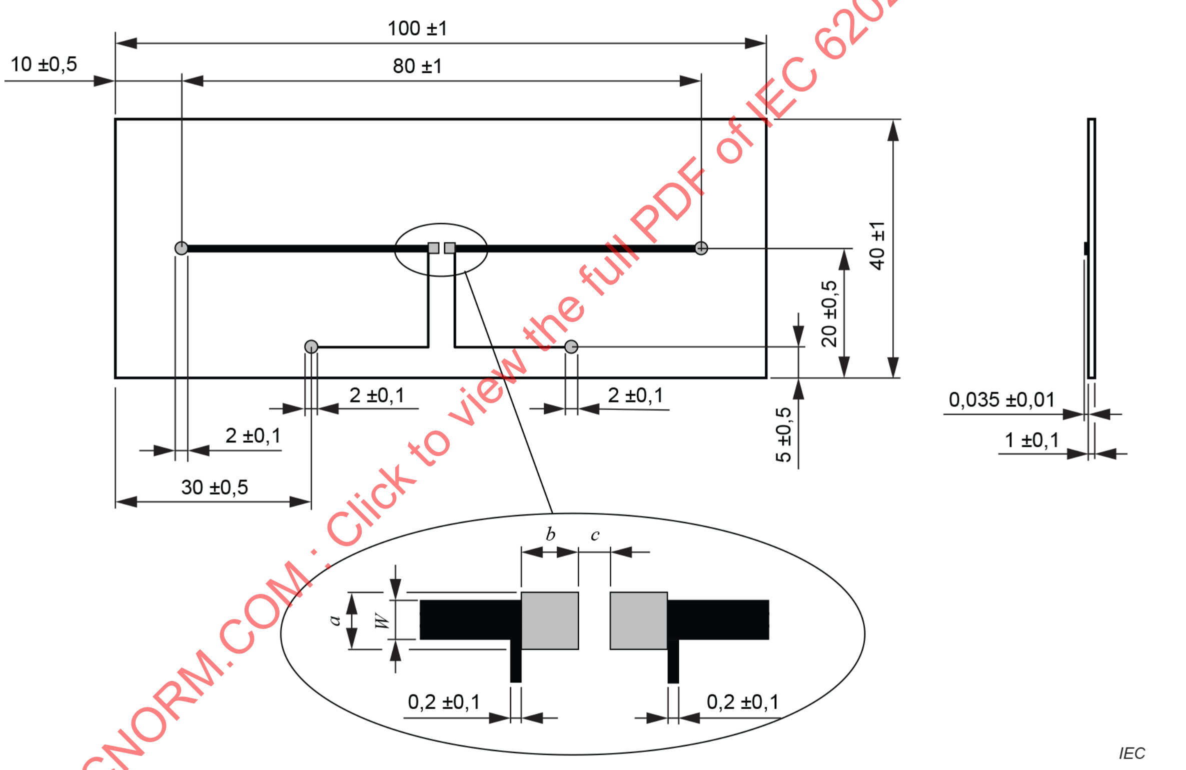
Table 2 – Circuit pattern width and thickness

Rated current class	Pattern width W mm	Pattern thickness t µm	Example application
$I_{class\ A}$	(1,0 to 22,0) ± 0,2 to 0,5	35 ± 10	Consumer application (single-sided printed circuit boards application)
$I_{class\ B}$	40 ± 0,2	35 ± 10	Consumer application (double-sided printed circuit boards application)
$I_{class\ C}$	40 ± 0,2	105 ± 10	Consumer application (multilayer printed circuit boards application)
$I_{class\ D}$	40 ± 0,2	1000 ± 50	Automotive or large current power line application

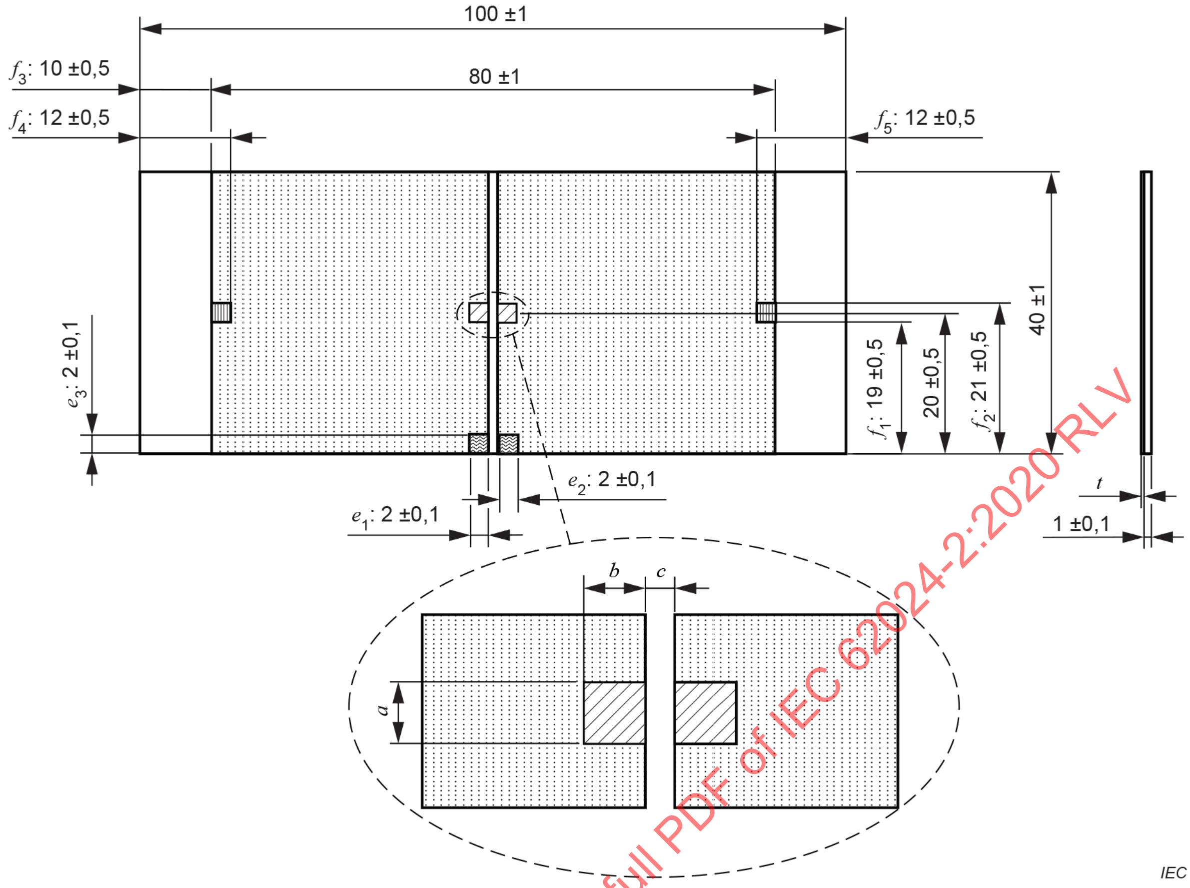
NOTE 1 $I_{class\ A}$: see Figure 2a).

NOTE 2 $I_{class\ B}$, $I_{class\ C}$, $I_{class\ D}$: see Figure 2b).

Dimensions in millimetres

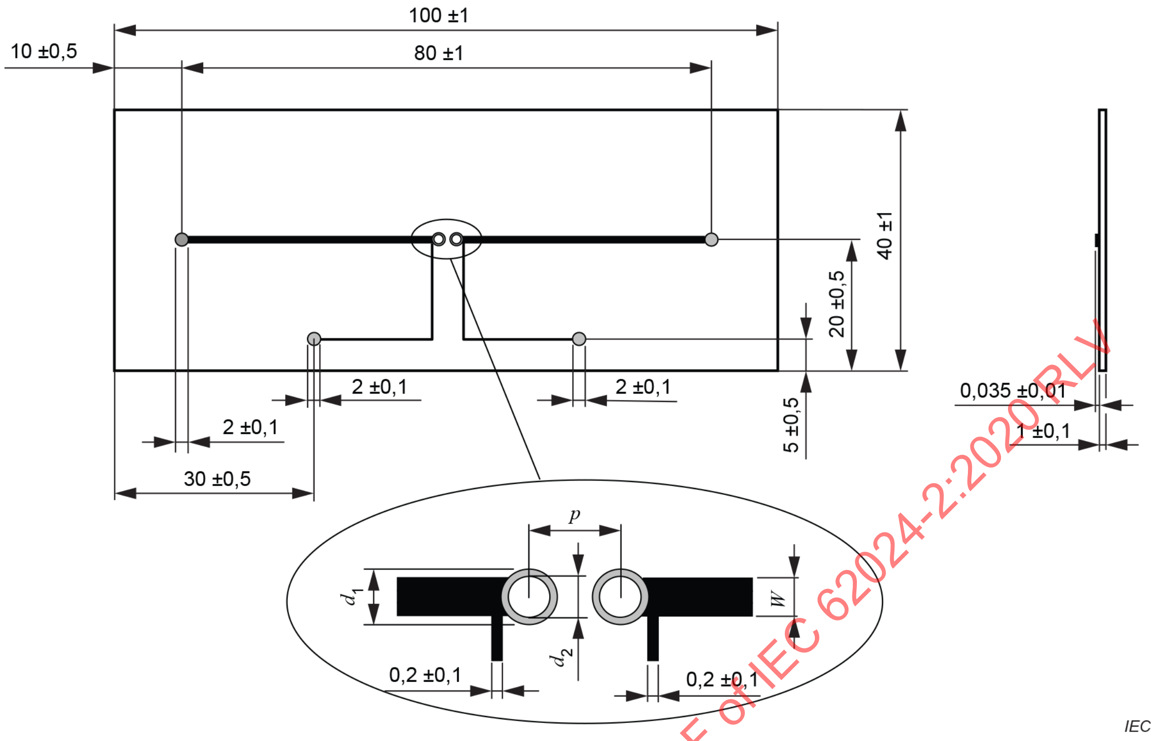


a) Example of printed-wiring board for SMD type (I class A)



b) Example of printed-wiring board for SMD type (*I* class B,C,D)

Dimensions in millimetres



c) Example of printed-wiring board for leaded type

Key

Solderable areas (only the recommended land pattern should be covered by soldering)

Current applying connection areas

Voltage measuring areas
(Voltage should be measured at the product's electrodes in case the DC resistance of the product is lower than the pattern resistance)

Non-solderable areas (covered with non-solderable lacquer)

Cu areas

NOTE 1 a, b, c, d_1, d_2 and p: according to the detail specification.

NOTE 2 Material of substrate: epoxide woven glass (FR4).

NOTE 3 Material of patterned areas: copper.

~~NOTE 4 Thickness of pattern: 0,035 mm ± 0,010 mm.~~

NOTE ~~5~~4 Pattern width (W): see Table 1 and Table 2.

NOTE 5 e_1, e_2, e_3, f_1, f_2, f_3, f_4 and f_5: according to the detail specification

Figure 2 – Example of printed-wiring boards

6.3.3 Lead wire method

Unless otherwise specified in the detail specification, the wire diameter of the lead wire to connect the inductor and the ~~measurement~~ measuring circuit shall be in accordance with Table 3.

Table 3 – Wire size of circuits

Rated current of inductors I A	Wire size	
	mm	AWG (for reference)
$I \leq 3$	0,50 ± 0,05	24
$3 < I \leq 5$	0,65 ± 0,05	22
$5 < I \leq 11$	0,8 ± 0,1	20
$11 < I \leq 16$	1,0 ± 0,1	18
$16 < I \leq 22$	1,3 ± 0,1	16
$22 < I$	According to the detail specification	

NOTE 1 The wire size refers to MIL standard (MIL-PRF-15733).

NOTE 2 AWG is a wire diameter number of American Wire Gauge.

6.4 Measuring method and calculation

6.4.1 General

The measuring method shall be either the resistance substitution method of 6.4.2 or the thermo-couple method of 6.4.3, and shall be specified in the detail specification.

6.4.2 Resistance substitution method

a) The specimen shall be connected to the circuit shown in Figure 3, by using the ~~measurement~~ measuring jig specified in 6.3.

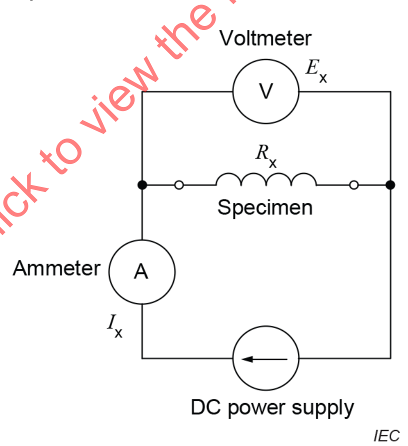


Figure 3 – Temperature rise ~~measurement~~ measuring circuit by resistance substitution method

b) When the specimen is connected by soldering, it shall be left until it ~~becomes cool enough~~ cools to the test ambient.

c) The specimen should be measured inside a cubic box of roughly 20 cm on each side to prevent temperature change from air flow. The box may have some vents in the top to prevent trapping heat inside.

The specimen shall be measured on the condition that it does not contact directly with the test board. When it is measured by mounting on the printed-wiring board, the printed-circuit board on which the specimen is mounted shall not contact directly with the test board.

d) The resistance value of the specimen and ambient temperature t_{a1} shall be measured before DC current is supplied.

e) DC current shall be supplied to the specimen from a direct power supply. After the DC voltage value of the specimen becomes steady, DC current value I_x and DC voltage value E_x shall be measured by the ammeter and the voltmeter, and also ambient temperature t_{a2} shall be measured. Then the resistance value R_x shall be calculated by the following formula.

$$R_x = \frac{E_x}{I_x}$$

where

I_x is the DC current value;

E_x is the DC voltage;

R_x is the resistance of the specimen.

f) The temperature rise value t of the specimen shall be calculated by the following formula, by using the resistivity coefficient of the metal and the resistance of the specimen.

$|t_{a1} - t_{a2}|$ shall be 5 °C or less.

$$t = t_2 - t_{a2} = \left(\frac{R_2 - R_1}{R_1}\right)(C + t_{a1}) + t_{a1} - t_{a2}$$

where

t is the temperature rise value (°C);

t_2 is the temperature of the specimen when DC current is supplied (°C);

t_{a1} is the initial ambient temperature (°C);

t_{a2} is the ambient temperature when DC current is supplied (°C);

R_1 is the resistance of winding at temperature $t_1 = t_{a1}$ (Ω);

R_2 is the resistance of winding at temperature t_2 (Ω);

C is a material constant. C for copper = 234,5.

g) The value of the supplied DC current shall be modulated and the temperature rise value shall be measured.

h) The temperature rise limited current shall be determined by measuring DC current when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings are made, 1 min apart and shown not to vary by more than 1°.

i) The temperature rise value that is specified in the detail specification should be 20 °C or 40 °C.

6.4.3 Thermo-couple method

a) The specimen shall be connected to the circuit shown in Figure 4, by using the ~~measurement~~ measuring jig specified in 6.3.

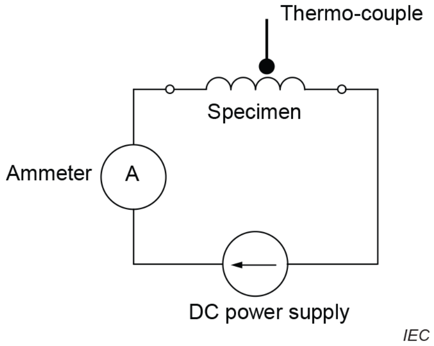


Figure 4 – Temperature rise ~~measurement~~ measuring circuit by thermo-couple method

b) When the specimen is connected by soldering, it shall be left until it ~~becomes cool enough~~ cools to the test ambient.

c) The specimen should be measured inside a cubic box of roughly 20 cm on each side to prevent temperature change from air flow. The box may have some vents in the top to prevent trapping heat inside.

The specimen shall be measured on the condition that it does not contact directly with the test board. When it is measured by mounting on the printed-wiring board, the printed-wiring board on which the specimen is mounted shall not contact directly with the test board.

d) Consideration shall be given to the correct ~~measurement~~ measuring position of the thermo-couple for the temperature measurement. It should be placed at the location where the maximum temperature of the inductor will occur. The best location may be direct contact at the surface of the specimen, or within the coil by placing the thermo-couple inside, or under the coil by positioning it prior to winding.

The ~~measurement~~ measuring position shall be specified in the detail specification.

e) The temperature of the specimen t_1 and ambient temperature t_{a1} shall be measured before DC current is supplied.

f) DC current shall be supplied to the specimen from a DC power supply. After the temperature of the specimen becomes steady, the temperature of the specimen t_2 and ambient temperature t_{a2} shall be measured again.

Criteria of temperature stability: ΔT <1 (°C /min).

g) The value of the supplied DC current shall be modulated and the temperature rise value shall be calculated by the following formula.

$$t = (t_2 - t_{a2}) - (t_1 - t_{a1})$$

where

t is the temperature rise value (°C);

t_1 is the initial temperature of the specimen (°C);

t_2 is the temperature of the specimen when DC current is supplied (°C);

t_{a1} is the initial ambient temperature (°C);

t_{a2} is the ambient temperature when DC current is supplied (°C).

h) The temperature rise limited current shall be determined by measuring DC current when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings are made, 1 min apart and shown not to vary by more than 1°C.

i) The temperature rise value that is specified in the detail specification should be 20 °C or 40 °C.

6.5 Quality conformance inspection

The DC current specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 6.3 to 6.4, and then the temperature rise value shall be measured.

The temperature rise value of the specimen shall be within the specified value.

7 Determination of rated current

For any inductor that is given a current rating, a DC saturation limited current value or a temperature rise limited current value, whichever is less, defined and measured as shown in this document, shall be adopted as the rated current.

8 Information to be given in the detail specification

8.1 General

The following information shall be given in the detail specification.

8.2 Measuring method of DC saturation limited current

a) Frequency f_s and voltage E_s (see 5.3.2, 5.5 d)).

b) Attachment jig (see 5.4).

c) Allowable decrease in inductance (see 5.5 f)).

d) DC saturation limited current (see 5.6).

8.3 Measuring method of temperature rise limited current

a) ~~Measurement~~ Measuring jig (see 6.3).

b) Measuring method (see 6.4).

c) Temperature rise value (see 6.4.2 h), 6.4.3 h)).

d) ~~Measurement~~ Measuring position (if thermo-couple method applied) (see 6.4.2 d)), 6.4.3 d)).

e) Temperature rise limited current (see 6.5).

Annex A
(informative)

Example of recommended description on product specification sheets and catalogues

Both the DC saturation limited current value and the temperature rise limited current value should be described on product specification sheets and catalogues.

It should be specified whether the DC saturation limited current value is determined when the allowable decrease in inductance value is at 10 % or 30 %.

Sharp saturation is defined as inductance that decreases by more than 8 % for a 10 % increase in bias current, measured where bias current has already reduced the inductance by 30 % compared with the unbiased inductance. Soft saturation is defined as inductance that decreases by less than 8 % for a 10 % increase in bias current, measured where bias current has already reduced the inductance by 30 % compared with the unbiased inductance.

Sharp saturating inductors have a steep drop in inductance beyond an inflection point, and therefore they are specified and designed to operate at load currents that are less than the current at the inflection point. 10 % is used for a standard specification point because it is a typical design point. Other values, such as 20 % or 30 %, may be used by mutual agreement between manufacture and user.

Soft saturating inductors have a continual and gradual drop in inductance, without a well-defined inflection point, and therefore they are specified and designed to operate at load currents that typically push inductance down by 20 % to 50 %, or even more as the application allows. 30 % is used for a standard specification point because it is a typical design point (but not necessarily a requisite design point). Other values, such as 20 % or 50 %, may be used by mutual agreement between manufacturer and user.

It should be specified whether the temperature rise limited current value is determined when the temperature rise of the inductor is 20 °C or 40 °C.

When the ~~definition called a~~ rated current is used, it should be the lower one of the DC saturation limited current values and the temperature rise limited current values.

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

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Composants inductifs à haute fréquence – Caractéristiques électriques et méthodes de mesure –
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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 62024-2 has been prepared IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials.

This second edition cancels and replaces the first edition published in 2008. This edition constitutes a technical revision.

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

a) addition of Table 2 and Figure 2 b).

The text of this International Standard is based on the following documents:

CDV	Report on voting
51/1303/CDV	51/1325/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts of IEC 62024 series, published under the general title *High frequency inductive components – Electrical characteristics and measuring methods* can be found on the IEC website.

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

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

HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 2: Rated current of inductors for DC-to-DC converters

1 Scope

This part of IEC 62024 specifies the measuring methods of the rated direct current limits for small inductors.

Standardized measuring methods for the determination of ratings enable users to accurately compare the current ratings given in various manufacturers' data books.

This document is applicable to leaded and surface mount inductors with dimensions according to IEC 62025-1 and generally with rated current less than 22 A, although inductors with rated current greater than 22 A are available that fall within the dimension restrictions of this document (no larger than a 12 mm × 12 mm footprint approximately). These inductors are typically used in DC-to-DC converters built on PCBs, for electric and telecommunication equipment, and small size switching power supply units.

The measuring methods are defined by the saturation and temperature rise limitations induced solely by direct current.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 62025-1, *High frequency inductive components – Non-electrical characteristics and measuring methods – Part 1: Fixed, surface mounted inductors for use in electronic and telecommunication equipment*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
DC saturation limited current
allowable value of DC current for which the decrease of the inductance is within the specified value

3.2
temperature rise limited current
allowable value of DC current for which the self-generation heat of the inductor results in temperature rise within the specified value

4 Standard atmospheric conditions

4.1 Standard atmospheric conditions for testing

Standard atmospheric conditions for testing shall be as follows (see IEC 60068-1:2013, 4.3):

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

In the event of dispute or where required, the measurements shall be repeated using the referee temperatures and such other conditions as given in 4.2.

4.2 Reference conditions

For reference purposes, one of the standard atmospheric conditions for referee tests taken from IEC 60068-1:2013, 4.2, shall be selected and shall be as follows:

– temperature: 20 °C ± 2 °C;
– relative humidity: 60 % to 70 %;
– air pressure: 86 kPa to 106 kPa.

5 Measuring method of DC saturation limited current

5.1 General

When alternating current in which DC current is superimposed is supplied to an inductor, the inductance of the inductor decreases according to the DC current value.

In a typical application, the saturation current results from the peak current of the superposition of AC on DC current. In this document, the saturation current is measured as DC current offsetting a small signal AC current.

NOTE It is not practical to set a standard for AC saturation limited current, because there is an unlimited number of different ways to apply AC current in an application. Therefore, manufacturers and users have generally defined DC saturation limited current as a common point of reference. This document does the same.

5.2 Test conditions

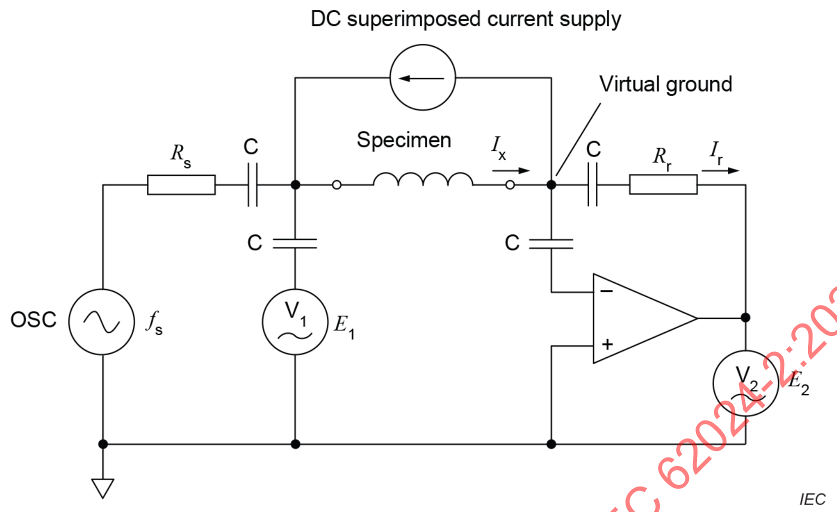
Unless otherwise specified in the detail specification, the test conditions shall be in accordance with Clause 4.

NOTE The variation of the value of DC saturation limited current, as a function of temperature, is dependent on the magnetic material and the structure of the magnetic core of the inductor. However, measurement of DC saturating currents at elevated temperatures is generally not practical for inspection purposes. Therefore, the measurement at room temperature as provided by this document is generally applied for specification purposes. De-rating curves indicating variation of DC saturation limited current as a function of maximum operating temperature of the inductor can be generated. These curves can be used to correlate the DC saturation limited current at room temperature to the DC saturation limited current at typical operating temperatures. In some cases, it will become necessary for the manufacturer and user to agree on an additional specification at a high temperature such as 85 °C, 105 °C or 125 °C.

5.3 Measuring circuit and calculation

5.3.1 Measuring circuit

The measuring circuit is as shown in Figure 1.



Components

R_s source resistor R = R_s

R_r range resistor R = R_r

V_1 voltmeter V_1 = E_1

V_2 voltmeter V_2 = E_2

C DC current blocking capacitor

Supplies

f_s frequency of source

I_r supplied current to range resistor

I_x supplied current to specimen

$I_x = I_r$

Figure 1 – Inductance measuring circuit under application of DC saturation condition

5.3.2 Calculation

Voltages E_1 and E_2 shall be measured when frequency f_s and voltage E_s of the signal generator are supplied in accordance with the detail specification, and an initial value of the inductance shall be calculated by the following formulae.

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

$$Z_x = |Z_x| \cos\theta + j |Z_x| \sin\theta$$

$$Z_x = R_x + jX_x$$

$$L_x = \frac{X_x}{\omega} = \frac{X_x}{2\pi f_s}$$

where

R_x is the resistance of the specimen;

X_x is the reactance of the specimen;

Z_x is the impedance of the specimen;

L_x is the equivalent series inductance of the specimen;

E_1 is the applied voltage to the specimen;

E_2 is the applied voltage to the range resistor (= $I_r R_r$) (E_2 can be regarded as current);

θ is the phase angle difference between E_1 and E_2.

5.4 Attachment jig of inductor

The attachment jig of the specimen shall be specified in the detail specification.

5.5 Measuring method

a) A short compensation shall be done before measurement.

b) The specimen shall be connected to the circuit shown in Figure 1, by using the attachment jig specified in 5.4.

c) When the specimen is connected by soldering, it shall be left until it becomes cool enough.

d) Voltages E_1 and E_2 shall be measured when frequency f_s and voltage E_s of the signal generator are supplied in accordance with the detail specification, and an initial value of the inductance shall be calculated by the formulae of 5.3.2.

e) The value of the DC current that is superimposed on the specimen shall be modulated and the inductance value shall be measured.

f) The decrease from the initial value of the inductance shall be calculated. DC saturation limited current shall be determined by measuring the DC current when the decrease in inductance matches the specified value in the detail specification.

g) The decrease in inductance that is specified in the detail specification should be 10 % or 30 %.

NOTE 10 % is one of the design points typical for sharp-saturating inductors, and 30 % is one of the design points typical for soft-saturating inductors. See Annex A.

5.6 Quality conformance inspection

The DC current specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 5.3 to 5.5, and then inductance shall be measured. The decrease in inductance shall be within the specified value.

6 Measuring method of temperature rise limited current

6.1 General

When DC current is supplied to an inductor, the inductor generates heat by itself according to the supplied DC current value because of its DC current resistance.

NOTE 1 Temperature rise results from self-heating of the inductor. The sources of heating are DC copper losses, AC copper losses and AC core losses. This document defines the temperature rise induced only by DC currents. AC copper losses and AC core losses are considered for the temperature rise. AC losses are highly affected by waveform, amplitude and frequency.

NOTE 2 It is not practical to set a standard for AC temperature rise limited current, because there is an unlimited number of different ways to apply AC current in an application. Therefore, manufacturers and users have generally defined DC temperature rise limited current as a common point of reference. This document does the same.

6.2 Test conditions

Unless otherwise specified in the detail specification, for example an elevated ambient temperature, the test conditions shall be in accordance with Clause 4.

Since the value of DC current resistance increases as a function of temperature, some applications require a high ambient temperature such as 85 °C, 105 °C or 125 °C for the temperature rise test.

NOTE 1 The overall power loss of an inductor is a combination of DC power loss due to DC current resistance, as well as AC power loss due to AC current in the windings, and losses due to the corresponding AC flux induced in the magnetic core. The value of AC and DC current resistance (the conductor resistance) increases with temperature, thus the power loss associated with conductor resistance increases with temperature. The loss associated with the magnetic core is all due to AC excitation. The core loss decreases with increasing temperature up to a temperature typically referred to as the core loss minima temperature, above which point this loss begins to increase. The minima temperature and magnitude of loss are dependent on the magnetic material type and grade. Some ferrites exhibit sharp minima temperatures. These considerations are taken into account when applying temperature rise currents to applications with high operating temperatures and a non-trivial amount of AC power loss in addition to DC power loss. The overall total loss at any given temperature can be dominated by DC loss or AC loss depending on the power loss distribution at room temperature as well as the variation of each of these power losses with temperature.

NOTE 2 Regarding DC temperature rise limited currents at high temperatures, the variation in DC temperature rise limited current with ambient temperature variation can be modeled. Measurement at room temperature is commonly applied for detail specifications. In any event, the ambient temperature for the test is specified in the detail specification.

6.3 Measuring jig

6.3.1 General

The measuring jig shall be either printed-wiring board method given in 6.3.2 or lead wire method given in 6.3.3, and shall be specified in the detail specification.

6.3.2 Printed-wiring board method

The printed-wiring board shall be made of epoxide woven glass (FR4). Unless otherwise specified in the detail specification, the dimensions shall be as shown in Table 1, Table 2 and Figure 2.

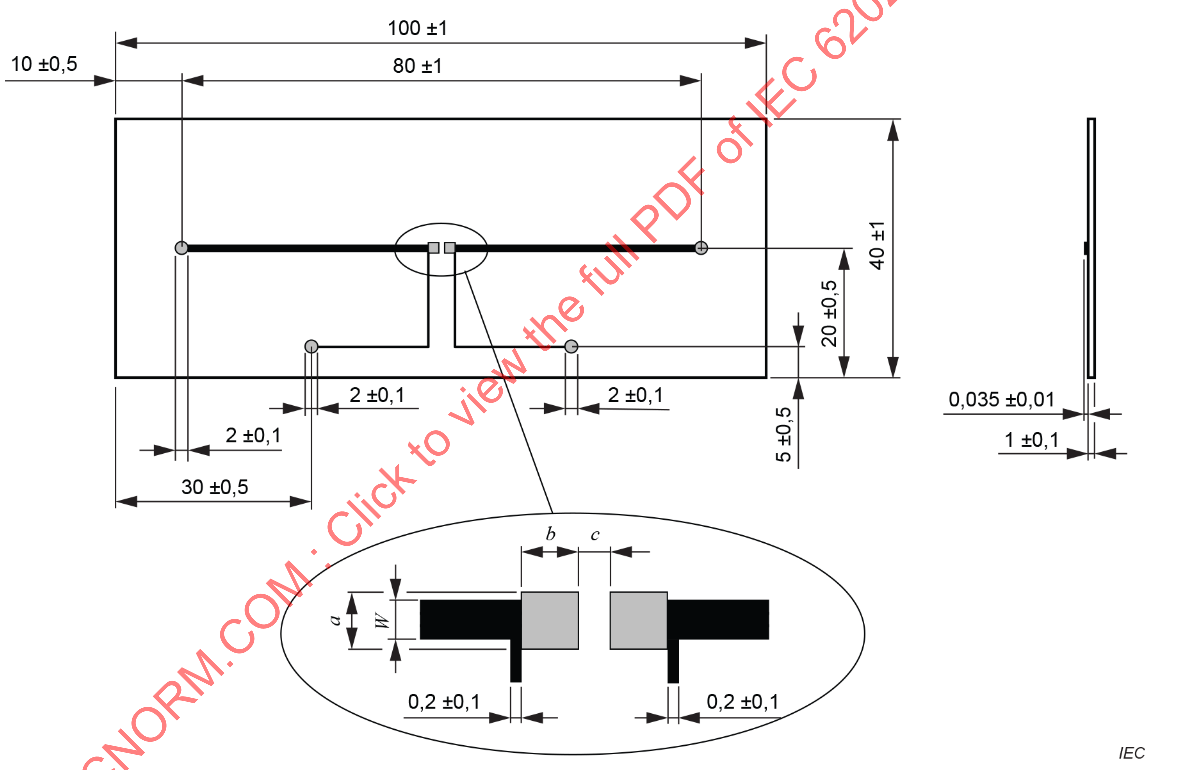
Table 1 – Width of circuits

Rated current class	Rated current of inductor I A	Pattern width W mm
$I_{\text{class A}}$	$I \leq 1$	1,0 ± 0,2
	$1 < I \leq 2$	2,0 ± 0,2
	$2 < I \leq 3$	3,0 ± 0,3
	$3 < I \leq 5$	5,0 ± 0,3
	$5 < I \leq 7$	7,0 ± 0,5
	$7 < I \leq 11$	11,0 ± 0,5
	$11 < I \leq 16$	16,0 ± 0,5
	$16 < I \leq 22$	22,0 ± 0,5
	$22 < I$	According to the detail specification
NOTE See Figure 2a).		

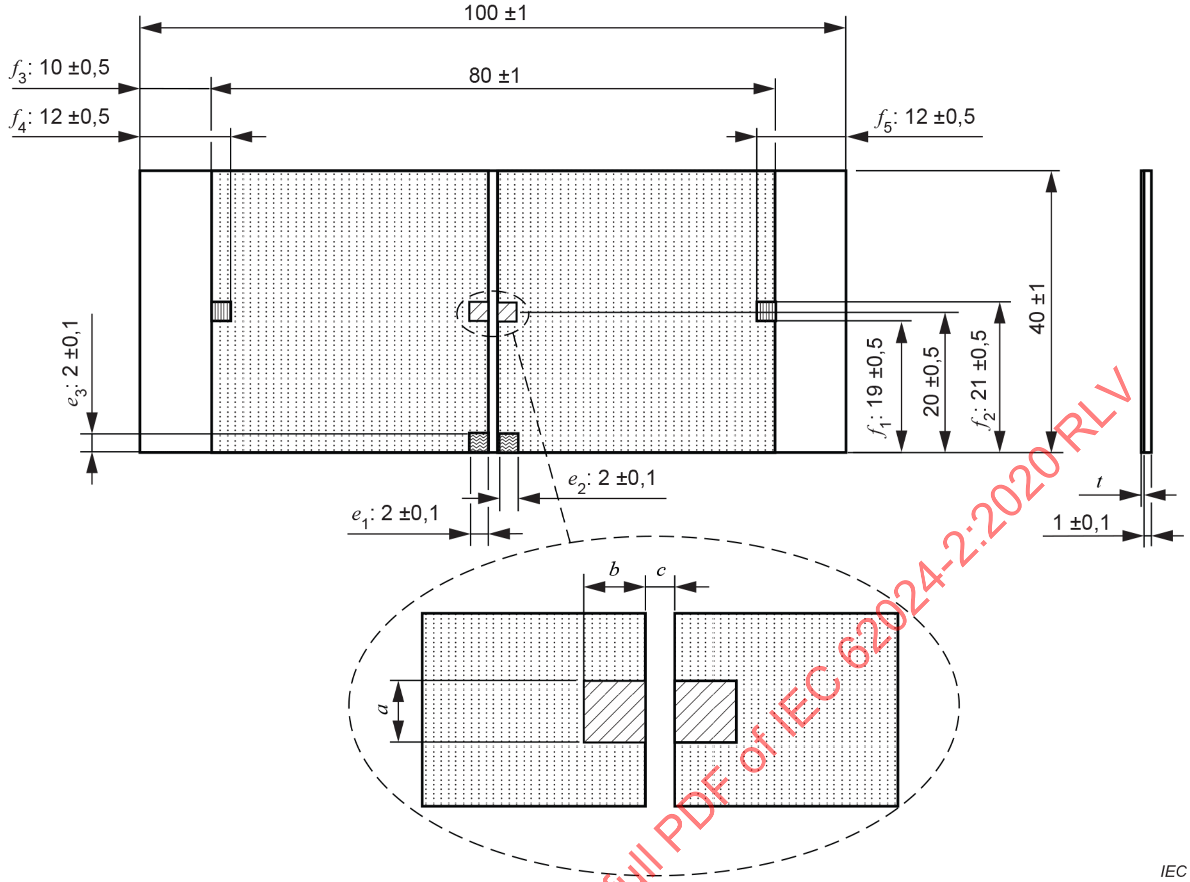
Table 2 – Circuit pattern width and thickness

Rated current class	Pattern width W mm	Pattern thickness t µm	Example application
$I_{class\ A}$	(1,0 to 22,0) ± 0,2 to 0,5	35 ± 10	Consumer application (single-sided printed circuit boards application)
$I_{class\ B}$	40 ± 0,2	35 ± 10	Consumer application (double-sided printed circuit boards application)
$I_{class\ C}$	40 ± 0,2	105 ± 10	Consumer application (multilayer printed circuit boards application)
$I_{class\ D}$	40 ± 0,2	1000 ± 50	Automotive or large current power line application
NOTE 1 $I_{class\ A}$: see Figure 2a). NOTE 2 $I_{class\ B}$, $I_{class\ C}$, $I_{class\ D}$: see Figure 2b).			

Dimensions in millimetres

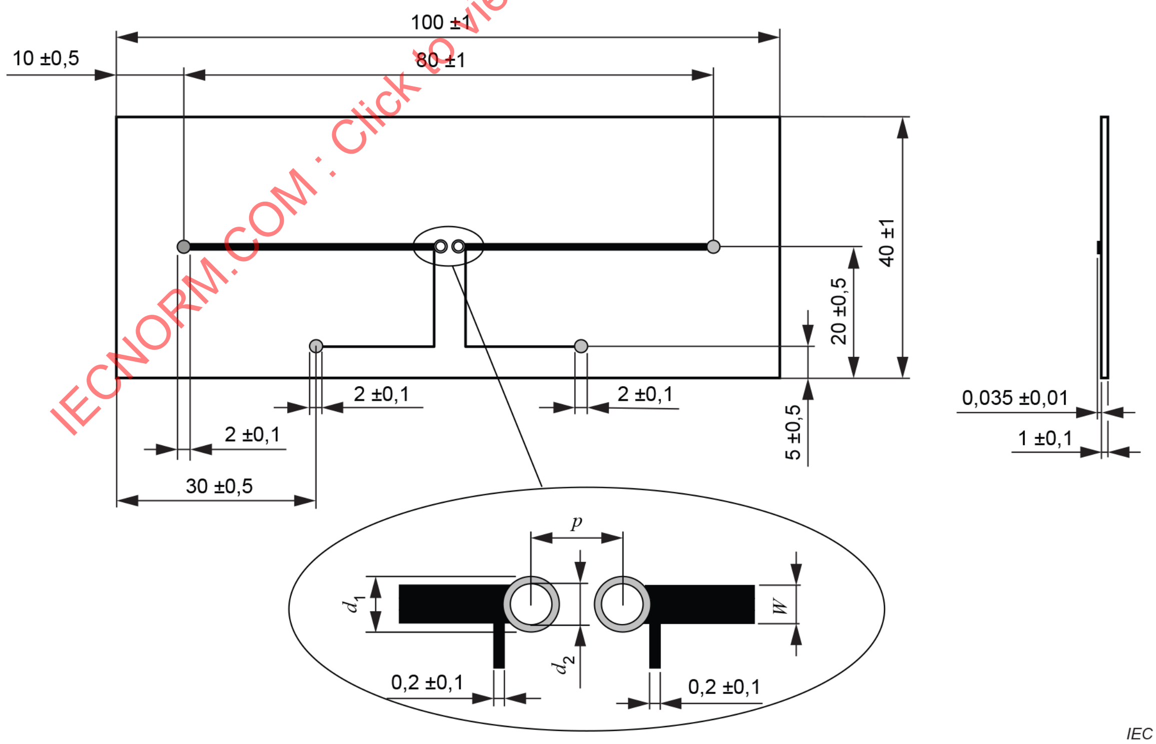


a) Example of printed-wiring board for SMD type (I class A)



b) Example of printed-wiring board for SMD type (I class B,C,D)

Dimensions in millimetres



c) Example of printed-wiring board for leaded type

Key

Solderable areas (only the recommended land pattern should be covered by soldering)

Current applying connection areas

Voltage measuring areas
(Voltage should be measured at the product's electrodes in case the DC resistance of the product is lower than the pattern resistance)

Non-solderable areas (covered with non-solderable lacquer)

Cu areas

NOTE 1 a, b, c, d_1, d_2 and p: according to the detail specification.

NOTE 2 Material of substrate: epoxide woven glass (FR4).

NOTE 3 Material of patterned areas: copper.

NOTE 4 Pattern width (W): see Table 1 and Table 2.

NOTE 5 e_1, e_2, e_3, f_1, f_2, f_3, f_4 and f_5: according to the detail specification

Figure 2 – Example of printed-wiring boards

6.3.3 Lead wire method

Unless otherwise specified in the detail specification, the wire diameter of the lead wire to connect the inductor and the measuring circuit shall be in accordance with Table 3.

Table 3 – Wire size of circuits

Rated current of inductors I A	**Wire size**	
	mm	AWG (for reference)
$I \leq 3$	0,50 ± 0,05	24
$3 < I \leq 5$	0,65 ± 0,05	22
$5 < I \leq 11$	0,8 ± 0,1	20
$11 < I \leq 16$	1,0 ± 0,1	18
$16 < I \leq 22$	1,3 ± 0,1	16
$22 < I$	According to the detail specification	

NOTE 1 The wire size refers to MIL standard (MIL-PRF-15733).

NOTE 2 AWG is a wire diameter number of American Wire Gauge.

6.4 Measuring method and calculation

6.4.1 General

The measuring method shall be either the resistance substitution method of 6.4.2 or the thermo-couple method of 6.4.3, and shall be specified in the detail specification.

6.4.2 Resistance substitution method

a) The specimen shall be connected to the circuit shown in Figure 3, by using the measuring jig specified in 6.3.

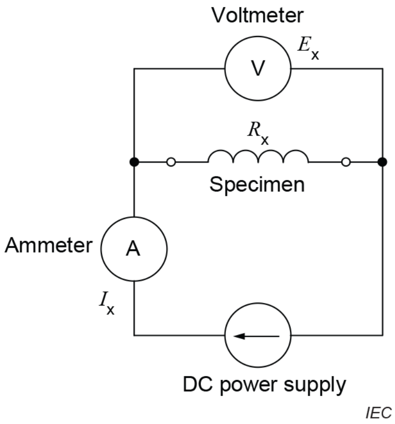


Figure 3 – Temperature rise measuring circuit by resistance substitution method

b) When the specimen is connected by soldering, it shall be left until it cools to the test ambient.

c) The specimen should be measured inside a cubic box of roughly 20 cm on each side to prevent temperature change from air flow. The box may have some vents in the top to prevent trapping heat inside.

The specimen shall be measured on the condition that it does not contact directly with the test board. When it is measured by mounting on the printed-wiring board, the printed-circuit board on which the specimen is mounted shall not contact directly with the test board.

d) The resistance value of the specimen and ambient temperature t_{a1} shall be measured before DC current is supplied.

e) DC current shall be supplied to the specimen from a direct power supply. After the DC voltage value of the specimen becomes steady, DC current value I_x and DC voltage value E_x shall be measured by the ammeter and the voltmeter, and also ambient temperature t_{a2} shall be measured. Then the resistance value R_x shall be calculated by the following formula.

$$R_x = \frac{E_x}{I_x}$$

where

I_x is the DC current value;

E_x is the DC voltage;

R_x is the resistance of the specimen.

f) The temperature rise value t of the specimen shall be calculated by the following formula, by using the resistivity coefficient of the metal and the resistance of the specimen.

$|t_{a1} - t_{a2}|$ shall be 5 °C or less.

$$t = t_2 - t_{a2} = \left(\frac{R_2 - R_1}{R_1}\right)(C + t_{a1}) + t_{a1} - t_{a2}$$

where

t is the temperature rise value (°C);

t_2 is the temperature of the specimen when DC current is supplied (°C);

t_{a1} is the initial ambient temperature (°C);

t_{a2} is the ambient temperature when DC current is supplied (°C);

R_1 is the resistance of winding at temperature $t_1 = t_{a1}$ (Ω);

R_2 is the resistance of winding at temperature t_2 (Ω);

C is a material constant. C for copper = 234,5.

g) The value of the supplied DC current shall be modulated and the temperature rise value shall be measured.

h) The temperature rise limited current shall be determined by measuring DC current when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings are made, 1 min apart and shown not to vary by more than 1°.

i) The temperature rise value that is specified in the detail specification should be 20 °C or 40 °C.

6.4.3 Thermo-couple method

a) The specimen shall be connected to the circuit shown in Figure 4, by using the measuring jig specified in 6.3.

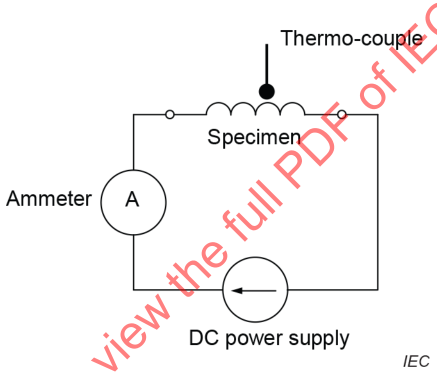


Figure 4 – Temperature rise measuring circuit by thermo-couple method

b) When the specimen is connected by soldering, it shall be left until it cools to the test ambient.

c) The specimen should be measured inside a cubic box of roughly 20 cm on each side to prevent temperature change from air flow. The box may have some vents in the top to prevent trapping heat inside.

The specimen shall be measured on the condition that it does not contact directly with the test board. When it is measured by mounting on the printed-wiring board, the printed-wiring board on which the specimen is mounted shall not contact directly with the test board.

d) Consideration shall be given to the correct measuring position of the thermo-couple for the temperature measurement. It should be placed at the location where the maximum temperature of the inductor will occur. The best location may be direct contact at the surface of the specimen, or within the coil by placing the thermo-couple inside, or under the coil by positioning it prior to winding.

The measuring position shall be specified in the detail specification.

e) The temperature of the specimen t_1 and ambient temperature t_{a1} shall be measured before DC current is supplied.

f) DC current shall be supplied to the specimen from a DC power supply. After the temperature of the specimen becomes steady, the temperature of the specimen t_2 and ambient temperature t_{a2} shall be measured again.

Criteria of temperature stability: ΔT <1 (°C /min).

g) The value of the supplied DC current shall be modulated and the temperature rise value shall be calculated by the following formula.

$$t = (t_2 - t_{a2}) - (t_1 - t_{a1})$$

where

t is the temperature rise value (°C);

t_1 is the initial temperature of the specimen (°C);

t_2 is the temperature of the specimen when DC current is supplied (°C);

t_{a1} is the initial ambient temperature (°C);

t_{a2} is the ambient temperature when DC current is supplied (°C).

h) The temperature rise limited current shall be determined by measuring DC current when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings are made, 1 min apart and shown not to vary by more than 1°C.

i) The temperature rise value that is specified in the detail specification should be 20 °C or 40 °C.

6.5 Quality conformance inspection

The DC current specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 6.3 to 6.4, and then the temperature rise value shall be measured.

The temperature rise value of the specimen shall be within the specified value.

7 Determination of rated current

For any inductor that is given a current rating, a DC saturation limited current value or a temperature rise limited current value, whichever is less, defined and measured as shown in this document, shall be adopted as the rated current.

8 Information to be given in the detail specification

8.1 General

The following information shall be given in the detail specification.

8.2 Measuring method of DC saturation limited current

a) Frequency f_s and voltage E_s (see 5.3.2, 5.5 d)).

b) Attachment jig (see 5.4).

c) Allowable decrease in inductance (see 5.5 f)).

d) DC saturation limited current (see 5.6).

8.3 Measuring method of temperature rise limited current

a) Measuring jig (see 6.3).

b) Measuring method (see 6.4).

c) Temperature rise value (see 6.4.2 h), 6.4.3 h)).

d) Measuring position (if thermo-couple method applied) (see 6.4.2 d)), 6.4.3 d)).

e) Temperature rise limited current (see 6.5).

Annex A
(informative)

Example of recommended description on product specification sheets and catalogues

Both the DC saturation limited current value and the temperature rise limited current value should be described on product specification sheets and catalogues.

It should be specified whether the DC saturation limited current value is determined when the allowable decrease in inductance value is at 10 % or 30 %.

Sharp saturation is defined as inductance that decreases by more than 8 % for a 10 % increase in bias current, measured where bias current has already reduced the inductance by 30 % compared with the unbiased inductance. Soft saturation is defined as inductance that decreases by less than 8 % for a 10 % increase in bias current, measured where bias current has already reduced the inductance by 30 % compared with the unbiased inductance.

Sharp saturating inductors have a steep drop in inductance beyond an inflection point, and therefore they are specified and designed to operate at load currents that are less than the current at the inflection point. 10 % is used for a standard specification point because it is a typical design point. Other values, such as 20 % or 30 %, may be used by mutual agreement between manufacture and user.

Soft saturating inductors have a continual and gradual drop in inductance, without a well-defined inflection point, and therefore they are specified and designed to operate at load currents that typically push inductance down by 20 % to 50 %, or even more as the application allows. 30 % is used for a standard specification point because it is a typical design point (but not necessarily a requisite design point). Other values, such as 20 % or 50 %, may be used by mutual agreement between manufacturer and user.

It should be specified whether the temperature rise limited current value is determined when the temperature rise of the inductor is 20 °C or 40 °C.

When the rated current is used, it should be the lower one of the DC saturation limited current values and the temperature rise limited current values.

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

Bibliography

MIL-PRF-15733, *Filters and Capacitors, Radio Frequency Interference, General Specification for*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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COMPOSANTS INDUCTIFS À HAUTE FRÉQUENCE – CARACTÉRISTIQUES ÉLECTRIQUES ET MÉTHODES DE MESURE –

Partie 2: Courant assigné des bobines d'induction pour des convertisseurs continu-continu

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La Norme internationale IEC 62024-2 a été établie par le comité d'études 51 de l'IEC: Composants magnétiques, ferrites et matériaux en poudre magnétique.

Cette deuxième édition annule et remplace la première édition parue en 2008. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout du Tableau 2 et de la Figure 2 b).

Le texte de cette Norme internationale est issu des documents suivants:

CDV	Rapport de vote
51/1303/CDV	51/1325/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 62024, publiées sous le titre général *Composants inductifs à haute fréquence – Caractéristiques électriques et méthodes de mesure*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
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- remplacé par une édition révisée, ou
- amendé.

COMPOSANTS INDUCTIFS À HAUTE FRÉQUENCE – CARACTÉRISTIQUES ÉLECTRIQUES ET MÉTHODES DE MESURE –

Partie 2: Courant assigné des bobines d'induction pour des convertisseurs continu-continu

1 Domaine d'application

La présente partie de l'IEC 62024 spécifie les méthodes de mesure des limites de courant continu assigné pour de petites bobines d'induction.

Les méthodes de mesure normalisées pour la détermination des caractéristiques assignées permettent aux utilisateurs de comparer avec précision les caractéristiques assignées courantes figurant dans les différents recueils de données fabricants.

Le présent document s'applique aux bobines d'induction à sorties et pour montage en surface dont les dimensions sont conformes à l'IEC 62025-1 et dont le courant assigné est généralement inférieur à 22 A, même si des bobines d'induction de courant assigné supérieur à 22 A sont disponibles et respectent les restrictions de dimensions de ce document (empreinte ne dépassant pas environ 12 mm × 12 mm). Ces bobines d'induction sont habituellement utilisées dans des convertisseurs continu-continu montés sur des cartes à circuit imprimé (CCI), pour des matériels électriques et de télécommunications, ainsi que pour des unités d'alimentation de puissance de commutation de petite taille.

Les méthodes de mesure sont définies par les limites de saturation et d'échauffement induites uniquement par le courant continu.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences 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 60068-1:2013, *Essai d'environnement – Partie 1: Généralités et lignes directrices*

IEC 62025-1, *Composants inductifs à haute fréquence – Caractéristiques non électriques et méthodes de mesure – Partie 1: Inductances fixes pour montage en surface utilisées dans les matériels électroniques et les équipements de télécommunications*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
courant continu limité en saturation
valeur admissible de courant continu pour laquelle la diminution de l'inductance se situe dans les limites de la valeur spécifiée

3.2
courant limité en échauffement
valeur admissible de courant continu pour laquelle la chaleur en autoproduction de la bobine d'induction donne lieu à un échauffement dans les limites de la valeur spécifiée

4 Conditions atmosphériques normales

4.1 Conditions atmosphériques normales pour les essais

Les conditions atmosphériques normales pour les essais doivent être les suivantes (voir 4.3 de l'IEC 60068-1:2013):

– température: 15 °C à 35 °C;
– humidité relative: 25 % à 75 %;
– pression atmosphérique: 86 kPa à 106 kPa.

En cas de litige ou si nécessaire, les mesures doivent être répétées en utilisant les températures de référence et les autres conditions données en 4.2.

4.2 Conditions de référence

A titre de référence, l'une des conditions atmosphériques normales pour les essais de référence issus du 4.2 de l'IEC 60068-1:2013 doit être choisie et doit correspondre à ce qui suit:

– température: 20 °C ± 2 °C;
– humidité relative: 60 % à 70 %;
– pression atmosphérique: 86 kPa à 106 kPa.

5 Méthode de mesure du courant continu limité en saturation

5.1 Généralités

Lorsque le courant alternatif sur lequel est superposé le courant continu alimente une bobine d'induction, l'inductance de la bobine d'induction diminue selon la valeur du courant continu.

Dans une application type, le courant de saturation résulte du courant de crête de la superposition du courant alternatif sur le courant continu. Dans le présent document, le courant de saturation est mesuré comme un courant continu compensant un courant alternatif de faible signal.

NOTE Il n'est pas pratique d'établir une norme pour le courant alternatif limité en saturation, car il existe un nombre infini de façons différentes d'appliquer un courant alternatif dans une application. De ce fait, les fabricants et les utilisateurs ont généralement défini un courant continu limité en saturation comme point commun de référence. Le présent document suit la même approche.

5.2 Conditions d'essai

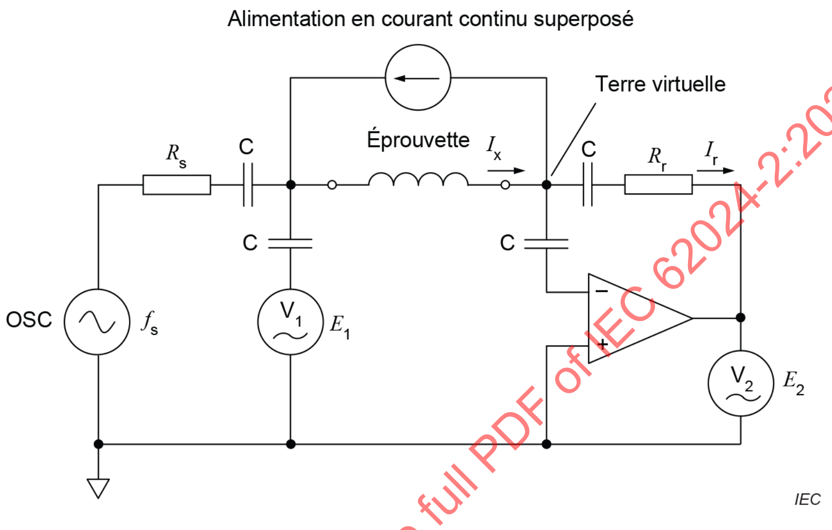
Sauf indication contraire dans la spécification particulière, les conditions d'essai doivent être conformes à l'Article 4.

NOTE La variation de la valeur du courant continu limité en saturation, en fonction de la température, dépend du matériau magnétique et de la structure du noyau magnétique de la bobine d'induction. Cependant, la mesure des courants continus de saturation à températures élevées n'est généralement pas pratique dans le cadre des examens. De ce fait, la mesure à température ambiante fournie par le présent document est généralement appliquée à des fins de spécifications. Des courbes du taux de réduction indiquant la variation du courant continu limité en saturation en fonction de la température de fonctionnement maximale de la bobine d'induction peuvent être générées. Ces courbes peuvent être utilisées en vue d'une corrélation entre le courant continu limité en saturation à température ambiante et le courant continu limité en saturation à des températures de fonctionnement types. Dans certains cas, il s'avère nécessaire pour le fabricant et l'utilisateur d'établir par accord une spécification supplémentaire pour des températures élevées telles que 85 °C, 105 °C ou 125 °C.

5.3 Circuit de mesure et calcul

5.3.1 Circuit de mesure

Le circuit de mesure est représenté à la Figure 1.



Composants

R_s résistance de source $R = R_s$

R_r gamme de résistance $R = R_r$

V_1 voltmètre $V_1 = E_1$

V_2 voltmètre $V_2 = E_2$

C condensateur de blocage à courant continu

Alimentations

f_s fréquence de la source

I_r courant fourni à la gamme de résistance

I_x courant fourni à l'éprouvette

$I_x = I_r$

Figure 1 – Circuit de mesure de l'inductance sous application de la condition de saturation en courant continu

5.3.2 Calcul

Les tensions E_1 et E_2 doivent être mesurées lorsque la fréquence f_s et la tension E_s du générateur de signal sont fournies conformément à la spécification particulière, et une valeur initiale de l'inductance doit être calculée à l'aide des formules suivantes.

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

$$Z_x = |Z_x|\cos\theta + j|Z_x|\sin\theta$$

$$Z_x = R_x + jX_x$$

$$L_x = \frac{X_x}{\omega} = \frac{X_x}{2\pi f_s}$$

où

R_x est la résistance de l'éprouvette;

X_x est la réactance de l'éprouvette;

Z_x est l'impédance de l'éprouvette;

L_x est l'inductance série équivalente de l'éprouvette;

E_1 est la tension appliquée à l'éprouvette;

E_2 est la tension appliquée à la gamme de résistance (= $I_r R_r$) (E_2 peut être considérée comme le courant);

θ est la différence d'angle de phase entre E_1 et E_2.

5.4 Gabarit de fixation de la bobine d'induction

Le gabarit de fixation de l'éprouvette doit être décrit dans la spécification particulière.

5.5 Méthode de mesure

a) Une légère compensation doit être effectuée avant la mesure.

b) L'éprouvette doit être reliée au circuit représenté à la Figure 1, en utilisant le gabarit de fixation spécifié en 5.4.

c) Lorsque l'éprouvette est reliée par brasage, elle doit rester telle quelle jusqu'à ce qu'elle ait suffisamment refroidi.

d) Les tensions E_1 et E_2 doivent être mesurées lorsque la fréquence f_s et la tension E_s du générateur de signal sont fournies conformément à la spécification particulière, et une valeur initiale de l'inductance doit être calculée à l'aide des formules du 5.3.2.

e) La valeur du courant continu qui est superposé à l'éprouvette doit être modulée et la valeur de l'inductance doit être mesurée.

f) La diminution par rapport à la valeur initiale de l'inductance doit être calculée. Le courant continu limité en saturation doit être déterminé en mesurant le courant continu lorsque la diminution de l'inductance correspond à la valeur indiquée dans la spécification particulière.

g) Il convient que la diminution d'inductance indiquée dans la spécification particulière soit de 10 % ou de 30 %.

NOTE La valeur de 10 % correspond à un des points de conception types pour les bobines d'induction à saturation marquée, et la valeur de 30 % correspond à un des points de conception types pour les bobines d'induction à saturation faible. Voir Annexe A.

5.6 Contrôle de conformité de la qualité

Le courant continu indiqué dans la spécification particulière doit être fourni à une éprouvette conformément aux méthodes spécifiées du 5.3 au 5.5, puis l'inductance doit être mesurée. La diminution de l'inductance doit se situer dans les limites de la valeur spécifiée.

6 Méthode de mesure du courant limité en échauffement

6.1 Généralités

Lorsqu'un courant continu est fourni à une bobine d'induction, celle-ci génère d'elle-même de la chaleur en fonction de la valeur du courant continu fourni, du fait de sa résistance au courant continu.

NOTE 1 L'échauffement résulte de l'autoéchauffement de la bobine d'induction. Les sources de chauffage correspondent à des pertes du cuivre en courant continu, des pertes du cuivre en courant alternatif et des pertes du noyau en courant alternatif. Le présent document définit uniquement l'échauffement induit par des courants continus. Les pertes du cuivre en courant alternatif et les pertes du noyau en courant alternatif sont prises en compte pour l'échauffement. Les pertes en courant alternatif sont considérablement affectées par la forme d'onde, l'amplitude et la fréquence.

NOTE 2 Il n'est pas pratique d'établir une norme pour le courant alternatif limité en échauffement, car il existe un nombre infini de façons différentes d'appliquer un courant alternatif dans une application. De ce fait, les fabricants et les utilisateurs ont généralement défini un courant continu limité en échauffement comme point commun de référence. Le présent document suit la même approche.

6.2 Conditions d'essai

Sauf indication contraire dans la spécification particulière (une température ambiante élevée, par exemple), les conditions d'essai doivent être conformes à l'Article 4.

Etant donné que la valeur de la résistance en courant continu augmente en fonction de la température, certaines applications nécessitent une température ambiante élevée, telle que 85 °C, 105 °C ou 125 °C, pour l'essai d'échauffement.

NOTE 1 La perte de puissance globale d'une bobine d'induction est une combinaison de pertes de puissance en courant continu due à la résistance en courant continu, ainsi que de pertes de puissance en courant alternatif due au courant alternatif dans les enroulements et de pertes dues au flux alternatif correspondant induit dans le noyau magnétique. La valeur de la résistance en courants alternatif et continu (la résistance du conducteur) augmente avec la température, ainsi la perte de puissance associée à la résistance du conducteur augmente avec la température. La perte associée au noyau magnétique est entièrement due à l'excitation en courant alternatif. La perte dans le noyau diminue avec l'augmentation de la température jusqu'à une température habituellement désignée comme la température minimale de perte dans le noyau, au-dessus de laquelle cette perte commence à augmenter. La température et l'amplitude minimales de perte dépendent du type et de la qualité du matériau magnétique. Certaines ferrites présentent des températures minimales marquées. Ces considérations sont prises en compte lors de l'emploi de courants d'échauffement dans des applications qui possèdent de hautes températures de fonctionnement et qui ont des pertes de puissance conséquentes en courant alternatif en plus de la perte de puissance en courant continu. La perte totale à une température donnée quelconque peut être dominée par une perte en courant continu ou en courant alternatif en fonction de la répartition de la perte de puissance à température ambiante ainsi que de la variation de chacune de ces pertes de puissance en fonction de la température.

NOTE 2 Concernant les courants continus limités en échauffement à hautes températures, la variation du courant continu limité en échauffement en fonction de la variation de la température ambiante peut être modélisée. La mesure à température ambiante est couramment appliquée pour les spécifications particulières. Dans tous les cas, la température ambiante de l'essai est indiquée dans la spécification particulière.

6.3 Gabarit de mesure

6.3.1 Généralités

Le gabarit de mesure doit être soit la méthode de la carte à circuit imprimé donnée en 6.3.2, soit la méthode du fil de sortie donnée en 6.3.3, et il doit être décrit dans la spécification particulière.

6.3.2 Méthode de la carte à circuit imprimé

La carte à circuit imprimé doit être constituée de tissu de fibres de verre époxyde (FR4). Sauf indication contraire dans la spécification particulière, les dimensions doivent être celles qui figurent dans le Tableau 1, dans le Tableau 2 et sur la Figure 2.