IEC 62024-2

Edition 3.0 2024-12
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 62024-2:2024-12 RLV(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 62024-2

Edition 3.0 2024-12
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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.100.10

ISBN 978-2-8327-0120-1

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

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

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.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62024-2:2008. 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.

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

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 DC limits for ~~small~~ inductors as defined below.

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~~ 125 A, although inductors with rated current greater than ~~22~~ 125 A are available that fall within the dimension restrictions of this document (no larger than a ~~12 mm × 12 mm~~ 625 mm^2 footprint ~~approximately~~). These inductors are typically used in DC-to-DC converters built on printed circuit boards (PCBs), for ~~electric~~ electronic 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 (DC).

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 terminology databases for use in standardization at the following addresses:

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

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

3.2
temperature rise limited current
allowable value of direct current (DC) 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 direct saturation limited current (DC)

5.1 General

When alternating current (AC) in which direct current (DC) 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 alternating current (AC) on direct current (DC). In this document, the saturation current is measured as direct current (DC) offsetting a small signal alternating current (AC).

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

5.2 Test conditions

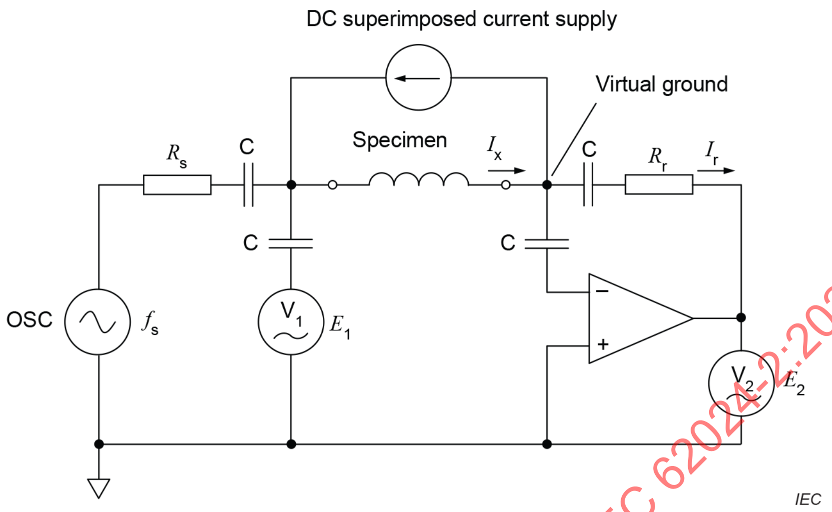
Unless otherwise specified in the detail specification, the test conditions shall be in accordance with Clause 4.

NOTE The variation of the value of direct saturation limited current (DC), as a function of temperature, is dependent on the magnetic material and the structure of the magnetic core of the inductor. However, measurement of direct 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 direct saturation limited current (DC) as a function of maximum operating temperature of the inductor can be generated. These curves can be used to correlate the direct saturation limited current (DC) at room temperature to the direct saturation limited current (DC) at typical operating temperatures. In some cases, ~~it will become necessary for~~ the manufacturer and user ~~to~~ will 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.



Key

Components

R_s source resistor R = R_s

R_r range select resistor R = R_r

V_1 voltmeter ~~V_1 = E_1~~

V_2 voltmeter ~~V_2 = E_2~~

E_1 RMS voltage value measured by voltmeter V_1

E_2 RMS voltage value measured by voltmeter V_2

E_s RMS voltage value of source

C DC current blocking capacitor

Supplies

f_s frequency of source

I_r supplied current to range select 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 select resistor (= $I_r R_r$) ~~(E_2 can be regarded as current)~~;

θ is the phase angle ~~difference between E_1 and E_2~~ of the complex impedance.

5.4 Attachment jig of inductor

The attachment jig of the specimen shall be specified in a detail specification (see Clause 8).

5.5 Measuring method

a) A short compensation shall be done before measurement.

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

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

c) 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.

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

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

f) 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 direct current (DC) 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 direct current (DC) is supplied to an inductor, the inductor generates heat by itself according to the supplied DC value because of its DC 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 direct currents (DC). In actual operating conditions, AC copper losses and AC core losses ~~are considered~~ for the temperature rise will be considered. AC losses are highly affected by waveform, amplitude and frequency.

NOTE 2 It is not practical to set a standard for alternating temperature rise limited current (AC), because there is an unlimited number of different ways to apply alternating current (AC) in an application. Therefore, manufacturers and users have generally defined ~~DC~~ direct 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 1 Power losses are factors that affect the efficiency of the DC-to-DC converter and the temperature rise of the inductor during actual operation, regardless of the operating temperature. In this document, temperature rise currents are defined in terms of direct currents (DC), so including alternating currents (AC) would be confusing and will be removed from the test conditions. The power ferrite core losses decrease 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 material type and grade. Some ferrite materials components exhibit sharp minima temperature. The temperature variation of the loss of the metal powder core, depending on the type of material, is considerably smaller than that of the ferrite core and does not tend to vary with temperature as the ferrite core exhibits.

NOTE 2 Regarding direct temperature rise limited currents (DC) at high temperatures, the variation in direct temperature rise limited current (DC) with ambient temperature variation can be modelled. 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 the 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

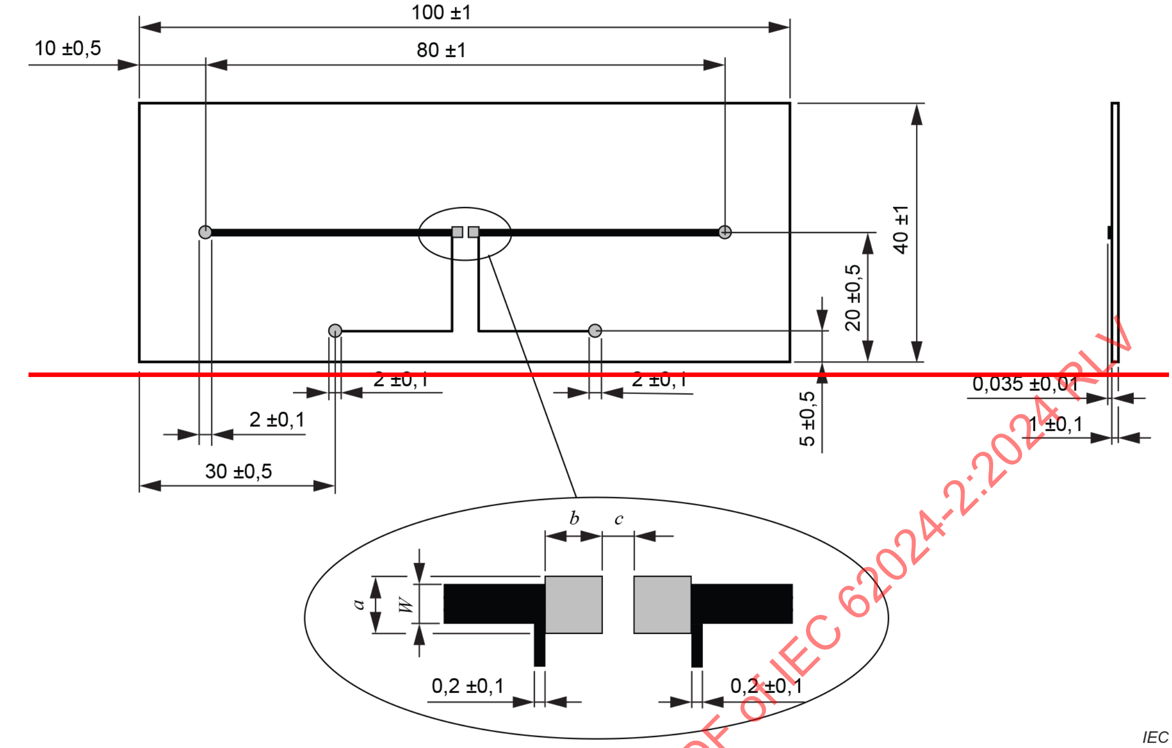
~~Rated current class~~	~~Rated current of inductor I A~~	~~Pattern width W mm~~
~~$I_{\text{class A}}$~~	~~$I \leq 1$~~	~~1,0 ± 0,2~~
	~~$1 < I \leq 2$~~	~~2,0 ± 0,2~~
	~~$2 < I \leq 3$~~	~~3,0 ± 0,3~~
	~~$3 < I \leq 5$~~	~~5,0 ± 0,3~~
	~~$5 < I \leq 7$~~	~~7,0 ± 0,5~~
	~~$7 < I \leq 11$~~	~~11,0 ± 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).~~		

Rated current class	Rated current of inductor I A	Pattern width W mm	Pattern thickness t µm	Test board	Thermal Environment	Example application
$I_{\text{class A}}$	$I \leq 1$	1,0 ± 0,2	35 ± 10	Figure 2a) Figure 2g)	Low heat dissipation environments	Consumer
	$1 < I \leq 2$	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				
$I_{\text{class B}}$	$I \leq 22$	40,0 ± 1.0		Figure 2b) Figure 2c) Figure 2d) Figure 2h)	Standard heat dissipation environments	Consumer/Automotive
$I_{\text{class C}}$	$I \leq 46$		105 ± 10		High heat dissipation environments	Consumer/Automotive
$I_{\text{class D}}$	$I \leq 125$		1 000 ± 50	Figure 2b) Figure 2e) Figure 2f) Figure 2i) Figure 2j)	Very high heat dissipation environments	Automotive/Large current power line (data centers, network infrastructure, etc.)
NOTE Winding cable to board: See Table 2.						

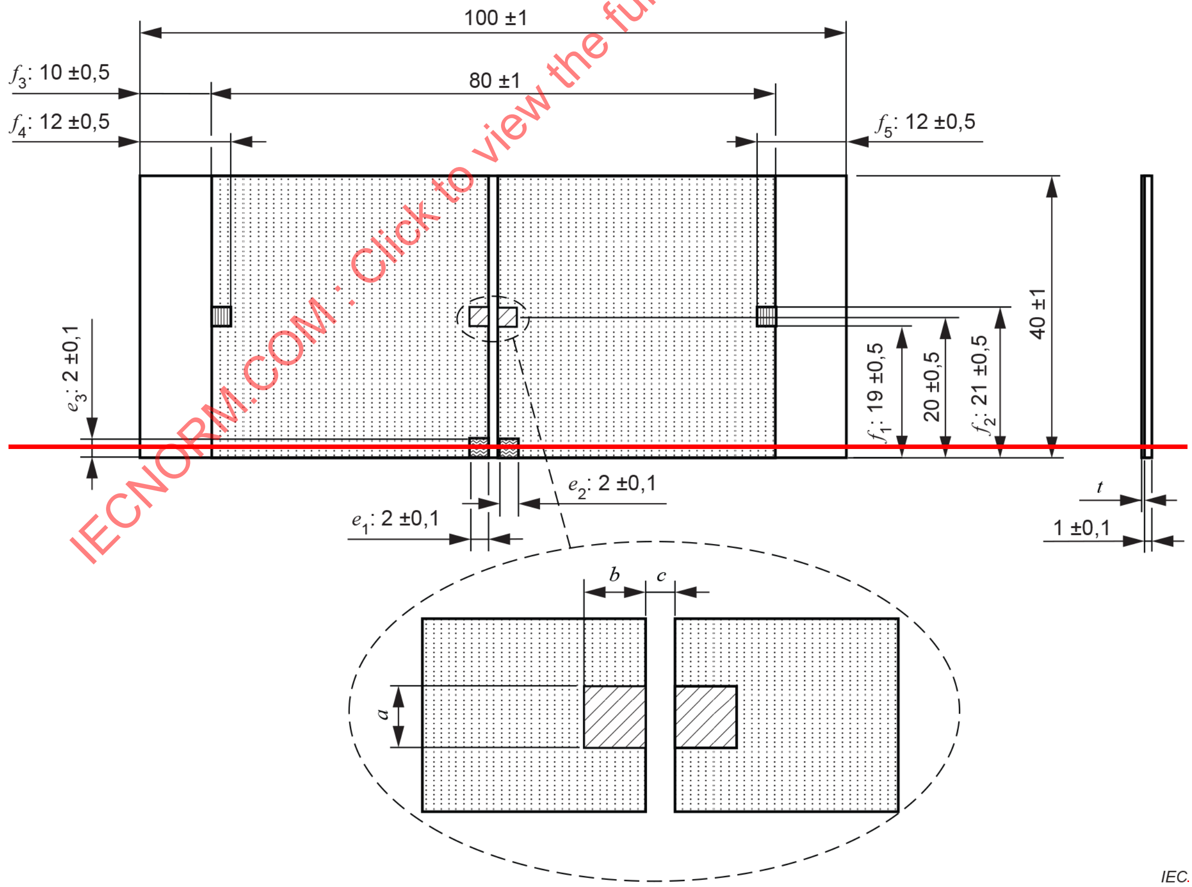
~~Table 2 – Circuit pattern width and thickness~~

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

~~Dimensions in millimetres~~

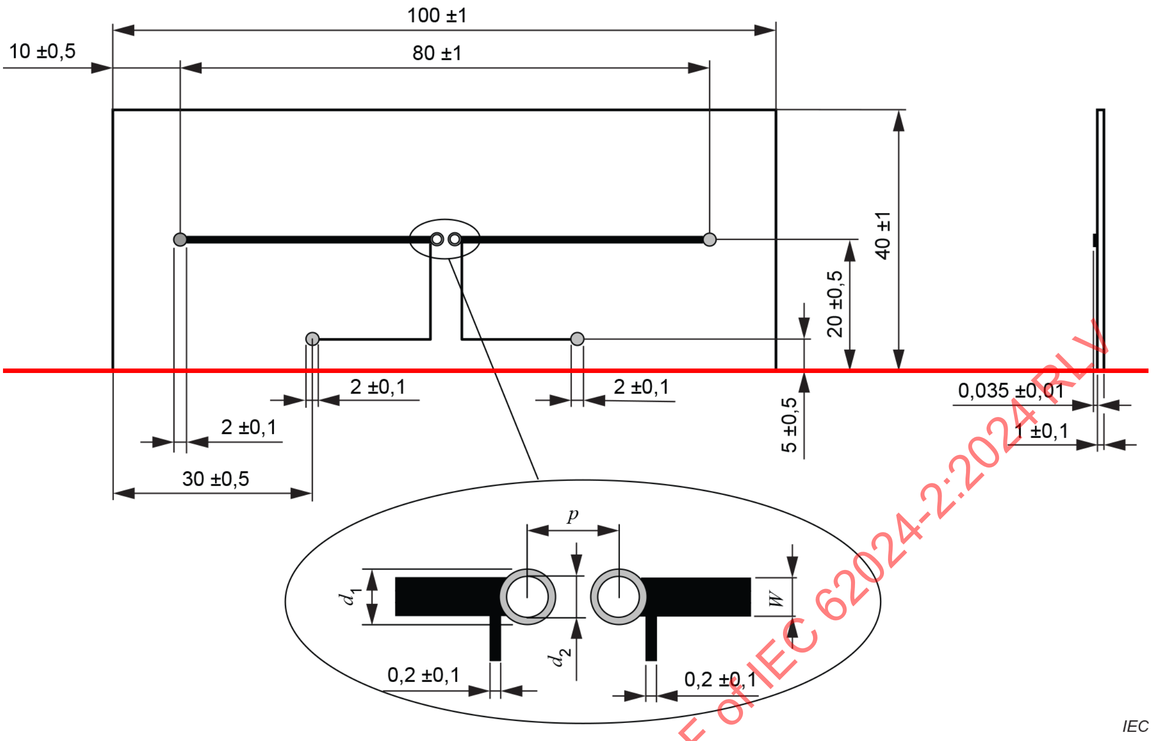


~~a) Example of printed-wiring board for SMD type (*I* class A)~~



~~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.~~

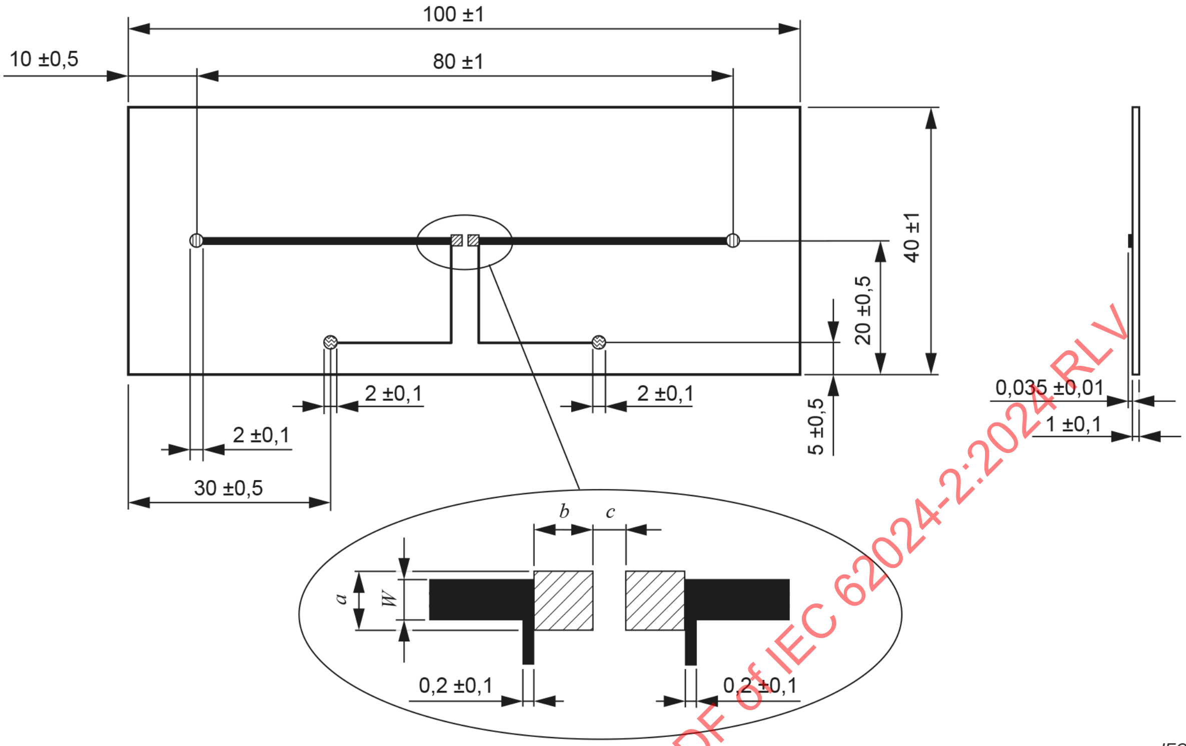
~~NOTE 2 Material of substrate: epoxide woven glass (FR4).~~

~~NOTE 3 Material of patterned areas: copper.~~

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

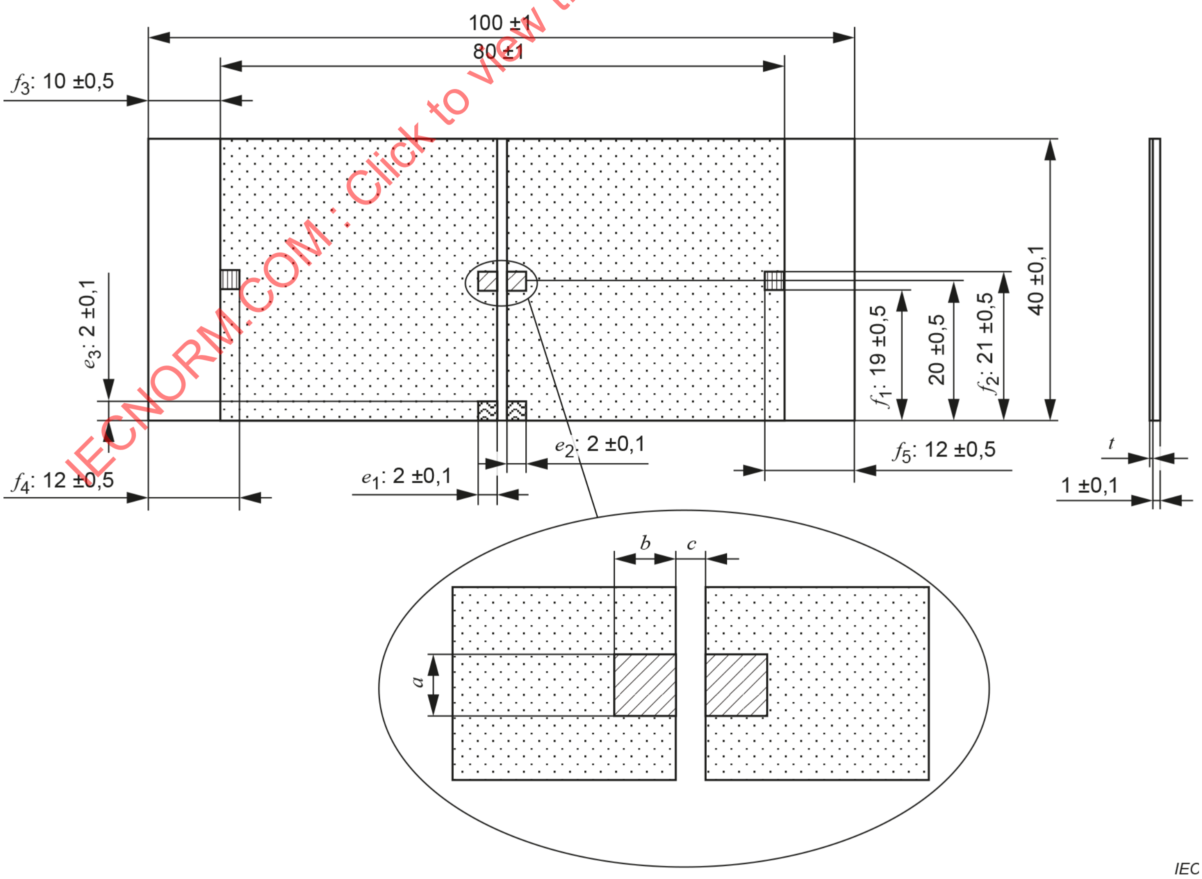
~~NOTE 5 e_1, e_2, e_3, f_1, f_2, f_3, f_4 and f_5: according to the detail specification~~

Dimensions in millimetres



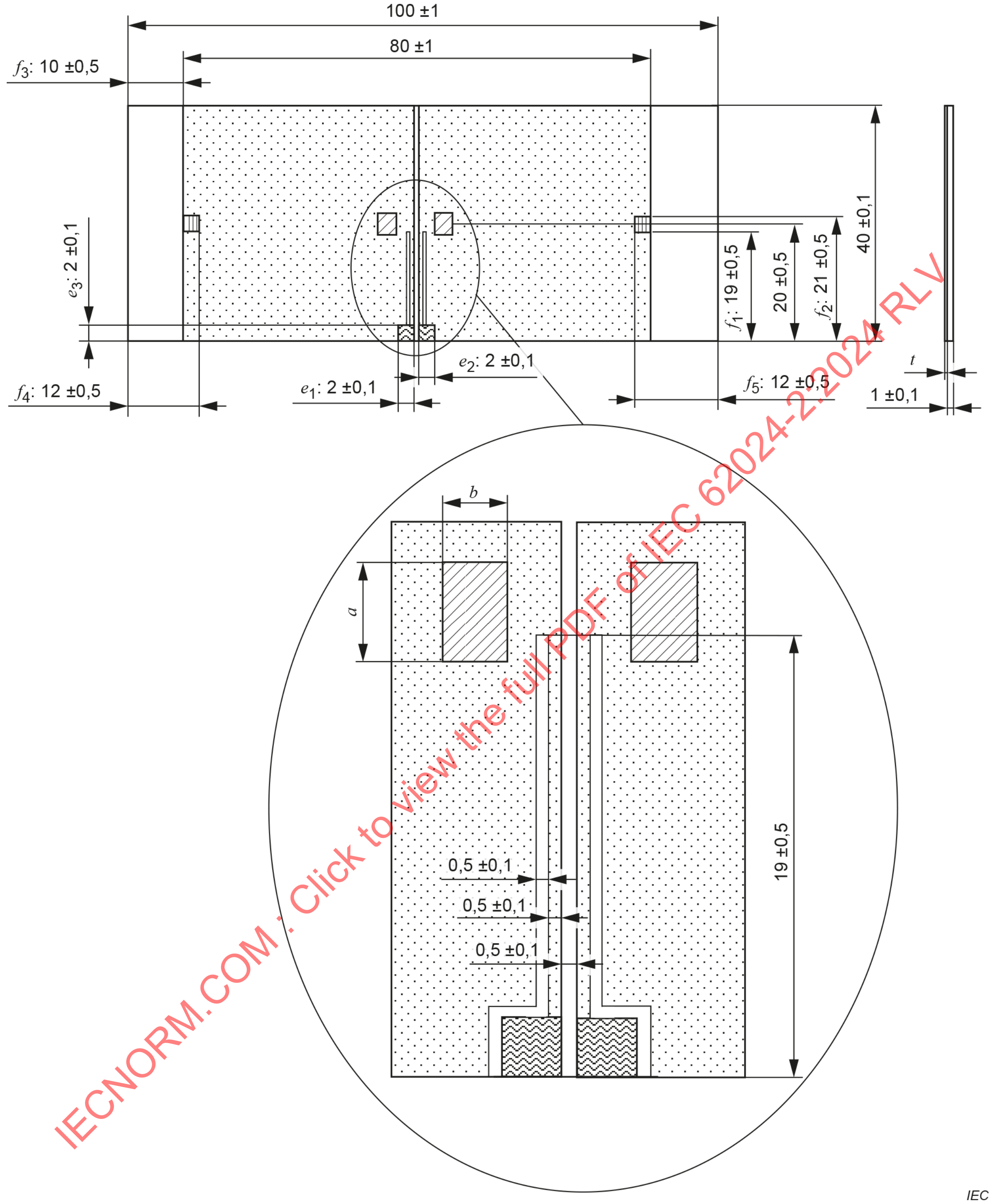
a) **Example of printed-wiring board for SMD type ($I_{\text{class A}}$)**

Dimension in millimetres



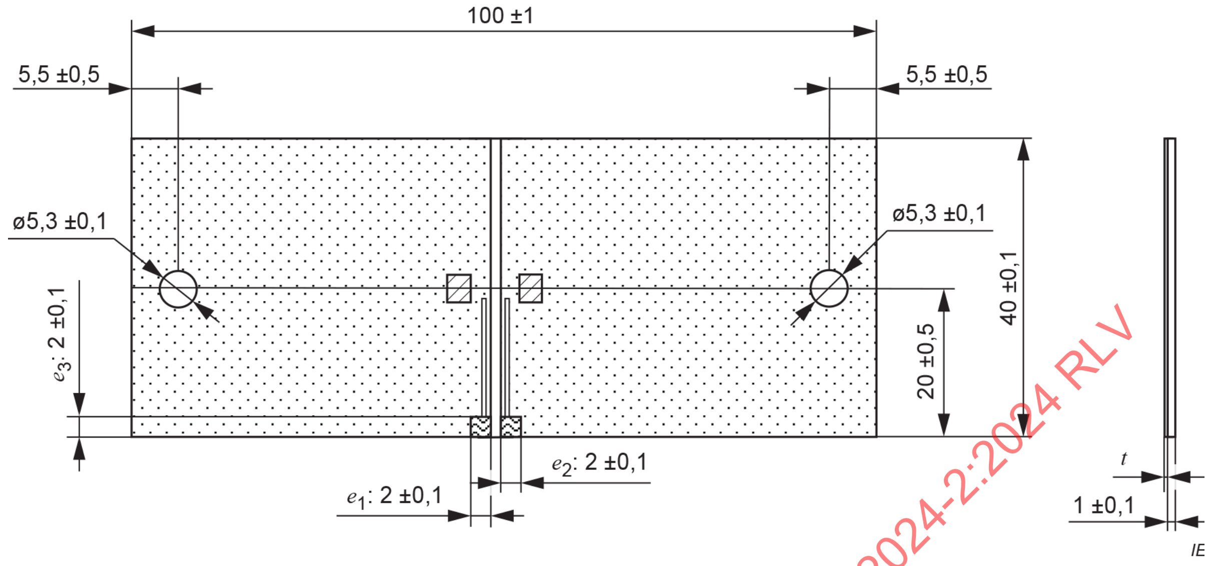
b) **Example of printed-wiring board for SMD type ($I_{\text{class B}}$, $I_{\text{class C}}$, $I_{\text{class D}}$)**

Dimension in millimetres



c) Example of printed-wiring board for SMD type ($I_{\text{class B}}$, $I_{\text{class C}}$)

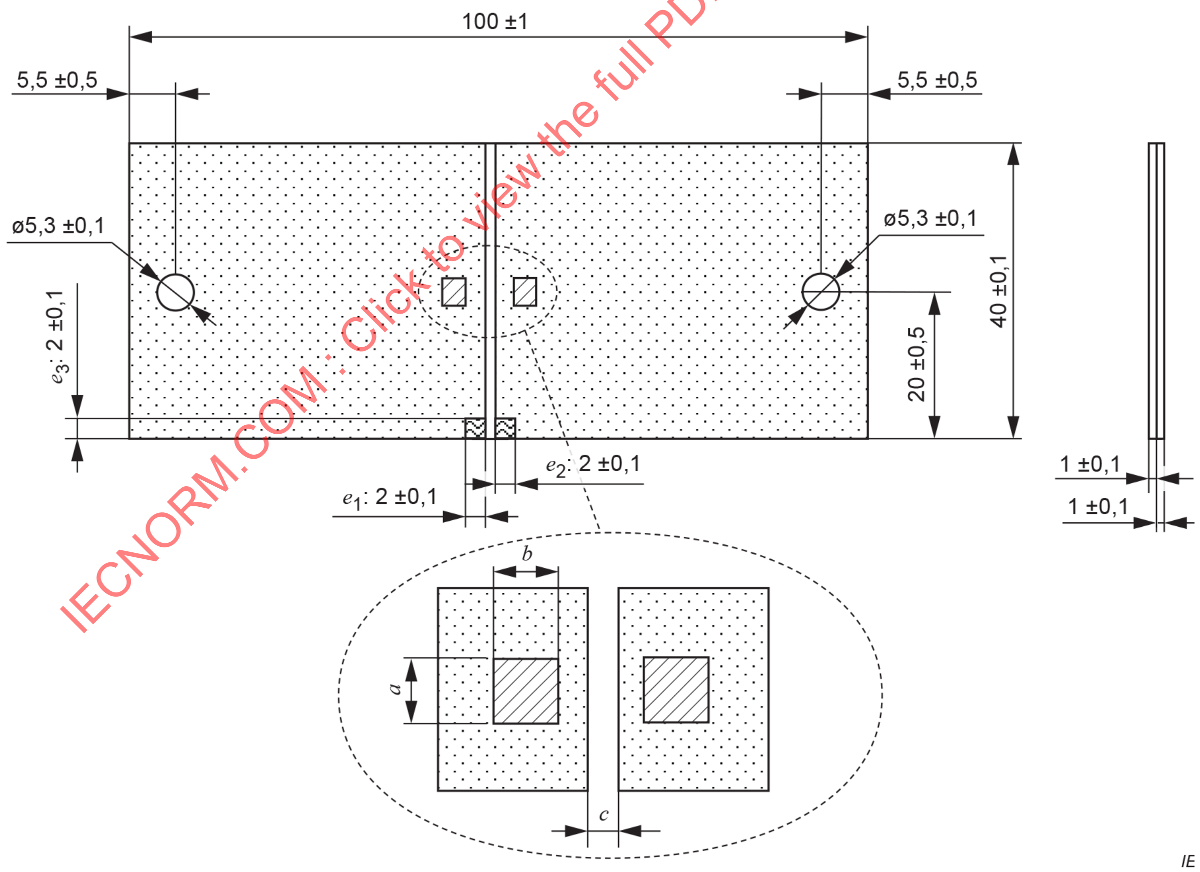
Dimensions in millimetres



NOTE Install crimp terminals suitable for the wire size. (See Table 2.)

d) Example of printed-wiring board for SMD type ($I_{class\ B}$, $I_{class\ C}$)

Dimensions in millimetres

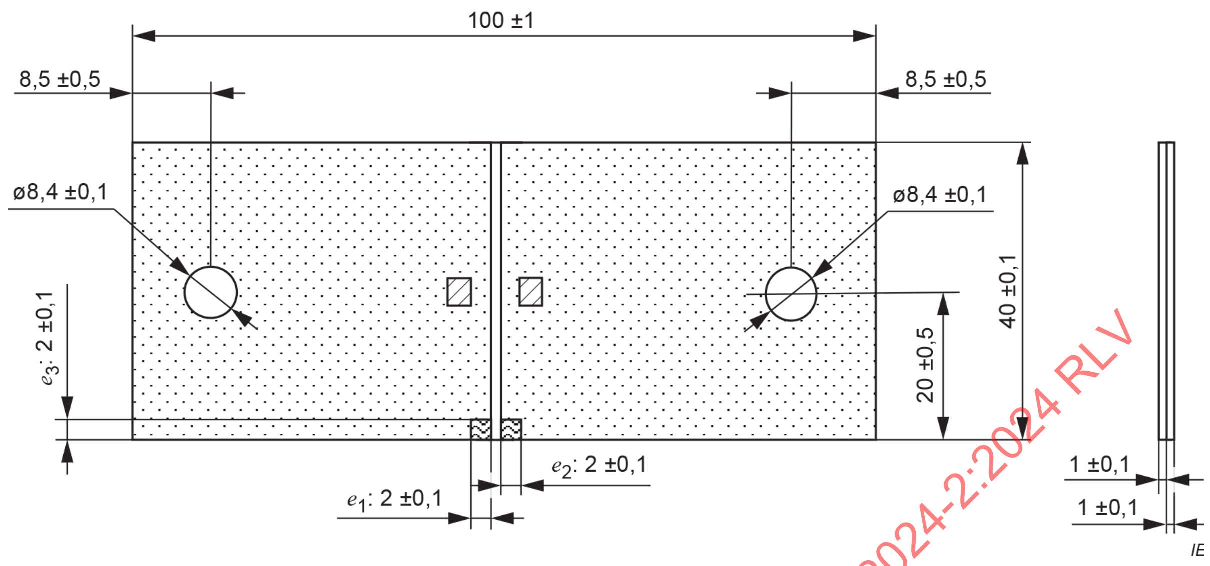


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

e) Example of printed-wiring board for SMD type ($I_{class\ D}$)

Dimensions in millimetres

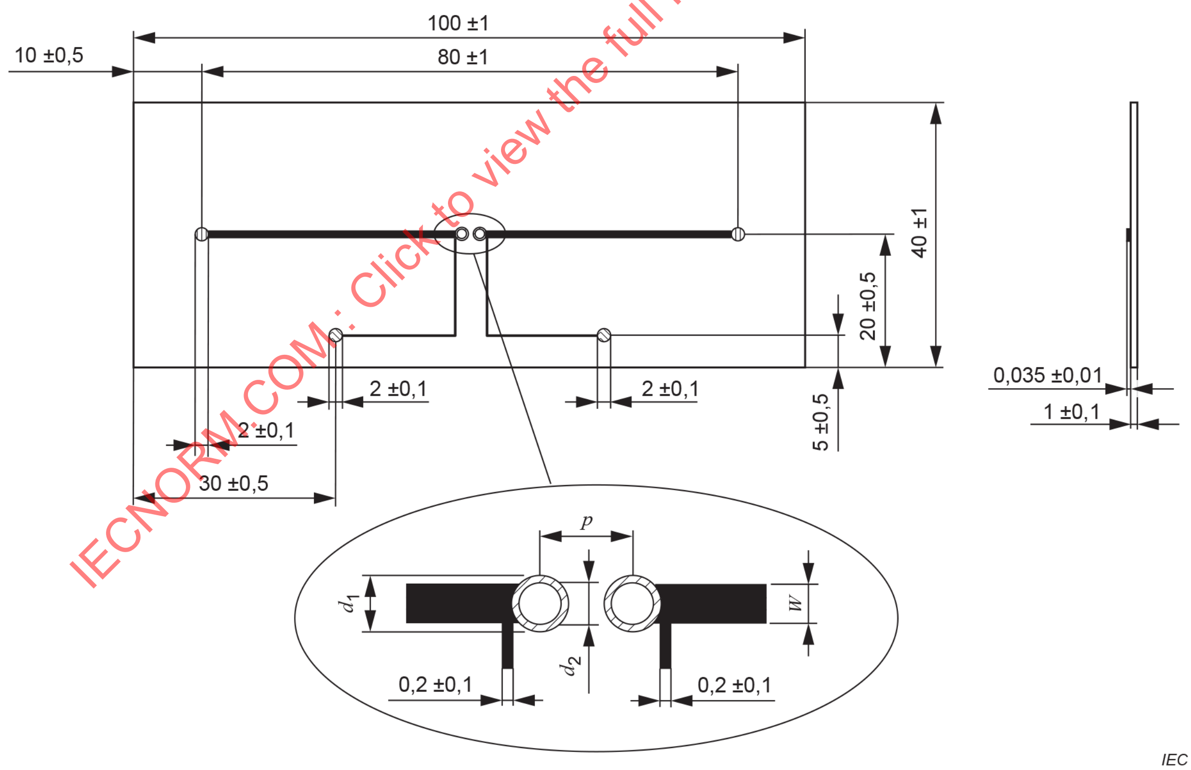


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

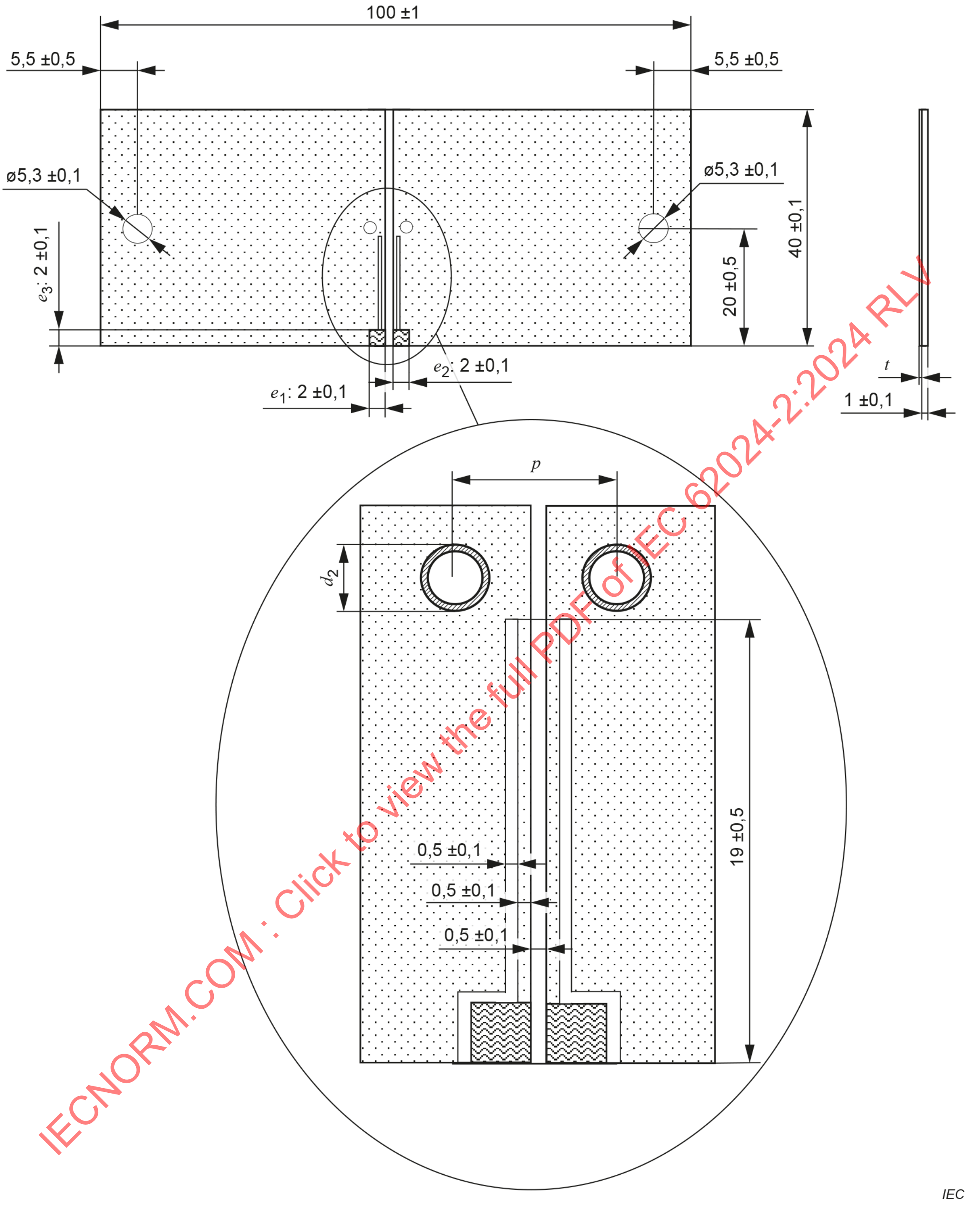
f) Example of printed-wiring board for SMD type ($I_{\text{class D}}$)

Dimensions in millimetres



g) Example of printed-wiring board for lead type ($I_{\text{class A}}$)

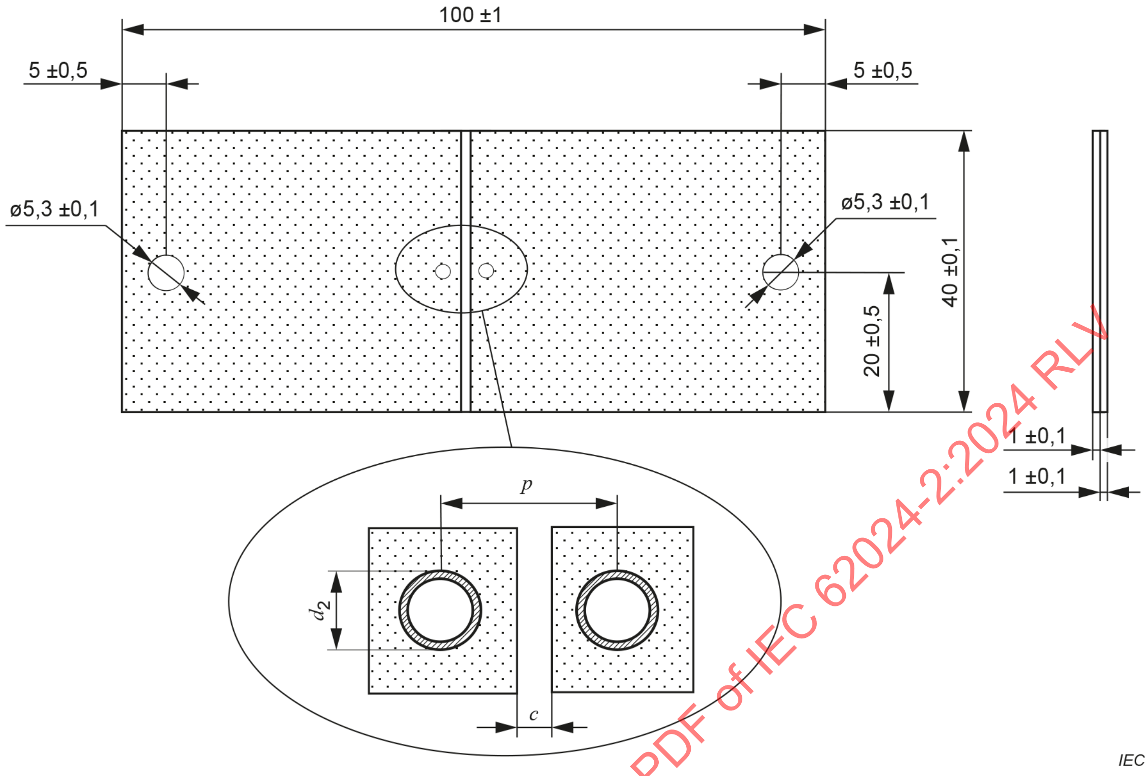
Dimensions in millimetres



NOTE Install crimp terminals suitable for the wire size. (See Table 2.)

h) Example of printed-wiring board for lead type ($I_{\text{class B}}$, $I_{\text{class C}}$)

Dimensions in millimetres

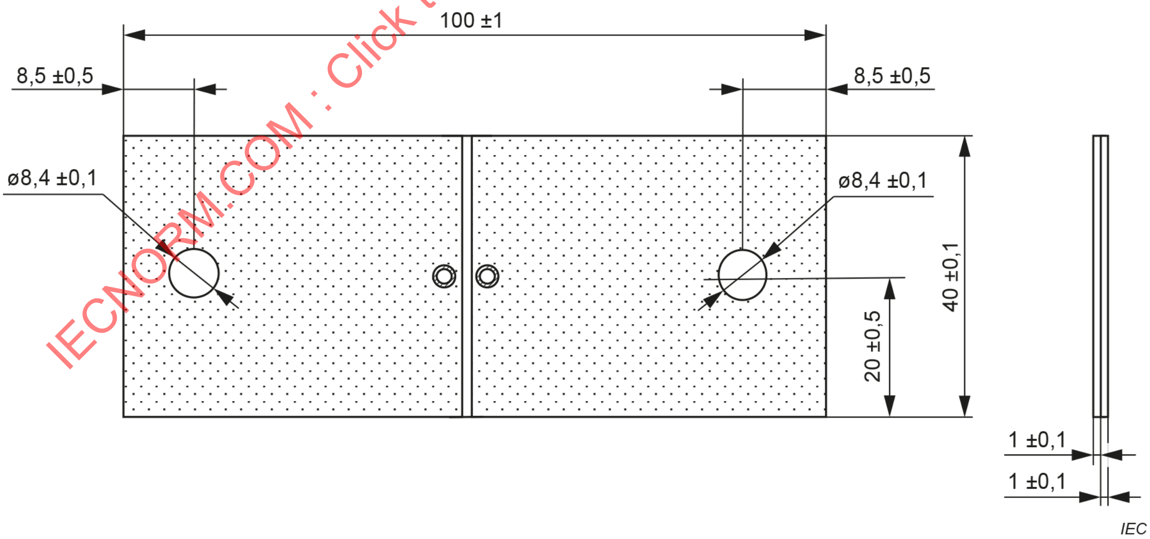


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

i) Example of printed-wiring board for lead type ($I_{\text{class D}}$)

Dimensions in millimetres



NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

j) Example of printed-wiring board for lead type ($I_{\text{class D}}$)

Key

Solderable areas (only the recommended surface 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)

Copper 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.

NOTE 5 e_1, e_2, e_3 and $f_{1\text{-}5}$: 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 2.

Table 2 – 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.~~

Rated current of inductors I	**Wire size**		**To connect to the test board**
A	mm	AWG (for reference)	Crimp terminals
$I \leq 3$	0,65 ± 0,05	22	R1.25-5
$3 < I \leq 5$	0,8 ± 0,05	20	R1.25-5
$5 < I \leq 11$	1,3 ± 0,1	16	R1.25-5
$11 < I \leq 16$	1,65 ± 0,1	14	R2-5
$16 < I \leq 22$	2,0 ± 0,1	12	R5.5-5
$22 < I \leq 35$	3,3 ± 0,1	8	R8-5
$35 < I \leq 46$	4,1 ± 0,1	6	R14-5
$46 < I \leq 55$	5,2 ± 0,1	4	R22-8

$55 < I \leq 90$	6,5 ± 0,1	2	R38-8
$90 < I \leq 125$	8,3 ± 0,1	0	R60-8
NOTE 1 AWG is a wire diameter number of American Wire Gauge. NOTE 2 Multiple strands of finer conductor wire gauges can be used in lieu of a single wire gauge if the composite cross section area of the conductor remains the same.			

6.4 Measuring method and calculation

6.4.1 General

The measuring method shall be the resistance substitution method of 6.4.2, the thermocouple method of 6.4.3, or the thermal camera method of 6.4.4, 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.

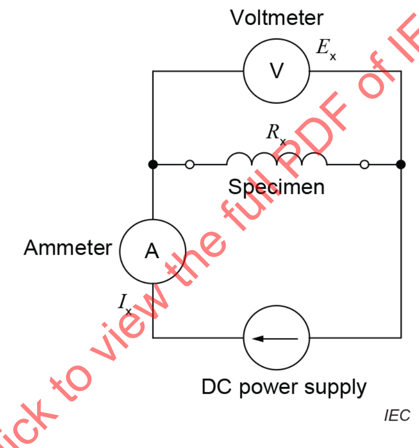


Figure 3 – Temperature rise measuring circuit by resistance substitution method

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~~ any surface. 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~~ any surface.

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

e) Direct current (DC) 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; ambient temperature t_{a2} shall also be measured. The resistance value R_x shall then 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 direct current (DC) is supplied (°C);

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

t_{a2} is the ambient temperature when direct current (DC) 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~~ related to the thermal coefficient of resistivity of the winding conductor. For the purposes of this document the value for copper shall be taken as 234,5.

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

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

i) The temperature rise of connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.4.3 Thermocouple method

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

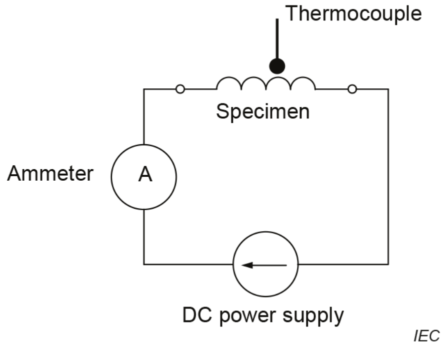


Figure 4 – Temperature rise measuring circuit by thermocouple method

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~~ The thermocouple shall be ~~given to~~ in 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 thermocouple 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 direct current (DC) is supplied.

f) Direct current (DC) 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: $\Delta T < 1$ (°C /min).

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

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

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

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 direct current (DC) is supplied (°C);

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

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

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

i) The temperature rise of the connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.4.4 Thermal camera method

a) The specimen shall be connected to the circuit shown in Figure 5, by using the measuring jig specified in 6.3.

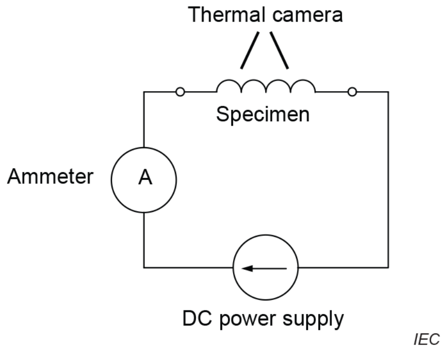


Figure 5 – Temperature rise measuring circuit by thermal camera method

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

c) The test piece and the conductor of the test current should be painted black or the emissivity should be pre-set so that the appropriate temperature can be measured.

d) 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 box may have an opening for the thermal camera to have line of sight access to the top of the test specimen.

The specimen shall be measured on the condition that it does not contact directly with any surface. 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 any surface.

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 direct current (DC) is supplied.

f) Direct current (DC) 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: $\Delta T < 1$ (°C /min).

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

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

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

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 direct current (DC) 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 direct current (DC) when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings made 1 min apart should not vary by more than 1 °C.

i) The temperature rise of the connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.5 Quality conformance inspection

The direct current (DC) specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 6.3 and 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 direct saturation limited current (DC) 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 direct saturation limited current (DC)

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) Direct saturation limited current (DC) (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), 6.4.4 h)).

d) Measuring position (if thermocouple method is applied) (see 6.4.3 d)).

e) Temperature rise limited current (see 6.4.4).

Annex A
(informative)

Example of recommended description on product specification sheets and catalogues

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

It should be specified whether the direct saturation limited current (DC) 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 manufacturer 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~~ indicated in a specification sheet or catalogue, it should be the lower one of the direct saturation limited current (DC) value and the temperature rise limited current value.

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

Bibliography

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*

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

___

IEC 62024-2

Edition 3.0 2024-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Composants inductifs à haute fréquence – Caractéristiques électriques et méthodes de mesure –
Part 2: Courant assigné des bobines d'inductance pour les convertisseurs continu-continu

IEC 62024-2:2024-12(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

**HIGH FREQUENCY INDUCTIVE COMPONENTS –
ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –**

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

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch [and/or] www.iso.org/patents. IEC shall not be held responsible for identifying any or all such patent rights.

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

This third edition cancels and replaces the second edition published in 2020. This edition constitutes a technical revision.

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

a) extension of scope by increase of range of rated current from 22 A to 125 A;
b) extension of scope by increase of footprint limitation from 12 mm × 12 mm to 625 mm^2;
c) addition of upper current limitation for $I_{\text{class B}}$, $I_{\text{class C}}$ and $I_{\text{class D}}$ board to Table 1;
d) revised application examples for Table 1;

e) addition of wire size references for current ranges between 22 A ≤ I ≤ 125 A to Table 2;
f) addition of crimp terminal references to Table 2;
g) addition of thermal camera method.

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

Draft	Report on voting
51/1522/FDIS	51/1532/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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 DC limits for inductors as defined below.

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 125 A, although inductors with rated current greater than 125 A are available that fall within the dimension restrictions of this document (no larger than a 625 mm^2 footprint). These inductors are typically used in DC-to-DC converters built on printed circuit boards (PCBs), for electronic 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 (DC).

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*

3 Terms and definitions

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

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

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

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

3.2
temperature rise limited current
allowable value of direct current (DC) 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 direct saturation limited current (DC)

5.1 General

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

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

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

5.2 Test conditions

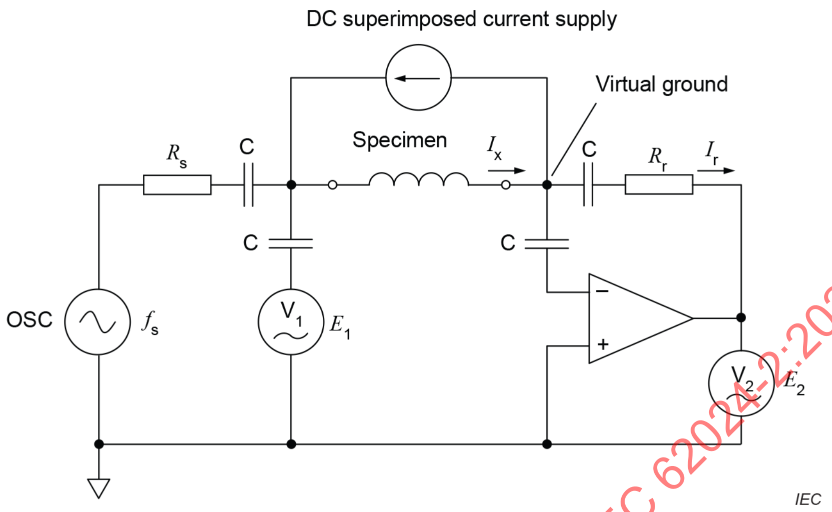
Unless otherwise specified in the detail specification, the test conditions shall be in accordance with Clause 4.

NOTE The variation of the value of direct saturation limited current (DC), as a function of temperature, is dependent on the magnetic material and the structure of the magnetic core of the inductor. However, measurement of direct 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 direct saturation limited current (DC) as a function of maximum operating temperature of the inductor can be generated. These curves can be used to correlate the direct saturation limited current (DC) at room temperature to the direct saturation limited current (DC) at typical operating temperatures. In some cases, the manufacturer and user will 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.



Key

Components

R_s source resistor $R = R_s$

R_r range select resistor $R = R_r$

V_1 voltmeter

V_2 voltmeter

E_1 RMS voltage value measured by voltmeter V_1

E_2 RMS voltage value measured by voltmeter V_2

E_s RMS voltage value of source

C DC current blocking capacitor

Supplies

f_s frequency of source

I_r supplied current to range select 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 select resistor (= $I_r R_r$);

θ is the phase angle of the complex impedance.

5.4 Attachment jig of inductor

The attachment jig of the specimen shall be specified in a detail specification (see Clause 8).

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. Direct saturation limited current (DC) shall be determined by measuring the direct current (DC) 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 direct current (DC) 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 direct current (DC) is supplied to an inductor, the inductor generates heat by itself according to the supplied DC value because of its DC 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 direct currents (DC). In actual operating conditions, AC copper losses and AC core losses for the temperature rise will be considered. AC losses are highly affected by waveform, amplitude and frequency.

NOTE 2 It is not practical to set a standard for alternating temperature rise limited current (AC), because there is an unlimited number of different ways to apply alternating current (AC) in an application. Therefore, manufacturers and users have generally defined direct 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 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 Power losses are factors that affect the efficiency of the DC-to-DC converter and the temperature rise of the inductor during actual operation, regardless of the operating temperature. In this document, temperature rise currents are defined in terms of direct currents (DC), so including alternating currents (AC) would be confusing and will be removed from the test conditions. The power ferrite core losses decrease 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 material type and grade. Some ferrite materials components exhibit sharp minima temperature. The temperature variation of the loss of the metal powder core, depending on the type of material, is considerably smaller than that of the ferrite core and does not tend to vary with temperature as the ferrite core exhibits.

NOTE 2 Regarding direct temperature rise limited currents (DC) at high temperatures, the variation in direct temperature rise limited current (DC) with ambient temperature variation can be modelled. 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 the 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.

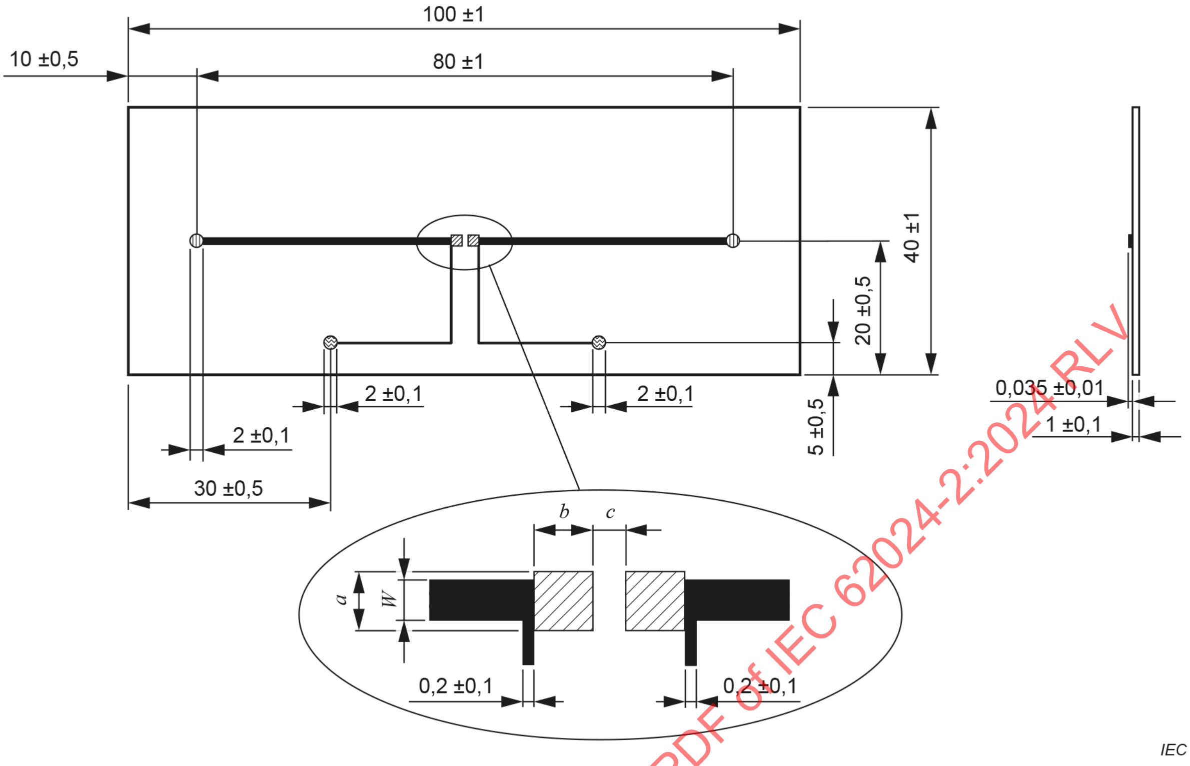
6.3.2 Printed-wiring board method

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

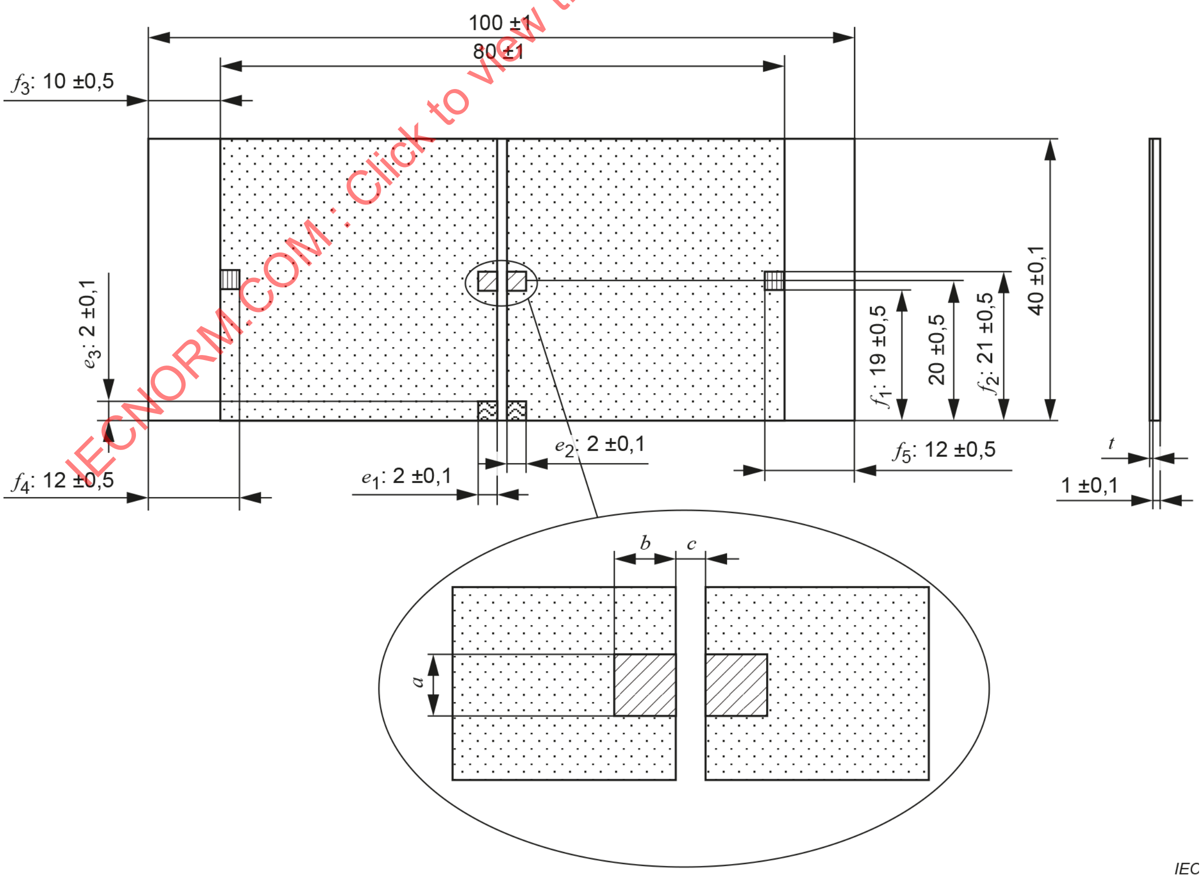
Rated current class	**Rated current of inductor** I A	**Pattern width** W mm	**Pattern thickness** t µm	**Test board**	**Thermal Environment**	**Example application**
$I_{\text{class A}}$	$I \leq 1$	1,0 ± 0,2	35 ± 10	Figure 2a) Figure 2g)	Low heat dissipation environments	Consumer
	$1 < I \leq 2$	2,0 ± 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				
$I_{\text{class B}}$	$I \leq 22$	40,0 ± 1.0		Figure 2b) Figure 2c) Figure 2d) Figure 2h)	Standard heat dissipation environments	Consumer/Automotive
$I_{\text{class C}}$	$I \leq 46$		105 ± 10		High heat dissipation environments	Consumer/Automotive
$I_{\text{class D}}$	$I \leq 125$		1 000 ± 50	Figure 2b) Figure 2e) Figure 2f) Figure 2i) Figure 2j)	Very high heat dissipation environments	Automotive/Large current power line (data centers, network infrastructure, etc.)
NOTE Winding cable to board: See Table 2.						

Dimensions in millimetres



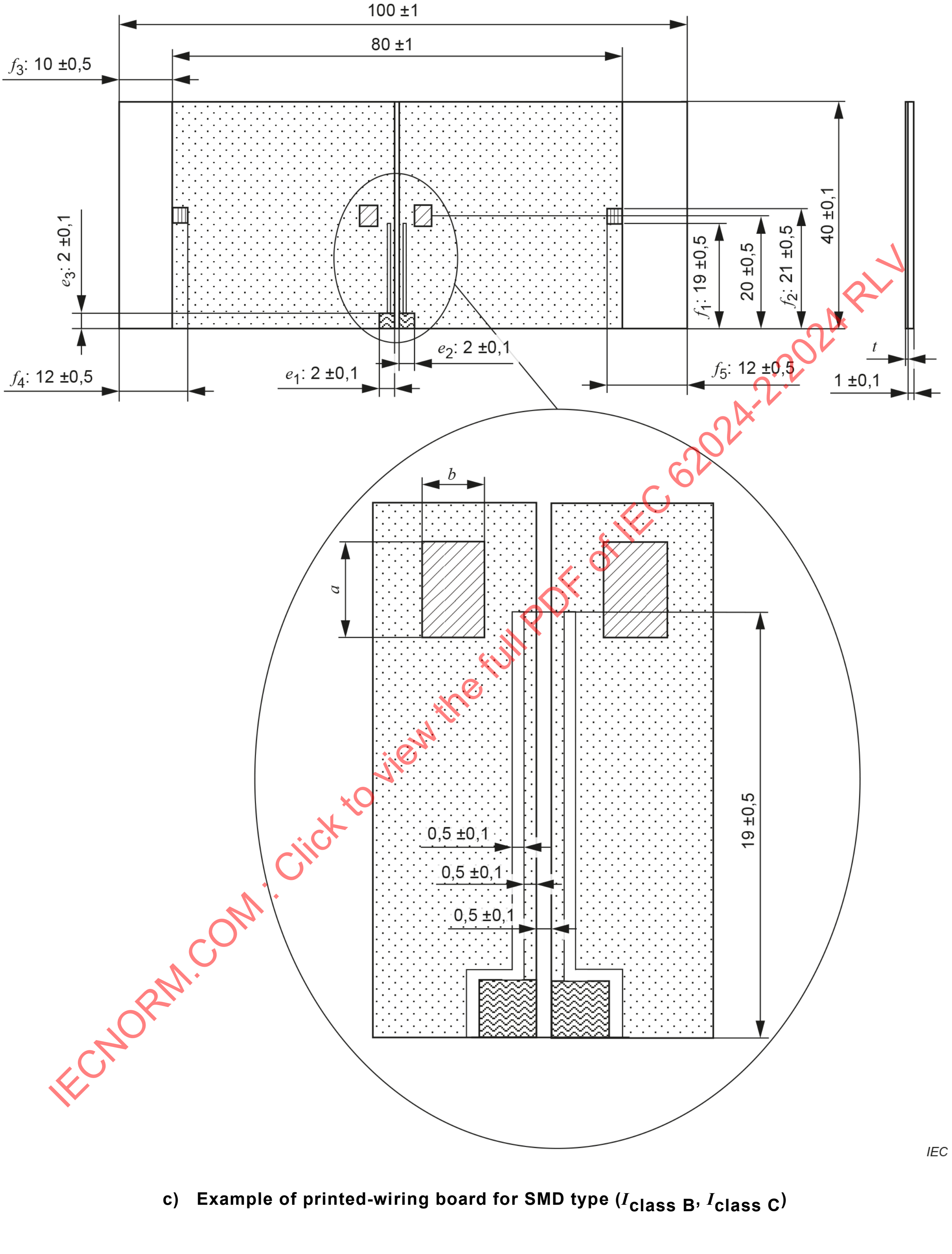
a) **Example of printed-wiring board for SMD type ($I_{\text{class A}}$)**

Dimension in millimetres



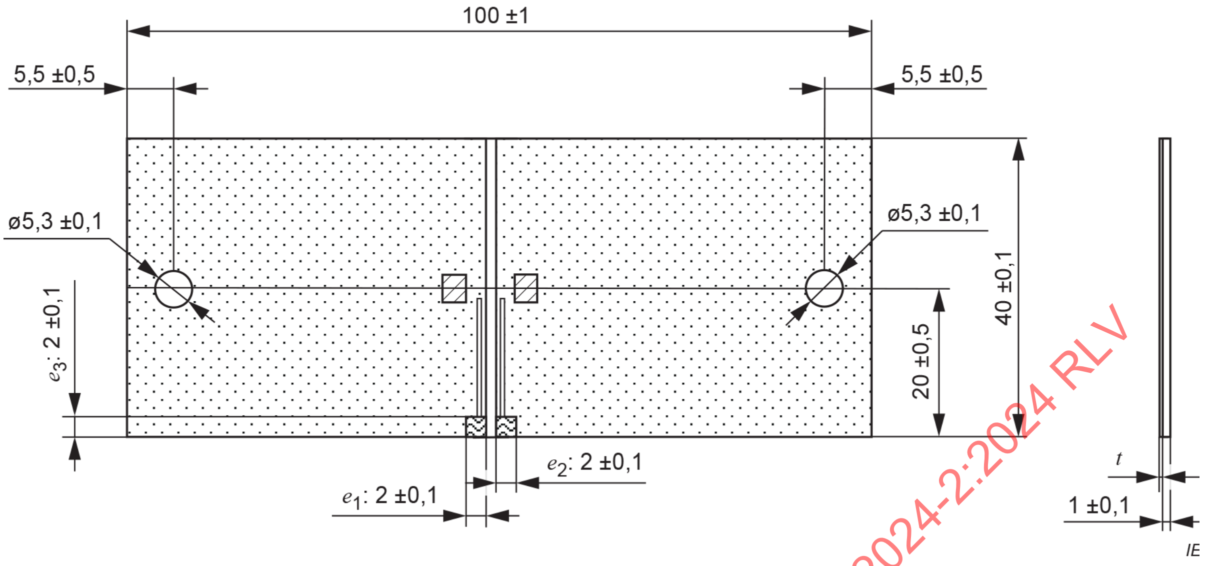
b) **Example of printed-wiring board for SMD type ($I_{\text{class B}}$, $I_{\text{class C}}$, $I_{\text{class D}}$)**

Dimension in millimetres



c) **Example of printed-wiring board for SMD type ($I_{\text{class B}}$, $I_{\text{class C}}$)**

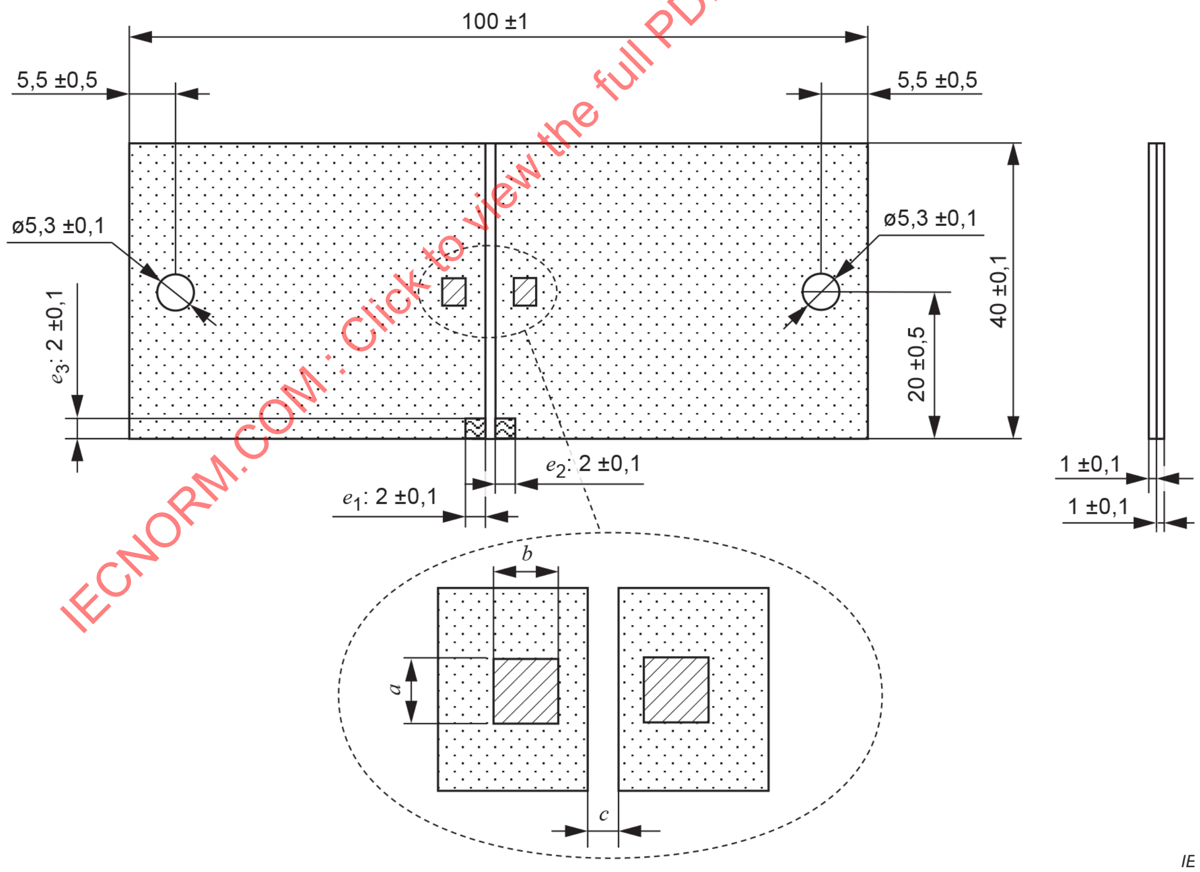
Dimensions in millimetres



NOTE Install crimp terminals suitable for the wire size. (See Table 2.)

d) Example of printed-wiring board for SMD type ($I_{class\ B}$, $I_{class\ C}$)

Dimensions in millimetres

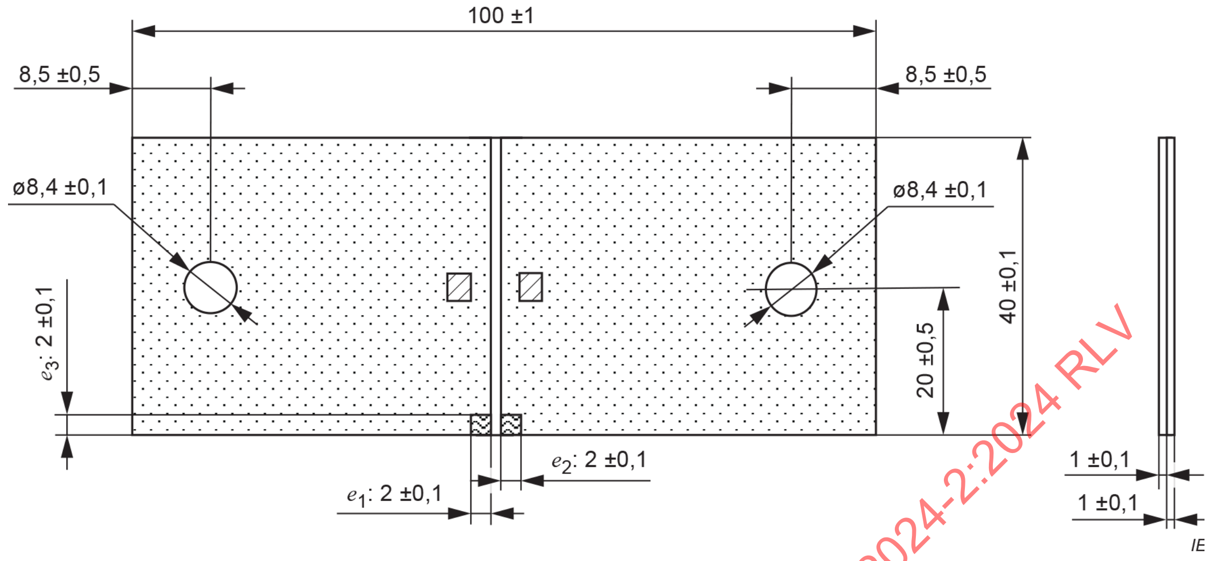


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

e) Example of printed-wiring board for SMD type ($I_{class\ D}$)

Dimensions in millimetres

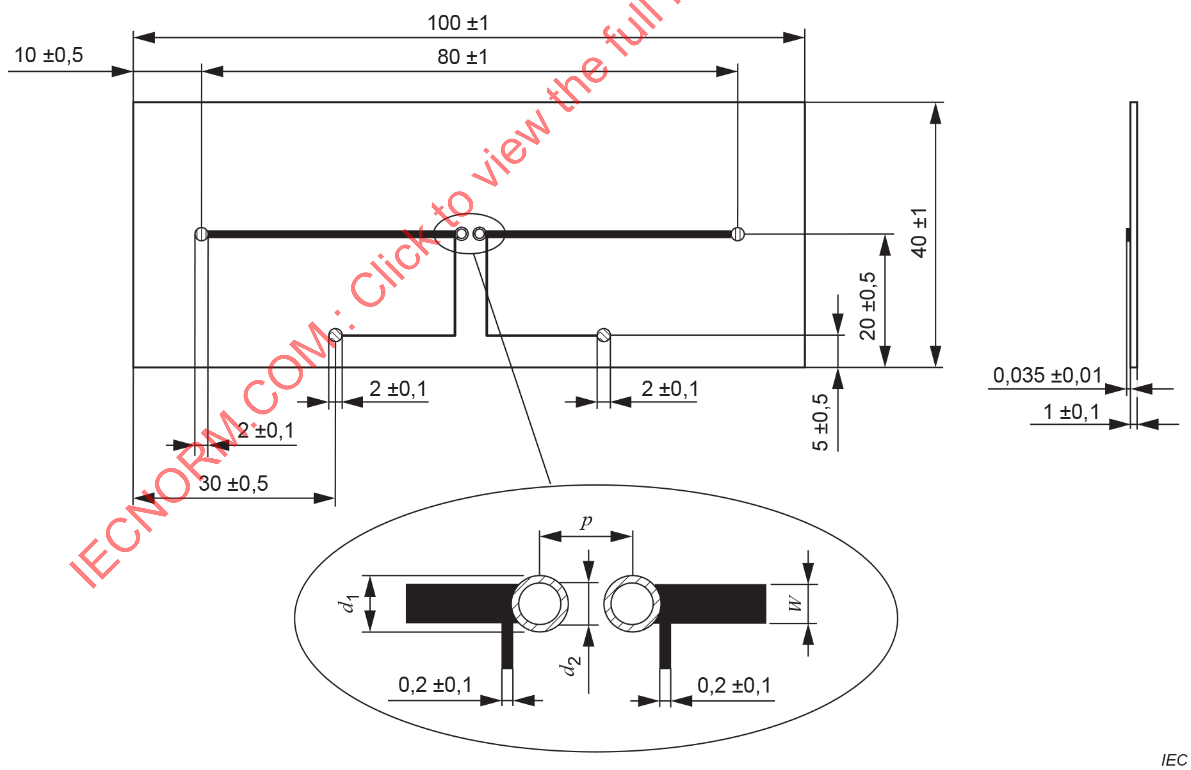


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

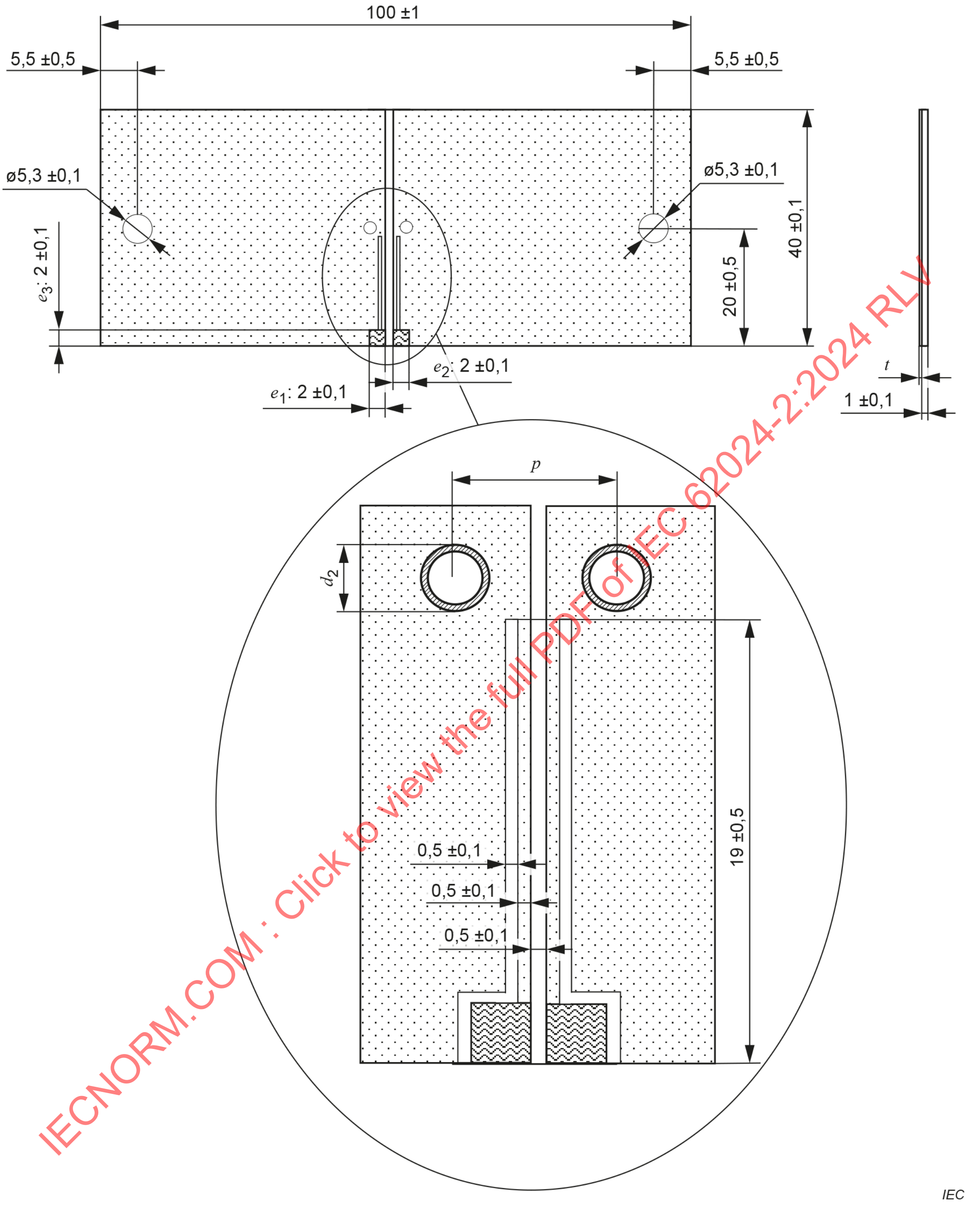
f) Example of printed-wiring board for SMD type ($I_{\text{class D}}$)

Dimensions in millimetres



g) Example of printed-wiring board for lead type ($I_{\text{class A}}$)

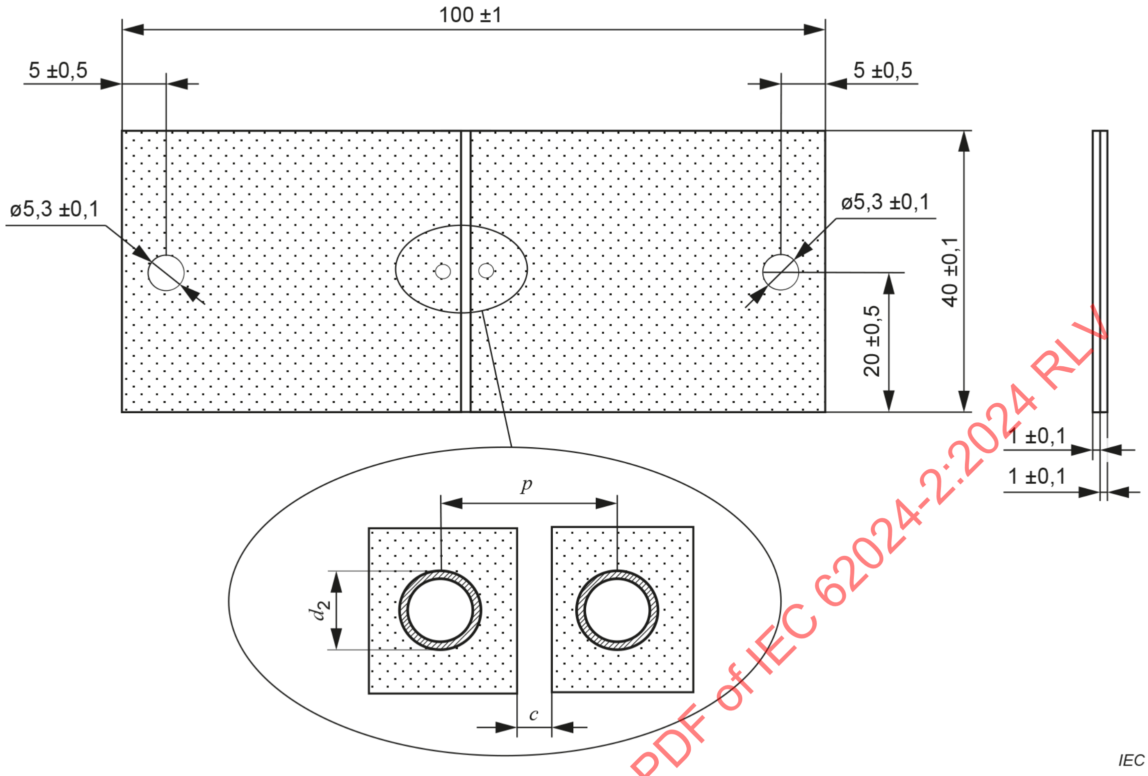
Dimensions in millimetres



NOTE Install crimp terminals suitable for the wire size. (See Table 2.)

h) Example of printed-wiring board for lead type ($I_{\text{class B}}$, $I_{\text{class C}}$)

Dimensions in millimetres

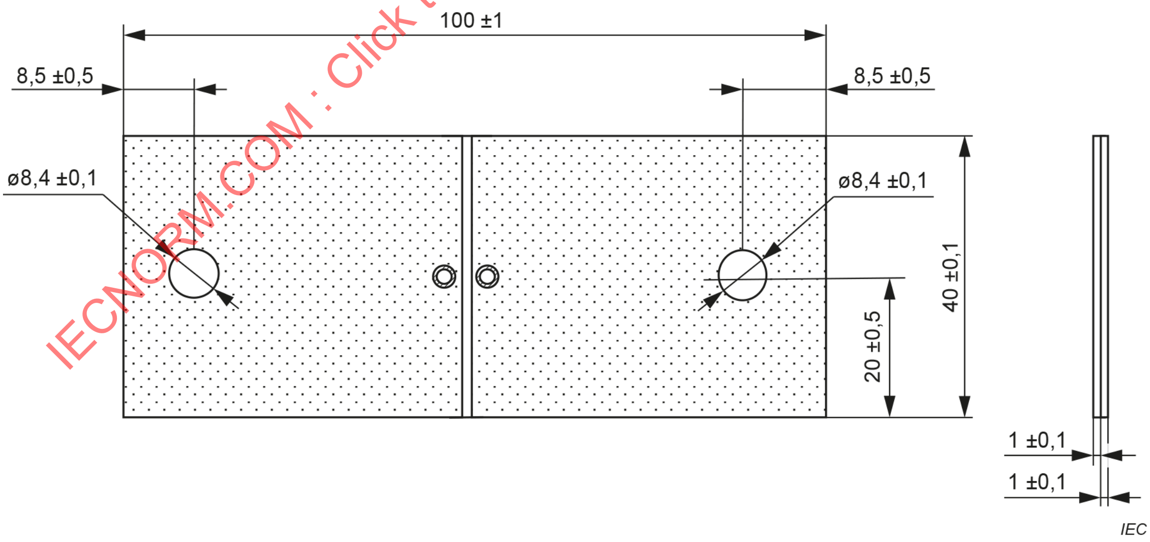


NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

i) Example of printed-wiring board for lead type ($I_{\text{class D}}$)

Dimensions in millimetres



NOTE 1 Install crimp terminals suitable for the wire size. (See Table 2.)

NOTE 2 Lead wires can also be fitted near the inductor terminals as a sense trace on a class D board.

j) Example of printed-wiring board for lead type ($I_{\text{class D}}$)

Key

Solderable areas (only the recommended surface 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)

Copper 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.

NOTE 5 e_1, e_2, e_3 and $f_{1\text{-}5}$: 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 2.

Table 2 – Wire size of circuits

Rated current of inductors I	Wire size		To connect to the test board
A	mm	AWG (for reference)	Crimp terminals
$I \leq 3$	0,65 ± 0,05	22	R1.25-5
$3 < I \leq 5$	0,8 ± 0,05	20	R1.25-5
$5 < I \leq 11$	1,3 ± 0,1	16	R1.25-5
$11 < I \leq 16$	1,65 ± 0,1	14	R2-5
$16 < I \leq 22$	2,0 ± 0,1	12	R5.5-5
$22 < I \leq 35$	3,3 ± 0,1	8	R8-5
$35 < I \leq 46$	4,1 ± 0,1	6	R14-5
$46 < I \leq 55$	5,2 ± 0,1	4	R22-8
$55 < I \leq 90$	6,5 ± 0,1	2	R38-8
$90 < I \leq 125$	8,3 ± 0,1	0	R60-8

NOTE 1 AWG is a wire diameter number of American Wire Gauge.

NOTE 2 Multiple strands of finer conductor wire gauges can be used in lieu of a single wire gauge if the composite cross section area of the conductor remains the same.

6.4 Measuring method and calculation

6.4.1 General

The measuring method shall be the resistance substitution method of 6.4.2, the thermocouple method of 6.4.3, or the thermal camera method of 6.4.4, 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.

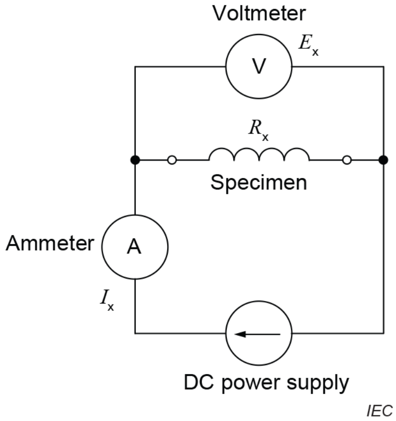


Figure 3 – Temperature rise measuring circuit by resistance substitution method

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 any surface. 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 any surface.

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

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

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

where

I_x is the DC 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 direct current (DC) is supplied (°C);

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

t_{a2} is the ambient temperature when direct current (DC) 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 related to the thermal coefficient of resistivity of the winding conductor. For the purposes of this document the value for copper shall be taken as 234,5.

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

h) Temperature rise limited current shall be determined by measuring direct current (DC) when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings made 1 min apart should not vary by more than 1 °C.

i) The temperature rise of connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.4.3 Thermocouple method

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

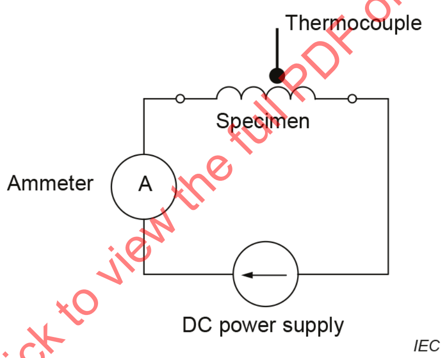


Figure 4 – Temperature rise measuring circuit by thermocouple method

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) The thermocouple shall be in the correct measuring position 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 thermocouple 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 direct current (DC) is supplied.

f) Direct current (DC) 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: $\Delta T < 1$ (°C /min).

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

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

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

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 direct current (DC) is supplied (°C);

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

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

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

i) The temperature rise of the connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.4.4 Thermal camera method

a) The specimen shall be connected to the circuit shown in Figure 5, by using the measuring jig specified in 6.3.

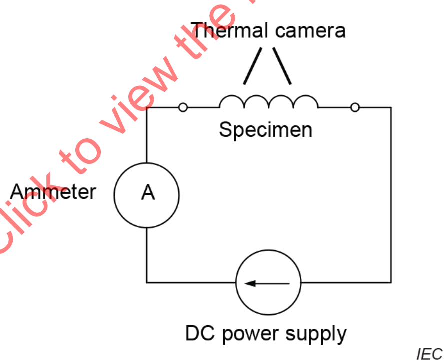


Figure 5 – Temperature rise measuring circuit by thermal camera method

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

c) The test piece and the conductor of the test current should be painted black or the emissivity should be pre-set so that the appropriate temperature can be measured.

d) 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 box may have an opening for the thermal camera to have line of sight access to the top of the test specimen.

The specimen shall be measured on the condition that it does not contact directly with any surface. 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 any surface.

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 direct current (DC) is supplied.

f) Direct current (DC) 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 direct current (DC) shall be modulated, and the temperature rise value shall be calculated by the following formula.

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

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

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 direct current (DC) 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 direct current (DC) when the temperature rise value becomes the specified value in the detail specification. Two consecutive temperature readings made 1 min apart should not vary by more than 1 °C.

i) The temperature rise of the connecting conductor shall be less than 50 % of the temperature rise of the specimen.

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

6.5 Quality conformance inspection

The direct current (DC) specified in the detail specification shall be supplied to a specimen in accordance with the methods specified in 6.3 and 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 direct saturation limited current (DC) 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 direct saturation limited current (DC)

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) Direct saturation limited current (DC) (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), 6.4.4 h)).

d) Measuring position (if thermocouple method is applied) (see 6.4.3 d)).

e) Temperature rise limited current (see 6.4.4).

Annex A
(informative)

Example of recommended description on product specification sheets and catalogues

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

It should be specified whether the direct saturation limited current (DC) 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 manufacturer 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 indicated in a specification sheet or catalogue, it should be the lower one of the direct saturation limited current (DC) value and the temperature rise limited current value.

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

Bibliography

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*

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

___

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

____

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

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

AVANT-PROPOS

1) La Commission Électrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. À cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
2) Les décisions ou accords officiels de l'IEC concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux de l'IEC intéressés sont représentés dans chaque comité d'études.
3) Les Publications de l'IEC se présentent sous la forme de recommandations internationales et sont agréées comme telles par les Comités nationaux de l'IEC. Tous les efforts raisonnables sont entrepris afin que l'IEC s'assure de l'exactitude du contenu technique de ses publications; l'IEC ne peut pas être tenue responsable de l'éventuelle mauvaise utilisation ou interprétation qui en est faite par un quelconque utilisateur final.
4) Dans le but d'encourager l'uniformité internationale, les Comités nationaux de l'IEC s'engagent, dans toute la mesure possible, à appliquer de façon transparente les Publications de l'IEC dans leurs publications nationales et régionales. Toutes divergences entre toutes Publications de l'IEC et toutes publications nationales ou régionales correspondantes doivent être indiquées en termes clairs dans ces dernières.
5) L'IEC elle-même ne fournit aucune attestation de conformité. Des organismes de certification indépendants fournissent des services d'évaluation de conformité et, dans certains secteurs, accèdent aux marques de conformité de l'IEC. L'IEC n'est responsable d'aucun des services effectués par les organismes de certification indépendants.
6) Tous les utilisateurs doivent s'assurer qu'ils sont en possession de la dernière édition de cette publication.
7) Aucune responsabilité ne doit être imputée à l'IEC, à ses administrateurs, employés, auxiliaires ou mandataires, y compris ses experts particuliers et les membres de ses comités d'études et des Comités nationaux de l'IEC, pour tout préjudice causé en cas de dommages corporels et matériels, ou de tout autre dommage de quelque nature que ce soit, directe ou indirecte, ou pour supporter les coûts (y compris les frais de justice) et les dépenses découlant de la publication ou de l'utilisation de cette Publication de l'IEC ou de toute autre Publication de l'IEC, ou au crédit qui lui est accordé.
8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'IEC attire l'attention sur le fait que la mise en application du présent document peut entraîner l'utilisation d'un ou de plusieurs brevets. L'IEC ne prend pas position quant à la preuve, à la validité et à l'applicabilité de tout droit de brevet revendiqué à cet égard. À la date de publication du présent document, l'IEC n'a pas reçu notification qu'un ou plusieurs brevets pouvaient être nécessaires à sa mise en application. Toutefois, il est rappelé aux responsables de cette mise en œuvre qu'il ne s'agit peut-être pas des informations les plus récentes, qui peuvent être obtenues dans la base de données disponible à l'adresse https://patents.iec.ch. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets.

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

Cette troisième édition annule et remplace la deuxième édition parue en 2020. Cette édition constitue une révision technique.

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

a) le domaine d'application a été élargi en portant la plage du courant assigné de 22 A à 125 A;
b) le domaine d'application a été élargi en portant les limites de l'empreinte de 12 mm × 12 mm à 625 mm^2;
c) une limite haute de courant a été ajoutée pour les cartes $I_{\text{classe B}}$, $I_{\text{classe C}}$ et $I_{\text{classe D}}$ dans le Tableau 1;
d) les exemples d'application ont été révisés pour le Tableau 1;
e) des tailles de fils de référence ont été ajoutées pour les courants d'intensité 22 A ≤ I ≤ 125 A dans le Tableau 2;
f) des bornes à sertir de référence ont été ajoutées dans le Tableau 2;
g) la méthode par caméra thermique a été ajoutée.

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

Projet	Rapport de vote
51/1522/FDIS	51/1532/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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*, se trouve 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 webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé, ou
- révisé.

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

Partie 2: Courant assigné des bobines d'inductance pour les 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 les bobines d'inductance, définies ci-après.

Les méthodes de mesure normalisées pour la détermination des caractéristiques assignées permettent aux utilisateurs de comparer avec exactitude les caractéristiques assignées de courant indiquées dans les fiches de données des différents fabricants.

Le présent document s'applique aux bobines d'inductance plombées et à montage en surface dont les dimensions sont conformes à l'IEC 62025-1 et dont le courant assigné est généralement inférieur à 125 A, même si des bobines d'inductance de courant assigné supérieur à 125 A sont disponibles et respectent les limites de dimensions du présent document (empreinte inférieure ou égale à 625 mm^2). Ces bobines d'inductance sont habituellement utilisées dans des convertisseurs continu-continu montés sur des cartes à circuit imprimé (PCB, *printed circuit boards*), pour des équipements électroniques et de télécommunications, ainsi que pour les blocs d'alimentation à découpage de petite taille.

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

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, *Essais d’environnement – Partie 1: Généralités et lignes directrices*

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

3.1
courant continu (DC) limite de saturation
valeur admissible de courant continu (DC) pour laquelle la diminution de l'inductance se situe dans les limites de la valeur spécifiée

Note à l’article: L’abréviation "DC" est dérivée du terme anglais développé correspondant "*direct current*".

3.2
courant limite d'échauffement
valeur admissible de courant continu (DC) pour laquelle l'autoéchauffement de la bobine d'inductance 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 l'IEC 60068-1:2013, 4.3):

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

En cas de litige ou si cela est exigé, les mesurages doivent être répétés en utilisant les températures de référence et les autres conditions données au 4.2.

4.2 Conditions de référence

Pour les conditions de référence, l'une des conditions atmosphériques normales pour les essais de référence données au 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 (DC) limite de saturation

5.1 Généralités

Lorsque le courant alternatif (AC, *alternating current*) sur lequel est superposé le courant continu (DC) alimente une bobine d'inductance, l'inductance de la bobine d'inductance diminue proportionnellement à la valeur du courant continu.

Dans une application type, le courant de saturation résulte du courant de crête lié à la superposition du courant alternatif (AC) sur le courant continu (DC). Dans le présent document, le courant de saturation est mesuré comme un courant continu (DC) qui décale un courant alternatif (AC) de faible signal.

NOTE Il n'est pas envisageable d'établir une norme pour le courant alternatif (AC) limite de saturation, car les méthodes d'application d'un courant alternatif (AC) dans une application donnée sont très nombreuses et variées. De ce fait, les fabricants et les utilisateurs ont généralement défini un courant continu (DC) limite de saturation comme point commun de référence. Le présent document suit la même approche.

5.2 Conditions d'essai

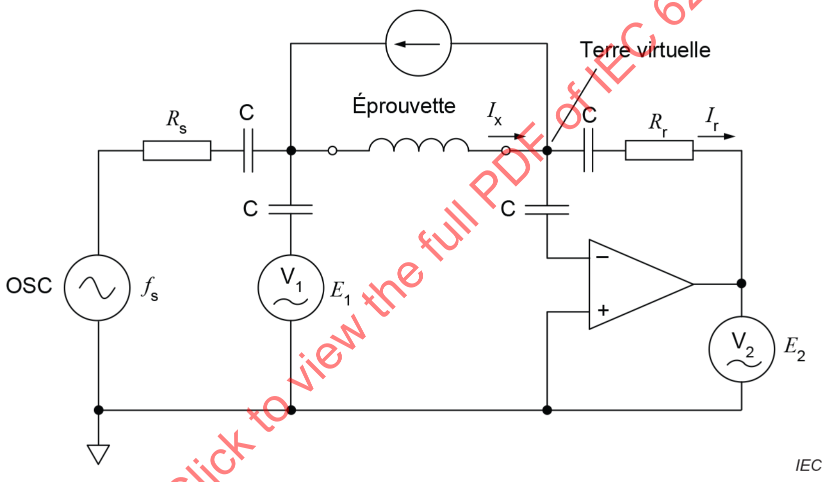
Sauf indication contraire dans la spécification particulière, les conditions d'essai doivent être conformes à l'Article 4.

NOTE La variation de la valeur du courant continu (DC) limite de saturation, en fonction de la température, dépend du matériau magnétique et de la structure du noyau magnétique de la bobine d'inductance. Cependant, le mesurage des courants continus de saturation à températures élevées n'est généralement pas envisageable pour les besoins des examens. De ce fait, le mesurage à température ambiante décrit dans le présent document est généralement appliqué pour les besoins des spécifications. Des courbes du taux de réduction indiquant la variation du courant continu (DC) limite de saturation en fonction de la température de fonctionnement maximale de la bobine d'inductance peuvent être établies. Ces courbes peuvent être utilisées à des fins de corrélation entre le courant continu (DC) limite de saturation à température ambiante et le courant continu (DC) limite de saturation à des températures de fonctionnement types. Dans certains cas, le fabricant et l'utilisateur établiront par accord une spécification supplémentaire pour les températures élevées, comme 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.



Légende

Composants

R_s résistance de la source $R = R_s$

R_r gamme de résistance de sélection $R = R_r$

V_1 voltmètre

V_2 voltmètre

E_1 tension efficace mesurée par le voltmètre V_1

E_2 tension efficace mesurée par le voltmètre V_2

E_s tension efficace de la source

C condensateur de blocage à courant continu

Alimentations

f_s fréquence de la source

I_r courant fourni à la gamme de résistance de sélection

I_x courant fourni à l'éprouvette

$I_x = I_r$

Figure 1 – Circuit de mesure de l'inductance sous application d'une 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 aux bornes de l'éprouvette;

E_2 est la tension appliquée aux bornes de la gamme de résistance de sélection (= $I_r R_r$);

θ est le déphasage de l'impédance complexe.

5.4 Gabarit de fixation de la bobine d'inductance

Le gabarit de fixation de l'éprouvette doit être décrit dans une spécification particulière (voir l'Article 8).

5.5 Méthode de mesure

a) Une légère compensation doit être effectuée avant le mesurage.

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

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

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 (DC) limite de saturation doit être déterminé en mesurant le courant continu (DC) lorsque la diminution de l'inductance correspond à la valeur indiquée dans la spécification particulière.

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

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

5.6 Examen de conformité de la qualité

Le courant continu (DC) 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 limite d'échauffement

6.1 Généralités

Lorsqu'un courant continu (DC) est fourni à une bobine d'inductance, la bobine induit un autoéchauffement en fonction de la valeur du courant continu appliqué, du fait de sa résistance en courant continu.

NOTE 1 L'échauffement résulte de l'autoéchauffement de la bobine d'inductance. Les sources de chauffage correspondent aux pertes en courant continu dans le cuivre, aux pertes en courant alternatif dans le cuivre et aux pertes en courant alternatif dans le noyau. Le présent document définit l'échauffement induit par des courants continus (DC) uniquement. En conditions de fonctionnement réelles, les pertes en courant alternatif dans le cuivre et les pertes en courant alternatif dans le noyau pour évaluer l'échauffement seront prises en compte. Les pertes en courant alternatif sont considérablement influencées par la forme d'onde, l'amplitude et la fréquence.

NOTE 2 Il n'est pas envisageable d'établir une norme pour le courant alternatif (AC) limite d'échauffement, car les méthodes d'application d'un courant alternatif (AC) dans une application donnée sont très nombreuses et variées. De ce fait, les fabricants et les utilisateurs ont généralement défini un courant continu limite d'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.

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

NOTE 1 Les pertes de puissance sont des facteurs qui affectent le rendement du convertisseur continu-continu et l'échauffement de la bobine d'inductance en conditions de fonctionnement réelles, indépendamment de la température de fonctionnement. Dans le présent document, les courants d'échauffement sont définis en termes de courants continus (DC), par conséquent le fait d'inclure des courants alternatifs (AC) serait une source de confusion et sera retiré des conditions d'essai. Les pertes de puissance dans le noyau de ferrite diminuent lorsque la température augmente jusqu'à une température habituellement désignée comme la température minimale de pertes dans le noyau, au-dessus de laquelle ces pertes commencent à augmenter. La température et l'amplitude minimales des pertes dépendent du type et de la qualité du matériau. Certains composants en ferrite présentent une température minimale marquée. La variation de la température des pertes du noyau en poudre métallique, selon le type de matériau, est considérablement inférieure à celle du noyau de ferrite et n'a pas tendance à varier avec la température, comme le montre le noyau de ferrite.

NOTE 2 Concernant les courants continus (DC) limites d'échauffement à hautes températures, la variation du courant continu (DC) limite d'échauffement en fonction de la variation de la température ambiante peut être modélisée. Le mesurage à température ambiante est couramment appliqué 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 au 6.3.2, soit la méthode du fil connecteur donnée au 6.3.3. La méthode choisie doit être indiquée 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 époxy (FR4). Sauf indication contraire dans la spécification particulière, les dimensions doivent être conformes au Tableau 1, au Tableau 2 et à la Figure 2.

Tableau 1 – Largeur des circuits

Classe de courant assigné	Courant assigné de la bobine d'inductance I A	Largeur de l'impression W mm	Épaisseur de l'impression t µm	Carte d'essai	Environnement thermique	Exemple d'application
$I_{\text{classe A}}$	$I \leq 1$	1,0 ± 0,2	35 ± 10	Figure 2a) Figure 2g)	Environnements à faible dissipation thermique	Consommateur
	$1 < I \leq 2$	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				
$I_{\text{classe B}}$	$I \leq 22$	40,0 ± 1,0		Figure 2b) Figure 2c) Figure 2d) Figure 2h)	Environnements à dissipation thermique normale	Consommateur/Automobile
$I_{\text{classe C}}$	$I \leq 46$		105 ± 10		Environnements à forte dissipation thermique	Consommateur/Automobile
$I_{\text{classe D}}$	$I \leq 125$		1 000 ± 50	Figure 2b) Figure 2e) Figure 2f) Figure 2i) Figure 2j)	Environnements à très forte dissipation thermique	Automobile/Ligne d'alimentation à courant élevé (centres de données, infrastructure de réseau, etc)
NOTE Connexion du câble d'enroulement à la carte: Voir le Tableau 2.						