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inside

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

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition 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- withdrawn,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.

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

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

1 Scope

This part of IEC 62024 specifies the measuring methods of the rated 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

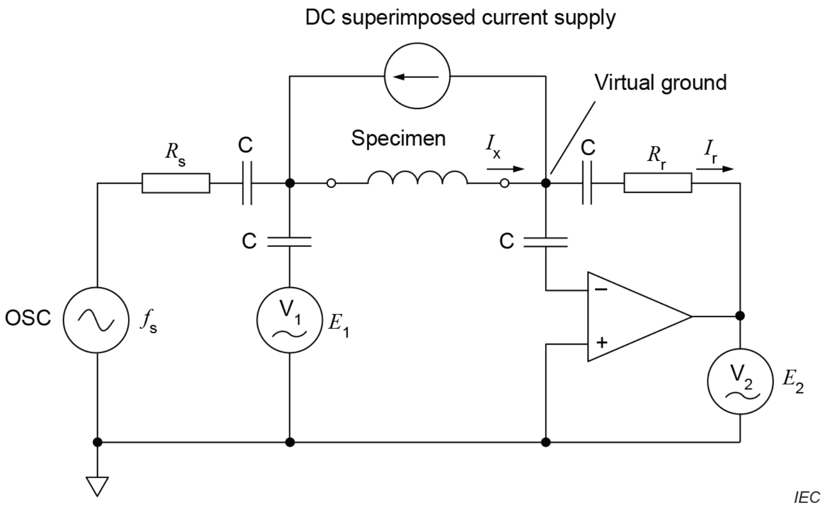
Unless otherwise specified in the detail specification, the test conditions shall be in accordance with Clause 4.

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. Derating 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).~~