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REDLINE VERSION

INTERNATIONAL STANDARD

High frequency inductive components – Electrical characteristics and measuring methods –
Part 1: Nanohenry range chip inductor

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 1: Nanohenry range chip inductor

FOREWORD

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IEC 62024-1 has been prepared by IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2017. This edition constitutes a technical revision.

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

a) addition of S parameter measurement;
b) addition of the inductance, Q-factor and impedance of an inductor which are measured by the reflection coefficient method with a network analyzer;
c) addition of the resonance frequency of an inductor which is measured by a two-port network analyzer;
d) addition of the mounting method for a surface mounting inductor with Pb-free solder.

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

Draft	Report on voting
51/1500/FDIS	51/1511/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 the 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,
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- revised.

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

Part 1: Nanohenry range chip inductor

1 Scope

This part of IEC 62024 specifies the electrical characteristics and measuring methods for the nanohenry range chip inductor that is normally used in the high frequency (over 100 kHz) range.

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 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test) copper-clad*

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*

ISO 6353-3, *Reagents for chemical analysis – Part 3: Specifications – Second series*

ISO 9453, *Soft solder alloys – Chemical compositions and forms*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Inductance, Q-factor and impedance

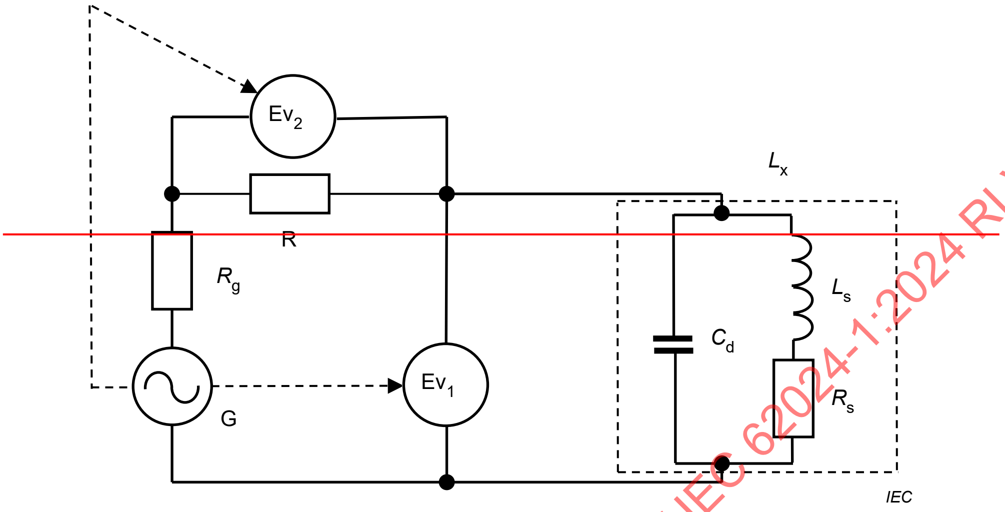
4.1 Inductance

4.1.1 Measuring method

The inductance of an inductor is measured by either the vector voltage/current method (impedance analyzer) or the reflection coefficient method (network analyzer).

4.1.2 Measuring circuit

An example of the circuit for the vector voltage/current method is shown in Figure 1 and an example of the circuit for the reflection coefficient method is shown in Figure 2.



~~**Key**~~

~~R_g source resistance (50 Ω)~~

~~R resistor~~

~~L_x inductance of inductor under test~~

~~C_d distributed capacitance of inductor under test~~

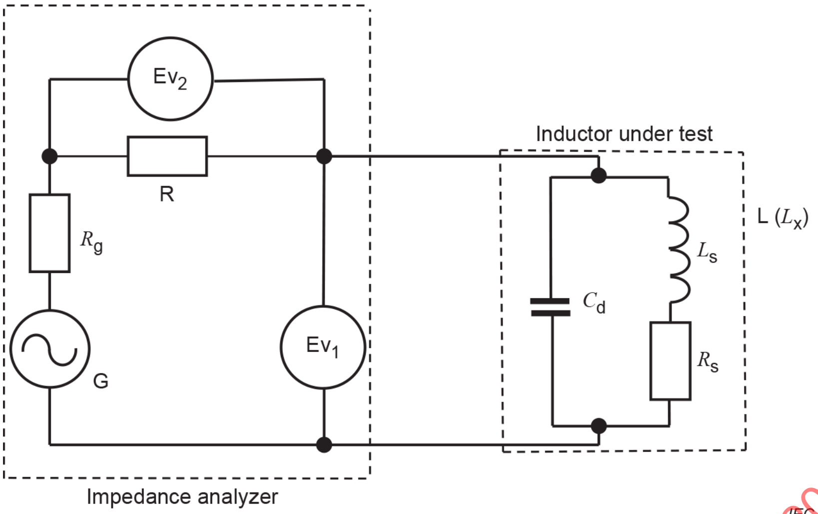
~~L_s series inductance of inductor under test~~

~~R_s series resistance of inductor under test~~

~~- - -▶ phase reference signal~~

~~Ev_1, Ev_2 vector voltmeter~~

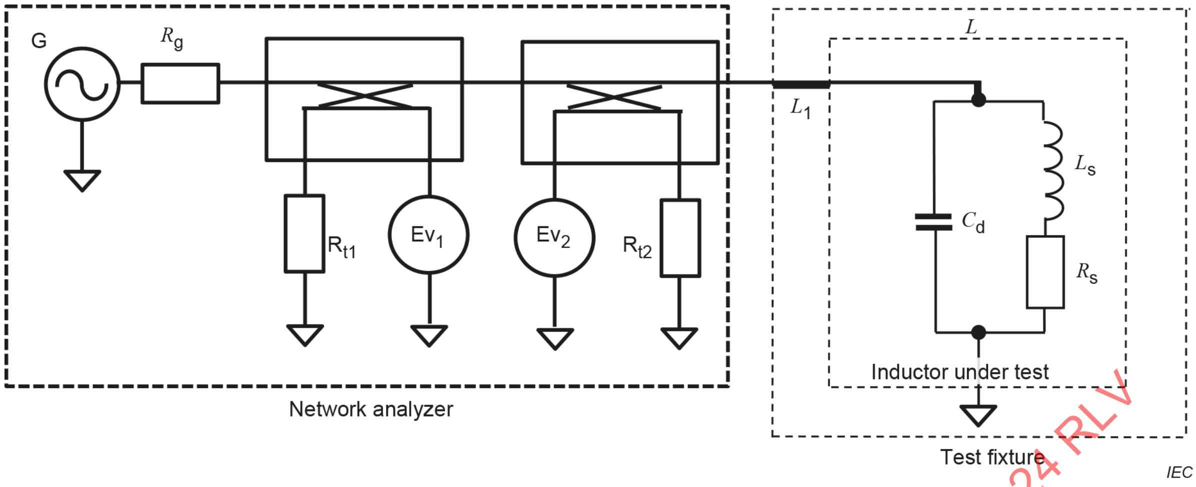
~~G signal generator~~



Key

R_g	source resistance (50 Ω)
R	resistor
L	inductor under test
L_x	inductance of inductor under test
C_d	parallel capacitance of inductor under test
L_s	series inductance of inductor under test
R_s	series resistance of inductor under test
Ev_1, Ev_2	vector voltmeter
G	signal generator

Figure 1 – Example of circuit for vector voltage/current method



Key

R_g	source resistance (50 Ω)
R_{t1}, R_{t2}	termination resistor (50 Ω)
L	inductor under test
C_d	parallel capacitance of inductor under test
L_s	series inductance of inductor under test
R_s	series resistance of inductor under test
Ev_1, Ev_2	vector voltmeter
G	signal generator
L_1	50 Ω micro-strip line or equivalent transmission line

Figure 2 – Example of circuit for reflection coefficient method

4.1.3 Mounting the inductor for the test

4.1.3.1 General

The inductor shall be ~~measured~~ mounted in a test fixture as specified in the relevant standard. If no fixture is specified, one of the following test fixtures A, B or C shall be used. The fixture used shall be reported.

4.1.3.2 Fixture A

The shape and dimensions of fixture A shall be as shown in Figure 3 and Table 1.

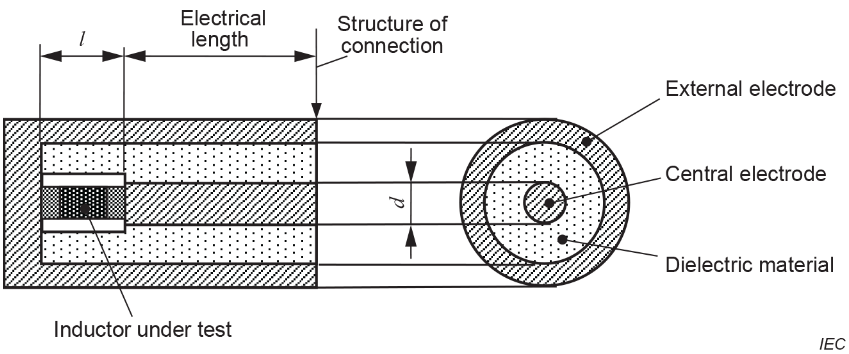


Figure 3 – Fixture A

Table 1 – Dimensions of *l* and *d*

Size of inductor under test[a]	*l* mm	*d* mm
1608	1,6	0,95
1005	1,0	0,60
0603	0,6	0,36
0402	0,4	0,26
0201	0,2	0,12

[a] The outline dimensions of the surface mounted inductor shall be indicated by a four-digit number based on two significant figures for each dimension *L* and *W* (or *H*) (refer to IEC 62025-1).

The electrodes of the test fixture shall contact the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The ~~electrode~~ mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω.

4.1.3.3 Fixture B

The test fixture B as shown in Figure 4 shall be used.

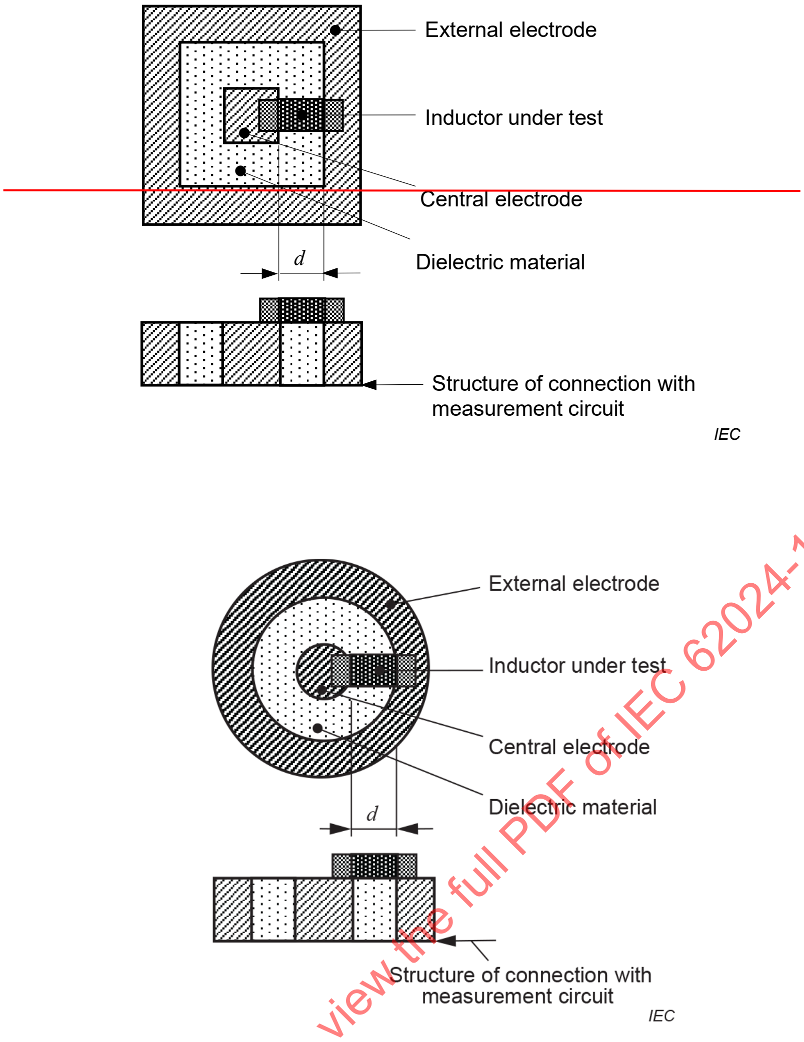


Figure 4 – Fixture B

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The ~~electrode~~ mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω. Dimension d shall be specified between the parties concerned.

4.1.3.4 Fixture C

The test fixture C as shown in Figure 5 shall be used.

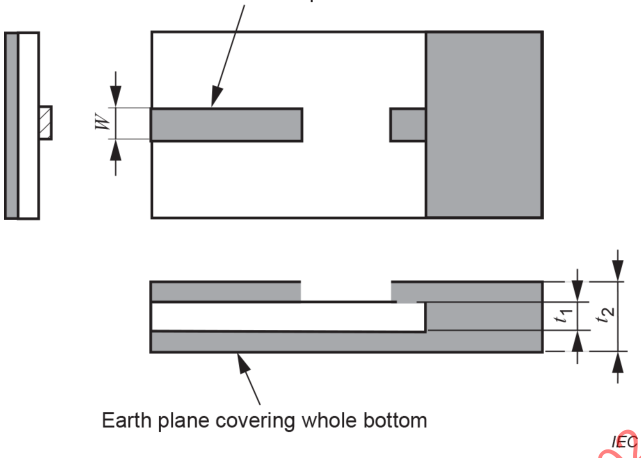


Figure 5 – Fixture C

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω. The dimensions of the patterns of the fixture and material of the fixture shall be specified between the parties concerned.

4.1.4 Measuring method and calculation formula

Inductance L_x of the inductor ~~L_x~~ L is defined by the vector sum of the reactance caused by L_s and C_d (see Figure 1 or Figure 2). The frequency f of the signal generator output signal shall be set to a frequency as separately specified. The inductor under test shall be connected to the measurement circuit by using the test fixture as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively. The inductance L_x shall be calculated by Formula (1) and Formula (2) for the vector voltage/current method, or Formula (3) to Formula (5) for the reflection coefficient method:

~~$$L_x = \frac{\text{Im}\left[R\frac{E_1}{E_2}\right]}{\omega} \qquad (1)$$~~

~~where~~

~~L_x is the inductance of the inductor under test;~~

~~Im is the imaginary part of the complex value;~~

~~R is the resistance of the resistor;~~

~~E_1 is the value indicated on vector voltmeter Ev_1;~~

~~E_2 is the value indicated on vector voltmeter Ev_2;~~

~~ω is the angular frequency: $2\pi f$.~~

$$L_x = \frac{\text{Im}[Z_x]}{\omega} \qquad (1)$$

$$Z_x = R\frac{E_1}{E_2} \qquad (2)$$

where

L_x is the inductance of the inductor under test;

Im is the imaginary part of the complex value;

Z_x is the impedance of the inductor under test;

R is the resistance of the resistor;

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2;

ω is the angular frequency: $2\pi f$.

$$L_x = \frac{\text{Im}[Z_x]}{\omega} \qquad (3)$$

$$Z_x = R\frac{E_1}{E_2} \qquad (4)$$

$$S_{11} = \frac{E_1}{E_2} \qquad (5)$$

where

L_x is the inductance of the inductor under test;

Im is the imaginary part of the complex value;

Z_x is the impedance of the inductor under test;

R is the resistance of the resistor;

S_{11} is the reflection coefficient of the inductor under test;

Z_0 is the system impedance of the measurement system (50 Ω);

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2;

ω is the angular frequency: $2\pi f$.

4.1.5 Notes on measurement

4.1.5.1 General

The electrical length of the test fixture shall be compensated by an appropriate method followed by open-short compensation. If an electrical length that is not commonly accepted is used, it shall be specified. Open-short compensation shall be calculated by ~~the following formulae~~ Annex B.

$$Z_x = A_c \frac{Z_m - B_c}{1 - Z_m C_c} \quad (2)$$

$$A_c = 1 + j0 \quad (3)$$

$$B_c = \frac{Z_{sm} - (1 - Y_{om} Z_{sm}) Z_{ss} - Z_{sm} Y_{os} Z_{ss}}{1 - Y_{om} Z_{sm} Y_{os} Z_{ss}} \quad (4)$$

$$C_c = \frac{Y_{om} - (1 - Y_{om} Z_{sm}) Y_{os} - Y_{om} Y_{os} Z_{ss}}{1 - Y_{om} Z_{sm} Y_{os} Z_{ss}} \quad (5)$$

where

Z_x is the impedance measurement value after compensation;

Z_m is the impedance measurement value before compensation;

Z_{sm} is the impedance measurement value of the short device;

Z_{ss} is the short device inductance as defined in 4.1.5.2;

Y_{om} is the admittance measurement value of the fixture with test device absent;

Y_{os} is the admittance measurement value of the test fixture as defined in 4.1.5.3.

4.1.5.2 Short compensation

For test fixture A, the applicable short device dimension and shape are as shown in Figure 6 and Table 2. The appropriate short device inductance shall be selected from Table 2 depending on the dimension of the inductor under test. The inductance of the selected short device shall be used as a compensation value.

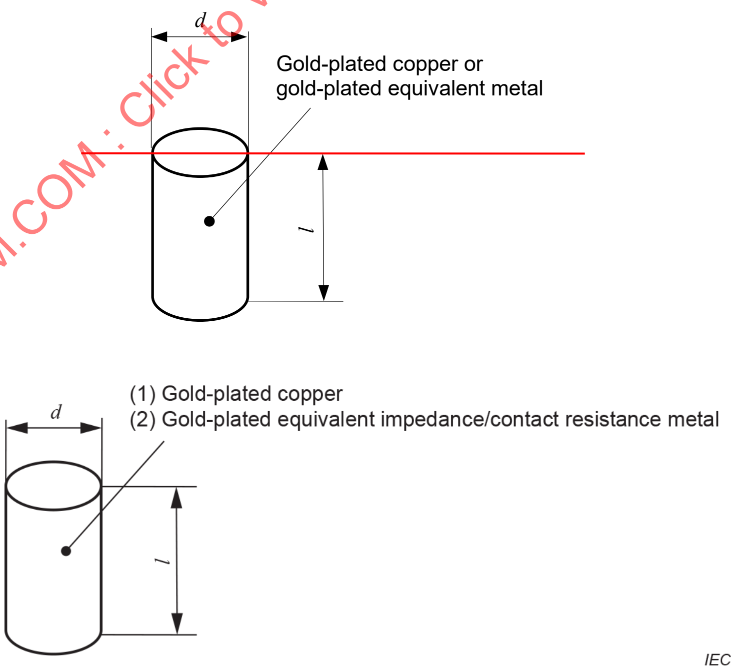


Figure 6 – Short device shape

Table 2 – Short device dimensions and inductances

Size of inductor under test	*l* mm	*d* mm	Inductance value nH
1608	1,6	0,95	0,43
1005	1,0	0,60	0,27
0603	0,6	0,36	0,16
0402	0,4	0,26	0,11
0201	0,2	0,12	0,05

If an inductance value other than those defined in Table 2 and if a short device shape other than that defined in Figure 6, such as rectangular shape, are used for test fixture A, the employed value shall be specified. For test fixtures B and C, the short device dimension, shape and inductance values shall be specified.

4.1.5.3 Open compensation

Open compensation for test fixture A shall be performed with test fixture electrodes at the same distance from each other as with the inductor under test mounted in the fixture. The admittance Y_{os} is defined as 0 S (zero Siemens) unless otherwise specified.

Open compensation for test fixtures B and C shall be performed without mounting the inductor. The admittance Y_{os} is defined as 0 S (zero Siemens) unless otherwise specified.

4.2 Quality factor

4.2.1 Measuring method

The Q of the inductor shall be measured by either the vector voltage/current method or the reflection coefficient method.

4.2.2 Measuring circuit

The measurement circuit is as shown in Figure 1 and Figure 2. The measurement equipment shall be suitably calibrated.

4.2.3 Mounting the inductor for test

Mounting of the inductor is as described in 4.1.3.

4.2.4 Measuring method and calculation formula

The frequency of the signal generator (Figure 1 or Figure 2) output signal shall be set to a frequency as separately specified. The inductor shall be connected to the measurement circuit by using the test fixtures as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively. The Q value shall be calculated by the following formula:

$$Q = \frac{\mathrm{Im}[E_1 / E_2]}{\mathrm{Re}[E_1 / E_2]}$$

$$Q = \frac{\mathrm{Im}[Z_x]}{\mathrm{Re}[Z_x]} \quad (6)$$

where

Q is the Q of the inductor under test;

Re is the real part of the complex value;

Im is the imaginary part of the complex value;

~~E_1 is the value indicated on vector voltmeter Ev_1;~~

~~E_2 is the value indicated on vector voltmeter Ev_2.~~

Z_x is the impedance of the inductor under test as calculated in Formula (2) or Formula (4).

4.2.5 Notes on measurement

Refer to 4.1.5.

4.3 Impedance

4.3.1 Measuring method

The impedance of an inductor shall be measured either by the vector voltage/current method or the reflection coefficient method. Those methods are as described in 4.3.2 to 4.3.5.

4.3.2 Measuring circuit

The measurement circuits are as shown in Figure 1 and Figure 2. The measurement equipment shall be suitably calibrated.

4.3.3 Mounting the inductor for test

Mounting of the inductor is as described in 4.1.3.

4.3.4 Measuring method and calculation

The frequency of the signal generator output signal (Figure 1 or Figure 2) shall be set to a frequency f as separately specified. The inductor shall be connected to the measurement circuit by using the test fixture as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively.

~~The impedance shall be calculated by the following formula:~~

$$|Z| = R\frac{|E_1|}{|E_2|} \quad (7)$$

~~where~~

~~$|Z|$ is the absolute value of the impedance;~~

~~R is the resistance;~~

~~$|E_1|$ is the absolute value of Ev_1;~~

~~$|E_2|$ is the absolute value of Ev_2.~~

The impedance shall be calculated by Formula (2) or Formula (4) in accordance with the method used.

4.3.5 Notes on measurement

Refer to 4.1.5.

5 Resonance frequency

5.1 Self-resonance frequency

The self-resonance frequency of the inductor shall be measured by the minimum output method in 5.2, by the reflection method in 5.3 or by the impedance analyser in 5.4 or by the impedance analyzer or network analyzer in 4.1.

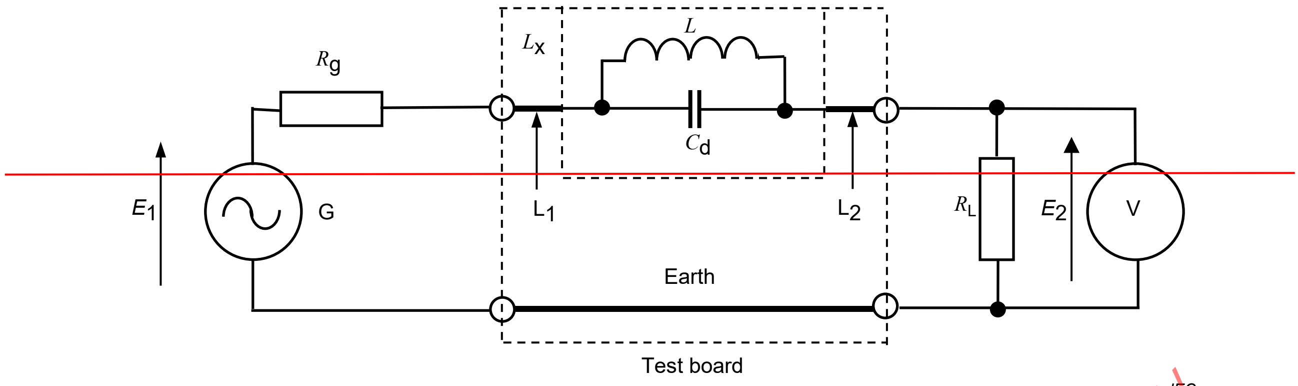
5.2 Minimum output method

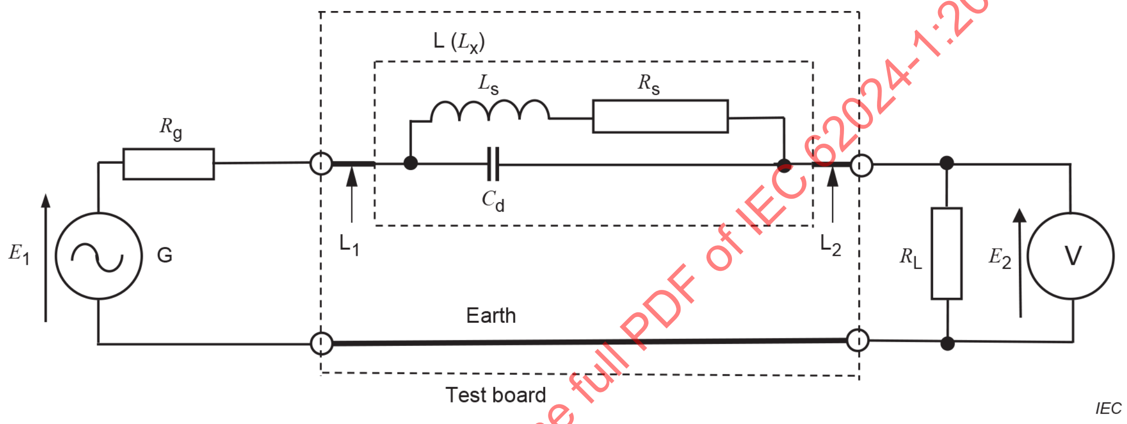
5.2.1 General

The minimum output method is as described in 5.2.2 to 5.2.5.

5.2.2 Measuring circuit

The measuring circuit is as shown in Figure 7.





Key

G signal generator

R_g source resistance of the signal generator (50 Ω)

L_x inductance of inductor under test

C_d ~~distributed~~ parallel capacitance of inductor under test

L ~~inductance of~~ inductor under test

L_1, L_2 50 Ω micro-strip line or equivalent transmission line

V RF voltmeter

R_L input resistance of RF voltmeter (50 Ω)

E_1 is the value indicated on vector voltmeter Ev_1

E_2 is the value indicated on vector voltmeter Ev_2

A suitably calibrated network analyzer may be used for the minimum output method in place of the signal generator and RF voltmeter

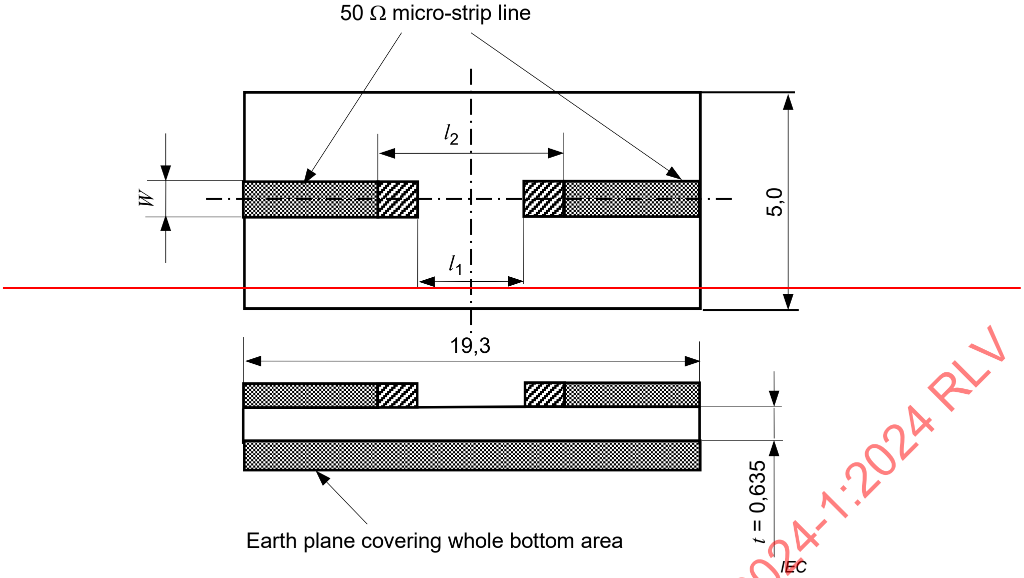
Figure 7 – Example of test circuit for the minimum output method

5.2.3 Mounting the inductor for test

The inductor shall be mounted on the self-resonance frequency test board specified in the individual standard for the particular inductor by the method specified in Annex A. If there is no individual standard, the self-resonance frequency test board shall be as shown in Figure 8.

The dimensions of the patterns of the fixture and material of the fixture shall be specified between parties concerned.

~~*Dimensions in millimetres*~~



~~**Key**~~

~~Board material~~	~~96 % alumina ceramic board (ε ≅ 9,4)~~
~~Conductive material~~	~~paste-printed or plated Cu, Ag-Pd to a total thickness of (15 to 30) µm~~
~~W~~	~~0,62 mm (reference value)~~
~~Solder joint field dimensions:~~	~~hatched area~~
~~W~~	~~same width as 50 Ω micro-strip line~~
~~l_1~~	~~1/2 length of the inductor under test~~
~~l_2~~	~~length of the inductor under test + 0,4 mm~~

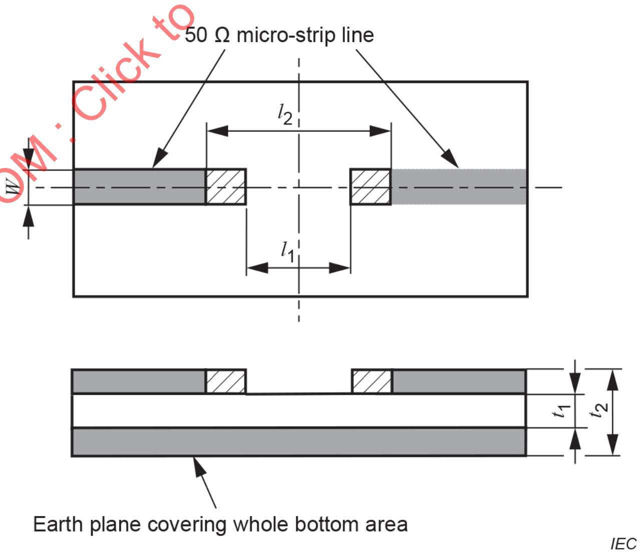


Figure 8 – Self-resonance frequency test board (minimum output method)

5.2.4 Measuring method and calculation formula

Using a circuit of the kind shown in Figure 7, keeping E_1 fixed, the oscillating frequency of the signal generator should be gradually increased until resonance is obtained as indicated by E_2 assuming its minimum value, which is then taken as the self-resonant value.

However, if the range of frequencies where E_2 is minimal is wide, and the frequency of the minimal value is not easily determined, the two frequencies f_1 and f_2 at which E_2 is greater than the minimum by A (dB) ($A \leq 3$) shall be measured, and the self-resonance frequency shall be obtained using the following formula:

$$\mathrm{SRF} = \frac{f_1 + f_2}{2} \tag{7}$$

where

SRF is the self-resonance frequency;

5.2.5 Note on measurement

The width W of the micro-strip line shall be such that the characteristic impedance is as close as possible to 50 Ω. The E_1 value of the micro-strip line selected shall also allow easy identification of the minimum value of E_2.

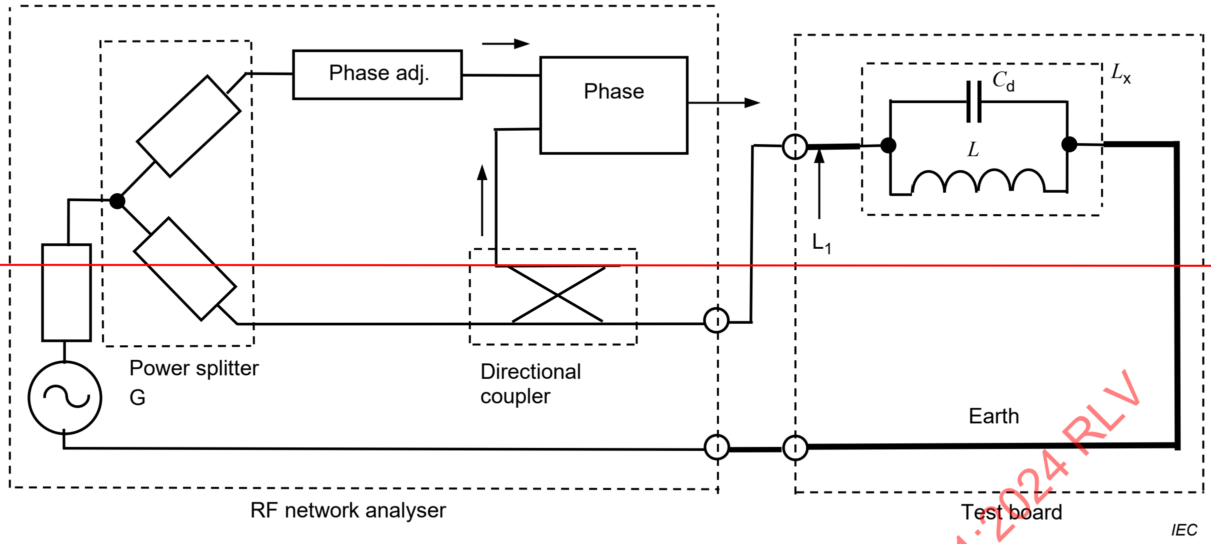
~~5.3 Reflection method~~

~~5.3.1 General~~

~~The reflection method is as described in 5.3.2 to 5.3.5.~~

~~5.3.2 Measuring circuit~~

~~The measurement circuit is as shown in Figure 7. The network analyser circuit used for measurement shall be configured as shown in Figure 7, or shall have equivalent circuit functions. In single port (S_{11}) reflection measurement mode, phase measurement shall be possible and the analyser shall be suitably calibrated.~~



Key

G signal generator

L_x inductance of inductor under test

C_d distributed capacitance of inductor under test

L inductance of inductor under test

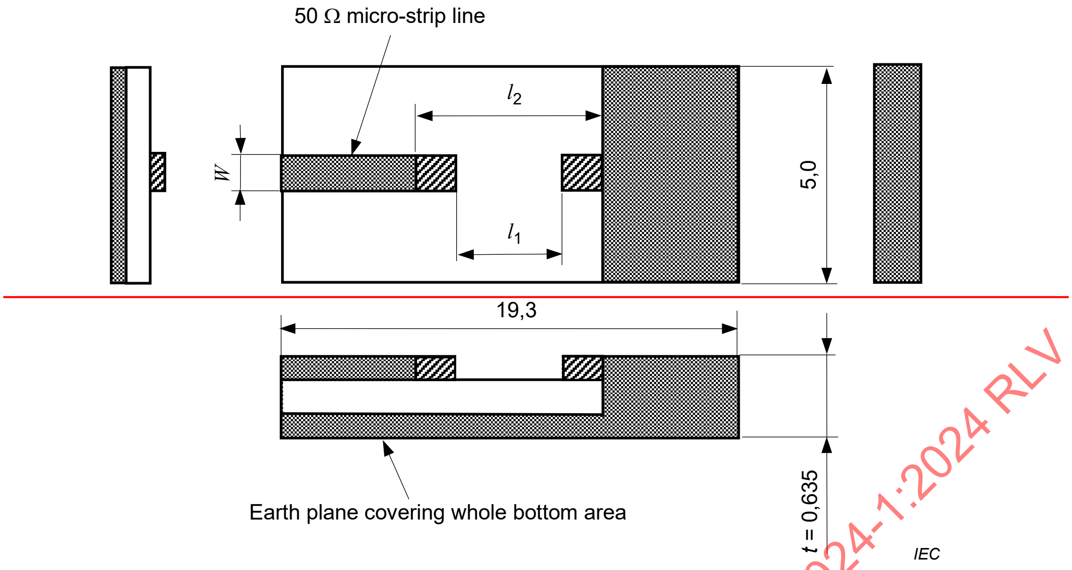
L_1 50 Ω micro-strip line

Figure 7 – Example of test circuit for the reflection method

5.3.3 Mounting the inductor for test

The inductor shall be mounted on the self-resonance frequency test board specified in the individual standard for the particular inductor by the method specified in Annex A. If there is no individual standard, the self-resonance frequency test board shall be as in Figure 8.

Dimensions in millimetres



Key

Board material: 96 % alumina ceramic board (ε ≅ 9,4)

Conductive material: paste-printed or plated Cu, Ag-Pd to a total thickness of (15 to 30) µm

W 0,62 mm (reference value)

Solder joint field dimensions: hatched area

W same width as 50 Ω micro-strip line

l_1 1/2 length of the inductor under test

l_2 length of the inductor under test + 0,4 mm

Figure 8 – Self-resonance frequency test board (reflection method)

5.3.4 Measuring method

The test board (on which the inductor has not yet been mounted) shall be connected to a suitably calibrated network analyser, and the phase adjuster shall be adjusted so that within the range of oscillating frequencies of the scanning signal generator, the output of the phase comparator shows the minimum phase difference (absolute value) between the incident and reflected waves.

The inductor for test shall then be mounted on the test board, and the oscillating frequency of the scanning signal generator shall gradually be swept from the low end to the high end.

The oscillating frequency of the scanning signal generator when the output of the phase comparator shows the minimum phase difference (absolute value) between the incident and reflected waves shall be taken as the self-resonance frequency.

5.3.5 Notes on measurement

The width W of the micro-strip line shall be such that the characteristics impedance is as close as possible to 50 Ω. The output of the scanning signal generator shall be set within a range that ensures stable operation of the phase comparator.

5.3 Measurement by analyzer

5.3.1 Measurement by impedance analyzer and one-port network analyzer

Self-resonance frequency can be measured by measuring the frequency characteristic of the impedance of the inductor using the impedance analyzer. A one-port network analyzer may be used to substitute the impedance analyzer as described in 4.1.2. When measuring self-resonance frequency, after compensating for the unwanted capacitance (refer to 4.1.5.3), the inductor for test shall be connected to the test fixture.

The exact value of the self-resonance frequency shall be the frequency where the first imaginary part value of impedance equals zero, when sweeping the frequency of the impedance analyzer from the lower value to the higher value.

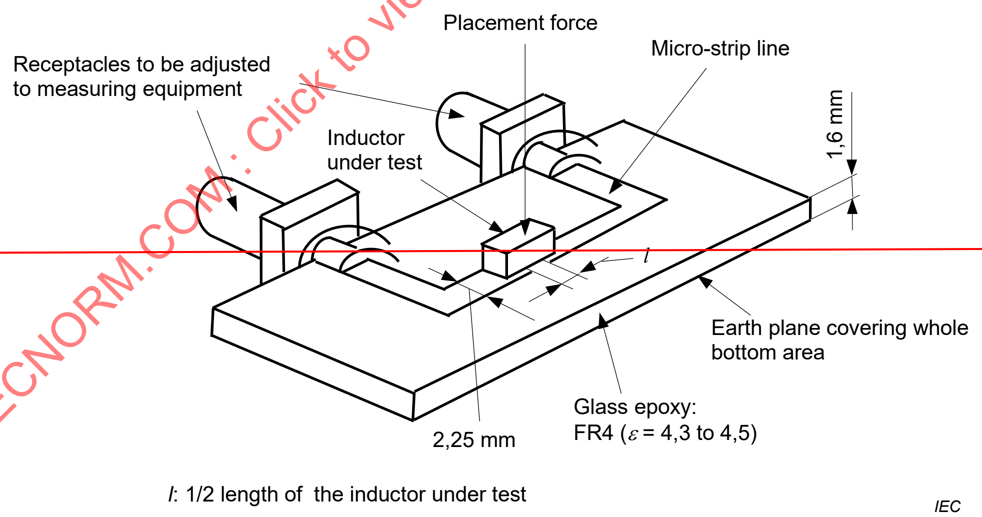
The test fixture for the measurement of the self-resonance frequency shall be the same as that of the inductance.

5.3.2 Measurement by two-port network analyzer

The self-resonance frequency of the inductor can be measured by the power attenuation method using the network analyzer. During the measurement of the self-resonance frequency, ~~care shall be taken to avoid~~ the influence of electromagnetic interference from other electronic equipment shall be avoided. The sweeping frequency range of the network analyzer shall include the self-resonance frequency of the inductor.

The self-resonance frequency of the inductor shall be the frequency where the power attenuation becomes a maximum. It shall be confirmed that the measured self-resonance frequency is not the resonance of the test fixture.

An example of a test fixture for measurement of self-resonance frequency by the power attenuation method is described in ~~Figure 9~~ 5.2.3.



~~Figure 9 – Suitable test fixture for measuring self-resonance frequency~~

6 DC resistance

6.1 Voltage-drop method

6.1.1 Measuring circuit

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

6.1.2 Measuring method and calculation formula

Use the circuit as shown in Figure 9.

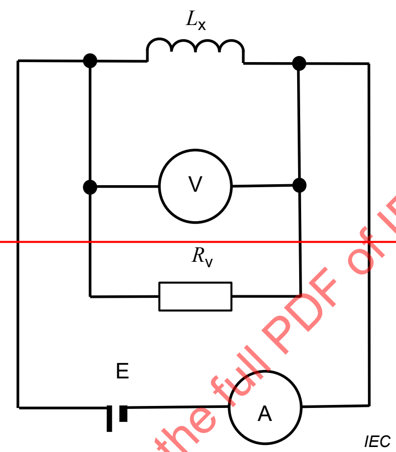
Calculate DC resistance R_x of the ~~coil~~ inductor from the following formula:

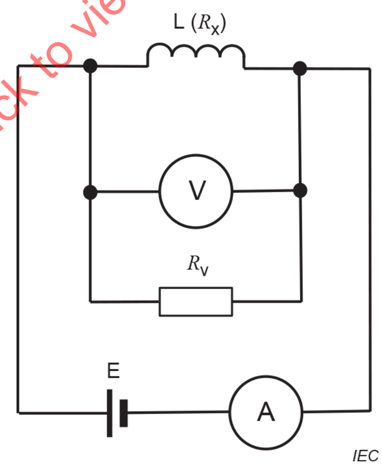
$$R_x = \frac{V}{I} \tag{8}$$

where

V is the value indicated on V;

I is the value indicated on A.





Key

~~L_x inductance of inductor under test~~

L inductor under test

E DC power supply

V DC voltmeter

A DC ammeter

R_x DC resistance of inductor under test

R_v internal resistance of DC voltmeter: $R_v >> R_x$

Figure 9 – Example of test circuit for voltage-drop method

6.2 Bridge method

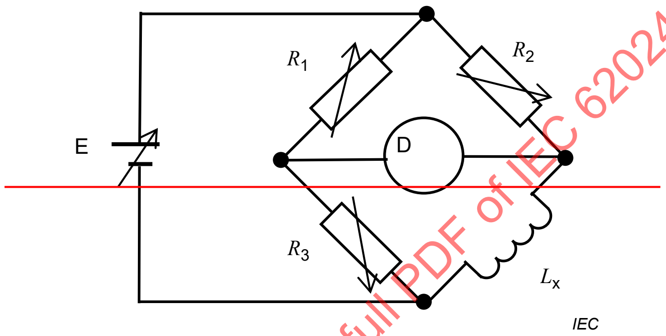
6.2.1 Measuring circuit

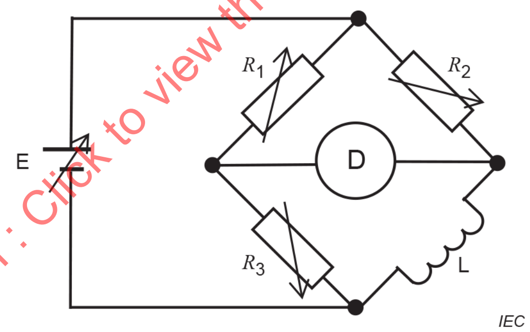
An example of the measuring circuit for DC resistance is shown in Figure 10.

6.2.2 Measuring method and calculation formula

Use the circuit as shown in Figure 10, balance the bridge by adjusting the proportional arm resistors R_1 and R_2 and standard variable resistor R_3, and calculate DC resistance R_x of the ~~coil~~ inductor from the following formula:

$$R_x = \frac{R_2}{R_1} \times R_3 \tag{9}$$





Key

R_1, R_2 resistance of proportional arm resistors R_1, R_2

R_3 resistance of standard variable resistor R_3

~~L_x inductance of inductor under test~~

L inductor under test

E DC power supply

D detector

Figure 10 – Example of test circuit for bridge method

6.3 Notes on measurement

The precautions for measurements are as follows:

– measurement of resistance shall be made by using a direct voltage of a small magnitude for as short a time as practicable, in order that the temperature of the resistance element does not rise appreciably during measurement;

- measuring voltage: ≤ 0,5 V;
- measurement uncertainty ±0,5 % of measured value or ±0,001 Ω, whichever is greater;
- take care so that the temperature of the specimen coincides should coincide with the ambient temperature;
- keep the current passed through the specimen within a range so that the resistance of coil the inductor will not change greatly;
- use of a double bridge is recommended for adequate accuracy when high measurement accuracy is required for DC resistance of 0,1 Ω or less desirable for measuring especially low resistance.

6.4 Measuring temperature

The DC resistance shall meet the specified limits at a temperature of (20 ± 1) °C. When the test is made at a temperature T_e other than 20 °C, the result shall be corrected to 20 °C by means of Formula (11):

$$R_{20} = \frac{R_{Te}}{0{,}92 + 0{,}004 T_e}; \quad T_e \text{ in } °C \tag{11}$$

Measurement temperature is specified in IEC 62674-1.

7 S-parameter

7.1 Measurement setup and procedure

7.1.1 General

A network analyzer (50 Ω system) is used for measuring the S-parameters of a device under test (DUT). A vector network analyzer is an instrument with a function for determining S-parameters directly from measurement of the amplitudes and phases of the incident, reflected, and transmitted waves; this is achieved by combining a directional coupler and a sophisticated calibration mechanism with the tracking generator and measuring receiver. Below is the measurement setup for a two-port measurement.

S-parameters should be measured by inserting the DUT into the test fixture and by sweeping the measurement frequency with the network analyzer. The relationship between the S-parameters and the frequency should be recorded within the required frequency range.

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by either soldering or mechanical force provided by an appropriate method. The mechanical force shall be specified. This force shall be chosen to provide satisfactory measurement stability without influencing the characteristics of the inductor. Figure 11 shows a schematic diagram of the two-port S-parameter measurement setup and the network analyzer.

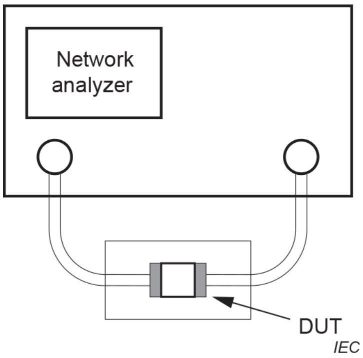
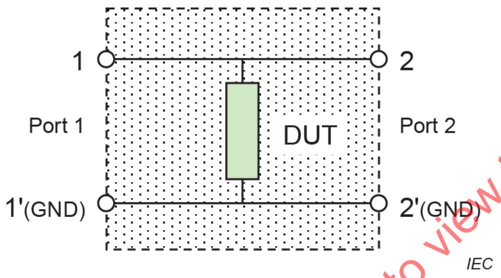


Figure 11 – Schematic diagram of the two-port S-parameter measurement setup and the network analyzer

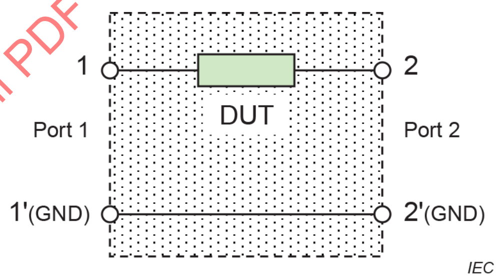
7.1.2 Two-port S-parameter

The characteristics of inductors can be evaluated in terms of the two-port S-parameters using a test fixture shown in Figure 12.

There are two possible configurations for connecting the two-terminal devices and fixture: one with a shunt connection and one with a series connection. One of these configurations should be chosen according to their impedance. The used configuration shall be specified.



a) Shunt connection



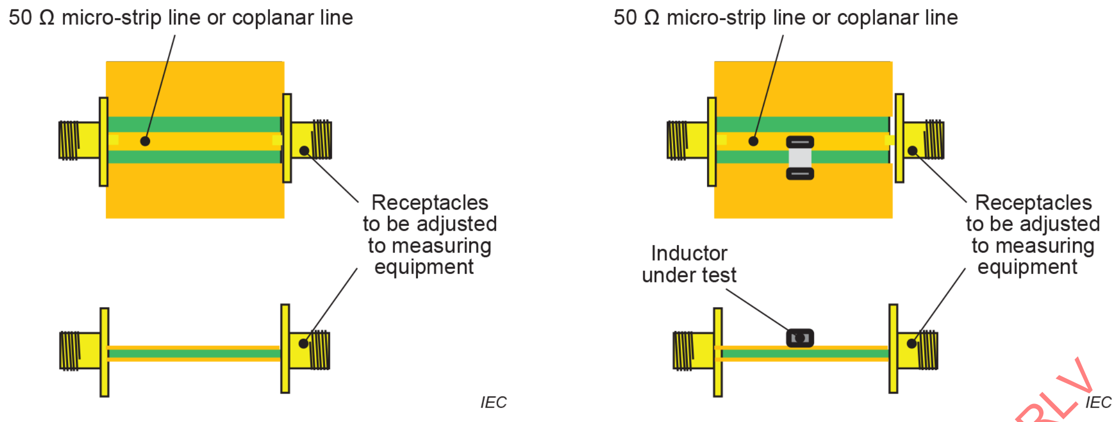
b) Series connection

Figure 12 – S-parameter test fixture for two-terminal devices

7.1.3 Test fixture

7.1.3.1 Shunt connection

Figure 13 shows a test fixture for measuring the S-parameters of a two-terminal device in a shunt connection. Maximum applicable frequency is around 60 GHz.



a) Fixture only **b) Two-terminal device mounted**

Key

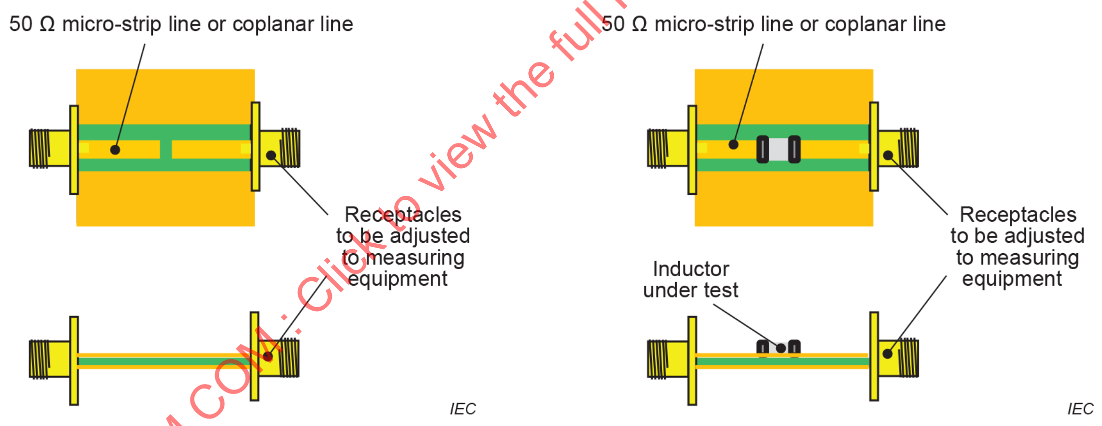
Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 13 – Test fixture for a two-terminal device (shunt connection)

7.1.3.2 Series connection

Figure 14 shows a test fixture for measuring the S-parameters of a two-terminal device in a series connection. Maximum applicable frequency is around 60 GHz.



a) Fixture only **b) Two-terminal device mounted**

Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 14 – Test fixture for a two-terminal device (series connection)

7.2 Calibrations and verification of test setup

7.2.1 General

The calibration of the vector network analyzer (VNA) removes effects from the internal circuitry of the instrument (directional couplers, transmission lines, discontinuities from physical signal transitions) and establishes measurement reference planes.

De-embedding is a second-tier calibration that removes imperfections of the test fixtures or other interconnects between the coaxial/microprobes reference plane and the measurement reference plane.

A direct fixturing method, such as a micro-probe, is an alternative fixturing method to adapt higher frequency measurement.

The exact positions of the measurement reference planes shall be specified between the parties concerned.

7.2.2 Calibration

7.2.2.1 Full two-port calibration

One of the following full two-port calibration methods shall be used.

a) SOLT calibration:

   Four types of calibration standards (short/open/load/thru) or an integrated electrical-cal module with the same capability are used to calibrate the test system at the coaxial ports.

b) TRL calibration:

   Four types of microstrip line standards (thru/reflect/line/match) on the test fixture boards are used to calibrate the test system at the measurement point.

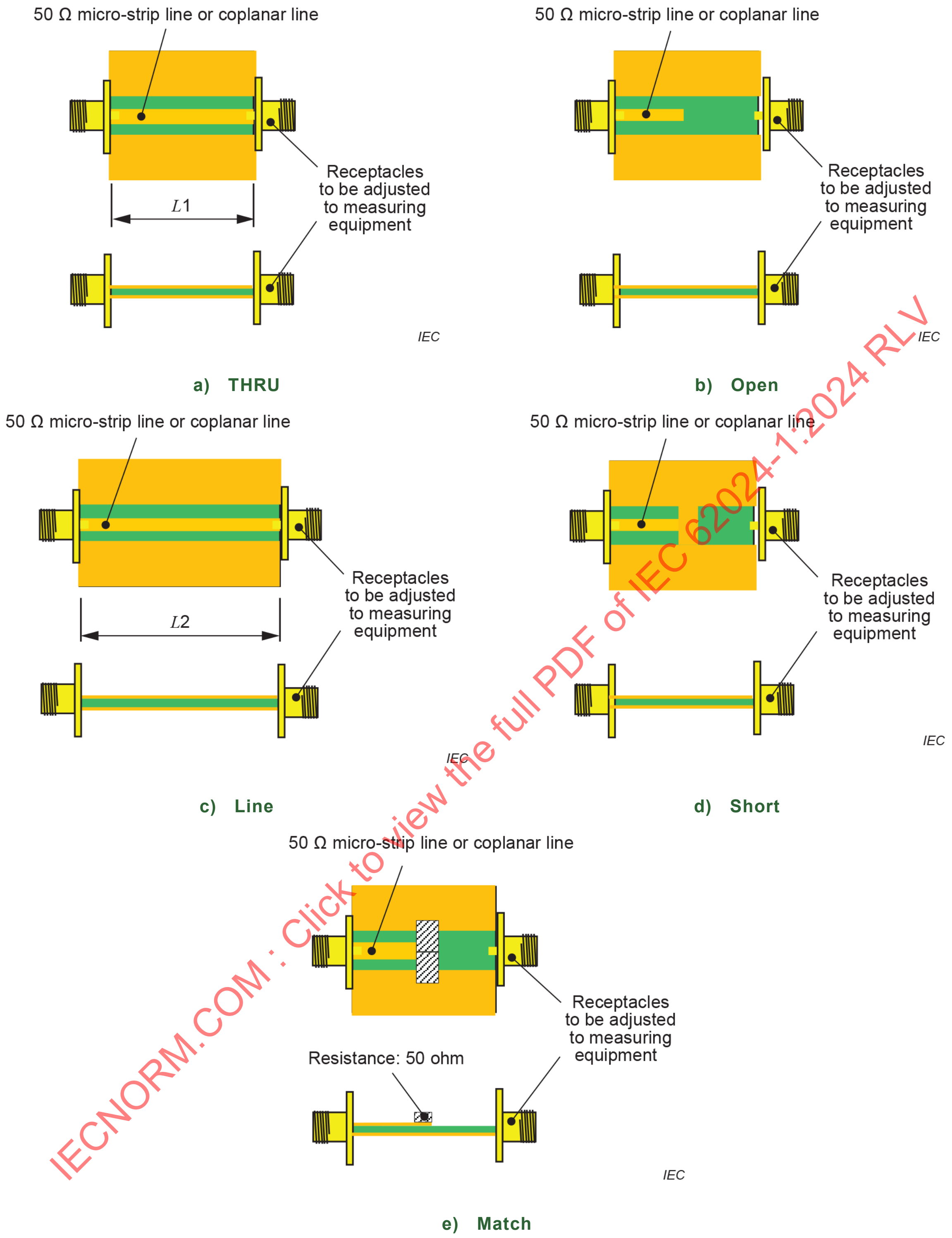
When the SOLT method is used and the reference planes are established at the coaxial connectors, additional de-embedding shall be performed as described in 7.2.2.2.

When the TRL standards on the test fixture are used as the first-tier calibration and the reference planes are established at the measurement point, de-embedding is not required. The TRL standards shall be fabricated with good dimensional tolerances to obtain satisfactory line impedance accuracy.

When a direct fixturing method, such as a micro-probe, is used, appropriate calibration and de-embedding shall be performed as described in 7.2.2.2.

Refer to the instruction manual of the analyzer for details of the calibration procedure.

Examples of a calibration standard (micro-strip lines) for the TRL calibration are shown in Figure 15.



Key

Board low-dielectric resin-based board (ε: 3 to 5)

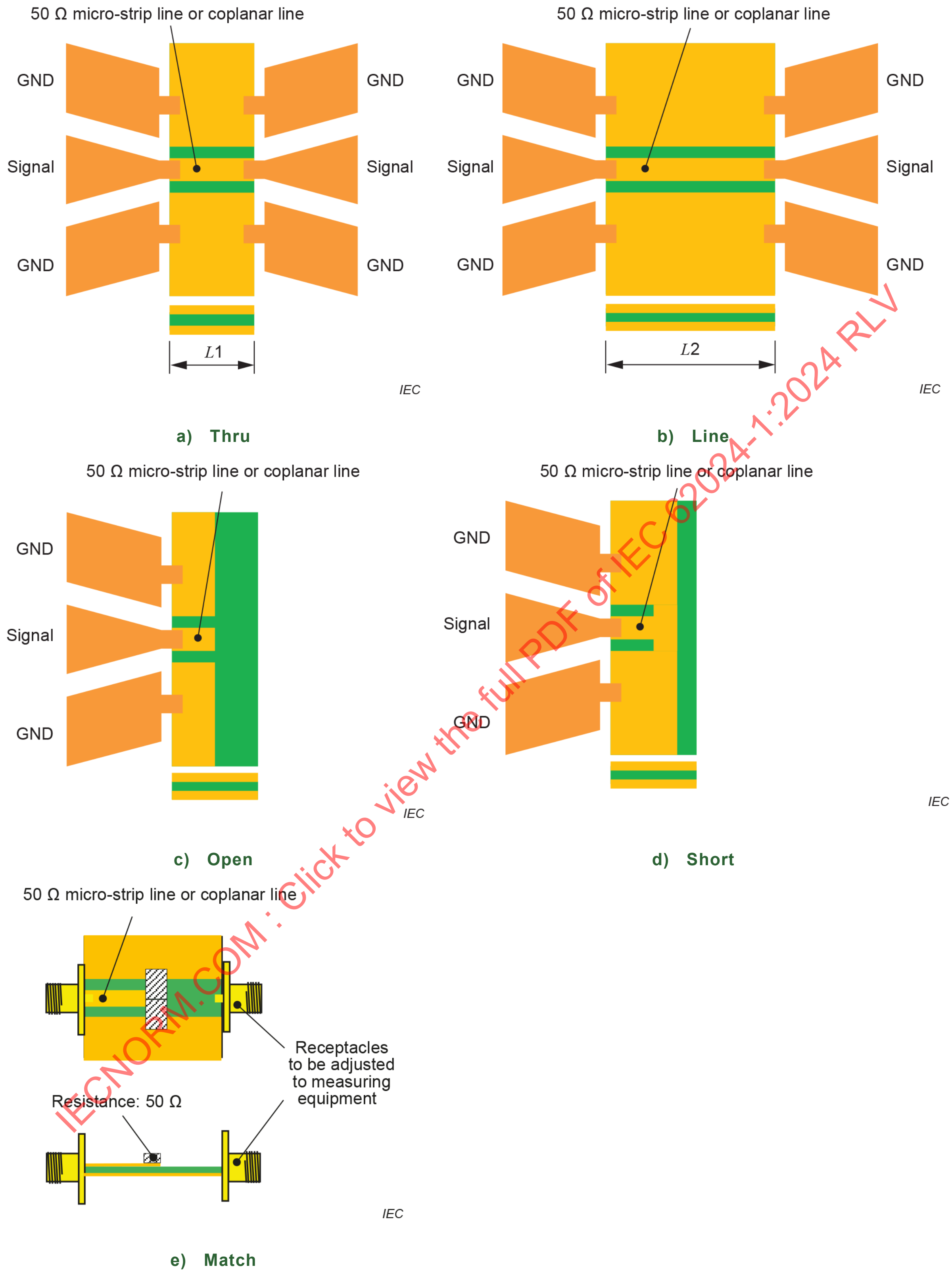
Conductive material: Cu

Board length: $L1$ not equal to $L2$

Figure 15 – Examples of the standards for TRL calibration

7.2.2.2 Calibration with microprobes

One of the full two-port calibration methods with microprobes shall be used. Refer to the instruction manual of the analyzer for details of the calibration procedure. Figure 16 shows examples of the standards for TRL calibration with microprobes.



Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Board length: $L1$ length is not equal to $L2$

Figure 16 – Examples of the standards for TRL calibration with microprobes

7.2.3 De-embedding

7.2.3.1 Full two-port de-embedding

One of the following full two-port de-embedding methods shall be used. Below are examples of full two-port de-embedding.

a) port extension;

b) open-short;

c) TRL;

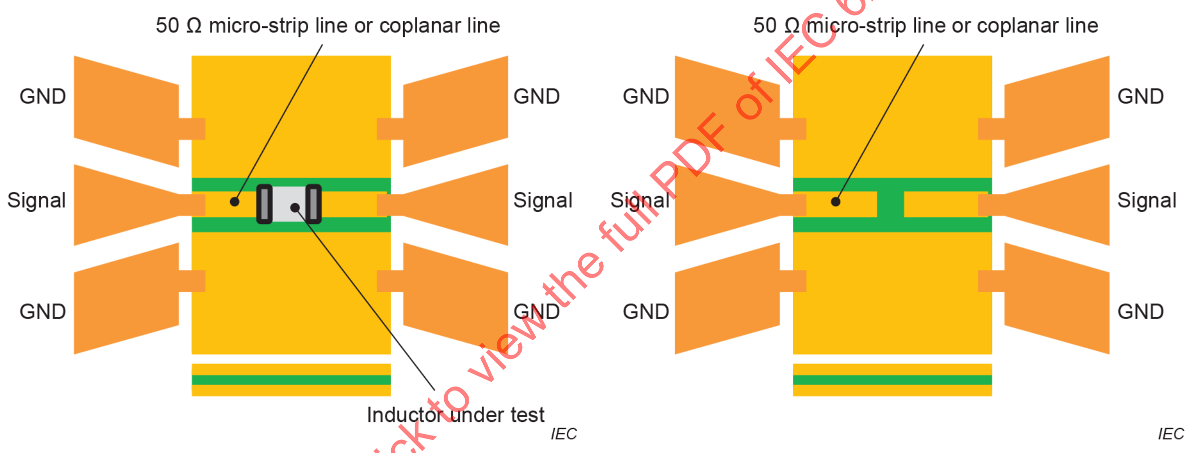
d) direct de-embedding with S-parameter file;

e) automated fixture removal using multiple techniques:

Refer to the instruction manual of the analyzer for details of the de-embedding procedure.

7.2.3.2 Full two-port de-embedding with microprobes

One of the following full two-port de-embedding methods shall be used. Figure 17 shows examples of full two-port de-embedding with microprobes.



a) **DUT** b) **Port extension**

Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 17 – Examples of full two-port de-embedding with microprobes

7.3 Indirect method of impedance

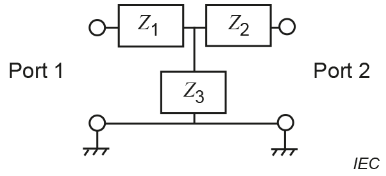
It is possible to evaluate the impedance of a DUT from its S-parameters. In this case, the S-parameters are measured using a network analyzer. See 7.1 for a description of the S-parameter measurement setup.

The impedance of a DUT can be calculated from S parameters. The measured values for the S-parameters should be those of the DUT only, and free of any effects of the test fixture.

7.4 Evaluation from the two-port S-parameter

The impedance of a DUT can be evaluated from S-parameter measurements with a vector network analyzer using an appropriate test fixture as illustrated in Figure 18 and Figure 19.

Figure 18 shows a two-port measurement of a two-terminal device in shunt connection. Figure 19 a shows two-port measurement of a two-terminal device in series connection.



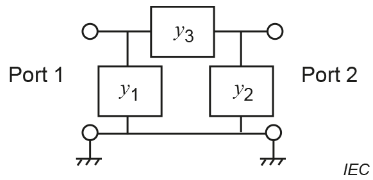
Key

Z_1 stray impedance

Z_2 stray impedance

Z_3 impedance of inductor

Figure 18 – Two-port measurement of a two-terminal device in shunt connection



Key

y_1 stray admittance

y_2 stray admittance

y_3 admittance of inductor

Figure 19 – Two-port measurement of a two-terminal device in series connection

The calibration reference plane for port 1 and port 2 in the fixture shall be specified between the parties concerned.

Assuming symmetrical properties of the DUT, the mean reflection and transmission coefficients are given by:

$$R = \frac{S_{11} + S_{22}}{2} \text{ and } T = \frac{S_{12} + S_{21}}{2} \quad (10)$$

If the condition $|2T| \gg \left|(1-T)^2 - R^2\right|$ is satisfied, then the impedance of the device, Z_x is calculated from Formula (11) and Formula (12):

$$Z_x = Z_0 \frac{2T}{(1-R)^2 - T^2} \text{ in shunt connection} \quad (11)$$

$$Z_x = Z_0 \frac{(1+R)^2 - T^2}{2T} \text{ in shunt connection} \quad (12)$$

where Z_0 is the characteristic impedance of the test fixture.

If the above condition is not fulfilled, the test fixture can affect the measurements, and Formula (11) and Formula (12) can yield erroneous results.

Impedances given by the two-port S-parameter described in this 7.4 can be different to some extent at high frequencies from those described in 4.1, because the one-port S-parameter can depend on the structure of the test fixture used.

Q and L should be calculated as follows:

$$Z_{\mathrm{x}} = R + jX \quad (13)$$

$$Q = X / R \quad (14)$$

$$L = X / (2\pi f) \quad (15)$$

Annex A
(normative)

Mounting method for a surface mounting coil inductor

A.1 Overview

Annex A specifies the method for mounting a surface mounting coil inductor to be tested (hereinafter referred to as "specimen") to the testing printed-circuit board.

A.2 Mounting printed-circuit board and mounting land

A mounting printed-circuit board suitable to the construction of the specimen shall be used, and it shall be specified in the detail specification. If there is no provision in the detail specification, the board (thickness (1,6 ± 0,19) mm, copper foil 0,035 mm $^{+0,010}_{-0,005}$ mm) of epoxide woven glass fabric copper-clad laminate sheet specified in IEC 61249-2-7 shall be used. It shall be a printed-circuit board on which the land for mounting the specimen is previously located. The configuration of the land is indicated by the detail specification.

A.3 Solder

The solder shall be a solder paste prepared in such a way that a weakly active flux of the colophonium system is added to the solder of composition H60A or H63A specified in ISO 9453 with a grain size of 200 mesh or more to form a creamy paste. The viscosity is subjected to agreement between the parties concerned with acceptance. Pb-free solder used in preform or paste form shall be Sn96,5Ag3,0Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58, or as defined in the relevant specification.

A.4 Preparation

The solder paste shall be coated on the lands of the testing printed-circuit board specified in the detail specification to a thickness of (200 ± 50) µm and the specimen shall be placed so that its terminations or electrodes are positioned on the pasted lands.

A.5 Pre-heating

The printed-circuit board on which the specimen is placed shall be heated at (150 ± 10) °C for (60 to 120) s.

A.6 Soldering

After the pre-heating, the soldering shall be carried out immediately by using the reflow soldering device. The soldering temperature shall be (235 ± 5) °C, and the time shall be within 10 s.

A.4 Test condition

See IEC 60068-2-58, with the following details:

a) The solder paste shall be applied to the test substrate.

b) The thickness of solder deposit shall be specified in the detail specification.

c) The terminations of the specimen shall be placed on the solder paste.

d) Solder alloy: Sn-Pb

Unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in the infrared and forced gas convection soldering system.

The temperature of the reflow system shall be quickly raised until the specimen has reached (215 ± 3) °C and maintained at this temperature for (10 ± 1) s.

e) Solder alloy: Sn-Ag-Cu

Unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 5) °C to (180 ± 5) °C for 60 s to 120 s in the infrared and forced gas convection soldering system.

The temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 3) °C. The time above 225 °C shall be (20 ± 5) s.

f) The temperature profile of d) or e) shall be specified in the detail specification.

A.5 Cleaning

After the soldering, the printed-circuit board shall be cleaned by using the 2-propanol specified in ISO 6353-3 to remove the flux. If necessary, the precaution for the cleaning method shall be specified in the detail specification.

Annex B
(normative)

Elimination of residual parameter effects in test fixture

B.1 Overview

In general, these residual and stray factors can be represented by the ABCD parameters of a two-terminal pair as shown in Figure B.1. Using this model, the residual and stray factors can be eliminated.

B.2 Test fixture represented by the ABCD matrix of a two-terminal pair network

The actual impedance value of the DUT (Z_x) and the measurement value (Z_m) are represented by the input and output current and voltage as follows:

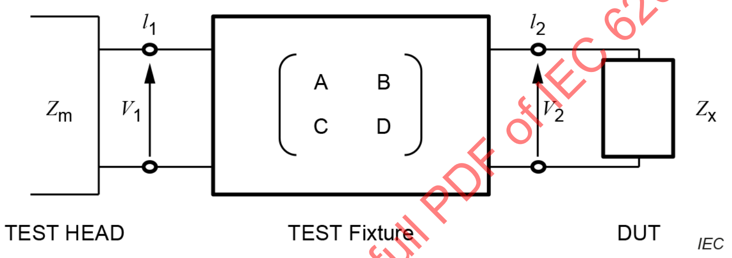


Figure B.1 – Test fixture represented by the ABCD matrix

$$Z_m = \frac{V_1}{I_1} \tag{B.1}$$

$$Z_x = \frac{V_2}{I_2} \tag{B.2}$$

Then, Z_x is

$$Z_x = A_c \frac{Z_m - B_c}{1 - Z_m C_c} \tag{B.3}$$

When open and short compensations are used for thru fixture compensation, one additional condition is required to solve the Z_x formula. This condition as follows:

Assuming the following symmetric circuit:

$$A = D \tag{B.4}$$

Then the compensation coefficients (A_c,B_c,C_c) are as follows:

$$A_c = 1 + j0 \tag{B.5}$$

$$B_c = \frac{Z_{sm} - (1 - Y_{om}Z_{sm})Z_{ss} - Z_{sm}Y_{os}Z_{ss}}{1 - Y_{om}Z_{sm}Y_{os}Z_{ss}} \tag{B.6}$$

$$C_c = \frac{Y_{om} - (1 - Y_{om}Z_{sm})Y_{os} - Y_{om}Y_{os}Z_{ss}}{1 - Y_{om}Z_{sm}Y_{os}Z_{ss}} \tag{B.7}$$

where

Z_x is the impedance measurement value after compensation;

Z_m is the impedance measurement value before compensation;

Z_{sm} is the impedance measurement value of the short device;

Z_{ss} is the short device inductance as defined in 4.1.5.2;

Y_{om} is the admittance measurement value of the fixture with the test device absent;

Y_{os} is the admittance measurement value of the test fixture as defined in 4.1.5.3.

Bibliography

IEC 62674-1, *High frequency inductive components – Part 1: Fixed surface mount inductors for use in electronic and telecommunication equipment*

IEC 62024-1

Edition 4.0 2024-07

INTERNATIONAL STANDARD

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colour inside

**High frequency inductive components – Electrical characteristics and measuring methods –
Part 1: Nanohenry range chip inductor**

**Composants inductifs à haute fréquence – Caractéristiques électriques et méthodes de mesure –
Partie 1: Bobine d'inductance pastille de l'ordre du nanohenry**

IEC 62024-1:2024-07(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 1: Nanohenry range chip inductor

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IEC 62024-1 has been prepared by IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2017. This edition constitutes a technical revision.

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

a) addition of S parameter measurement;
b) addition of the inductance, Q-factor and impedance of an inductor which are measured by the reflection coefficient method with a network analyzer;

c) addition of the resonance frequency of an inductor which is measured by a two-port network analyzer;

d) addition of the mounting method for a surface mounting inductor with Pb-free solder.

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

Draft	Report on voting
51/1500/FDIS	51/1511/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 the IEC 62024 series, published under the general title *High frequency inductive components – Electrical characteristics and measuring methods*, can be found on the IEC website.

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- reconfirmed,
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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 1: Nanohenry range chip inductor

1 Scope

This part of IEC 62024 specifies the electrical characteristics and measuring methods for the nanohenry range chip inductor that is normally used in the high frequency (over 100 kHz) range.

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 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test) copper-clad*

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*

ISO 6353-3, *Reagents for chemical analysis – Part 3: Specifications – Second series*

ISO 9453, *Soft solder alloys – Chemical compositions and forms*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Inductance, Q-factor and impedance

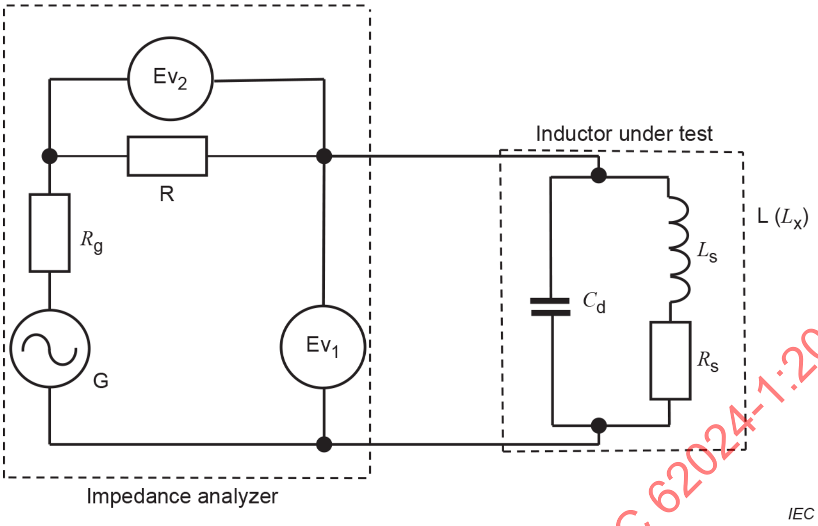
4.1 Inductance

4.1.1 Measuring method

The inductance of an inductor is measured by either the vector voltage/current method (impedance analyzer) or the reflection coefficient method (network analyzer).

4.1.2 Measuring circuit

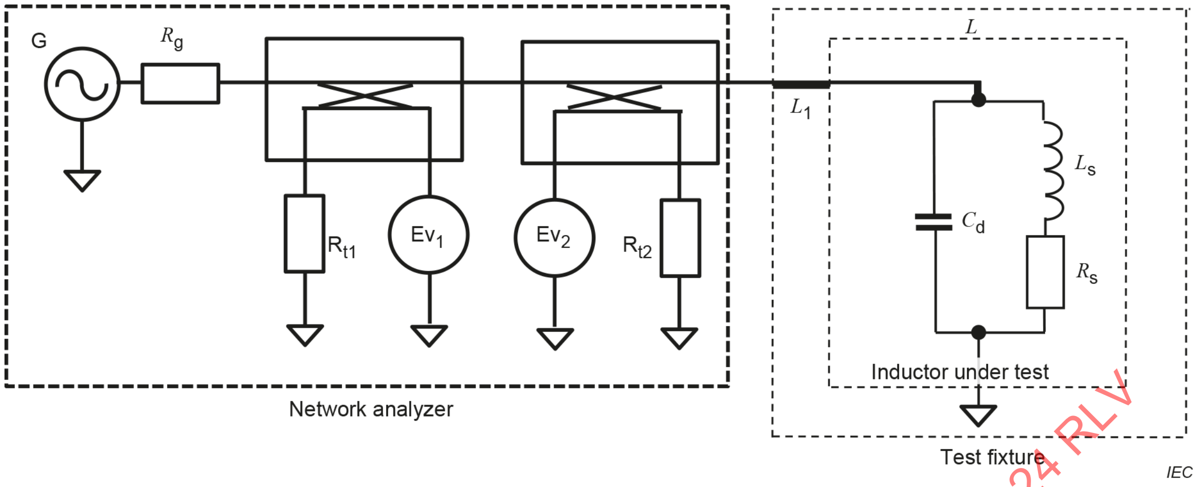
An example of the circuit for the vector voltage/current method is shown in Figure 1 and an example of the circuit for the reflection coefficient method is shown in Figure 2.



Key

R_g	source resistance (50 Ω)
R	resistor
L	inductor under test
L_x	inductance of inductor under test
C_d	parallel capacitance of inductor under test
L_s	series inductance of inductor under test
R_s	series resistance of inductor under test
Ev_1, Ev_2	vector voltmeter
G	signal generator

Figure 1 – Example of circuit for vector voltage/current method



Key

R_g	source resistance (50 Ω)
R_{t1}, R_{t2}	termination resistor (50 Ω)
L	inductor under test
C_d	parallel capacitance of inductor under test
L_s	series inductance of inductor under test
R_s	series resistance of inductor under test
Ev_1, Ev_2	vector voltmeter
G	signal generator
L_1	50 Ω micro-strip line or equivalent transmission line

Figure 2 – Example of circuit for reflection coefficient method

4.1.3 Mounting the inductor for the test

4.1.3.1 General

The inductor shall be mounted in a test fixture as specified in the relevant standard. If no fixture is specified, one of the following test fixtures A, B or C shall be used. The fixture used shall be reported.

4.1.3.2 Fixture A

The shape and dimensions of fixture A shall be as shown in Figure 3 and Table 1.

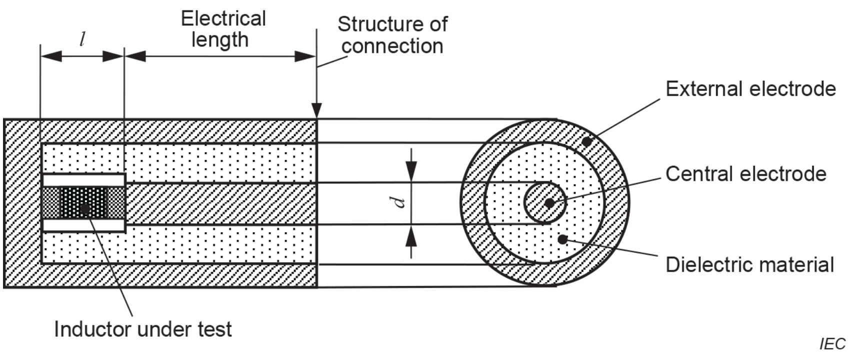


Figure 3 – Fixture A

Table 1 – Dimensions of *l* and *d*

Size of inductor under test[a]	*l* mm	*d* mm
1608	1,6	0,95
1005	1,0	0,60
0603	0,6	0,36
0402	0,4	0,26
0201	0,2	0,12

[a] The outline dimensions of the surface mounted inductor shall be indicated by a four-digit number based on two significant figures for each dimension *L* and *W* (or *H*) (refer to IEC 62025-1).

The electrodes of the test fixture shall contact the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω.

4.1.3.3 Fixture B

The test fixture B as shown in Figure 4 shall be used.

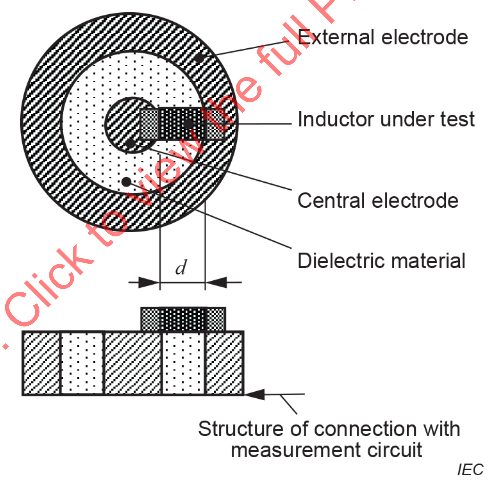


Figure 4 – Fixture B

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω. Dimension *d* shall be specified between the parties concerned.

4.1.3.4 Fixture C

The test fixture C as shown in Figure 5 shall be used.

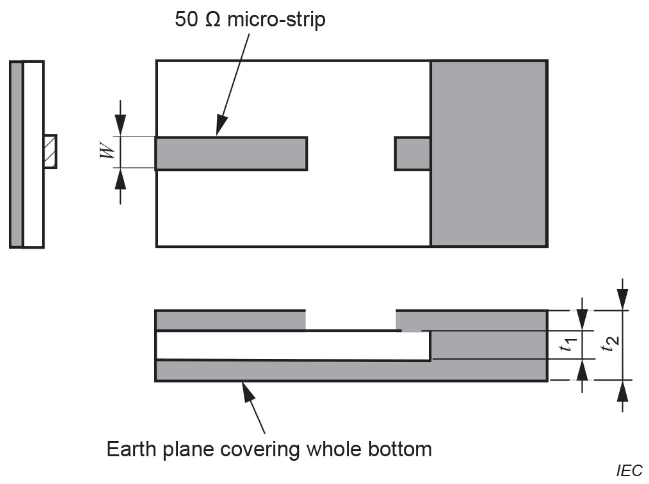


Figure 5 – Fixture C

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by mechanical force provided by an appropriate method. This force shall be chosen so as to provide satisfactory measurement stability without influencing the characteristics of the inductor. The mechanical force shall be specified. A characteristic impedance of the structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as close as possible to 50 Ω. The dimensions of the patterns of the fixture and material of the fixture shall be specified between the parties concerned.

4.1.4 Measuring method and calculation formula

Inductance L_x of the inductor L is defined by the vector sum of the reactance caused by L_s and C_d (see Figure 1 or Figure 2). The frequency f of the signal generator output signal shall be set to a frequency as separately specified. The inductor under test shall be connected to the measurement circuit by using the test fixture as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively. The inductance L_x shall be calculated by Formula (1) and Formula (2) for the vector voltage/current method, or Formula (3) to Formula (5) for the reflection coefficient method:

$$L_x = \frac{\mathrm{Im}[Z_x]}{\omega} \tag{1}$$

$$Z_x = R\frac{E_1}{E_2} \tag{2}$$

where

L_x is the inductance of the inductor under test;

Im is the imaginary part of the complex value;

Z_x is the impedance of the inductor under test;

R is the resistance of the resistor;

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2;

ω is the angular frequency: $2\pi f$.

$$L_x = \frac{\mathrm{Im}[Z_x]}{\omega} \quad (3)$$

$$Z_x = R\frac{E_1}{E_2} \quad (4)$$

$$S_{11} = \frac{E_1}{E_2} \quad (5)$$

where

L_x is the inductance of the inductor under test;

Im is the imaginary part of the complex value;

Z_x is the impedance of the inductor under test;

R is the resistance of the resistor;

S_{11} is the reflection coefficient of the inductor under test;

Z_0 is the system impedance of the measurement system (50 Ω);

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2;

ω is the angular frequency: $2\pi f$.

4.1.5 Notes on measurement

4.1.5.1 General

The electrical length of the test fixture shall be compensated by an appropriate method followed by open-short compensation. If an electrical length that is not commonly accepted is used, it shall be specified. Open-short compensation shall be calculated by Annex B.

4.1.5.2 Short compensation

For test fixture A, the applicable short device dimension and shape are as shown in Figure 6 and Table 2. The appropriate short device inductance shall be selected from Table 2 depending on the dimension of the inductor under test. The inductance of the selected short device shall be used as a compensation value.

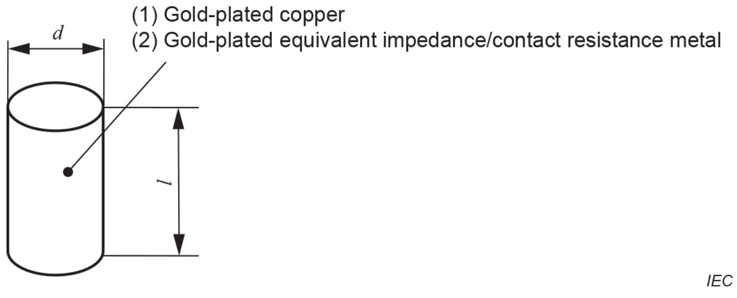


Figure 6 – Short device shape

Table 2 – Short device dimensions and inductances

Size of inductor under test	l mm	d mm	Inductance value nH
1608	1,6	0,95	0,43
1005	1,0	0,60	0,27
0603	0,6	0,36	0,16
0402	0,4	0,26	0,11
0201	0,2	0,12	0,05

If an inductance value other than those defined in Table 2 and if a short device shape other than that defined in Figure 6, such as rectangular shape, are used for test fixture A, the employed value shall be specified. For test fixtures B and C, the short device dimension, shape and inductance values shall be specified.

4.1.5.3 Open compensation

Open compensation for test fixture A shall be performed with test fixture electrodes at the same distance from each other as with the inductor under test mounted in the fixture. The admittance Y_{os} is defined as 0 S (zero Siemens) unless otherwise specified.

Open compensation for test fixtures B and C shall be performed without mounting the inductor. The admittance Y_{os} is defined as 0 S (zero Siemens) unless otherwise specified.

4.2 Quality factor

4.2.1 Measuring method

The Q of the inductor shall be measured by either the vector voltage/current method or the reflection coefficient method.

4.2.2 Measuring circuit

The measurement circuit is as shown in Figure 1 and Figure 2. The measurement equipment shall be suitably calibrated.

4.2.3 Mounting the inductor for test

Mounting of the inductor is as described in 4.1.3.

4.2.4 Measuring method and calculation formula

The frequency of the signal generator (Figure 1 or Figure 2) output signal shall be set to a frequency as separately specified. The inductor shall be connected to the measurement circuit by using the test fixtures as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively. The Q value shall be calculated by the following formula:

$$Q = \frac{\text{Im}[Z_{\text{x}}]}{\text{Re}[Z_{\text{x}}]} \tag{6}$$

where

Q is the Q of the inductor under test;

Re is the real part of the complex value;

Im is the imaginary part of the complex value;

Z_x is the impedance of the inductor under test as calculated in Formula (2) or Formula (4).

4.2.5 Notes on measurement

Refer to 4.1.5.

4.3 Impedance

4.3.1 Measuring method

The impedance of an inductor shall be measured either by the vector voltage/current method or the reflection coefficient method. Those methods are as described in 4.3.2 to 4.3.5.

4.3.2 Measuring circuit

The measurement circuits are as shown in Figure 1 and Figure 2. The measurement equipment shall be suitably calibrated.

4.3.3 Mounting the inductor for test

Mounting of the inductor is as described in 4.1.3.

4.3.4 Measuring method and calculation

The frequency of the signal generator output signal (Figure 1 or Figure 2) shall be set to a frequency f as separately specified. The inductor shall be connected to the measurement circuit by using the test fixture as described in 4.1.3.2 to 4.1.3.4. Vector voltages E_1 and E_2 shall be measured by vector voltage meters Ev_1 and Ev_2, respectively.

The impedance shall be calculated by Formula (2) or Formula (4) in accordance with the method used.

4.3.5 Notes on measurement

Refer to 4.1.5.

5 Resonance frequency

5.1 Self-resonance frequency

The self-resonance frequency of the inductor shall be measured by the minimum output method in 5.2, or by the impedance analyzer or network analyzer in 4.1.

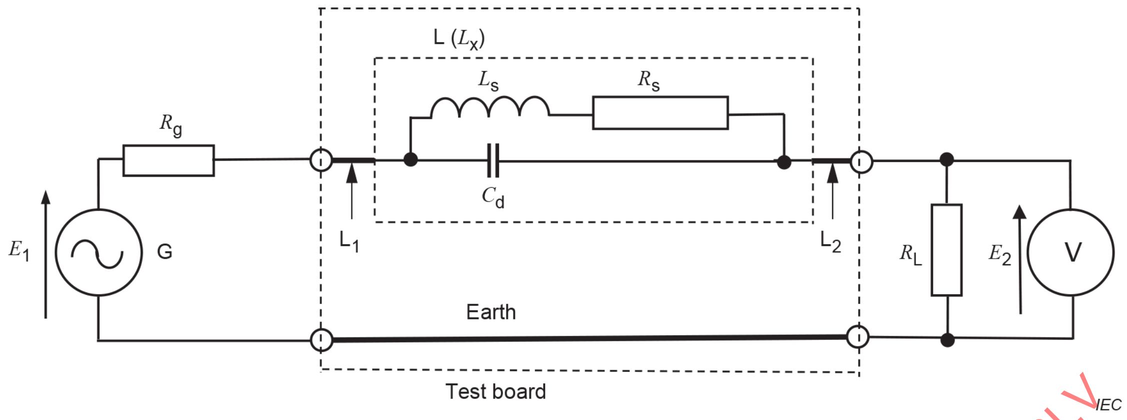
5.2 Minimum output method

5.2.1 General

The minimum output method is as described in 5.2.2 to 5.2.5.

5.2.2 Measuring circuit

The measuring circuit is as shown in Figure 7.



Key

G	signal generator
R_g	source resistance of the signal generator (50 Ω)
L_x	inductance of inductor under test
C_d	parallel capacitance of inductor under test
L	inductor under test
L_1, L_2	50 Ω micro-strip line or equivalent transmission line
V	RF voltmeter
R_L	input resistance of RF voltmeter (50 Ω)
E_1	is the value indicated on vector voltmeter Ev_1
E_2	is the value indicated on vector voltmeter Ev_2

A suitably calibrated network analyzer may be used for the minimum output method in place of the signal generator and RF voltmeter

Figure 7 – Example of test circuit for the minimum output method

5.2.3 Mounting the inductor for test

The inductor shall be mounted on the self-resonance frequency test board specified in the individual standard for the particular inductor by the method specified in Annex A. If there is no individual standard, the self-resonance frequency test board shall be as shown in Figure 8.

The dimensions of the patterns of the fixture and material of the fixture shall be specified between parties concerned.

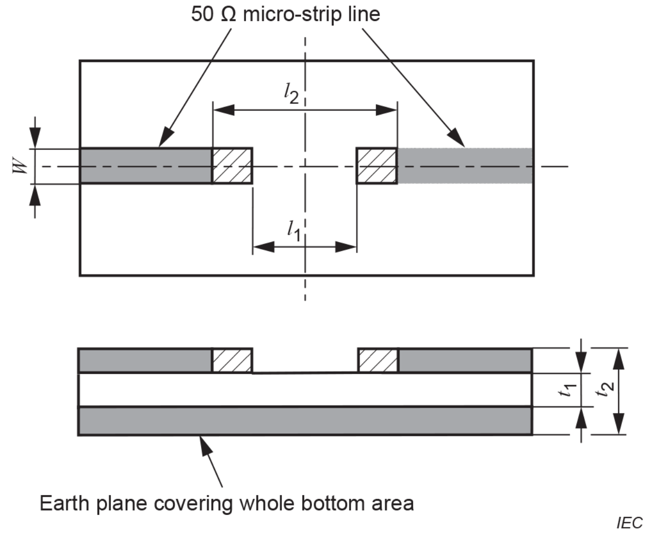


Figure 8 – Self-resonance frequency test board (minimum output method)

5.2.4 Measuring method and calculation formula

Using a circuit of the kind shown in Figure 7, keeping E_1 fixed, the oscillating frequency of the signal generator should be gradually increased until resonance is obtained as indicated by E_2 assuming its minimum value, which is then taken as the self-resonant value.

However, if the range of frequencies where E_2 is minimal is wide, and the frequency of the minimal value is not easily determined, the two frequencies f_1 and f_2 at which E_2 is greater than the minimum by A (dB) ($A \leq 3$) shall be measured, and the self-resonance frequency shall be obtained using the following formula:

$$\text{SRF} = \frac{f_1 + f_2}{2} \tag{7}$$

where

SRF is the self-resonance frequency;

5.2.5 Note on measurement

The width W of the micro-strip line shall be such that the characteristic impedance is as close as possible to 50 Ω. The E_1 value of the micro-strip line selected shall also allow easy identification of the minimum value of E_2.

5.3 Measurement by analyzer

5.3.1 Measurement by impedance analyzer and one-port network analyzer

Self-resonance frequency can be measured by measuring the frequency characteristic of the impedance of the inductor using the impedance analyzer. A one-port network analyzer may be used to substitute the impedance analyzer as described in 4.1.2. When measuring self-resonance frequency, after compensating for the unwanted capacitance (refer to 4.1.5.3), the inductor for test shall be connected to the test fixture.

The exact value of the self-resonance frequency shall be the frequency where the first imaginary part value of impedance equals zero, when sweeping the frequency of the impedance analyzer from the lower value to the higher value.

The test fixture for the measurement of the self-resonance frequency shall be the same as that of the inductance.

5.3.2 Measurement by two-port network analyzer

The self-resonance frequency of the inductor can be measured by the power attenuation method using the network analyzer. During the measurement of the self-resonance frequency, the influence of electromagnetic interference from other electronic equipment shall be avoided. The sweeping frequency range of the network analyzer shall include the self-resonance frequency of the inductor.

The self-resonance frequency of the inductor shall be the frequency where the power attenuation becomes a maximum. It shall be confirmed that the measured self-resonance frequency is not the resonance of the test fixture.

An example of a test fixture for measurement of self-resonance frequency by the power attenuation method is described in 5.2.3.

6 DC resistance

6.1 Voltage-drop method

6.1.1 Measuring circuit

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

6.1.2 Measuring method and calculation formula

Use the circuit as shown in Figure 9.

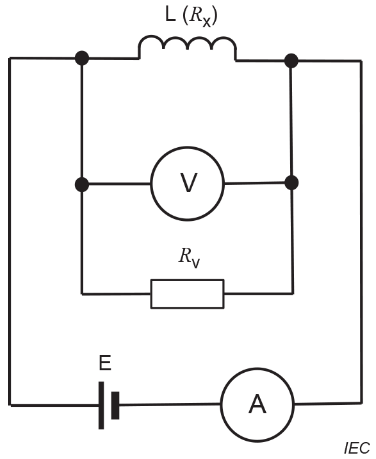
Calculate DC resistance R_x of the inductor from the following formula:

$$R_x = \frac{V}{I} \tag{8}$$

where

V is the value indicated on V;

I is the value indicated on A.



Key

L inductor under test

E DC power supply

V DC voltmeter

A DC ammeter

R_x DC resistance of inductor under test

R_v internal resistance of DC voltmeter: $R_v >> R_x$

Figure 9 – Example of test circuit for voltage-drop method

6.2 Bridge method

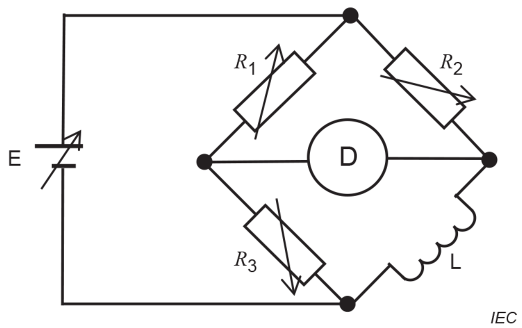
6.2.1 Measuring circuit

An example of the measuring circuit for DC resistance is shown in Figure 10.

6.2.2 Measuring method and calculation formula

Use the circuit as shown in Figure 10, balance the bridge by adjusting the proportional arm resistors R_1 and R_2 and standard variable resistor R_3, and calculate DC resistance R_x of the inductor from the following formula:

$$R_x = \frac{R_2}{R_1} \times R_3 \tag{9}$$



Key

R_1, R_2	resistance of proportional arm resistors R_1, R_2
R_3	resistance of standard variable resistor R_3
L	inductor under test
E	DC power supply
D	detector

Figure 10 – Example of test circuit for bridge method

6.3 Notes on measurement

The precautions for measurements are as follows:

– measurement of resistance shall be made by using a direct voltage of a small magnitude for as short a time as practicable, in order that the temperature of the resistance element does not rise appreciably during measurement;

– measuring voltage: ≤ 0,5 V;

– measurement uncertainty ±0,5 % of measured value;

– the temperature of the specimen should coincide with the ambient temperature;

– keep the current passed through the specimen within a range so that the resistance of the inductor will not change greatly;

– use of a double bridge is recommended for adequate accuracy when high measurement accuracy is required for DC resistance of 0,1 Ω or less.

6.4 Measuring temperature

Measurement temperature is specified in IEC 62674-1.

7 S-parameter

7.1 Measurement setup and procedure

7.1.1 General

A network analyzer (50 Ω system) is used for measuring the S-parameters of a device under test (DUT). A vector network analyzer is an instrument with a function for determining S-parameters directly from measurement of the amplitudes and phases of the incident, reflected, and transmitted waves; this is achieved by combining a directional coupler and a sophisticated calibration mechanism with the tracking generator and measuring receiver. Below is the measurement setup for a two-port measurement.

S-parameters should be measured by inserting the DUT into the test fixture and by sweeping the measurement frequency with the network analyzer. The relationship between the S-parameters and the frequency should be recorded within the required frequency range.

The electrodes of the test fixture shall be in contact with the electrodes of the inductor under test by either soldering or mechanical force provided by an appropriate method. The mechanical force shall be specified. This force shall be chosen to provide satisfactory measurement stability without influencing the characteristics of the inductor. Figure 11 shows a schematic diagram of the two-port S-parameter measurement setup and the network analyzer.

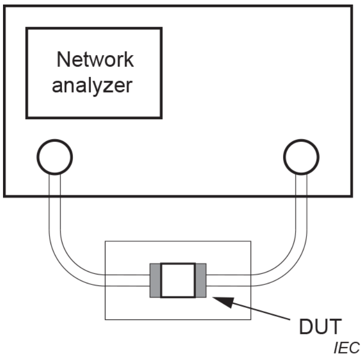
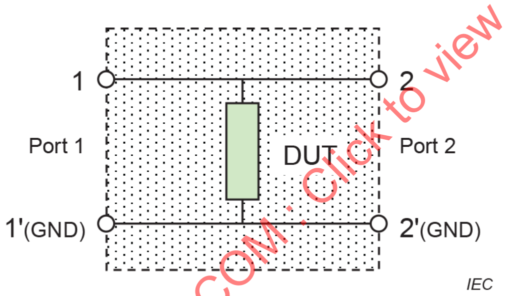


Figure 11 – Schematic diagram of the two-port S-parameter measurement setup and the network analyzer

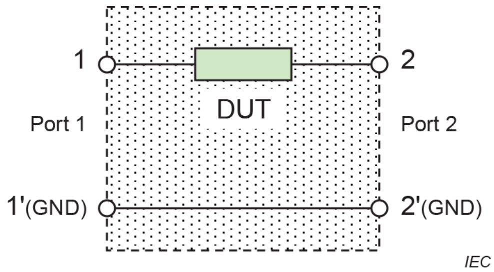
7.1.2 Two-port S-parameter

The characteristics of inductors can be evaluated in terms of the two-port S-parameters using a test fixture shown in Figure 12.

There are two possible configurations for connecting the two-terminal devices and fixture: one with a shunt connection and one with a series connection. One of these configurations should be chosen according to their impedance. The used configuration shall be specified.



a) Shunt connection



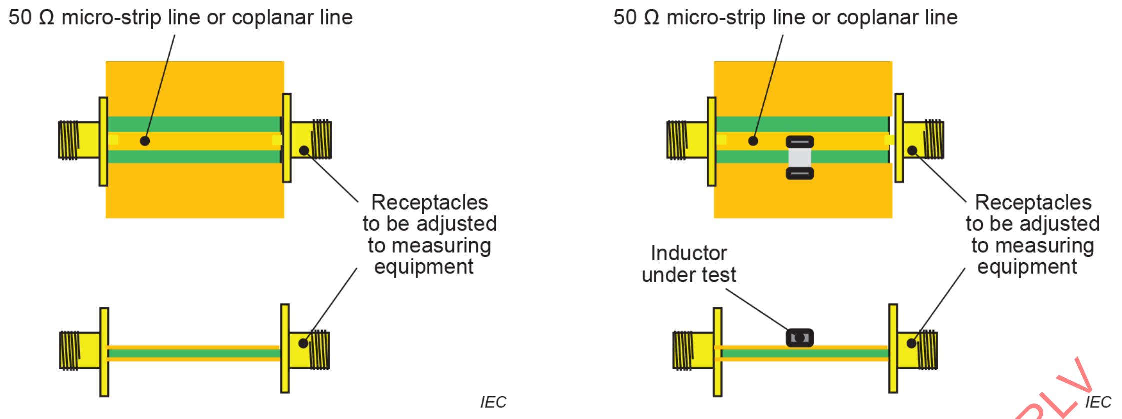
b) Series connection

Figure 12 – S-parameter test fixture for two-terminal devices

7.1.3 Test fixture

7.1.3.1 Shunt connection

Figure 13 shows a test fixture for measuring the S-parameters of a two-terminal device in a shunt connection. Maximum applicable frequency is around 60 GHz.



a) Fixture only **b) Two-terminal device mounted**

Key

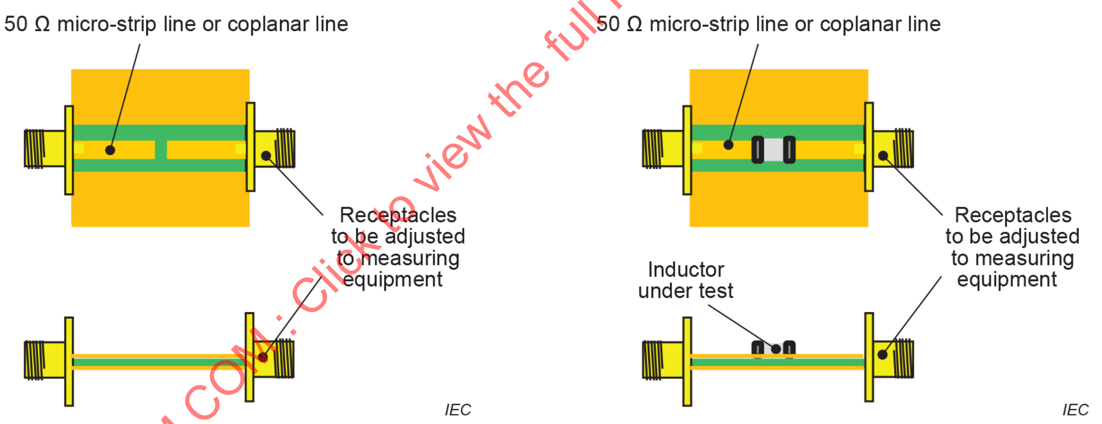
Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 13 – Test fixture for a two-terminal device (shunt connection)

7.1.3.2 Series connection

Figure 14 shows a test fixture for measuring the S-parameters of a two-terminal device in a series connection. Maximum applicable frequency is around 60 GHz.



a) Fixture only **b) Two-terminal device mounted**

Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 14 – Test fixture for a two-terminal device (series connection)

7.2 Calibrations and verification of test setup

7.2.1 General

The calibration of the vector network analyzer (VNA) removes effects from the internal circuitry of the instrument (directional couplers, transmission lines, discontinuities from physical signal transitions) and establishes measurement reference planes.

De-embedding is a second-tier calibration that removes imperfections of the test fixtures or other interconnects between the coaxial/microprobes reference plane and the measurement reference plane.

A direct fixturing method, such as a micro-probe, is an alternative fixturing method to adapt higher frequency measurement.

The exact positions of the measurement reference planes shall be specified between the parties concerned.

7.2.2 Calibration

7.2.2.1 Full two-port calibration

One of the following full two-port calibration methods shall be used.

a) SOLT calibration:

   Four types of calibration standards (short/open/load/thru) or an integrated electrical-cal module with the same capability are used to calibrate the test system at the coaxial ports.

b) TRL calibration:

   Four types of microstrip line standards (thru/reflect/line/match) on the test fixture boards are used to calibrate the test system at the measurement point.

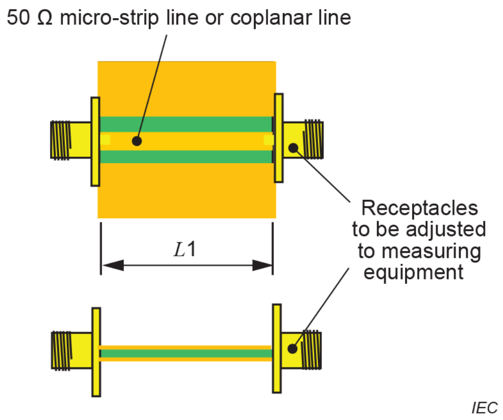
When the SOLT method is used and the reference planes are established at the coaxial connectors, additional de-embedding shall be performed as described in 7.2.2.2.

When the TRL standards on the test fixture are used as the first-tier calibration and the reference planes are established at the measurement point, de-embedding is not required. The TRL standards shall be fabricated with good dimensional tolerances to obtain satisfactory line impedance accuracy.

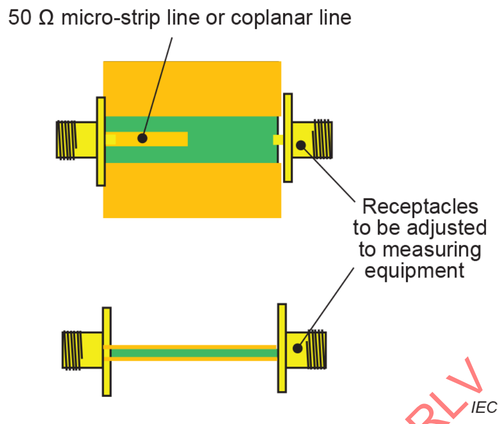
When a direct fixturing method, such as a micro-probe, is used, appropriate calibration and de-embedding shall be performed as described in 7.2.2.2.

Refer to the instruction manual of the analyzer for details of the calibration procedure.

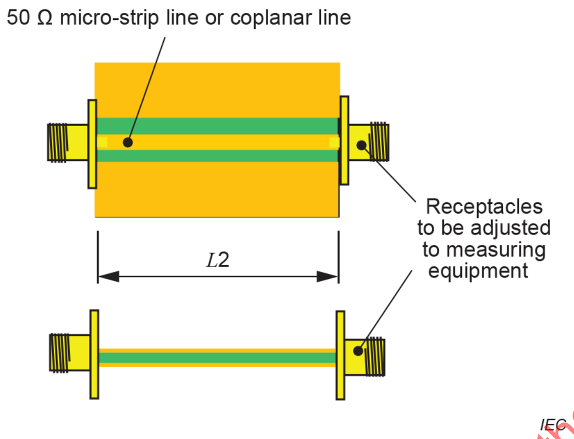
Examples of a calibration standard (micro-strip lines) for the TRL calibration are shown in Figure 15.



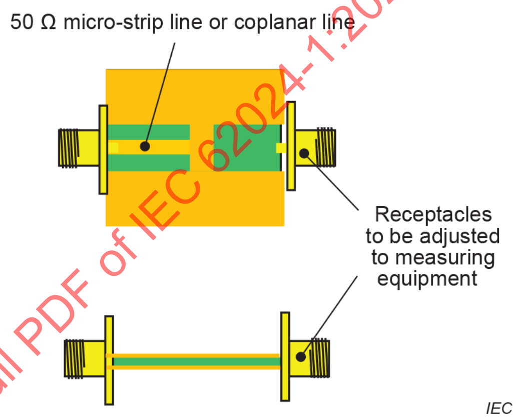
a) THRU



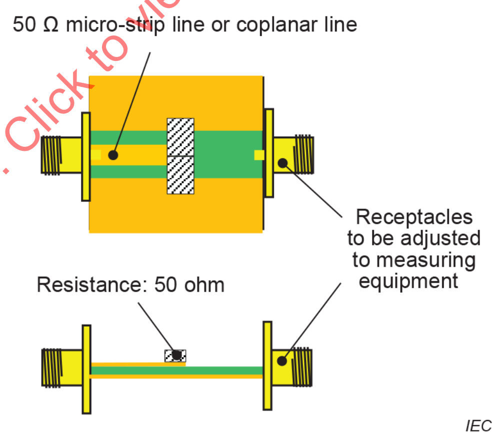
b) Open



c) Line



d) Short



e) Match

Key

Board: low-dielectric resin-based board (ε: 3 to 5)

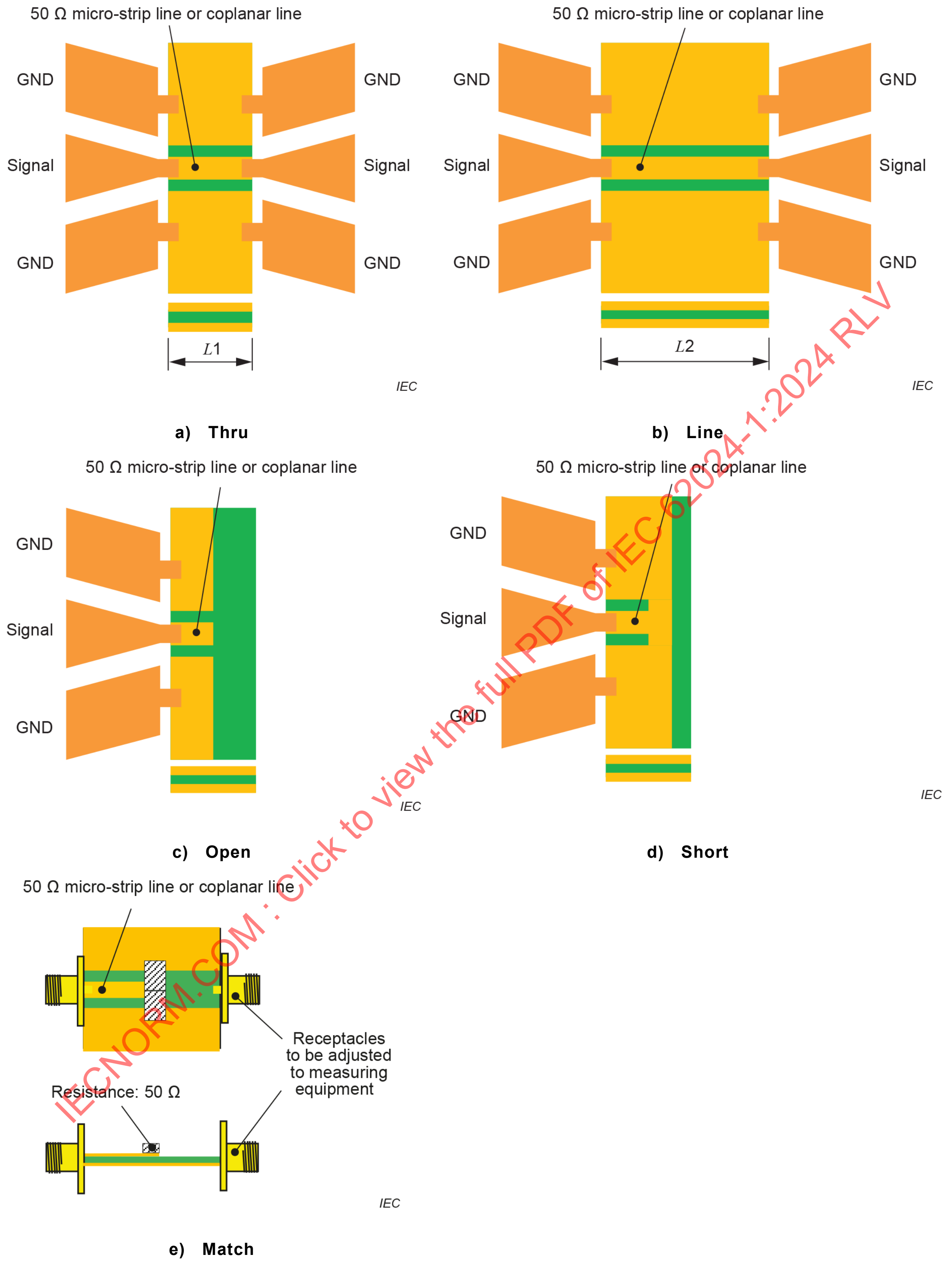
Conductive material: Cu

Board length: $L1$ not equal to $L2$

Figure 15 – Examples of the standards for TRL calibration

7.2.2.2 Calibration with microprobes

One of the full two-port calibration methods with microprobes shall be used. Refer to the instruction manual of the analyzer for details of the calibration procedure. Figure 16 shows examples of the standards for TRL calibration with microprobes.



Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Board length: $L1$ length is not equal to $L2$

Figure 16 – Examples of the standards for TRL calibration with microprobes

7.2.3 De-embedding

7.2.3.1 Full two-port de-embedding

One of the following full two-port de-embedding methods shall be used. Below are examples of full two-port de-embedding.

a) port extension;

b) open-short;

c) TRL;

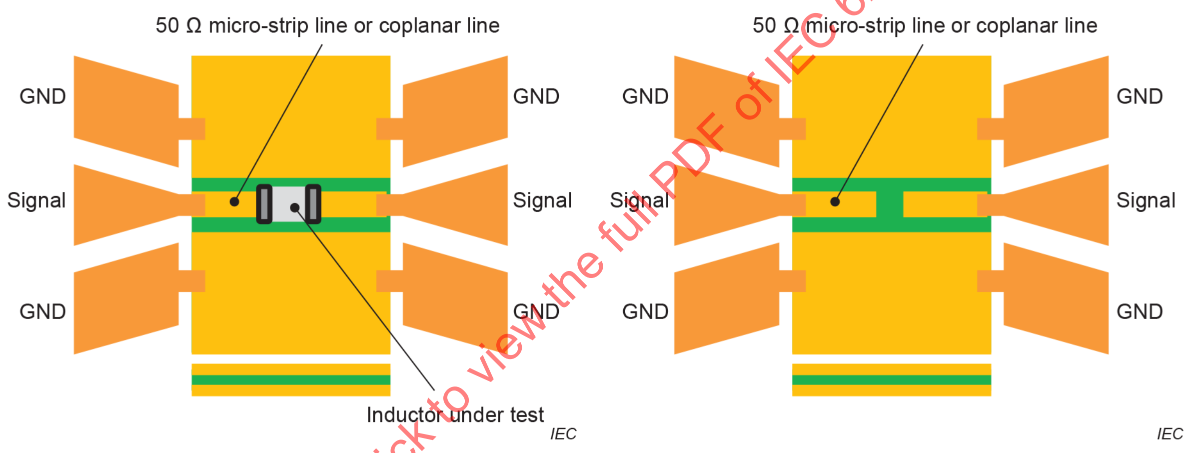
d) direct de-embedding with S-parameter file;

e) automated fixture removal using multiple techniques:

Refer to the instruction manual of the analyzer for details of the de-embedding procedure.

7.2.3.2 Full two-port de-embedding with microprobes

One of the following full two-port de-embedding methods shall be used. Figure 17 shows examples of full two-port de-embedding with microprobes.



a) **DUT** b) **Port extension**

Key

Board: low-dielectric resin-based board (ε:3 to 5)

Conductive material: Cu

Figure 17 – Examples of full two-port de-embedding with microprobes

7.3 Indirect method of impedance

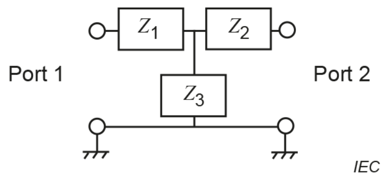
It is possible to evaluate the impedance of a DUT from its S-parameters. In this case, the S-parameters are measured using a network analyzer. See 7.1 for a description of the S-parameter measurement setup.

The impedance of a DUT can be calculated from S parameters. The measured values for the S-parameters should be those of the DUT only, and free of any effects of the test fixture.

7.4 Evaluation from the two-port S-parameter

The impedance of a DUT can be evaluated from S-parameter measurements with a vector network analyzer using an appropriate test fixture as illustrated in Figure 18 and Figure 19.

Figure 18 shows a two-port measurement of a two-terminal device in shunt connection. Figure 19 a shows two-port measurement of a two-terminal device in series connection.



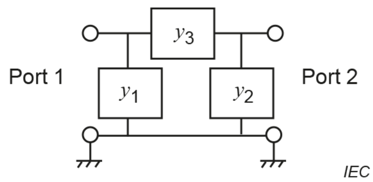
Key

Z_1 stray impedance

Z_2 stray impedance

Z_3 impedance of inductor

Figure 18 – Two-port measurement of a two-terminal device in shunt connection



Key

y_1 stray admittance

y_2 stray admittance

y_3 admittance of inductor

Figure 19 – Two-port measurement of a two-terminal device in series connection

The calibration reference plane for port 1 and port 2 in the fixture shall be specified between the parties concerned.

Assuming symmetrical properties of the DUT, the mean reflection and transmission coefficients are given by:

$$R = \frac{S_{11} + S_{22}}{2} \text{ and } T = \frac{S_{12} + S_{21}}{2} \qquad (10)$$

If the condition $|2T| \gg \left|(1-T)^2 - R^2\right|$ is satisfied, then the impedance of the device, Z_x is calculated from Formula (11) and Formula (12):

$$Z_x = Z_0 \frac{2T}{(1-R)^2 - T^2} \text{ in shunt connection} \qquad (11)$$

$$Z_x = Z_0 \frac{(1+R)^2 - T^2}{2T} \text{ in shunt connection} \qquad (12)$$

where Z_0 is the characteristic impedance of the test fixture.

If the above condition is not fulfilled, the test fixture can affect the measurements, and Formula (11) and Formula (12) can yield erroneous results.

Impedances given by the two-port S-parameter described in this 7.4 can be different to some extent at high frequencies from those described in 4.1, because the one-port S-parameter can depend on the structure of the test fixture used.

Q and L should be calculated as follows:

$$Z_{\mathrm{X}} = R + jX \tag{13}$$

$$Q = X / R \tag{14}$$

$$L = X / \left(2\pi f\right) \tag{15}$$

Annex A
(normative)

Mounting method for a surface mounting inductor

A.1 Overview

Annex A specifies the method for mounting a surface mounting inductor to be tested (hereinafter referred to as "specimen") to the testing printed-circuit board.

A.2 Mounting printed-circuit board and mounting land

A mounting printed-circuit board suitable to the construction of the specimen shall be used, and it shall be specified in the detail specification. If there is no provision in the detail specification, the board (thickness (1,6 ± 0,19) mm, copper foil 0,035 mm $^{+0,010}_{-0,005}$ mm) of epoxide woven glass fabric copper-clad laminate sheet specified in IEC 61249-2-7 shall be used. It shall be a printed-circuit board on which the land for mounting the specimen is previously located. The configuration of the land is indicated by the detail specification.

A.3 Solder

The solder shall be a solder paste prepared in such a way that a weakly active flux of the colophonium system is added to the solder of composition H60A or H63A specified in ISO 9453 with a grain size of 200 mesh or more to form a creamy paste. The viscosity is subjected to agreement between the parties concerned. Pb-free solder used in preform or paste form shall be Sn96,5Ag3,0Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58, or as defined in the relevant specification.

A.4 Test condition

See IEC 60068-2-58, with the following details:

a) The solder paste shall be applied to the test substrate.

b) The thickness of solder deposit shall be specified in the detail specification.

c) The terminations of the specimen shall be placed on the solder paste.

d) Solder alloy: Sn-Pb

   Unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 10) °C and maintained for 60 s to 120 s in the infrared and forced gas convection soldering system.

   The temperature of the reflow system shall be quickly raised until the specimen has reached (215 ± 3) °C and maintained at this temperature for (10 ± 1) s.

e) Solder alloy: Sn-Ag-Cu

   Unless otherwise specified in the detail specification, the specimen and test substrate shall be preheated to a temperature of (150 ± 5) °C to (180 ± 5) °C for 60 s to 120 s in the infrared and forced gas convection soldering system.

   The temperature of the reflow system shall be quickly raised until the specimen has reached (235 ± 3) °C. The time above 225 °C shall be (20 ± 5) s.

f) The temperature profile of d) or e) shall be specified in the detail specification.

A.5 Cleaning

After the soldering, the printed-circuit board shall be cleaned by using the 2-propanol specified in ISO 6353-3 to remove the flux. If necessary, the precaution for the cleaning method shall be specified in the detail specification.

Annex B
(normative)

Elimination of residual parameter effects in test fixture

B.1 Overview

In general, these residual and stray factors can be represented by the ABCD parameters of a two-terminal pair as shown in Figure B.1. Using this model, the residual and stray factors can be eliminated.

B.2 Test fixture represented by the ABCD matrix of a two-terminal pair network

The actual impedance value of the DUT (Z_x) and the measurement value (Z_m) are represented by the input and output current and voltage as follows:

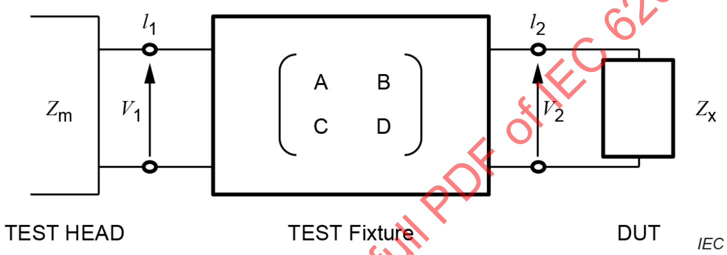


Figure B.1 – Test fixture represented by the ABCD matrix

$$Z_m = \frac{V_1}{I_1} \quad \text{(B.1)}$$

$$Z_x = \frac{V_2}{I_2} \quad \text{(B.2)}$$

Then, Z_x is

$$Z_x = A_c \frac{Z_m - B_c}{1 - Z_m C_c} \quad \text{(B.3)}$$

When open and short compensations are used for thru fixture compensation, one additional condition is required to solve the Z_x formula. This condition as follows:

Assuming the following symmetric circuit:

$$A = D \tag{B.4}$$

Then the compensation coefficients (A_c,B_c,C_c) are as follows:

$$A_c = 1 + j0 \tag{B.5}$$

$$B_c = \frac{Z_{sm} - (1 - Y_{om} Z_{sm}) Z_{ss} - Z_{sm} Y_{os} Z_{ss}}{1 - Y_{om} Z_{sm} Y_{os} Z_{ss}} \tag{B.6}$$

$$C_c = \frac{Y_{om} - (1 - Y_{om} Z_{sm}) Y_{os} - Y_{om} Y_{os} Z_{ss}}{1 - Y_{om} Z_{sm} Y_{os} Z_{ss}} \tag{B.7}$$

where

Z_x is the impedance measurement value after compensation;

Z_m is the impedance measurement value before compensation;

Z_{sm} is the impedance measurement value of the short device;

Z_{ss} is the short device inductance as defined in 4.1.5.2;

Y_{om} is the admittance measurement value of the fixture with the test device absent;

Y_{os} is the admittance measurement value of the test fixture as defined in 4.1.5.3.

Bibliography

IEC 62674-1, *High frequency inductive components – Part 1: Fixed surface mount inductors for use in electronic and telecommunication equipment*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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

Partie 1: Bobine d'inductance pastille de l'ordre du nanohenry

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Cette quatrième édition annule et remplace la troisième édition parue en 2017. Cette édition constitue une révision technique.

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

a) ajout du mesurage des paramètres S;
b) ajout des mesurages de l'inductance, du facteur Q et de l'impédance d'une bobine d'inductance par la méthode du facteur de réflexion au moyen d'un analyseur de réseau;
c) ajout du mesurage de la fréquence de résonance d'une bobine d'inductance par un analyseur de réseau à deux accès;
d) ajout de la méthode de montage d'une bobine d'inductance à montage en surface par brasage sans plomb.

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

Projet	Rapport de vote
51/1500/FDIS	51/1511/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. La version française de cette norme n'a pas été soumise au vote.

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.

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

Partie 1: Bobine d'inductance pastille de l'ordre du nanohenry

1 Domaine d'application

La présente partie de l'IEC 62024 spécifie les caractéristiques électriques et les méthodes de mesure pour l'inductance pastille de l'ordre du nanohenry qui est normalement utilisée dans la plage des hautes fréquences (supérieures à 100 kHz).

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 60068-2-58, *Essais d'environnement – Partie 2-58: Essais – Essai Td: Méthodes d'essai de la soudabilité, résistance de la métallisation à la dissolution et résistance à la chaleur de brasage des composants pour montage en surface (CMS)*

IEC 61249-2-7, *Matériaux pour circuits imprimés et autres structures d'interconnexion – Partie 2-7 : Matériaux de base renforcés, plaqués et non plaqués – Feuille stratifiée tissée de verre E avec de la résine époxyde, d'inflammabilité définie (essai de combustion verticale), plaquée cuivre*

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

ISO 6353-3, *Réactifs pour analyse chimique – Partie 3: Spécifications – Deuxième série*

ISO 9453, *Alliages de brasage tendre – Compositions chimiques et formes*

3 Termes et définitions

Aucun terme n'est défini dans le présent document.

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

4 Inductance, facteur Q et impédance

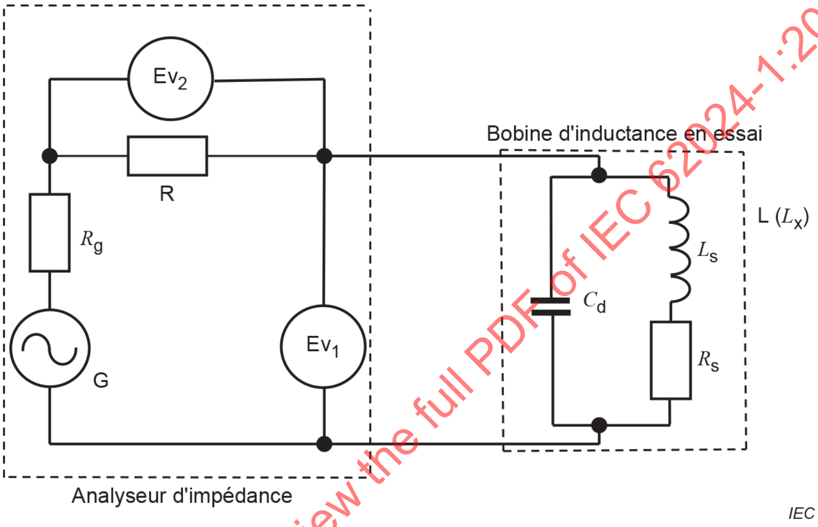
4.1 Inductance

4.1.1 Méthode de mesure

L'inductance d'une bobine d'inductance est mesurée par la méthode de tension/courant vectoriels (analyseur d'impédance) ou la méthode du facteur de réflexion (analyseur de réseau).

4.1.2 Circuit de mesure

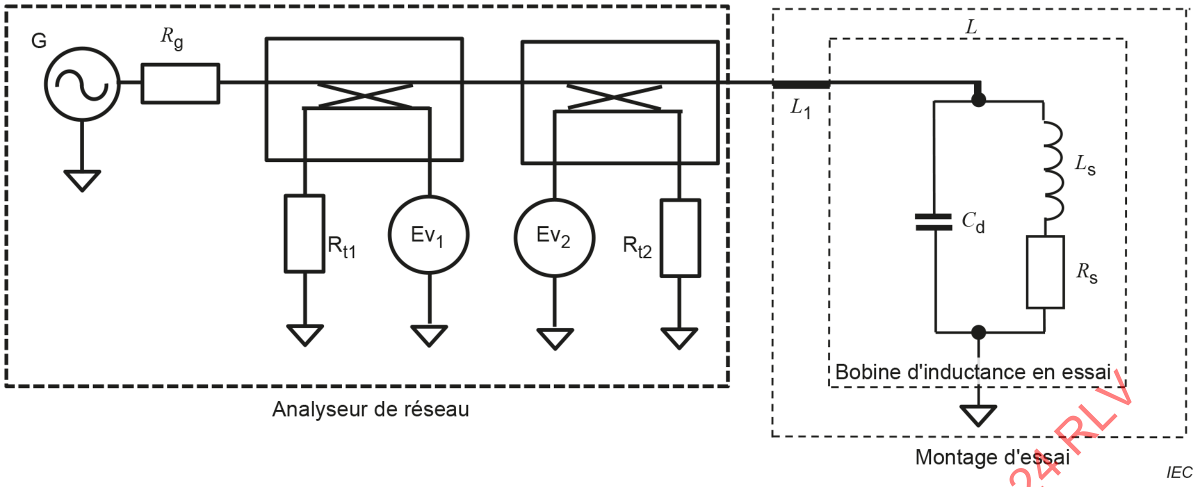
Un exemple de circuit pour la méthode de tension/courant vectoriels est représenté sur la Figure 1. Un exemple de circuit pour la méthode du facteur de réflexion est représenté sur la Figure 2.



Légende

R_g	résistance de la source (50 Ω)
R	résistance
L	bobine d'inductance en essai
L_x	inductance de la bobine d'inductance en essai
C_d	capacité parallèle de la bobine d'inductance en essai
L_s	inductance série de la bobine d'inductance en essai
R_s	résistance série de la bobine d'inductance en essai
Ev_1, Ev_2	voltmètres vectoriels
G	générateur de signaux

Figure 1 – Exemple de circuit pour la méthode de tension/courant vectoriels



Légende

R_g	résistance de la source (50 Ω)
R_{t1}, R_{t2}	résistances terminale (50 Ω)
L	bobine d'inductance en essai
C_d	capacité parallèle de la bobine d'inductance en essai
L_s	inductance série de la bobine d'inductance en essai
R_s	résistance série de la bobine d'inductance en essai
Ev_1, Ev_2	voltmètres vectoriels
G	générateur de signaux
L_1	ligne à microruban de 50 Ω ou ligne de transmission équivalente

Figure 2 – Exemple de circuit pour la méthode du facteur de réflexion

4.1.3 Montage de la bobine d'inductance pour l'essai

4.1.3.1 Généralités

La bobine d'inductance doit être montée dans un montage d'essai, comme cela est spécifié dans la norme correspondante. Si aucun montage n'est spécifié, l'un des montages d'essai A, B ou C suivants doit être utilisé. Le montage utilisé doit être consigné.

4.1.3.2 Montage A

La forme et les dimensions du montage A doivent être conformes à la Figure 3 et au Tableau 1.

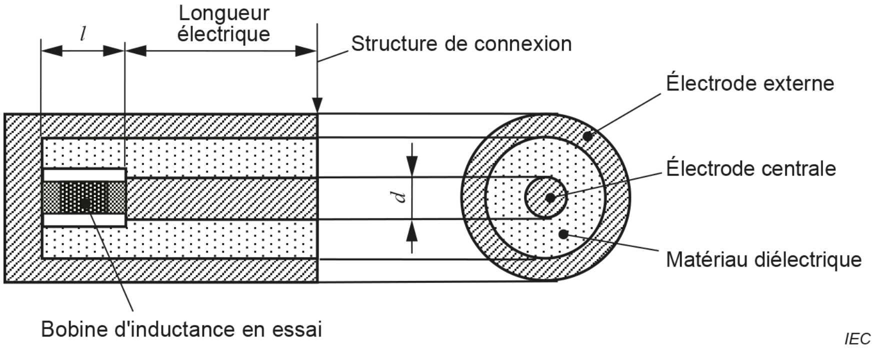


Figure 3 – Montage A

Tableau 1 – Dimensions *l* et *d*

Taille de la bobine d'inductance en essai [a]	l mm	d mm
1608	1,6	0,95
1005	1,0	0,60
0603	0,6	0,36
0402	0,4	0,26
0201	0,2	0,12

[a] Les dimensions extérieures de la bobine d'inductance à montage en surface doivent être indiquées par un numéro à quatre chiffres, avec deux chiffres significatifs pour chaque dimension L et W (ou H) (voir l'IEC 62025-1).

Les électrodes du montage d'essai doivent être mises en contact avec les électrodes de la bobine d'inductance en essai par application d'une force mécanique par une méthode appropriée. Cette force doit être choisie de manière à procurer une stabilité de mesure satisfaisante sans influencer les caractéristiques de la bobine d'inductance. La force mécanique doit être spécifiée. La structure entre le circuit de mesure et le montage d'essai doit maintenir une impédance caractéristique aussi proche que possible de 50 Ω.

4.1.3.3 Montage B

Le montage d'essai B représenté sur la Figure 4 doit être utilisé.

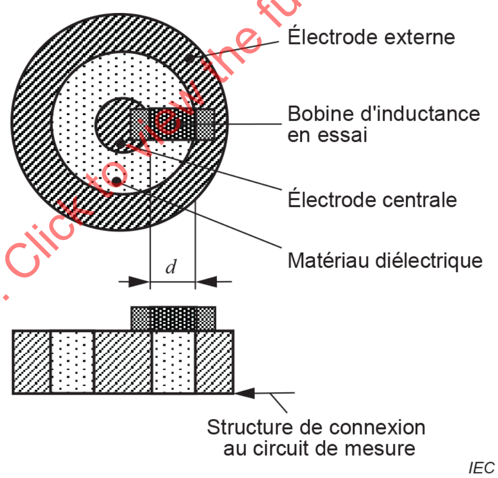


Figure 4 – Montage B

Les électrodes du montage d'essai doivent être mises en contact avec les électrodes de la bobine d'inductance en essai par application d'une force mécanique par une méthode appropriée. Cette force doit être choisie de manière à procurer une stabilité de mesure satisfaisante sans influencer les caractéristiques de la bobine d'inductance. La force mécanique doit être spécifiée. La structure entre le circuit de mesure et le montage d'essai doit maintenir une impédance caractéristique aussi proche que possible de 50 Ω. La dimension d doit être spécifiée par les parties concernées.

4.1.3.4 Montage C

Le support d'essai C représenté sur la Figure 5 doit être utilisé.

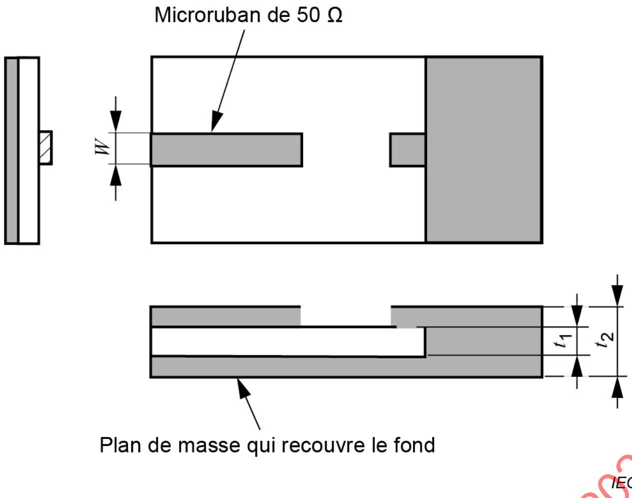


Figure 5 – Montage C

Les électrodes du montage d'essai doivent être mises en contact avec les électrodes de la bobine d'inductance en essai par application d'une force mécanique par une méthode appropriée. Cette force doit être choisie de manière à procurer une stabilité de mesure satisfaisante sans influencer les caractéristiques de la bobine d'inductance. La force mécanique doit être spécifiée. La structure entre le circuit de mesure et le montage d'essai doit maintenir une impédance caractéristique aussi proche que possible de 50 Ω. Les dimensions des impressions du montage et le matériau du montage doivent être spécifiés par les parties concernées.

4.1.4 Méthode de mesure et formule de calcul

L'inductance L_x de la bobine d'inductance L est définie par la somme vectorielle des réactances provoquées par L_s et C_d (voir la Figure 1 ou la Figure 2). La fréquence f du signal de sortie du générateur de signaux doit être réglée sur une fréquence spécifiée séparément. La bobine d'inductance en essai doit être connectée au circuit de mesure en utilisant le montage d'essai décrit dans les 4.1.3.2 à 4.1.3.4. Les tensions vectorielles E_1 et E_2 doivent être mesurées par les voltmètres vectoriels Ev_1 et Ev_2, respectivement. L'inductance L_x doit être calculée à l'aide de la Formule (1) et de la Formule (2) pour la méthode de tension/courant vectoriels, ou à l'aide des Formules (3) à (5) pour la méthode du facteur de réflexion:

$$L_x = \frac{\mathrm{Im}[Z_x]}{\omega} \tag{1}$$

$$Z_x = R\frac{E_1}{E_2} \tag{2}$$

où

L_x est la valeur d'inductance de la bobine d'inductance en essai;

Im est la partie imaginaire de la valeur complexe;

Z_x est la valeur d'impédance de la bobine d'inductance en essai;

R est la valeur de la résistance;

E_1 est la valeur indiquée par le voltmètre vectoriel Ev_1;

E_2 est la valeur indiquée par le voltmètre vectoriel Ev_2;

ω est la pulsation: $2\pi f$.

$$L_x = \frac{\mathrm{Im}[Z_x]}{\omega} \quad (3)$$

$$Z_x = R\frac{E_1}{E_2} \quad (4)$$

$$S_{11} = \frac{E_1}{E_2} \quad (5)$$

où

L_x est la valeur d'inductance de la bobine d'inductance en essai;

Im est la partie imaginaire de la valeur complexe;

Z_x est la valeur d'impédance de la bobine d'inductance en essai;

R est la valeur de la résistance;

S_{11} est le facteur de réflexion de la bobine d'inductance en essai;

Z_0 est l'impédance du réseau du système de mesure (50 Ω);

E_1 est la valeur indiquée par le voltmètre vectoriel Ev_1;

E_2 est la valeur indiquée par le voltmètre vectoriel Ev_2;

ω est la pulsation: $2\pi f$.

4.1.5 Notes sur le mesurage

4.1.5.1 Généralités

La longueur électrique du montage d'essai doit être compensée par une méthode appropriée suivie par une compensation de circuit ouvert/court-circuit. Si une longueur électrique qui n'est pas couramment acceptée est utilisée, celle-ci doit être spécifiée. La compensation de circuit ouvert/court-circuit doit être calculée selon l'Annexe B.

4.1.5.2 Compensation de court-circuit

Pour le montage d'essai A, les dimensions et la forme appropriées du dispositif de court-circuit sont indiquées sur la Figure 6 et dans le Tableau 2. L'inductance appropriée du dispositif de court-circuit doit être choisie dans le Tableau 2 selon les dimensions de la bobine d'inductance en essai. L'inductance du dispositif de court-circuit choisi doit être utilisée comme valeur de compensation.

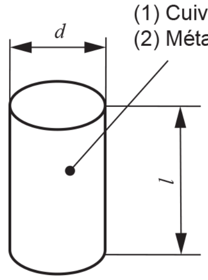


Figure 6 – Forme du dispositif de court-circuit

Tableau 2 – Dimensions et inductances du dispositif de court-circuit

Taille de la bobine d'inductance en essai	l mm	d mm	Valeur d'inductance nH
1608	1,6	0,95	0,43
1005	1,0	0,60	0,27
0603	0,6	0,36	0,16
0402	0,4	0,26	0,11
0201	0,2	0,12	0,05

Si le montage d'essai A n'utilise pas l'une des valeurs d'inductance indiquées dans le Tableau 2 et si le dispositif de court-circuit n'a pas la forme définie sur la Figure 6 (s'il est de forme rectangulaire, par exemple), la valeur choisie doit alors être spécifiée. Pour les montages d'essai B et C, les dimensions, la forme et les valeurs d'inductance du dispositif de court-circuit doivent être spécifiées.

4.1.5.3 Compensation de circuit ouvert

La compensation de circuit ouvert pour le montage d'essai A doit être réalisée en plaçant les électrodes du montage d'essai à équidistance de la bobine d'inductance en essai placée dans le montage. L'admittance Y_{os} est définie comme 0 S (zéro siemens), sauf spécification contraire.

La compensation de circuit ouvert pour le montage d'essai B et C doit être réalisée sans mettre en place la bobine d'inductance. L'admittance Y_{os} est définie comme 0 S (zéro siemens), sauf spécification contraire.

4.2 Facteur de qualité

4.2.1 Méthode de mesure

Le facteur Q de la bobine d'inductance doit être mesuré par la méthode de tension/courant vectoriels ou la méthode du facteur de réflexion.

4.2.2 Circuit de mesure

Le circuit de mesure est représenté sur la Figure 1 et sur la Figure 2. Le matériel de mesure doit être correctement étalonné.

4.2.3 Montage de la bobine d'inductance pour l'essai

Le montage de la bobine d'inductance est décrit en 4.1.3.

4.2.4 Méthode de mesure et formule de calcul

La fréquence du signal de sortie du générateur de signaux (Figure 1 ou Figure 2) doit être réglée sur une fréquence spécifiée séparément. La bobine d'inductance doit être connectée au circuit de mesure en utilisant les montages d'essai décrits dans les 4.1.3.2 à 4.1.3.4. Les tensions vectorielles E_1 et E_2 doivent être mesurées par les voltmètres vectoriels Ev_1 et Ev_2, respectivement. La valeur du facteur Q doit être calculée à l'aide de la formule suivante:

$$Q = \frac{\mathrm{Im}[Z_\mathrm{x}]}{\mathrm{Re}[Z_\mathrm{x}]} \qquad (6)$$

où

Q est le facteur Q de la bobine d'inductance en essai;

Re est la partie réelle de la valeur complexe;

Im est la partie imaginaire de la valeur complexe;

Z_x est la valeur d'impédance de la bobine d'inductance en essai, calculée à l'aide de la Formule (2) ou la Formule (4).

4.2.5 Notes sur le mesurage

Voir le 4.1.5.

4.3 Impédance

4.3.1 Méthode de mesure

L'impédance d'une bobine d'inductance doit être mesurée par la méthode de tension/courant vectoriels ou la méthode du facteur de réflexion. Ces méthodes sont décrites dans les 4.3.2 à 4.3.5.

4.3.2 Circuit de mesure

Les circuits de mesure sont représentés sur la Figure 1 et sur la Figure 2. Le matériel de mesure doit être correctement étalonné.

4.3.3 Montage de la bobine d'inductance pour l'essai

Le montage de la bobine d'inductance est décrit en 4.1.3.

4.3.4 Méthode de mesure et calcul

La fréquence du signal de sortie du générateur de signaux (Figure 1 ou Figure 2) doit être réglée sur une fréquence f spécifiée séparément. La bobine d'inductance doit être connectée au circuit de mesure en utilisant le montage d'essai décrit dans les 4.1.3.2 à 4.1.3.4. Les tensions vectorielles E_1 et E_2 doivent être mesurées par les voltmètres vectoriels Ev_1 et Ev_2, respectivement.

L'impédance doit être calculée à l'aide de la Formule (2) ou la Formule (4) conformément à la méthode utilisée.

4.3.5 Notes sur le mesurage

Voir le 4.1.5.