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

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HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 1: Nanohenry range chip inductor

FOREWORD

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

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

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

a) addition of voltage-drop method of DC resistance measuring;
b) unification of technical terms.

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

CDV	Report on voting
51/1187/CDV	51/1202/RVC

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

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

A list of all parts of 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

HIGH FREQUENCY INDUCTIVE COMPONENTS – ELECTRICAL CHARACTERISTICS AND MEASURING METHODS –

Part 1: Nanohenry range chip inductor

1 Scope

This part of IEC 62024 specifies electrical characteristics and measuring methods for the nanohenry range chip inductor that is normally used in 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 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 terminological databases for use in standardization at the following addresses:

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

4 Inductance, Q-factor and impedance

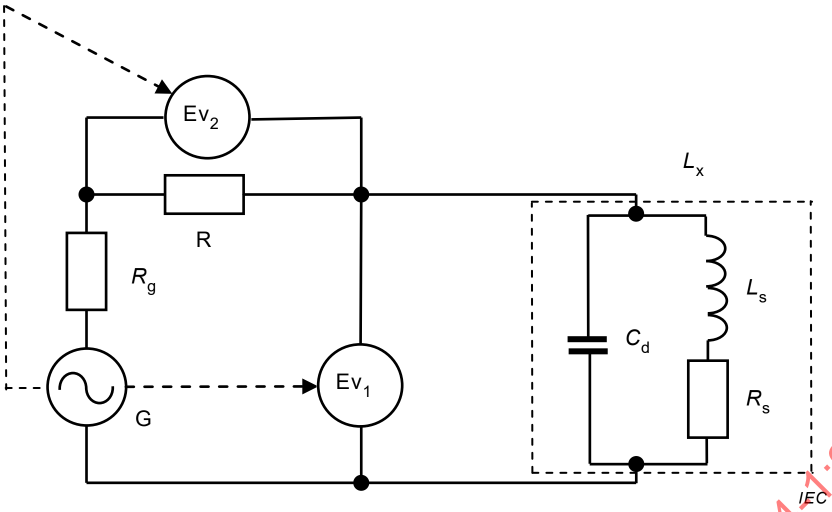
4.1 Inductance

4.1.1 Measuring method

The inductance of an inductor is measured by the vector voltage/current method.

4.1.2 Measuring circuit

An example of the circuit for the vector voltage/current method is shown in Figure 1.



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

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

4.1.3 Mounting the inductor for the test

4.1.3.1 General

The inductor shall be measured in a test fixture as specified in the relevant standard. If no fixture is specified, one of the following test fixtures A or B 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 2 and Table 1.

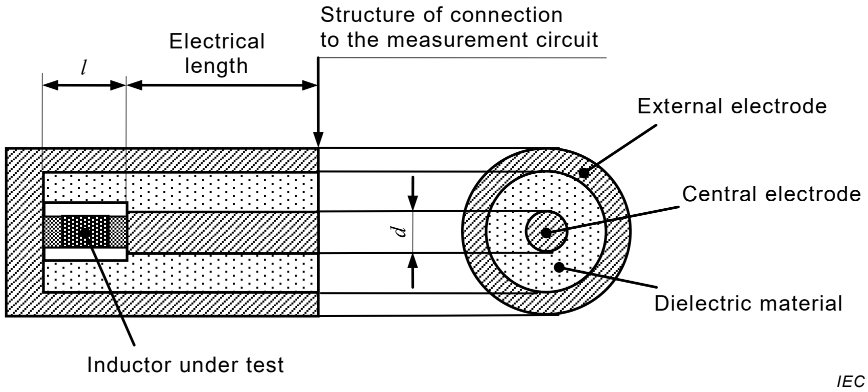


Figure 2 – Fixture A

Table 1 – Dimensions of l and d

Size of inductor under test[a]	l mm	d mm
1 608	1,6	0,95
1 005	1,0	0,60
0 603	0,6	0,36
0 402	0,4	0,26

[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 force shall be specified. The structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as near as possible to 50 Ω.

4.1.3.3 Fixture B

The test fixture B as shown in Figure 3 shall be used.

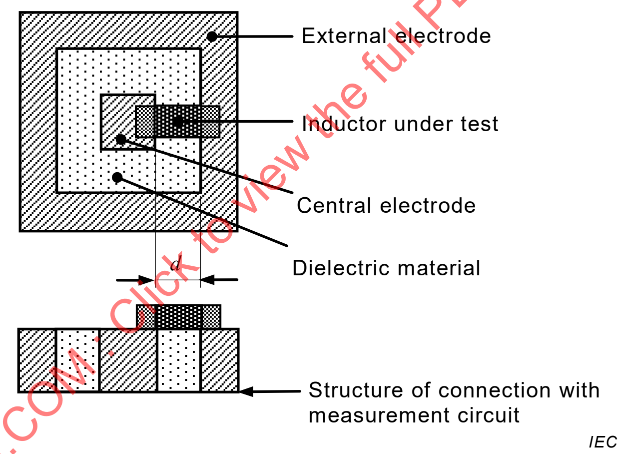


Figure 3 – Fixture B

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 force shall be specified.

The structure between the measurement circuit and the test fixture shall maintain a characteristic impedance as near as possible to 50 Ω.

Dimension d shall be specified between parties concerned.

4.1.4 Measuring method and calculation formula

Inductance L_x of the inductor L_x is defined by the vector sum of reactance caused by L_s and C_d (see Figure 1). 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 above. Vector voltage 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 the following formula:

$$L_x = \frac{\mathrm{Im}\left[R\frac{E_1}{E_2}\right]}{\omega} \tag{1}$$

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: $2\pi f$.

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:

$$Z_x = A_c \frac{Z_m - B_c}{1 - Z_m C_c} \tag{2}$$

$$A_c = 1 + j0 \tag{3}$$

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

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

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 4 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.

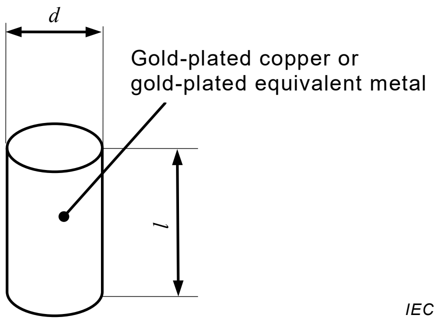


Figure 4 – Short device shape

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

If an inductance value other than defined in Table 2 is used for test fixture A, the employed value shall be specified. For test fixture B, 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 apart 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 fixture B 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 the vector voltage/current method.

4.2.2 Measuring circuit

The measurement circuit is as shown in Figure 1.

4.2.3 Mounting the inductor for test

Mounting of the inductor is described in 4.1.3.

4.2.4 Measuring methods and calculation formula

The frequency of the signal generator (Figure 1) output signal shall be set to a frequency as separately specified. The inductor shall be connected to the measurement circuit by using the test fixture as described above. Vector voltage 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:

$$Q = \frac{\text{Im}[E_1 / E_2]}{\text{Re}[E_1 / E_2]} \tag{6}$$

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;

E_1 is the value indicated on vector voltmeter Ev_1;

E_2 is the value indicated on vector voltmeter Ev_2.

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 by the vector voltage/current method. The vector voltage/current method is as described in 4.3.2 to 4.3.5.

4.3.2 Measuring circuit

The measurement circuit is as shown in Figure 1.

4.3.3 Mounting the inductor for test

Mounting of the inductor is described in 4.1.3.

4.3.4 Measuring method and calculation

The frequency of the signal generator (Figure 1) output signal 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 above. Vector voltage 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:

$$|Z| = R\frac{|E_1|}{|E_2|} \tag{7}$$

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.

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.

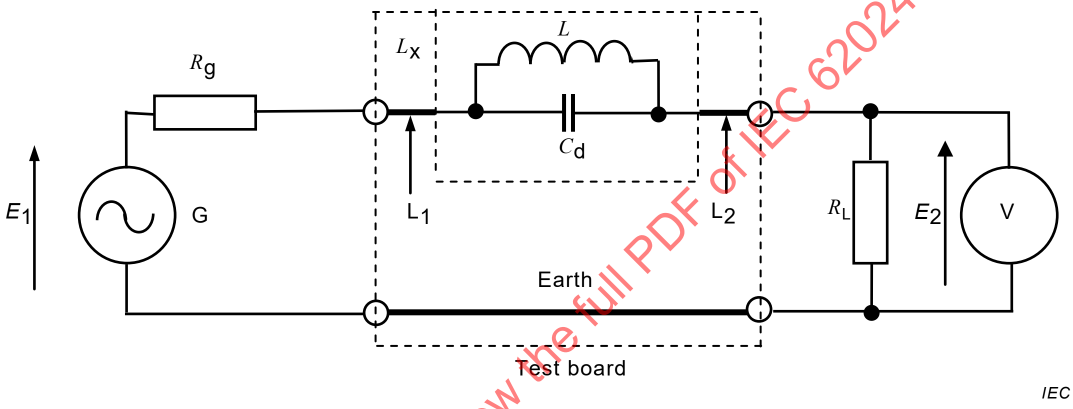
5.2 Minimum output method

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 5.



Key

G	signal generator
R_g	source resistance of signal generator (50 Ω)
L_x	inductance of inductor under test
C_d	distributed capacitance of inductor under test
L	inductance of inductor under test
L_1, L_2	50 Ω micro-strip line
V	RF voltmeter
R_L	input resistance of RF voltmeter (50 Ω)

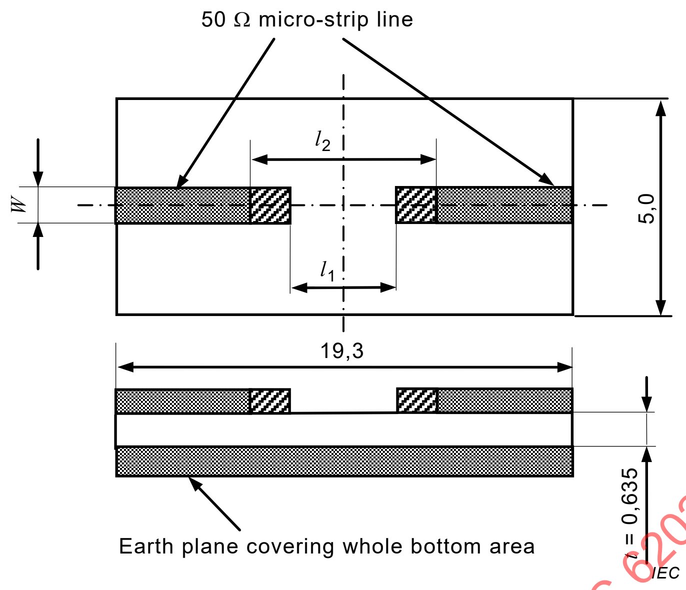
A suitably calibrated network analyser may be used for the minimum output method in place of the signal generator and RF voltmeter.

Figure 5 – 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 6.

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 6 – 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 5, 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:

$$\text{Self-resonance frequency} = \frac{f_1 + f_2}{2} \qquad (8)$$

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.

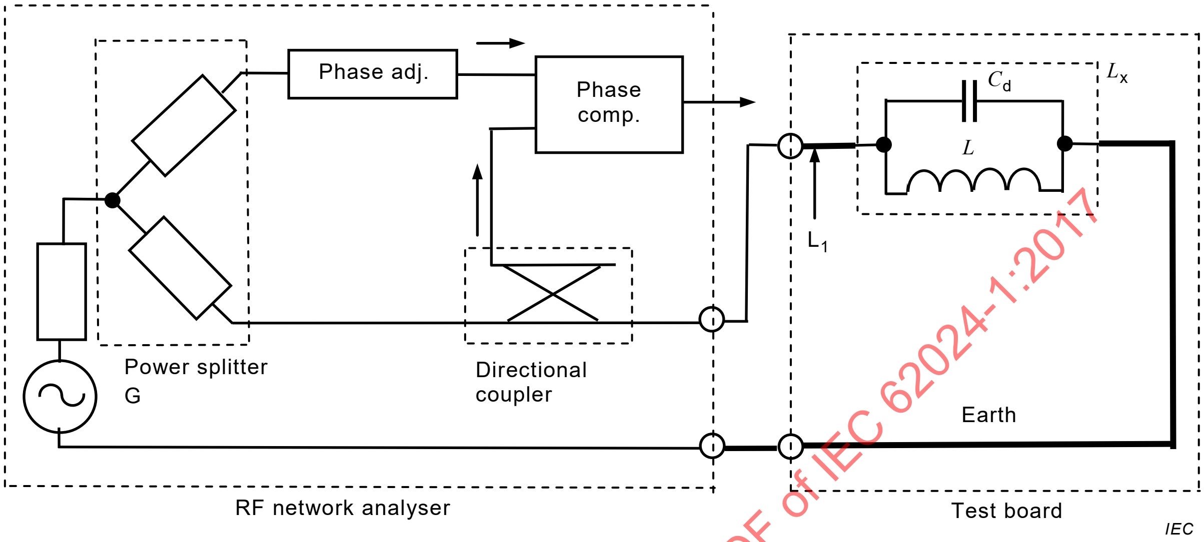
5.3 Reflection method

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

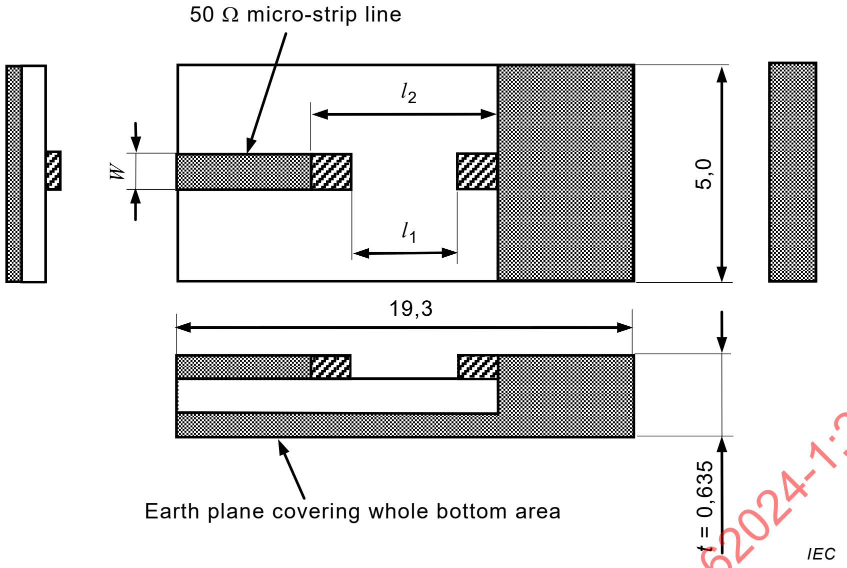
L_1 50 Ω micro-strip line

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.

5.4 Measurement by analyser

5.4.1 Measurement by impedance analyser

Self-resonance frequency can be measured by measuring the impedance of the inductor using the impedance analyser. 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 analyser 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.

5.4.2 Measurement by network analyser

The self-resonance frequency of the inductor can be measured by the power attenuation method using the network analyser. During the measurement of the self-resonance frequency, care shall be taken to avoid the influence of electromagnetic interference from other electronic equipment. The sweeping frequency range of the network analyser 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 shown in Figure 9.

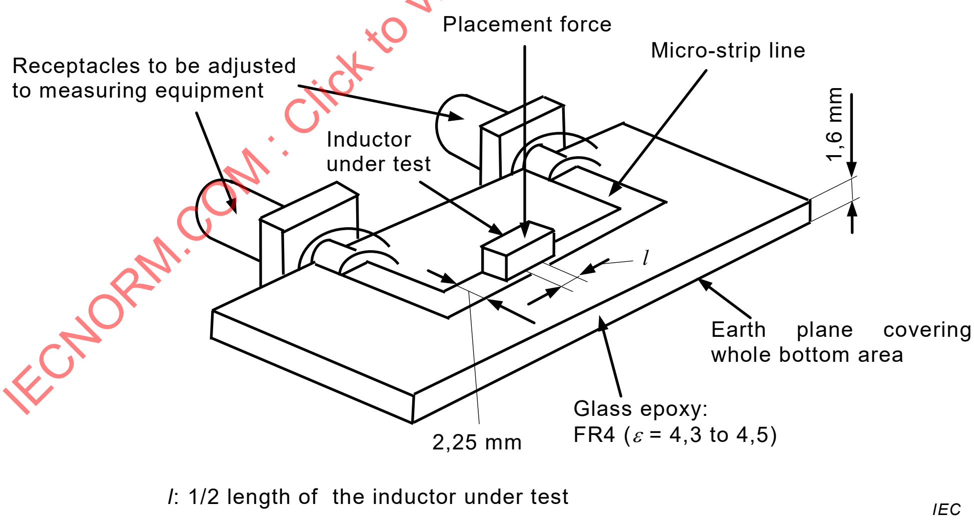


Figure 9 – Suitable test fixture for measuring self-resonance frequency

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 10.

6.1.2 Measuring method and calculation formula

Use the circuit as shown in Figure 10.

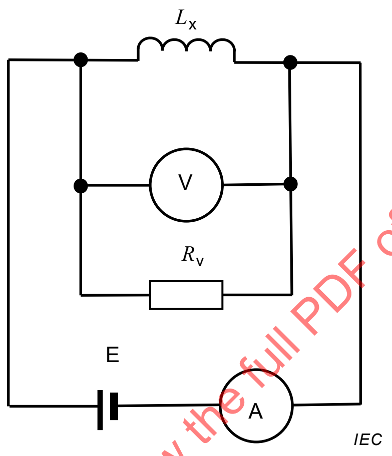
Calculate DC resistance R_x of the coil from the following formula:

$$R_x = \frac{V}{I} \quad (9)$$

where

V is the value indicated on (V)

I is the value indicated on (A)



Key

L_x inductance of inductor under test

E DC power supply

V DC voltmeter

A DC ammeter

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

Figure 10 – 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 11.

6.2.2 Measuring method and calculation formula

Use the circuit as shown in Figure 11, balance the bridge by adjusting the proportional arm resistors R_1 and R_2 and standard variable resister R_3, and calculate DC resistance R_x of the coil from the following formula:

$$R_x = \frac{R_2}{R_1} \times R_3 \quad (10)$$