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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 and ferrite materials.

This second edition cancels and replaces the first edition published in 2002. This edition constitutes a technical revision.

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

a) sizes 0402 added in Table 1 and Table 2;
b) contents of 4.4 reviewed for easier understanding;
c) correct errors in 3.1.4.2.

The text of this standard is based on the following documents:

FDIS	Report on voting
51/908/FDIS	51/915/RVD

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

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

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication 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- withdrawn,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 referenced documents are indispensable for the application 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*

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

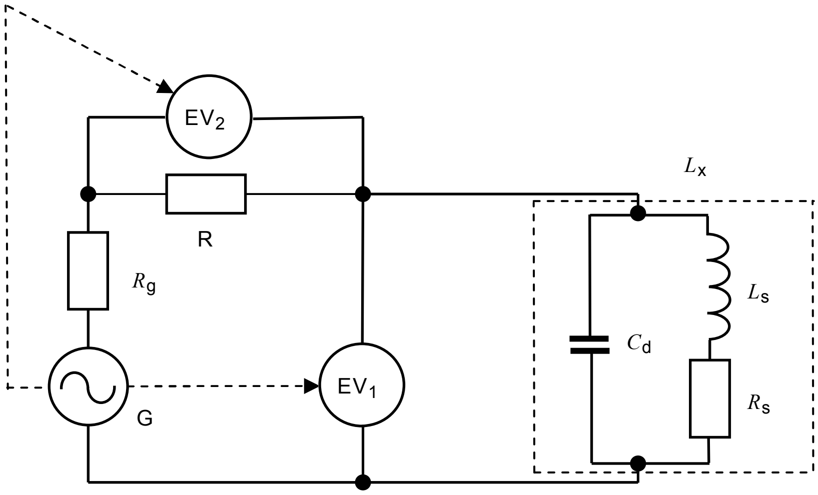
ISO 9453, *Soft solder alloys – Chemical compositions and forms*

3 Inductance, Q-factor and impedance

3.1 Inductance

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

3.1.1 Measuring circuit



Components

R_g	source resistance (50 Ω)
R	resistor
L_x	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

3.1.2 Mounting of the inductor to the test fixture

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.

3.1.2.1 Fixture A

The shape and dimensions of fixture A shall be as shown in Figure 2.

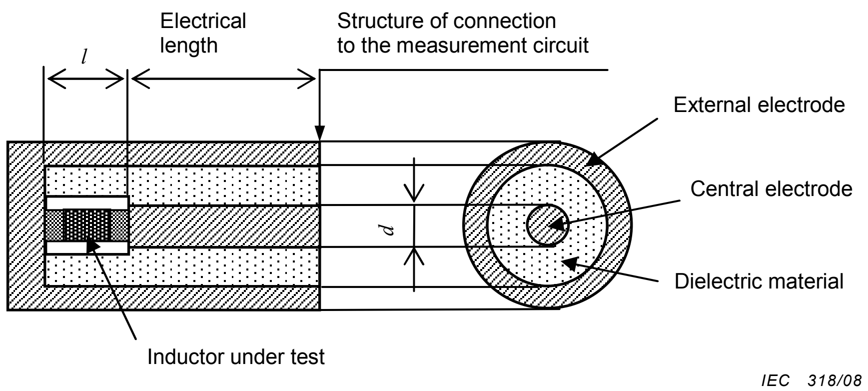


Figure 2 – Fixture A

Table 1 – Dimensions of *l* and *d*

Size of inductor under test	*l* mm	*d* mm
1608	1,6	0,95
1005	1,0	0,60
0603	0,6	0,36
0402	0,4	0,26

The electrodes of test fixture shall contact the electrodes of 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 test fixture shall maintain a characteristic impedance as near as possible to 50 Ω.

3.1.2.2 Fixture B

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

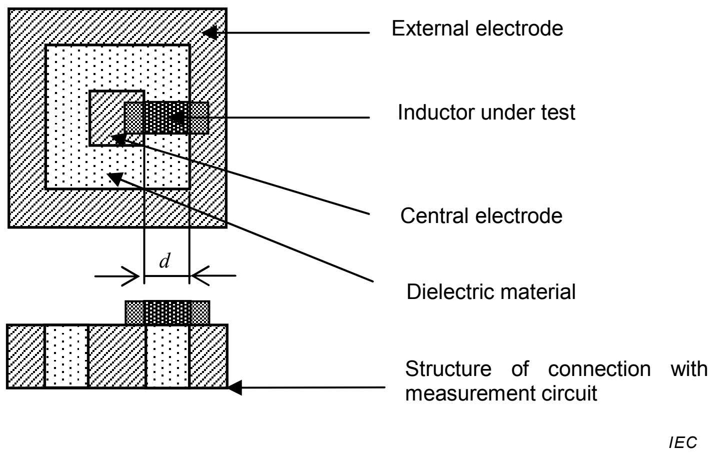


Figure 3 – Fixture B

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 test fixture shall maintain a characteristic impedance as near as possible to 50 Ω.

Dimension d shall be specified between parties concerned.

3.1.3 Measurement method and calculation

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:

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

where

L_x is the inductance of inductor under test;

Im is the imaginary part of the complex value;

R is the resistance of 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: $2\pi f$.

3.1.4 Notes on measurement

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 impedance measurement value after compensation;

Z_m is impedance measurement value before compensation;

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

Z_{ss} is the short device inductance as defined in 3.1.4.1;

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 3.1.4.2.

3.1.4.1 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.

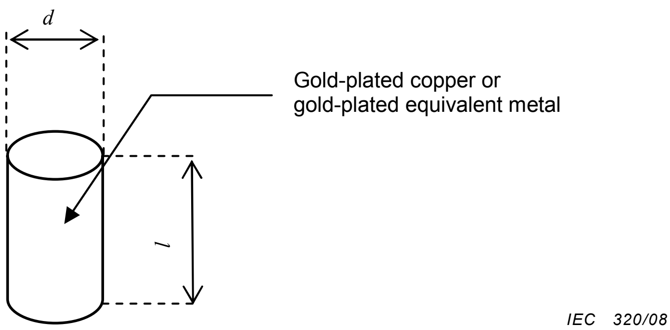


Figure 4 – Short device shape

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.

3.1.4.2 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 0S (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 0S (zero Siemens) unless otherwise specified.

3.2 Quality factor

3.2.1 Measurement method

The Q of the inductor shall be measured by the vector voltage/current method.

3.2.2 Measurement circuit

The measurement circuit is as shown in Figure 1.

3.2.3 Mounting of the inductor

Mounting of the inductor is described in 3.1.2.

3.2.4 Methods of measurement and calculation

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:

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

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.

3.2.5 Notes on measurement

Refer to 3.1.4 in the inductance measurement part.

3.3 Impedance

3.3.1 Measurement method

The impedance of an inductor shall be measured by the vector voltage/current method. The vector voltage/current method is as follows:

3.3.2 Measurement circuit

The measurement circuit is as shown in Figure 1. Mounting of the inductor to the test fixture as described in 3.1.2.

3.3.3 Measurement 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.

3.3.4 Notes on measurement

Refer to 3.1.4 in the inductance measurement part.

4 Resonance frequency

4.1 Self-resonance frequency

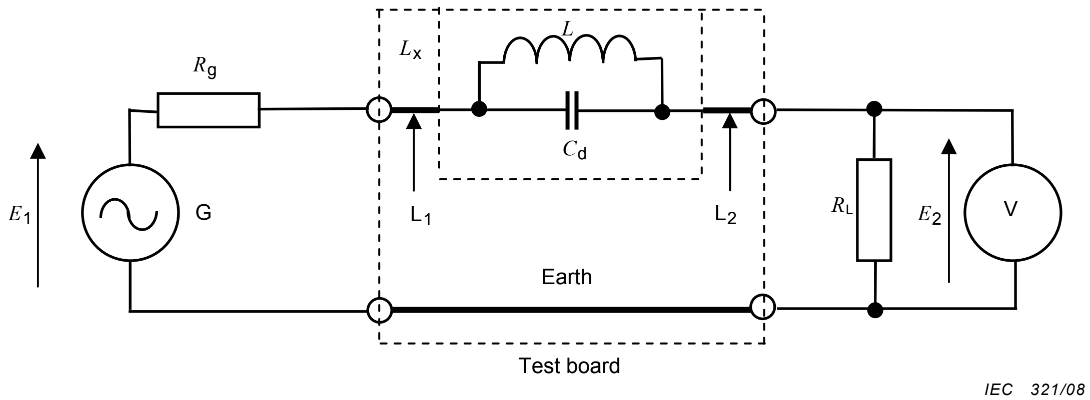
The self-resonance frequency of the inductor shall be measured by the minimum output method 4.2 or by the reflection method 4.3 or by the impedance analyser 4.4.

4.2 Minimum output method

The minimum output method is as follows:

4.2.1 Measurement circuit

The measurement circuit is as shown in Figure 5 below.



Components

G signal generator

R_g source resistance of signal generator (50 Ω)

L_x inductance 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)

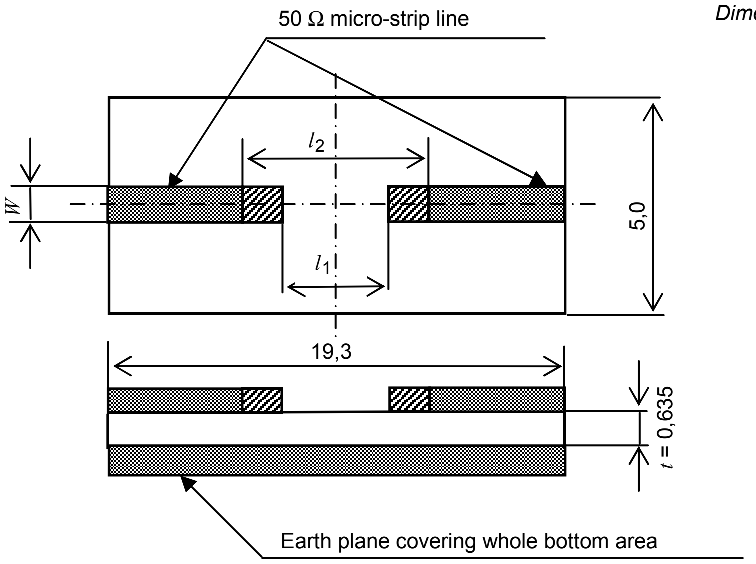
NOTE A suitably calibrated network analyser may be used for the minimum output method in place of the signal generator and RF voltmeter.

Figure 5 – Example of test circuit for the minimum output method

4.2.2 Mounting the inductor for test

The inductor shall be mounted on the self-resonance frequency test board prescribed in the individual standard for the particular inductor by the method prescribed 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)

4.2.3 Measuring method

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 ≤ 3) shall be measured, and the self-resonance frequency shall be obtained using the following formula:

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

4.2.4 Note on measurement

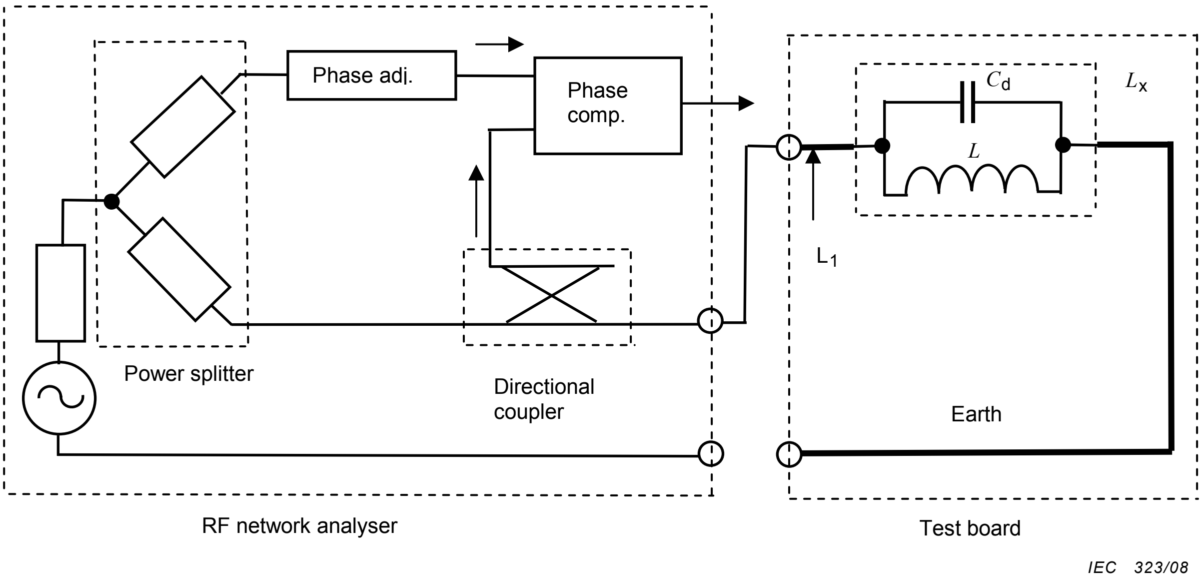
The width W of the micro-strip line shall be such that the characteristic impedance is as close as possible to 50 Ω. The E_1 value of the micro-strip line selected shall also allow easy identification of the minimum value of E_2.

4.3 Reflection method

The reflection method is as follows:

4.3.1 Measurement 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 have equivalent circuit functions. In single port (S_{11}) reflection measurement mode, phase measurement shall be possible and the analyser shall be suitably calibrated.



Components

G signal generator

L_x inductor under test

C_d distributed capacitance of inductor under test

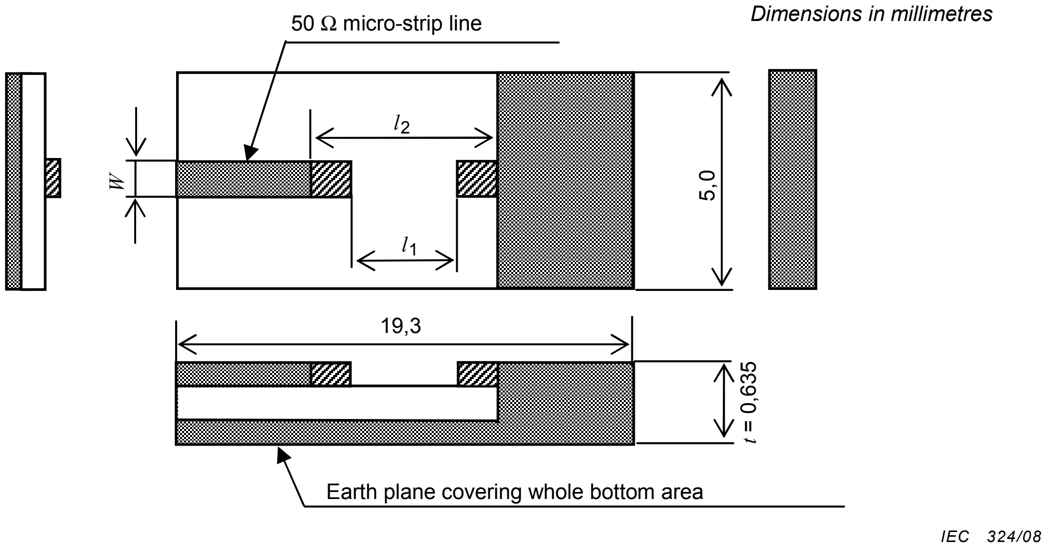
L inductance of inductor under test

L_1 50 Ω micro-strip line

Figure 7 – Example of test circuit for the reflection method

4.3.2 Mounting the inductor for test

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



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)

4.3.3 Measurement 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.

4.3.4 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.

4.4 Measurement by analyser

4.4.1 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 3.1.4.2), 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 0, 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.

4.4.2 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 equipments. 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.

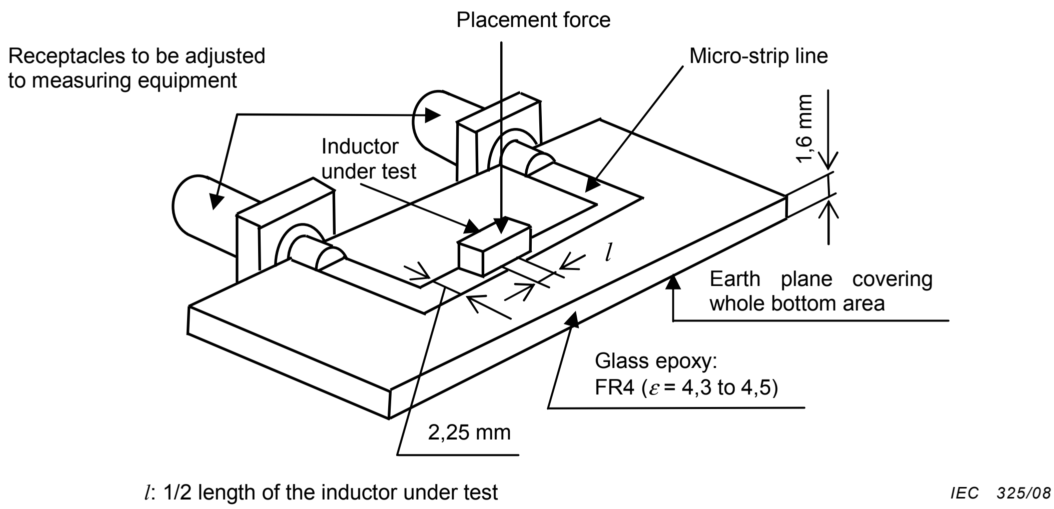


Figure 9 – Suitable test fixture for measuring self-resonance frequency

5 DC resistance

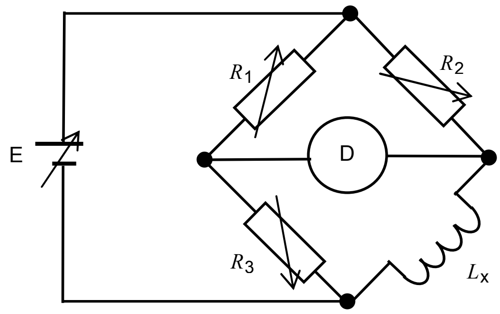
5.1 Measuring circuit (Bridge method)

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

5.2 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 resister R_3 and calculate DC resistance R_x of the coil from the following formula:

$$R_x = \frac{R_2}{R_1} \times R_3 \quad (9)$$



Components

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

Figure 10 – Example of measuring circuit of d.c. resistance

5.3 Precaution for 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 will 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 with the ambient temperature;
- keep the current passed through the specimen within a range so that the resistance of coil will not change so much;
- use of double bridge is desirable for measuring especially low resistance.

5.4 Measuring temperature

The d.c. 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 the formula:

$$R_{20} = \frac{R_{Te}}{0{,}92 + 0{,}04T_e}; \ T_e \text{ in } °C \quad (10)$$

Annex A
(normative)

Mounting method for a surface mounting coil

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

A.1 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.2 Solder

The solder shall be a solder paste prepared in such a way that a weakly active flux of colophonium system is added to the solder of composition H60A or H63A specified in ISO 9453 having a grain size 200 mesh or more to form a creamy paste. The viscosity is subjected to agreement between the parties concerned with acceptance.

A.3 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.4 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.5 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.6 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.

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