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Methods of test for high frequency
inductors and intermediate frequency
transformers for electronic equipment

ICS 29.180

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently, JIS C 5321 : 1990 has been revised and replaced with this Standard.

In this revision, addition and modification of provisions are carried out for the purpose of enlarging the application of this Standard to chips inductors, choke coils, etc.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right (including the application for registration of utility model after opening to the public applied before December 31, 1993) or application for registration of utility model after opening to the public which have the said technical properties.

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Methods of test for high frequency inductors and intermediate frequency transformers for electronic equipment

Introduction This is the Japanese Industrial Standard prepared by adding the provisions to **JIS C 5321** published in 1990 because its test methods become insufficient for present situation and by reviewing the previous provisions.

1 Scope This Japanese Industrial Standard specifies methods of test for high frequency coils and intermediate frequency transformers (hereafter referred to as "coils" in this Standard generically) which are mainly used in electronic equipment. If there is any discrepancy between this Standard and the detail specifications, the provision of the detail specifications shall take precedence.

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. In the normative references the standard appended with the year of issue means such that the edition of the stated year only constitutes provisions of this Standard, and the revised edition and amendment thereafter are out of such constitution. For the normative references not appended with the year of issue, the most recent editions of the standards shall be applied (including the amendments).

JIS B 7502-1994 *Micrometer callipers*

JIS B 7507-1993 *Vernier, dial and digital callipers*

JIS C 0010-1993 *Environmental testing. Part 1: General and guidance*

JIS C 0020-1995 *Environmental testing procedures Part 2: Tests, Tests A: Cold*

JIS C 0021-1995 *Basic environmental testing procedures Part 2: Tests, Test B: Dry heat*

JIS C 0022-1987 *Basic environmental testing procedures Part 2: Tests, Test Ca: Damp heat, steady state*

JIS C 0025-1988 *Basic environmental testing procedures Part 2: Tests, Test N: Change of temperature*

JIS C 0040-1995 *Basic environmental testing procedures Part 2: Tests Test Fc and guidance: Vibration (sinusoidal)*

JIS C 0041-1995 *Basic environmental testing procedures Part 2: Tests Test Ea and guidance: Shock*

JIS C 0050-1985 *Basic environmental testing procedures Part 2: Tests, Test T: Soldering*

JIS C 0051-1994 *Basic environmental testing procedures Part 2: Tests Test U: Robustness of terminations and integral mounting devices*

JIS C 1303-1972 *High insulation resistance meters*

- JIS C 5320-1994 *General rules of high frequency coils and intermediate frequency transformers for electronic equipment*
- JIS C 5602-1986 *Glossary of passive components for electronic equipment*
- JIS C 6484-1991 *Copper-clad laminates for printed wiring boards – Glass fabric base, epoxy resin*
- JIS K 5902-1969 *Colophonium*
- JIS K 8101-1994 *Ethanol (99.5)*
- JIS K 8839-1995 *2-Propanol*
- JIS Z 3282-1986 *Soft solder*

3 Definitions For the purpose of this Standard, in addition to the definitions specified in **JIS C 0010**, **JIS C 5320** and **JIS C 5602**, the following principal definitions apply.

- a) **rotating torque** The torque necessary to rotate the core when a variable coil is adjusted.
The torque at the start of rotation of the core is called “starting torque” and the torque in rotation of the core is called “steady torque”.
- b) **no-load Q (Q_U)** The Q of the tuning circuit when the load is not connected to the coil.
- c) **on-load Q (Q_L)** The Q of the tuning circuit when the specified load is connected to the coil.
- d) **primary impedance** The impedance at the input side of a coil.
- e) **secondary impedance** The impedance at the output side of a coil.
- f) **magnetic field characteristic** The change of inductance or resonance frequency when the specified magnetic field is externally applied to the coil.
- g) **d.c. superposition characteristics** The change of inductance or resonance frequency when the specified d.c. current is passed through the coil.
- h) **surface mounting coil** The coil equipped with terminals or electrodes suitable for surface mounting.

4 Test conditions

4.1 Standard conditions Unless otherwise specified, the tests and measurements shall be carried out to the extent of standard conditions specified in **5.3.1** of **JIS C 0010** (temperature of 15 °C to 35 °C, relative humidity of 25 % to 75 % and air pressure of 86 kPa to 106 kPa). However, if there is a dispute on the decision based on the measured values under standard conditions, or if required, the conditions of **4.3** shall be employed. If conversion is necessary the conditions of **4.2** shall be employed.

If it is difficult to carry out the measurement under the standard conditions, the tests and measurements may be carried out under conditions other than the standard ones if there is no dispute on the decision.

4.2 Reference conditions The reference conditions shall be the reference conditions specified in 5.1 of **JIS C 0010** (temperature of 20 °C and air pressure of 101.3 kPa). However, only the temperature may be employed as the reference condition.

4.3 Referee conditions The referee conditions shall be a temperature of (20 ± 2) °C, relative humidity of 60 % to 70 % and air pressure of 86 kPa to 106 kPa, as selected from the table of atmospheric conditions specified in 5.2 of **JIS C 0010**.

5 Tests for appearance, marking and dimensions

5.1 Appearance The test for appearance shall be carried out visually.

5.2 Marking The test for marking shall be carried out visually.

5.3 Dimensions The test for dimensions shall be carried out using the vernier calliper of class 2 or better specified in **JIS B 7507** or micrometer callipers for external measurement specified in **JIS B 7502**. However, other measuring instruments may be used, unless doubt arises on the decision.

6 Electrical performance test

6.1 Common precautions for carrying out tests The common precautions for carrying out tests are as follows:

- a) The coil under test shall be so arranged that it will not be influenced by the approach of other metal parts.
- b) The error in measurement caused by the wiring connecting the measuring instrument and the coil under test shall be minimized.
- c) The measurement of variable coil under test shall be made at such a position of the adjusting core that the coil is tuned with the frequency specified in the relevant detail specification.
- d) If there is a shielding case on the coil under test, the case shall be grounded. If there are terminals having nothing to do with the measurement, they shall not be connected.
- e) The connecting jig used at the time of measurement shall be such that the stray capacitance between terminals will not vary at each measurement as much as possible and that the value is small.
- f) If required, a coil accommodating a capacitor shall be tested with the tuning capacitor removed.
- g) The units of parameters used for calculation shall be inductance (H), capacitance (F), frequency (Hz), resistance (Ω), current (A) and voltage (V).

Test items and measuring methods (informative)

Measuring method	Test item																
	6.2 Inductance	6.3 Q	6.4 Resonance frequency	6.5 Distributed capacitance	6.6 Coupling coefficient	6.7 Voltage ratio	6.8 Voltage proof	6.9 Insulation resistance	6.10 Bandwidth	6.11 Insertion loss	6.12 Spurious characteristic	6.13 Large-input characteristic	6.14 Characteristic test of coil for FM detection	6.15 Magnetic-field characteristic	6.16 D.C. resistance	6.17 D.C. superposition characteristics	
Series resonance method	○	○															
Bridge method	○																
Voltmeter and ammeter method	○																
Parallel resonance method		○															
Minimum output method			○														
Two-frequency method			○	○													
One-frequency method				○													
Open- and short-circuit method					○												
Double tuning method					○												
Voltage proof test method							○										
Insulation test method								○									
Operating characteristic method		○	○			○			○	○	○	○	○	○			
D.C. resistance test method															○		
D.C. superposition method																○	

Remarks : The mark ○ in this table shows applicable test method.

6.2 Inductance

6.2.1 Measuring methods The inductance of the coil shall be measured by one of series resonance method [6.2.1 a)], bridge method [6.2.1 b)] or voltmeter and ammeter method [6.2.1 c)].

a) **Series resonance method** The series resonance method shall be as follows:

1) **Measuring circuit** Use the circuit as shown in Fig. 1.

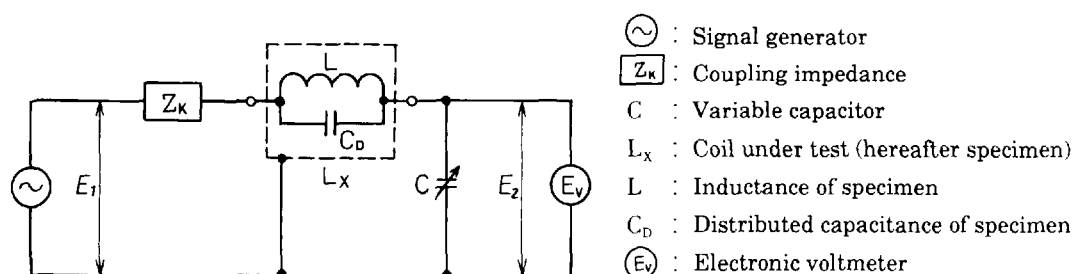


Fig. 1 Example of circuit for measurement by series resonance method

- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 1, and adjust the frequency of the signal generator to the value specified in the detail specification. Connect the specimen, adjust the variable capacitor so that E_2 becomes the maximum, measure the capacitance of the variable capacitor at that time and then calculate inductance L from one of the following formulas:

$$2.1) \quad L = \frac{1}{\omega^2 \left(1 + \frac{C_D}{C}\right) C} - L_K$$

$$2.2) \quad L = \frac{1}{\omega^2 \left(1 + \frac{C_D}{C}\right) C} \quad \text{..... to be used when there is no doubt even if } L_K \text{ is ignored.}$$

$$2.3) \quad L = \frac{1}{\omega^2 C} \quad \text{..... to be used when there is no doubt even if } L_K \text{ and } C_D \text{ are ignored.}$$

where, L_K : inductive component of coupling impedance

ω : angular frequency ($2\pi f$)

C : capacitance of variable capacitor

C_D : distributed capacitance of specimen

- b) **Bridge method** The bridge method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 2.

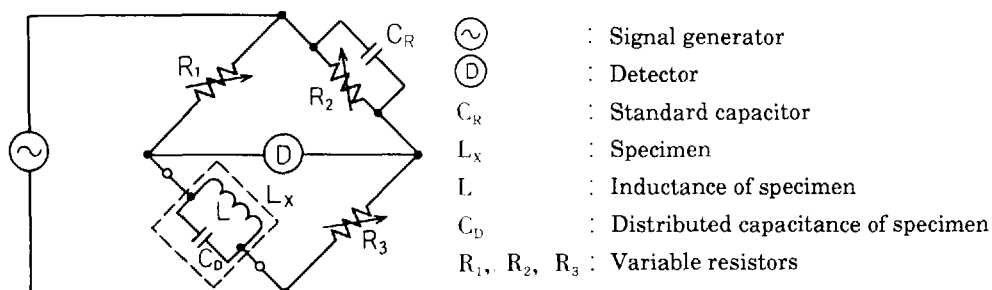


Fig. 2 Example of circuit for measurement by bridge method

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- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 2, and adjust the frequency and output of the signal generator to the respective values specified in the detail specification. Connect the specimen, adjust R_1 , R_2 and R_3 so that the indication of the detector becomes the minimum, read the resistances of R_1 and R_3 and the calculate inductance L from the following formula:

$$L = C_R \times R_1 \times R_3$$

where, L : inductance of specimen

C_R : capacitance of standard capacitor

R_1, R_3 : resistances of variable resistors

- 3) **Precaution for measurement** For specifying the measuring frequency, select the value in such a way, to minimize errors in the measurement, that the reactance in the distributed capacitance of the specimen becomes large enough as compared with the reactance in the inductance of the specimen.

- c) **Voltmeter and ammeter method** The voltmeter and ammeter method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 3.

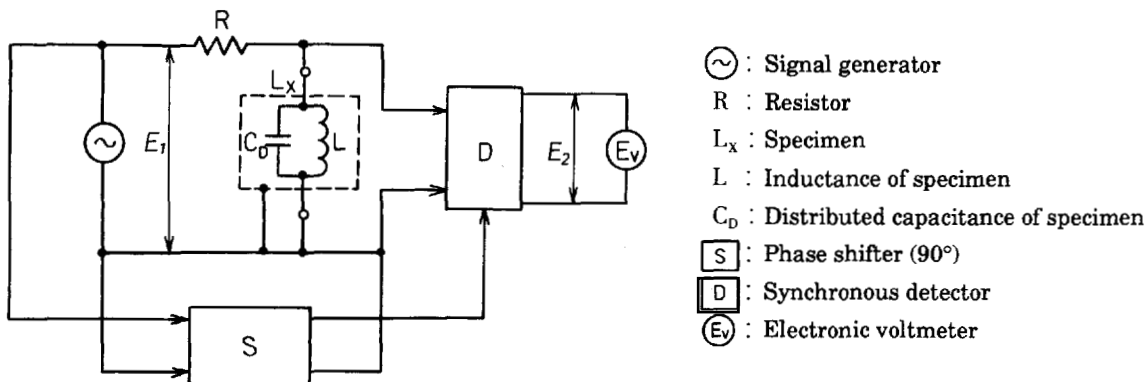


Fig. 3 Example of circuit for measurement by voltmeter and ammeter method

- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 3, adjust the frequency of the signal generator to the specified value. Connect the specimen, measure voltage E_2 by the electronic voltmeter and then calculate inductance L from the following formula:

$$L = \frac{R}{K\omega} \times \frac{E_2}{E_1}$$

where, L : inductance of specimen

R : resistance of resistor

K : conversion efficiency of synchronous detector

ω : angular frequency ($2\pi f$)

E_2 : indicated value of electronic voltmeter EV

E_1 : output voltage of signal generator

- 3) **Precaution for measurement** For specifying the measuring frequency, select the value in such a way, to minimize errors in the measurement, that the reactance in the distributed capacitance of the specimen becomes large enough as compared with the reactance in the inductance of the specimen.

6.2.2 Items to be specified in detail specification The following items shall be specified in detail specifications.

- a) Measuring circuit and constants [see 6.2.1 a) 1), 6.2.1 b) 1) and 6.2.1 c) 1)]
- b) Measuring frequency [see 6.2.1 a) 2), 6.2.1 b) 2) and 6.2.1 c) 2)]
- c) Output voltage of signal generator (if necessary)

6.3 Q

6.3.1 Measuring methods The Q of the coil shall be measured by one of series resonance method [6.3.1 a)], parallel resonance method [6.3.1 b)] or operating characteristic method [6.3.1 c)]. However, [6.3.1 c)] is applicable for tuning type coil only.

a) Series resonance method

- 1) **Measuring circuit** Use the circuit as shown in Fig. 1.
- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 1, and adjust the frequency of the signal generator to the value specified in the detail specification. Connect the specimen, adjust the variable capacitor so that E_2 becomes the maximum, measure E_2 at that time and then calculate Q from either of the following formulas:

$$2.1) \quad Q = \frac{E_2}{E_1} \left(1 + \frac{C_D}{C} \right)$$

$$2.2) \quad Q = \frac{E_2}{E_1} \quad \text{to be used when there is no doubt even if } C_D \text{ is ignored.}$$

where, E_1 : output voltage of signal generator

E_2 : indication of electronic voltmeter (voltage across both ends of C)

C : capacitance of variable capacitor

C_D : distributed capacitance of specimen

b) Parallel resonance method

- 1) **Measuring circuit** Use the circuit as shown in Fig. 4.

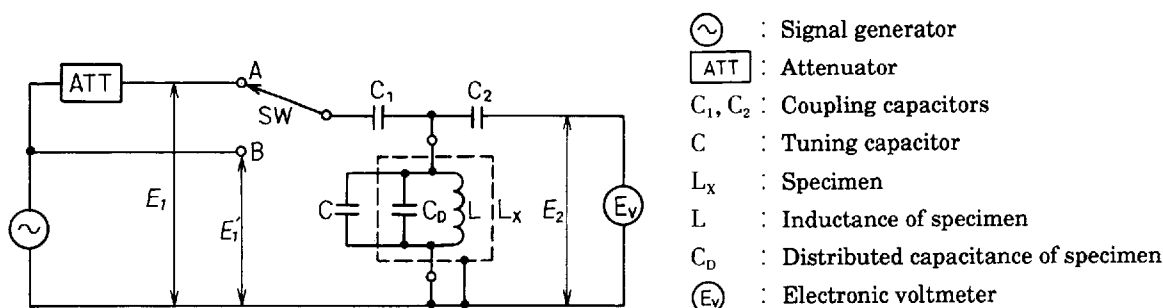


Fig. 4 Example of circuit for measurement by parallel resonance method

- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 4, place the change-over switch at A and adjust the frequency and output voltage of the signal generator to the respective specified values. Set the tuning capacitor to the specified value, and adjust the inductance of the specimen so that E_2 becomes the maximum. If the specimen is not equipped with a variable inductance mechanism, adjust the tuning capacitor. Place the change-over switch at B, measure two frequencies f_1, f_2 at which E_2 becomes equal to the value in the above procedure, and then calculate Q from the following formula:

$$Q = \frac{f_1 + f_2}{2|f_1 - f_2|}$$

- 3) **Precaution for measurement** The precaution for measurement is stated below.

- 3.1) The capacitances of coupling capacitors C_1 and C_2 shall be small enough as compared with the capacitance of tuning capacitor C .
- 3.2) The Q of coupling capacitors C_1 and C_2 shall be large enough so that they will not affect Q of the specimen.

- c) **Operating characteristic method** (applicable for tuning type coil only) The operating characteristic method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 5.

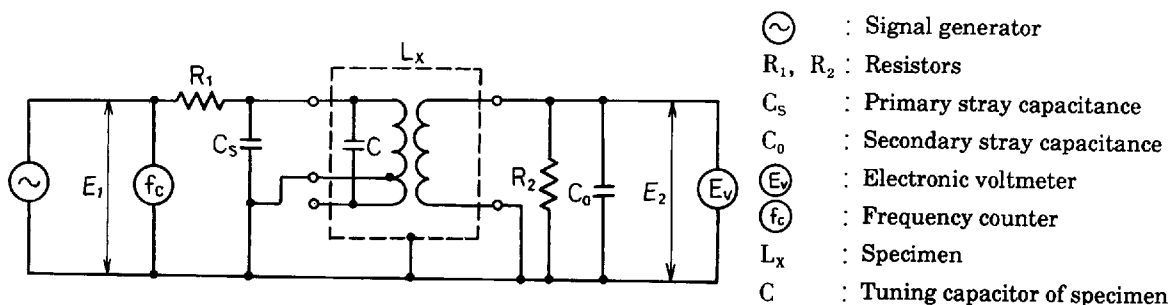


Fig. 5 Example of circuit for measurement by operating characteristic method

- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 5, make output voltage E_1 of the signal generator at 0.05 V to 1 V, and adjust the specimen so that secondary output voltage E_2 at rated frequency becomes the maximum. Raise E_1 by 3 dB, and measure the frequencies of signal generator f_1 and f_2 (for measurement of Q_U) or the frequencies f_3 and f_4 (for measurement of Q_L) at which the E_2 becomes equal to that in the above procedure (see Fig. 6). After such measurement, calculate Q_U and Q_L from the following formula:

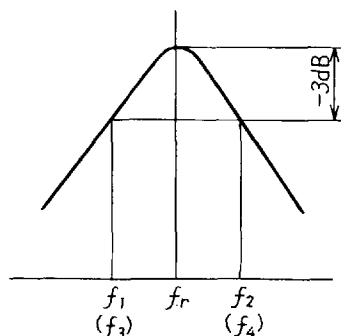


Fig. 6 Tuning characteristic of tuning type coil

$$2.1) \quad Q_U = \frac{f_1 + f_2}{2|f_1 - f_2|}$$

$$2.2) \quad Q_L = \frac{f_3 + f_4}{2|f_3 - f_4|}$$

3) Precaution for measurement

- 3.1) Unless specified in the detail specification, ground the secondary terminal of the same polarity as that of the primary grounded terminal.
- 3.2) The C_0 including stray capacitances of the electronic voltmeter and measuring circuit shall not exceed 10 pF.
- 3.3) The output impedance of signal generator is included in R_1 .
- 3.4) Allowable deviation on resistances of R_1 and R_2 is 1 %.
- 3.4.1) For measurement of Q_U : The R_1 shall be 1 M Ω , and remove R_2 . However, R_1 shall be not less than 10 times the primary impedance if the impedance exceeds 100 k Ω .
- 3.4.2) For measurement of Q_L : Use R_1 of a resistance corresponding to the primary impedance and use R_2 of a resistance corresponding to the secondary impedance.
- 3.5) Unless specified in the detail specification, the C_s which is located on the primary side should preferably be not exceeding $\frac{1}{20}$ of the tuning capacitance.

6.3.2 Items to be specified in detail specification The following items shall be specified in detail specifications.

- Measuring circuit and constants [see 6.3.1 a) 1), 6.3.1 b) 1) and 6.3.1 c) 1)]
- Measuring frequency [see 6.3.1 a) 2), 6.3.1 b) 2) and 6.3.1 c) 2)]
- Output voltage of signal generator (if necessary)

6.4 Resonance frequency

6.4.1 Measuring method The resonance frequency of the coil shall be measured by one of minimum output method [6.4.1 a)], two-frequency method [6.4.1 b)] or operating characteristic method [6.4.1 c)].

a) **Minimum output method** The minimum output method shall be as follows:

- Measuring circuit** Use the circuit as shown in Fig. 7 or Fig. 8.

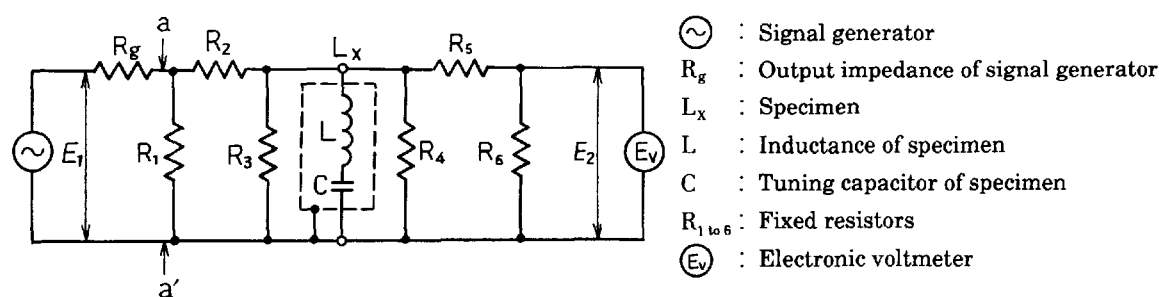


Fig. 7 Example of circuit for measurement by minimum output method (for series resonance)

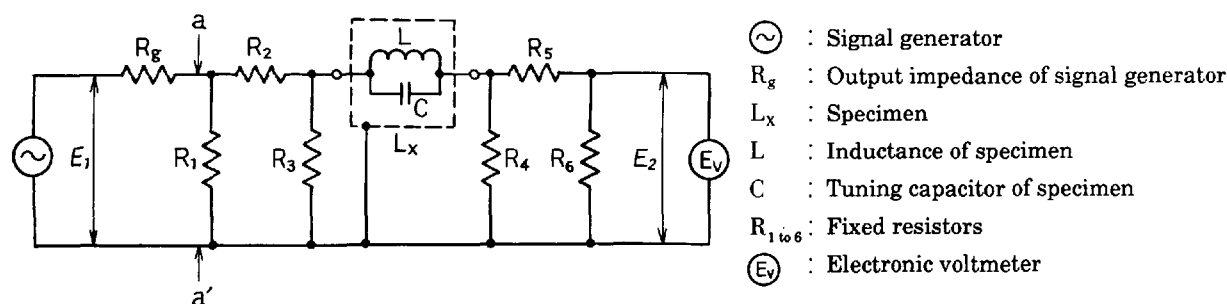


Fig. 8 Example of circuit for measurement by minimum output method (for parallel resonance)

- Measuring method and calculation formula** Use the circuit as shown in Fig. 7 or Fig. 8, maintain E_1 constant and adjust the frequency of the signal generator so that E_2 becomes the minimum. Measure two frequencies f_1 and f_2 at which E_2 increases by A dB (provided that $A \leq 3$) and then calculate the resonance frequency f_r from the following formula:

$$f_r = \frac{f_1 + f_2}{2}$$

- 3) **Precaution for measurement** Remove L_X in the case of Fig. 7, and short circuit it in the case of Fig. 8. In Fig. 7 and Fig. 8, make the resultant resistance of R_1 to R_6 viewed from a, a' equal to the resistance of R_g as much as possible. In this procedure, select the ratio of E_1 and E_2 so that the minimum point of E_2 is easily found.
- b) **Two-frequency method** The two-frequency method shall be as follows:
- 1) **Measuring circuit** Use the circuit as shown in Fig. 1.
 - 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 1, set C to an optional value C_1 , and obtain frequency f_1 at which E_2 becomes the maximum. Set C to a value C_2 different from C_1 ($C_1 < C_2$), measure frequency f_2 at which E_2 becomes the maximum in the later setting and then calculate resonance frequency f_r from the following formula:

$$f_r = \frac{1}{2\pi\sqrt{L'C'}}$$

$$\text{where, } C' = \frac{C_2 - \left(\frac{f_1}{f_2}\right)^2 C_1}{\left(\frac{f_1}{f_2}\right)^2 - 1}$$

$$L' = \frac{1}{(2\pi f_2)^2 (C' + C_2)}$$

c) **Operating characteristic method**

- 1) **Measuring circuit** Use the circuit shown in Fig. 5.
- 2) **Measuring method and calculation formula** Measure f_1 and f_2 in accordance with the method of 6.3.1 c) 2) and calculate resonance frequency f_r from the following formula:

$$f_r = \frac{f_1 + f_2}{2}$$

6.4.2 Items to be specified in detail specification The following items shall be specified in detail specifications.

- a) Measuring circuit [see 6.4.1 a) 1), 6.4.1 b) 1) and 6.4.1 c) 1)]
- b) Constants of measuring circuit (if necessary)

6.5 Distributed capacitance

6.5.1 Measuring method The distributed capacitance of the specimen shall be measured by either of two-frequency method [6.5.1 a)] or one-frequency method [6.5.1 b)].

a) **Two-frequency method** The two-frequency method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 1.



- 2) **Measuring method and calculation formula** Use the circuit as shown in Fig. 1, select frequency f_1 at which the tuning is accomplished at the smallest possible capacitance, and measure capacitance C_1 of the variable capacitor C at that frequency. Select frequency f_2 equal to $\frac{1}{2}$ or $\frac{1}{3}$ of f_1 , measure capacitance C_2 of the variable capacitor C at that frequency and calculate distributed capacitance C_D from the following formula:

$$C_D = \frac{C_2 - \left(\frac{f_1}{f_2}\right)^2 C_1}{\left(\frac{f_1}{f_2}\right)^2 - 1}$$

- b) **One-frequency method** The one-frequency method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 1 or Fig. 9.

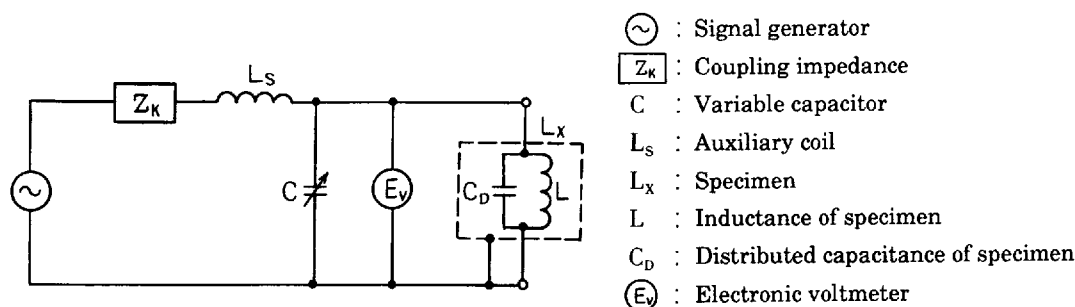


Fig. 9 Example of circuit for measurement by one-frequency method

- 2) **Measuring method and calculation formula** Measure the specimen in accordance with the method of 6.2.1 a), calculate the inductance L in accordance with 6.2.1 a) 2), and select an auxiliary coil L_S which has an inductance sufficiently smaller than this L . Use the circuit of Fig. 9, adjust the frequency of the signal generator to the value specified in the detail specification without the specimen connected, adjust C so that E_V becomes the maximum, and the measure capacitance C_1 of the variable capacitor C at that time.

Connect the specimen to the determined position of the circuit, measure capacitance C_2 of the variable capacitor C at that time and then calculate distributed capacitance C_D from the following formula:

$$2.1) \quad C_D = C_1 - C_2 + \frac{L_S}{L}(C_1 + C_0 + C_0')$$

$$2.2) \quad C_D = C_1 - C_2 \quad \text{to be used when } \frac{L_S}{L} \text{ is small sufficiently, and the third term of right side in formula 2.1) is negligible.}$$

where, C_0 : distributed capacitance of auxiliary coil

C_0' : stray capacitance of connecting jig of specimen

6.5.2 Items to be specified in detail specification The following items shall be specified in detail specifications.

- a) Measuring circuit [see 6.5.1 a) 1) and 6.5.1 b) 1)]
- b) Measuring frequency (if necessary) [see 6.5.1 a) 2) and 6.5.1 b) 2)]

6.6 Coupling coefficient

6.6.1 Measuring method The coupling coefficient of the coil shall be measured by either of 6.6.1 a) open- and short-circuit method or 6.6.1 b) double tuning method.

- a) **Open- and short-circuit method** The open- and short-circuit method shall be as follows:

- 1) **Measuring circuit** Use the circuit as shown in Fig. 1, Fig. 2 or Fig. 3.
- 2) **Measuring method and calculation formula** Connect primary terminals P, P' of the component shown in Fig. 10 to the inductance measuring terminals of the circuit shown in Fig. 1, Fig. 2 or Fig. 3, measure primary inductances L_0 and L_s when secondary terminals S, S' are opened and short-circuited, and then calculate coupling coefficient K from the following formula:

$$K = \sqrt{1 - \frac{L_s}{L_0}}$$

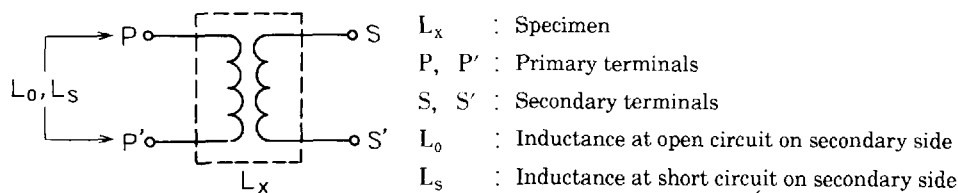


Fig. 10 Example of circuit for Open- and short-circuit method

- b) **Double tuning method**

- 1) **Measuring circuit** Use the circuit as shown in Fig. 1.
- 2) **Measuring method and calculation formula** As shown in Fig. 11 a, connect secondary terminals S, S' to the L_x measuring terminals of Fig. 1, set the frequency of the signal generator to an optional frequency f_P close to the rated frequency, and measure the Q when primary terminals P, P' are opened (denoted as Q_s). As shown in Fig. 11 b, connect primary terminals P, P', open S, S' and measure the Q (denoted as Q_P). As shown in Fig. 11 c, connect a tuning capacitor of capacitance C_r which makes tuning at frequency f_P , measure the Q under this state (denoted as Q_r) and then calculate coupling coefficient K from the following formula: