

JIS

JAPANESE INDUSTRIAL STANDARD

**Test methods of variable capacitors
for use in electronic equipment**

JIS C 6462—1996

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Contents

	Page
1. Scope	1
2. Definitions	3
3. Conditions for testing	3
3.1 Standard condition	3
3.2 Reference condition	4
3.3 Referee condition	4
3.4 Precaution	4
4. Treatment of specimen before and after test	5
4.1 Preconditioning	5
4.2 Recovery	5
4.3 Forced drying	5
4.4 Set value of capacitance in test	5
4.5 Mounting of specimen	5
4.6 Items to be prescribed in detail specification	5
5. Testing apparatus and equipment	5
5.1 Direct current power supply	5
5.2 Alternating current power supply	6
5.3 Test chamber	6
5.4 Other test apparatus and equipment	6
6. Appearance and dimension test	6
6.1 Equipment	6
6.2 Test	7
6.3 Items to be prescribed in detail specification	7
7. Electrical performance test	7
7.1 Voltage proof	7
7.2 Insulation resistance	10
7.3 Capacitance	10
7.4 Tangent of loss angle	13
7.5 Q	14

C 6462-1996

	Page
7.6 Rotor contact resistance	15
7.7 Backlash	16
7.8 Setting drift	17
7.9 Temperature characteristic of capacitance and capacitance drift	18
7.10 Spindle locking device	21
8. Mechanical performance test	22
8.1 Robustness of termination	22
8.2 Vibration (resistance to vibration)	25
8.3 Shock (resistance to shock)	27
8.4 Solderability (applicable to capacitors other than SMD)	31
8.5 Resistance to soldering heat (applicable to capacitors other than SMD)	37
8.6 Resistance to solvent	41
8.7 Torque	43
8.8 Total angle of rotation	43
8.9 Resistance to axial load	44
8.10 Spindle end stop property	46
8.11 Rotational endurance (no-load)	47
8.12 Robustness of termination (electrode) (applicable to SMD)	50
8.12.1 Resistance to bending of printed board (resistance to bending of substrate)	50
8.12.2 Pull-off strength	53
8.12.3 Shear strength (adhesion)	55
8.13 Solderability (applicable to SMD)	56
8.14 Resistance to soldering heat (applicable to SMD)	61
8.15 Resistance of electrode to dissolution of metallization (applicable to SMD)	64
8.16 Bump	65
8.17 Sealing (airtightness)	69
9. Climatic tests	72
9.1 Cold (resistance to cold)	72
9.2 Dry heat (resistance to heat)	73
9.3 Rapid change of temperature (cyclic temperature change)	75
9.4 Damp heat (steady state) [resistance to damp heat (steady state)]	76

	Page
9.5 Damp heat (cyclic)	78
9.5.5 Composite temperature / humidity cycle	78
9.5.6 Damp heat cycle (12 + 12-hour cycle)	79
9.6 Salt mist	84
9.7 Low air pressure	86
9.8 Loading under damp	88
9.9 Loading at elevated temperature (d.c. continuous)	89
9.10 Climatic sequence	91
Annex Mounting of SMD (chip) capacitor to testing printed wiring board	94
Related standards	96

JAPANESE INDUSTRIAL STANDARD

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Test methods of variable capacitors
for use in electronic equipment

C 6462-1996

1. **Scope** This Japanese Industrial Standard specifies test methods of variable capacitors mainly for use in electronic equipment (hereafter referred to as "capacitors". If there is any difference in the provisions between this Standard and the detail specification, the provisions of detail specification shall be followed.

Remarks 1. In the tests stated in this Standard, all the movements of the rotor are expressed by the words "rotation", "rotational direction" and so on. In the case of capacitors of linear operation type, contact (pressurized) type, etc., the said words shall be read as "operation", "operating direction" and so on.

2. The following standards are cited in this Standard:

JIS B 0251	Limit gauges for metric coarse screw threads
JIS B 0252	Limit gauges for metric fine screw threads
JIS B 7502	Micrometer callipers
JIS B 7507	Vernier, dial and digital callipers
JIS C 0010	Environmental testing. Part 1: General and guidance
JIS C 0020	Environmental testing procedures Part 2: Tests, Tests A: Cold
JIS C 0021	Basic environmental testing procedures Part 2: Tests, Test B: Dry heat
JIS C 0022	Basic environmental testing procedures Part 2: Tests, Test Ca: Damp heat, steady state
JIS C 0023	Basic environmental testing procedures Part 2: Tests - Test Ka: salt mist
JIS C 0025	Basic environmental testing procedures Part 2: Tests, Test N: Change of temperature
JIS C 0026	Basic environmental testing procedures Part 2: Tests - Test Q: Sealing
JIS C 0027	Basic environmental testing procedures Part 2: Tests, Test Db: Damp heat, cyclic (12 + 12-hour cycle)
JIS C 0028	Basic environmental testing procedures Part 2: Tests, Test Z/AD: Composite temperature/humidity cyclic test
JIS C 0029	Basic environmental testing procedures Part 2: Tests, Test M: Low air pressure
JIS C 0040	Basic environmental testing procedures Part 2: Tests, Test Fc and guidance: Vibration (sinusoidal)

JIS C 0041	Basic environmental testing procedures Part 2: Tests, Test Ea and guidance: Shock
JIS C 0042	Basic environmental testing procedures Part 2: Tests, Test Eb and guidance: Bump
JIS C 0050	Basic environmental testing procedures Part 2: Tests, Test T: Soldering
JIS C 0051	Basic environmental testing procedures Part 2: Tests, Test U: Robustness of terminations and integral mounting devices
JIS C 0052	Environmental testing procedures of electronic and electrical resistance to solvents (immersion in cleaning solvents)
JIS C 0054	Environmental testing Part 2: Tests - Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of Surface Mounting Devices (SMD)
JIS C 1303	High insulation resistance meters
JIS C 5102	Test methods of fixed capacitors for use in electronic equipment
JIS C 5602	Glossary of passive components for electronic equipment
JIS C 6461	General rules of variable capacitors for electronic equipment
JIS C 6484	Copper-clad laminates for printed wiring boards - Glass fabric base, epoxy resin
JIS K 5902	Colophonium
JIS K 8101	Ethanol (99.5)
JIS K 8839	2-Propanol
JIS Z 3282	Soft solder

3. The International Standards corresponding to this Standard are given below.

IEC 418-1 (1974)	Variable capacitors. Part 1: Terms and methods of test Amendment No. 1 (1976) Amendment No. 2 (1981)
IEC 418-2 (1976)	Variable capacitors. Part 2: Type specification for variable tuning capacitors Type A Amendment No. 1 (1981)
IEC 418-3 (1976)	Variable capacitors. Part 3: Type specification for variable trimmer capacitors Type B
IEC 418-4 (1976)	Variable capacitors. Part 4: Type specification for variable pre-set capacitors Type C

2. **Definitions** For the purposes of this Standard and the related detail specifications, the definitions specified in JIS C 6461 and JIS C 5602 shall apply.

The terms relating with classification by use of capacitor and the term "SMD" are stated below.

- (1) **type A capacitor (variable tuning capacitors type A)** Capacitors which are mainly used for tuning in such a way that the capacitance is changed at every use.
They are also called variable tuning capacitors.
Some of them accompany variable pre-set capacitor type C.
- (2) **type B capacitor (variable trimmer capacitors type B)** Capacitors which have small variation in capacitance and are mainly used for fine adjustment of capacitance.
They are also called variable trimmer capacitors.
- (3) **type C capacitor (variable pre-set capacitors type C)** Capacitors which are mainly used under fixed state after adjustment of capacitance.
They are also called semi-set capacitors.
- (4) **SMD** This is abbreviation of "surface mounting device".
Informative reference: The names stated parentheses in (1) to (3) are those used in IEC 418-1.

3. Conditions for testing

3.1 **Standard condition** Unless otherwise specified, test shall be carried out under the standard condition stated in Table 1 based on 5.3 of JIS C 0010. If there is any dispute on the decision based on the measured values under this standard condition or if especially requested, the provision of 3.3 shall be followed.

If conversion is necessary the provision of 3.2 shall be followed.

Table 1. Standard condition

Temperature	°C	15 to 35
Relative humidity	%	45 to 75
Air pressure	kPa	86 to 106

- Remarks
1. If the capacitor to be tested (hereafter called "specimen") is large or if it is difficult to maintain the temperature at testing place, the test may be made under a condition other than the standard condition. In this case the temperature shall be within the range of 10 °C to 40 °C.
 2. It is desirable to minimize the variation of temperature and humidity in a sequence of measurements carried out as a part of tests.

3. The relative humidity may be ignored if it does not affect the test results.
4. The temperature, relative humidity and air pressure in the respective range under the standard condition are sometimes called ordinary temperature, ordinary humidity and ordinary pressure, respectively, in this Standard.

3.2 Reference condition Reference condition is as stated in Table 2, based on the provision of 5.1 in JIS C 0010.

Table 2. Reference condition

Temperature °C	20
Air pressure kPa	101.3

Remarks: Requirements for relative humidity is not specified, because correction of data by calculation is generally impossible.

3.3 Referee condition The referee condition shall be the condition selected from among those in Table 3 and specified in the detail specification based on the provisions of 5.2 in JIS C 0010. If there is not such a provision, the condition of symbol A grade 2 in Table 3 shall be taken.

Table 3. Referee condition

Symbol	Grade 1			Grade 2		
	Temperature °C	Relative humidity %	Air pressure kPa	Temperature °C	Relative humidity %	Air pressure kPa
A	20	± 1	63 to 67	20	± 2	86 to 106
B	23		48 to 52	23		60 to 70
C	25			25		45 to 55
D	27		63 to 67	27		60 to 70

Remarks 1. The relative humidity may be ignored if it does not affect the test results.

2. The designation of classification by symbol and grade stated in Table 3 is not specified in 5.2 of JIS C 0010. In this Standard, the designation of classification by symbol and grade stated in 3.3 of JIS C 5102 is applied.

3.4 Precaution The specimens shall be free from such factors which may affect the test results as sunlight and heat radiation from other heat sources before, during and after the tests.

4. Treatment of specimen before and after test

4.1 Preconditioning At the test and measurement, the specimen shall be allowed to stand under the test temperature or measurement temperature for at least 30 min to be completely discharged.

4.2 Recovery Before final measurements the specimen shall be allowed to stand under the standard condition for 1 h to 2 h.

4.3 Forced drying Before initial measurements or final measurements, the specimens shall be dried under the conditions stated in Table 4.

After drying, the specimens shall be stored in a desiccator containing such desiccants as activated alumina or silica gel, or in the atmosphere of relative humidity not exceeding 20 %.

Table 4. Conditions for forced drying

Temperature	55 ± 2 °C
Relative humidity	20 % max.
Air pressure	86 to 106 kPa
Duration of exposure	6 ± 0.5 h

4.4 Set value of capacitance in test Unless otherwise specified, the capacitance of the specimen shall be set to almost the maximum capacitance.

4.5 Mounting of specimen The mounting of the specimen to a specific mounting device carried out in advance of a test and measurement, the mounting method, position of capacitance, and the state of spindle locking device, if provided, shall be as specified in the detail specification.

4.6 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Preconditioning (if applied) (see 4.1)
- (2) Recovery (if applied) (see 4.2)
- (3) Forced drying (if applied) (see 4.3)
- (4) Set value of capacitance in test (if specified) (see 4.4)
- (5) Mounting of specimen (if specified) (see 4.5)

5. Testing apparatus and equipment

5.1 Direct current power supply Unless otherwise specified, the d.c. power supply shall be of the two kinds shown in Table 5.

Table 5. Direct current power supply

Unit: %

Kind of d.c. power supply	Ripple content ⁽¹⁾		Stability of d.c. voltage ⁽²⁾
	50, 60 Hz	100, 120 Hz	
A	2 max.	1 max.	± 3
B	0.1 max.	0.1 max.	± 0.1

Notes ⁽¹⁾ The ripple content is the ratio of peak a.c. voltage superposed on d.c. voltage to the d.c. voltage.

⁽²⁾ The stability of d.c. voltage is the relative variation of d.c. output voltage in use to the initial set value of d.c. output voltage.

5.2 Alternating current power supply The a.c. power supply shall have substantially sinusoidal waveform at a frequency of 50 Hz or 60 Hz, and the capacity shall be not less than 500 VA and shall withstand the test current.

5.3 Test chamber The test chamber shall be capable of maintaining the specified testing temperature and relative humidity, and have such construction that the specimens will not receive heat radiation directly from the heat sources throughout the locations where the specimens are placed.

Damp-proof test chamber shall be of such construction that the condensed water does not drip from the ceiling or wall of chamber on the specimens.

Test chamber other than damp-proof test chamber shall be carefully designed so that the damp should not condensed on the specimens or their measurement terminations.

5.4 Other test apparatus and equipment Other test apparatus and equipment shall be adequate and have sufficient accuracy for respective tests.

6. Appearance and dimension test

6.1 Equipment The equipment shall be those prescribed below, unless particularly specified. If no doubt arises on the decision, other appropriate equipment may also be used.

- (1) The vernier calliper specified in JIS B 7507
- (2) The micrometer callipers for external measurement specified in JIS B 7502
- (3) The limit gauge for metric coarse screw thread specified in JIS B 0251
- (4) The limit gauge for metric fine screw thread specified in JIS B 0252
- (5) Projector or magnifier of suitable magnification (magnification shall be 10, if not specified)

6.2 Test

6.2.1 Appearance The appearance shall be checked visually.

6.2.2 Marking The marking shall be checked visually. When the detail specification prescribes resistance to solvent of marking, the resistance to solvent specified in 8.6 shall be checked.

6.2.3 Dimensions The dimensions specified in the detail specification shall be measured using the equipment specified in 6.1.

6.3 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Test equipment (when equipment other than that of 6.1 is used)
- (2) Application of projector or magnifier and its magnification (if applied) (see 6.1)
- (3) Resistance to solvent (if applied) (see 6.2.2)

7. Electrical performance test

7.1 Voltage proof

7.1.1 Equipment

(1) Power supply The power supply shall be the kind A d.c. supply of 5.1 or the a.c. supply of 5.2. Unless dispute arises on decision another power supply may be used.

(2) Test circuit and apparatus

- (a) Test circuit The test circuit shall, as a rule, be such circuit as illustrated in (1), (2), or (3) of Fig. 1. In the case of d.c. supply, (1) of Fig. 1 is recommended.
- (b) Voltmeter The voltmeter shall have an internal resistance of not less than 10 kΩ per 1 V.
- (c) Protective resistor The protective resistor shall be the one with a resistance value which satisfies the time constant or the charging currents specified in the relevant detail specification.
- (d) Capacitance of C₀ in Fig. 1 (1) The capacitance of C₀ shall be not less than 10 times the maximum capacitance of C_x, and shall satisfy the following formulae unless otherwise specified in the detail specification.

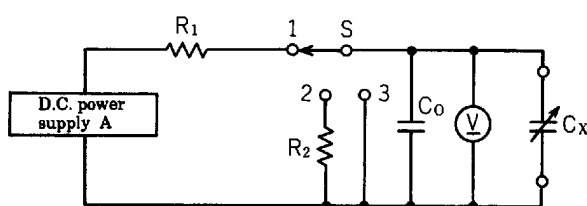
$$R_1 (C_0 + C_x) \leq 1 \text{ s}$$

$$R_2 (C_0 + C_x) \leq 1 \text{ s}$$

where, R_1 : protective resistor (including internal resistance of power supply) (Ω)
 R_2 : protective resistor (Ω)
 C_0 : capacitance of capacitor C_0 (F)
 C_x : maximum capacitance of specimen C_x (F)

Fig. 1. Voltage-proof test circuit

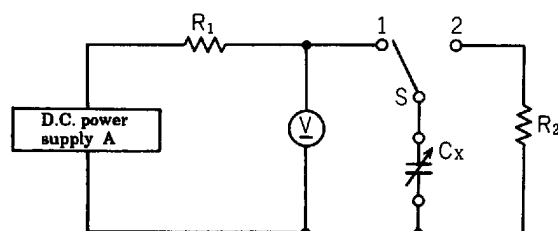
(1) Test circuit A by d.c. power supply



R_1, R_2 : protective resistors
 S : switch
 C_0 : capacitor
 C_x : specimen (capacitor under test)
 $\textcircled{V}$: d.c. voltmeter

Switch position
 1 : Application of test voltage
 2 : Discharge
 3 : Short circuit

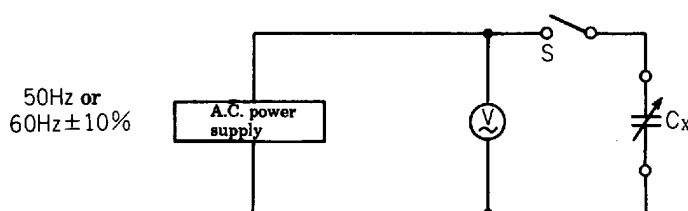
(2) Test circuit B by d.c. power supply



R_1, R_2 : protective resistors
 S : switch
 C_x : specimen (capacitor under test)
 $\textcircled{V}$: d.c. voltmeter
 $\textcircled{V}$: a.c. voltmeter

Switch position
 1 : Application of test voltage
 2 : Discharge
 [Fig. 1 (2) only]

(3) Test circuit by a.c. power supply



7.1.2 Preconditioning In advance of the test, the preconditioning specified in 4.1 shall be carried out.

7.1.3 Test The test voltage specified in the detail specification shall be applied to the specimen by either method (1) or (2) stated below, in accordance with the provisions of the detail specification.

The raise and lower of test voltage shall be as specified in (3) and the duration of test voltage application shall be as specified in (4).

- (1) Carry out the test by applying the test voltage across the terminations of specimen while rotating the rotor through the total angle of rotation. The direction of rotation shall be as specified in the detail specification (mainly applicable to type A capacitors).
- (2) Carry out the test by applying the test voltage across the terminations of specimen while the specimen is positioned at its maximum capacitance (mainly applicable to type C capacitors).
- (3) Raise the test voltage gradually starting from zero up to the specified voltage then maintain the voltage for the specified duration. Verify existence or non-existence of flashover and/or dielectric breakdown during the said period. After voltage application, lower the voltage gradually, then discharge the specimen through the protective resistor [In the case of Fig. 1 (1), lower the voltage until the reading of voltmeter becomes zero, and further turn the switch to position 3.], remove the specimen from the circuit and check the appearance. The charging and discharging may be carried out without gradual raise and lower of voltage, if there is no dispute on the test results and the detail specification specifies such operation.
- (4) Unless otherwise specified, the duration of test voltage application shall be 60 s. It may be made 2 s if there is no dispute on the decision.

7.1.4 Final measurements After the test, the check and measurements specified in the detail specification shall be carried out.

7.1.5 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Test circuit (see 7.1.1)
- (2) Limited current in charge and discharge, time constant or resistance (see 7.1.1)
- (3) Preconditioning (if different from that in 7.1.2)
- (4) Mounting of specimen (if specified) (see 4.5)
- (5) Test voltage and duration of test (see 7.1.3)
- (6) Method for test voltage application (see 7.1.3)
- (7) Check and measurements after test (if specified) (see 7.1.4)

7.2 Insulation resistance

7.2.1 Equipment The equipment shall be the high insulation resistance meter specified in JIS C 1303 or an instrument at least equivalent thereto in performance.

7.2.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.2.3 Measurement Apply the measuring voltage specified in Table 6 across the terminations and positions of the specimen specified in the detail specification and measure the resistance after lapse of $1 \text{ min} \pm 5 \text{ s}$. Even within the time specified above, if the measured value of the instrument stabilizes or further tends to increase above the specified insulation resistance, the decision may be made by such behavior.

If the measurement is made at a temperature other than the reference temperature, and the conversion is specified in the detail specification, carry out the conversion to the value at reference temperature by multiplying the specified temperature correction factor to the measured value.

Table 6. Measuring voltage of insulation resistance

Unit: V	
Rated voltage (E)	Measuring voltage
$E \leq 100$	Rated voltage
$100 \leq E < 500$	100 ± 15
$500 \leq E$	500 ± 50

7.2.4 Items to be prescribed in detail specification the following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that in 7.2.1)
- (2) Preconditioning (if different from that in 7.2.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring voltage and duration of voltage application (see 7.2.3)
- (5) Capacitance position or rotational indication (angle) of specimen (if other than maximum capacitance position) (see 7.2.3)
- (6) Conversion when measurement is done at a temperature other than reference temperature, and temperature correction factor (see 7.2.3)

7.3 Capacitance

7.3.1 Equipment The equipment shall be the one capable of measuring the capacitance under the conditions shown in Table 7.

The accuracy of measurement shall be within 10 % of the tolerance on capacitance.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

Table 7. Measuring conditions of capacitance

Measuring conditions	Measuring frequency		Measuring voltage
	Frequency	Tolerance	
1	100 kHz	± 20 %	The voltage shall be a low voltage which will not cause trouble in measurement. When a d.c. voltage is superimposed, the superposition shall be made so that the d.c. voltage is larger than the peak value of a.c. voltage, and the sum of the peak value of a.c. voltage and the d.c. voltage does not exceed the rated voltage.
2	1 MHz		

- Remarks
1. Measuring condition 1 is mainly applicable to type A capacitors.
 2. Measuring condition 2 is mainly applicable to type C capacitors.
 3. Measuring condition of type B capacitors shall be specified in the detail specification.

7.3.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.3.3 Measurements Carry out the measurements on the items of (1) to (6) given below under the conditions shown in Table 7.

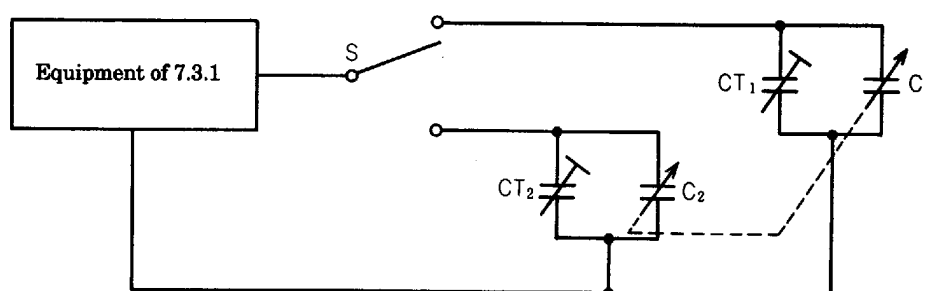
In the measurement of a type A capacitor equipped with a type C capacitor, set the capacitance of type C capacitor to the minimum, unless otherwise specified.

- (1) **Maximum capacitance** Rotate the rotor of specimen and measure the capacitance at a position where it becomes the maximum.
- (2) **Minimum capacitance** Rotate the rotor of specimen and measure the capacitance at a position where it becomes the minimum.
- (3) **Maximum variable capacitance** Obtain the difference between the maximum capacitance and the minimum capacitance and take it as the maximum variable capacitance.
- (4) **Capacitance at a rotational indication** (applicable to type A capacitors)
Measure the capacitance at a specified rotational indication (angle) of the specimen.
- (5) **Variable capacitance of linked section** (applicable to type A capacitors)
Unless otherwise specified, carry out the measurement in the circuit shown in Fig. 2 by either of the methods stated below.
 - (a) **Mechanical index method (M.I method)** Fix the specimen to a position where the capacitance is the minimum, and make the stray capacitance of the reference section equal to that of the linked section by means of separate capacitor or the attached type C capacitor.
Then determine the rotational indication (angle) specified in the detail specification mechanically, and measure the capacitance of linked section with the capacitance of reference section at that position as the base.

- (b) Electrical index method (E.I method) Fix the specimen to a position where the capacitance is the minimum, and make the stray capacitance of the reference section equal to that of the linked section by means of separate capacitor or the attached type C capacitor.

Then measure the capacitance of linked section at a rotational indication (angle) where the capacitance of reference section becomes the specified capacitance.

Fig. 2. Measuring circuit of variable capacitance of linked section



C_1 : capacitor of reference section

C_2 : capacitor of linked section

CT_1 : pre-set capacitor for adjustment of stray capacitance of reference section

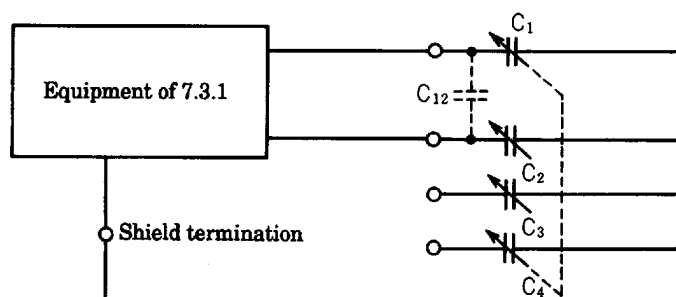
CT_2 : pre-set capacitor for adjustment of stray capacitance of linked section

S : switch

- (6) Coupling capacitance between sections (applicable to type A capacitors) Measure the capacitance between the sections specified in the detail specification by using the circuit illustrated in Fig. 3.

Set the specimen to a position where the capacitance is the minimum.

Fig. 3. Measuring circuit of coupling capacitance between sections



7.3.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that in 7.3.1 or 7.3.3)
- (2) Preconditioning (if different from that in 7.3.2)

- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring conditions (see 7.3.3)
- (5) Rotational indication (angle) or capacitance (if specified) (see 7.3.3)
- (6) Assignment of M.I method or E.I method [see 7.3.3 (5)]
- (7) Between sections to be measured [see 7.3.3 (6)]

7.4 Tangent of loss angle

7.4.1 Equipment The equipment shall be the one capable of measuring the tangent of loss angle under the conditions shown in Table 8.

The accuracy of measurement shall be within 1×10^{-4} or 10 % of the value specified in Standard whichever is the larger.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

Table 8. Measuring conditions of tangent of loss angle and Q

Measuring conditions	Measuring frequency		Set capacitance of capacitor		Measuring voltage
	Measuring frequency MHz	Tolerance %	Capacitance pF	Tolerance %	
1	100	± 10	10	± 10	Use a low voltage which will not cause trouble in measurement.
2	10		50		
3	1		Maximum capacitance	—	

7.4.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.4.3 Measurement Measure the tangent of loss angle of specimen under the conditions shown in Table 8 and specified in the detail specification.

7.4.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.4.1)
- (2) Preconditioning (if different from that of 7.4.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring conditions (see 7.4.3)

14
C 6462-1996

7.5 Q

Remarks: Q is the reciprocal of tangent of loss angle, therefore such procedures are allowed that the tangent of loss angle is measured and Q is obtained as the reciprocal thereof, if the measuring conditions are satisfied.

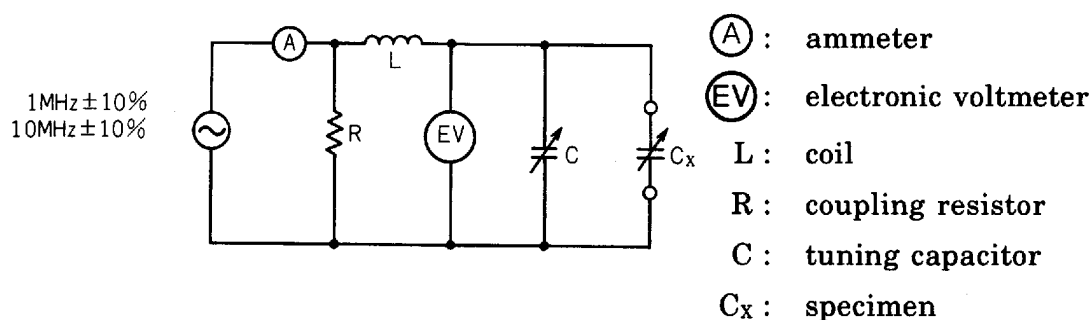
7.5.1 Equipment The equipment shall be the circuit exemplified in Fig. 4 which is capable of carrying out the measurements under the conditions specified in Table 8.

The accuracy of measurement shall be within 10 % of the value specified in the Standard.

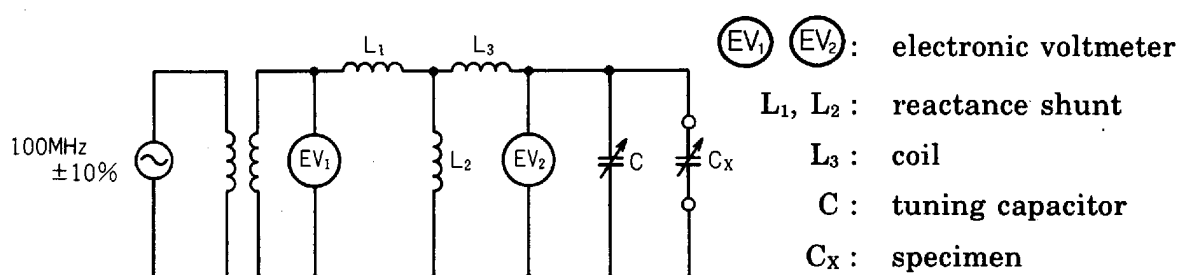
Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

Fig. 4. Measuring circuit of Q

(1) Measuring circuit A



(2) Measuring circuit B



7.5.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.5.3 Test In the test, carry out the measurements as specified in (1), and calculate the value of Q as specified in (2).

(1) **Measurement** Measure Q of the specimen under the conditions shown in Table 8 and specified in the detail specification.

- (2) Calculation Calculate Q from the following formula:

$$Q = \frac{(C_1 - C_2) Q_1 Q_2}{C_1 (Q_1 - Q_2)}$$

where, C_1 : capacitance of tuning capacitor when specimen is not connected (pF)
 C_2 : capacitance of tuning capacitor when specimen is connected (pF)
 Q_1 : value of Q when specimen is not connected
 Q_2 : value of Q when specimen is connected

7.5.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

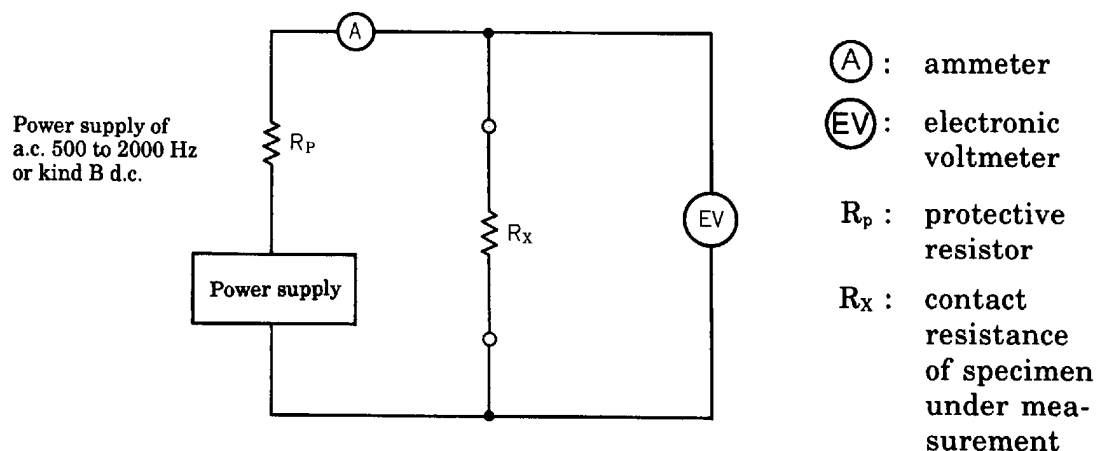
- (1) Measuring equipment (if different from that of 7.5.1)
- (2) Preconditioning (if different from that of 7.5.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring conditions [see 7.5.3 (1)]

7.6 Rotor contact resistance (mainly applicable to type A capacitors)

7.6.1 Equipment The equipment shall consist of the circuit as illustrated in Fig. 5.

The accuracy of measurement shall be within 10 % of the value specified in the Standard.

Fig. 5. Measuring circuit of contact resistance



7.6.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.6.3 Test In the test, carry out the measurements as specified in (1), and calculate the value of contact resistance as specified in (2).

- (1) **Measurement** Carry out the measurements in the circuit shown in Fig. 5. Connect the measuring terminations to the rotating spindle and grounding termination of the specimen, rotate the spindle at a rate of one reciprocation or one revolution per approximately 3 s, and measure the maximum value and minimum value of electronic voltmeter.

The measuring voltage shall not exceed 20 mV (d.c. or peak value of a.c.) and the measuring current shall be as specified in the detail specification. The frequency, when measured by a.c., shall be in a range of 500 Hz to 2000 Hz.

- (2) **Calculation** Calculate the contact resistance R (Ω) from the following formula:

$$R = \frac{U}{I}$$

where, U : voltage between spindle and grounding termination (V)

I : testing current (A)

7.6.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.6.1)
- (2) Preconditioning (if different from that of 7.6.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Testing frequency (identification of d.c. or a.c.) (see 7.6.3)
- (5) Measuring current (see 7.6.3)
- (6) Measuring voltage (if different from that of 7.6.3)

7.7 Backlash (applicable to type A capacitors)

7.7.1 Equipment The equipment shall be capable of measuring the capacitance under the conditions shown in Table 7.

The accuracy of measurement shall be within 10 % the value specified in the Standard.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

7.7.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.7.3 Test In the test, carry out the measurements as specified in (1), and calculate the backlash as specified in (2).

- (1) **Measurement** Reciprocate the rotor of specimen 5 strokes through 80% to 90 % of the effective rotational indication (angle) at a rate of approximately one stroke per 3 s, then rotate the rotor from the position of minimum capacitance in the direction to increase the capacitance and measure the capacitance at 50 % rotational indication (angle), under the conditions shown in Table 7. Further rotate the rotor to the position of maximum capacitance, then reversely rotate it in the direction to decrease the capacitance and measure the capacitance again at 50 % rotational indication (angle).

The condition for measuring the capacitance shall be as specified in Table 7.

The deviation of measuring position shall be within ± 0.1 %.

- (2) **Calculation** Calculate backlash d from the following formula:

$$d = \frac{(C_1 - C_2)}{C_1} \times 100$$

where, d : backlash (%)

C_1 : larger measured capacitance (pF)

C_2 : smaller measured capacitance (pF)

7.7.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.7.1)
- (2) Preconditioning (if different from that of 7.7.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring method [if different from that of 7.7.3 (1)]
- (5) Measuring frequency [see 7.7.3 (1)]
- (6) Calculation method [if different from that of 7.7.3 (2)]

7.8 Setting drift

7.8.1 Equipment The equipment shall be capable of measuring the capacitance under the conditions shown in Table 7.

The accuracy of measurement shall be within 10 % of the tolerance.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

7.8.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

7.8.3 Test In the test, measure the specimen as specified in (1) and calculate the setting drift as specified in (2).

- (1) **Measurement** Reciprocate or rotate the rotor of specimen 5 strokes or revolutions at a rate of approximately one stroke or revolution per 3 s and then fix it to a position of 50 % rotational indication. After 5 s, measure the capacitance, allow the specimen to stand for 5 min, then measure the capacitance again.

The conditions for measuring the capacitance shall be as specified in Table 7.

- (2) **Calculation** Calculate setting drift N from the following formula:

$$N = \frac{(C_1 - C_2)}{C_1} \times 100$$

where, N : setting drift (%)

C_1 : larger measured capacitance (pF)

C_2 : smaller measured capacitance (pF)

7.8.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.8.1)
- (2) Preconditioning (if different from that of 7.8.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Measuring method [if different from that of 7.8.3 (1)]
- (5) Measuring frequency [see 7.8.3 (1)]
- (6) Calculation method [if different from that of 7.8.3 (2)]

7.9 Temperature characteristic of capacitance and capacitance drift

7.9.1 Equipment The equipment shall be as follows:

- (1) **Thermostatic chamber** The thermostatic chamber shall be as specified in 5.3.
- (2) **Measuring device of capacitance** The measuring device of capacitance shall be capable of measuring the capacitance under the conditions of Table 7.
- (3) **Measuring accuracy** The accuracy of measurement shall be within 10 % of the tolerance.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

7.9.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

The capacitance of specimen shall be set to 40 % to 50 % of the nominal maximum capacitance for type A capacitors, and to 60 % to 80 % for type B and type C capacitors.

7.9.3 Test In the test, measure the specimen as specified in (1), and calculate the temperature characteristic of capacitance and capacitance drift as specified in (2).

- (1) **Measurement** Maintain the specimen at the temperature shown in Table 9 in the order shown in the same Table under the conditions specified in the detail specification, and measure the capacitance under the conditions shown in Table 7 and specified in the detail specification at each temperature step after the temperature was stabilized (thermal equilibrium).

Table 9. Condition of temperature change

Step	Condition		Unit: °C
	A ⁽³⁾	B ⁽⁴⁾	Capacitance symbol
1	20 ± 2		C ₁
2	Lower category temperature ± 2	Lower category temperature $\begin{smallmatrix} 0 \\ -3 \end{smallmatrix}$	C ₂
3	20 ± 2		C ₃
4	Upper category temperature ± 2	Upper category temperature $\begin{smallmatrix} +3 \\ 0 \end{smallmatrix}$	C ₄
5	20 ± 2		C ₅

Notes ⁽³⁾ Condition A is mainly applied to capacitors whose temperature characteristic of capacitance is expressed by the temperature coefficient and capacitance drift.

⁽⁴⁾ Condition B is mainly applied to capacitors whose temperature characteristic of capacitance is expressed by the variation rate of capacitance.

- (2) **Calculation** Calculate the variation rate, temperature coefficient and capacitance drift by means of the formulae stated below.

(2.1) **Variation rate of capacitance**

Variation rate on low temperature side

$$\frac{\Delta C}{C} = \frac{C_2 - C_3}{C_3} \times 100$$

Variation rate on high temperature side

$$\frac{\Delta C}{C} = \frac{C_4 - C_3}{C_3} \times 100$$

where, $\frac{\Delta C}{C}$: variation rate of capacitance (%)

C₁ : capacitance at step 1 (pF)

C₂ : capacitance at step 2 (pF)

C₃ : capacitance at step 3 (pF)

C₄ : capacitance at step 4 (pF)

C₅ : capacitance at step 5 (pF)

(2.2) Temperature coefficient of capacitanceTemperature coefficient of capacitance on low temperature side

$$\alpha = \frac{(C_2 - C_3)}{C_3(T_2 - T_3)} \times 10^6$$

Temperature coefficient of capacitance on high temperature side

$$\alpha = \frac{(C_4 - C_3)}{C_3(T_4 - T_3)} \times 10^6$$

where, α : temperature coefficient of capacitance (ppm/°C)

T_2 : temperature at measurement in step 2 (°C)

T_3 : temperature at measurement in step 3 (°C)

T_4 : temperature at measurement in step 4 (°C)

(2.3) Capacitance drift Calculate the capacitance drift according to either (a) or (b) stated below as specified in the detail specification.

(a)

$$\delta = \frac{C_{\max} - C_{\min}}{C_3} \times 100$$

where, δ : capacitance drift (%)

$C_{\max}$: maximum value among three measurement values in steps 1, 3 and 5 (pF)

$C_{\min}$: minimum value among three measured values in steps 1, 3 and 5 (pF)

(b)

$$\delta = C_{\max} - C_{\min}$$

where, δ : capacitance drift (pF)

7.9.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.9.1)
- (2) Preconditioning (if different from that of 7.9.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Setting (measuring) position of capacitance (if different from that of 7.9.2)
- (5) Condition of temperature change (see 7.9.3)
- (6) Lower and upper category temperatures (see 7.9.3)

- (7) Measuring frequency (see 7.9.3)
- (8) Measuring items (if different from those of 7.9.3)
- (9) Method of calculation (if different from that of 7.9.3)
- 7.10 Spindle locking device (applicable to capacitors with spindle locking device)

7.10.1 Equipment The equipment shall be capable of measuring the capacitance under the conditions shown in Table 7.

The accuracy of measurement shall be within 10 % of the permissible value.

Consideration shall be given to all the equipment to minimize the error in measurement due to stray capacitance or the like.

7.10.2 Preconditioning In advance of the test, the specimen shall be subjected to the preconditioning specified in 4.1.

The capacitance of specimen shall be set to 40 % to 60 % of the nominal maximum capacitance.

7.10.3 Test Carry out the test as stated in (1) to (4) given below. Measure the capacitance under the conditions shown in Table 7 and specified by the detail specification.

- (1) Do not lock the specimen and measure the capacitance (C_1).
- (2) Lock the specimen as it is by operating the spindle locking device at the operating torque specified in the detail specification. Measure the capacitance (C_2) under the said conditions.
- (3) Apply the test torque specified in the detail specification clockwise to the specimen with the spindle locking device being operated. Then measure the capacitance (C_3).
- (4) Apply the test torque specified in the detail specification anticlockwise to the specimen with the spindle locking device being operated. Then measure the capacitance (C_4).
- (5) Calculate the change of each of capacitances C_2 to C_4 from the capacitance C_1 of the specimen.

7.10.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Measuring equipment (if different from that of 7.10.1)
- (2) Preconditioning (if different from that of 7.10.2)
- (3) Mounting of specimen (if specified) (see 4.5)
- (4) Setting (measuring) position of capacitance (if different from that of 7.10.2)

- (5) Measuring frequency (see 7.10.3)
- (6) Operating torque to be applied to spindle locking device [see 7.10.3 (2)]
- (7) Test torque to be applied to spindle locking device [see 7.10.3 (3)]

8. Mechanical performance test

8.1 Robustness of termination (applicable to capacitors other than SMD) (see Test U in JIS C 0051)

8.1.1 Equipment The equipment shall not give the specimen scratches, strain, etc. which will affect the test results, at the time of testing.

8.1.2 Test Carry out the tests for one or some of the test items (1) to (4) stated below based on the provisions of the detail specification. Examine existence or non-existence of break or loosening of terminations and damage of the specimen body resulted from this test.

- (1) Tensile strength of termination (see Test Ua₁ in JIS C 0051) Fix the specimen body, apply a tensile force to the termination in its emergent direction gradually up to the value specified in Table 10, unless otherwise specified, and then maintain the force for the specified duration.

Table 10. Tensile force, thrust and duration of termination

Classification of terminations	Nominal sectional area (s) mm ²	Nominal diameter when cross section is circular (d) mm	Tolerance on tensile force ± 10 % N	Tolerance on thrust ± 10 % N	Duration of tensile force and thrust s
Lead wire termination (circular cross section or strip) or pin termination	$s \leq 0.05$	$d \leq 0.25$	1	0.25	10 ± 1
	$0.05 < s \leq 0.1$	$0.25 < d \leq 0.35$	2.5	0.5	
	$0.1 < s \leq 0.2$	$0.35 < d \leq 0.5$	5	1	
	$0.2 < s \leq 0.5$	$0.5 < d \leq 0.8$	10	2	
	$0.5 < s \leq 1.2$	$0.8 < d \leq 1.25$	20	4	
	$1.2 < s$	$1.25 < d$	40	8	
Other terminations (tag termination, stud with internal slit, screw termination)	As specified in the detail specification.				

- (2) Thrust strength of termination (applicable to screw termination or the like) (see Test Ua₂ of JIS C 0051) Fix the specimen body, apply a thrust to the termination in its axial direction gradually up to the value specified in Table 10, unless otherwise specified, and then maintain the thrust for the specified duration.

Remarks: This test should not apply to flexible terminations.

- (3) Bending strength of termination (applicable to pliable terminations only) (see Test Ub of JIS C 0051) Carry out the tests as stated in (a) to (c) given below.

- (a) For lead wire or strip terminations With the termination in its normal position, fix the specimen body in such a manner that the axis of termination is vertical, and suspend a weight of a mass which exert the bending force specified in Table 11 from the end of the termination.

Incline the specimen body through an angle of approximately 90 ° taking 2 s to 3 s in a vertical plane and then return it to its initial position at the same rate. Denote the above operation as one bend and carry out the test by either of the methods stated below as specified in the detail specification.

Method 1 Give one bend in opposite direction following to one bend, or give plural bends alternately as specified in the detail specification.

Method 2 Give one bend in the same direction following to one bend, or give plural bends in the same direction as specified in the detail specification.

Carry out this procedure in such a manner that formation of radius of curvature between the specimen body and the point to which the force is applied is avoided. Bend the strip termination perpendicular to the wide surface.

Table 11. Bending force of termination

Section modulus (Z) mm ³	Nominal wire diameter when cross section is circular (d) mm	Tolerance on bending force ± 10 % N	Information: Mass of weight corresponding to bending force kg
$Z \leq 1.5 \times 10^{-3}$	$d \leq 0.25$	0.5	0.051
$1.5 \times 10^{-3} < Z \leq 4.2 \times 10^{-3}$	$0.25 < d \leq 0.35$	1.25	0.13
$4.2 \times 10^{-3} < Z \leq 1.2 \times 10^{-2}$	$0.35 < d \leq 0.5$	2.5	0.25
$1.2 \times 10^{-2} < Z \leq 0.5 \times 10^{-1}$	$0.5 < d \leq 0.8$	5	0.51
$0.5 \times 10^{-1} < Z \leq 1.9 \times 10^{-1}$	$0.8 < d \leq 1.25$	10	1.0
$1.9 \times 10^{-1} < Z$	$1.25 < d$	20	2.0

Remarks: Calculate the section modulus Z (mm³) of strip termination by means of the formula stated below.

$$Z = \frac{ba^2}{6}$$

where, a : thickness of strip perpendicular to bending axis (mm)

b : dimension of the other side of rectangular cross section (mm)

- (b) For tag termination Bend the termination capable of being bent with the fingers through 45° and then return it to its initial position. Counting this operation as one bend, carry out the test according to the detail specification stipulating either of the following procedures:

Method 1 One bend immediately followed by a second bend in the opposite direction.

Method 2 Two bends in the same direction, without interruption.

If the detail specification prescribes use of pliers, place of bending, carry out the test as specified.

- (c) Strength of termination at simultaneous bending Clamp all terminations on one side of the specimen by clamp at the seating plane or, where it is not given, at a point approximately 3 mm from the seal between the termination and the specimen body so that the radius of curvature of bend is 0.1 mm.

Attach a mass to the clamp with the terminations pointing downwards. This mass, including the mass of the clamp, shall apply a force equal to that given in Table 11 multiplied by the number of terminations clamped. Incline the specimen body through an angle of 45° taking 2 s to 3 s for operation and return it to its initial position at the same rate. Then incline it to opposite direction and return it again in the initial position.

- (4) Strength of termination against torque (see Test Ud of JIS C 0051) Fix the specimen in normal way, apply the torque given in Table 12 without shock to every screw, or to each of the nuts normally fitted to terminations for a period of 10 s to 15 s according to the severity prescribed in the detail specification.

During these tests, place a washer or metal plate with a normal clearance hole for the screw thread between the screw head and the surface on to which it is tightened.

The thickness of the washer or metal plate shall be approximately equal to 6 times the nominal pitch of the screw. The nut thickness shall be equal to approximately 0.8 times the nominal screw diameter. The washers, metal plates and nuts shall be clean and dry.

The nut or screw shall be capable of being loosened after test.

Table 12. Strength of termination against torque

Nominal screw diameter mm		2.6	3.0	3.5	4.0	5.0	6.0
Torque Nm	Severity I	0.4	0.5	0.8	1.2	2.0	2.5
	Severity II	0.2	0.25	0.4	0.6	1.0	1.25

Remarks: The torque for a screw exceeding 6 mm in diameter shall be as specified in the detail specification.

8.1.3 Measurements before and after test If specified in the detail specification, electrical performances shall be measured and mechanical performances and appearance shall be examined before and after this test.

8.1.4 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Equipment (if different from that of 8.1.1)
- (2) Applicable test items (see 8.1.2)
- (3) Tensile force for other terminations [see 8.1.2 (1)]
- (4) Thrust for other terminations [see 8.1.2 (2)]
- (5) Designation of Method 1 or Method 2 in bending test [see 8.1.2 (3) (a), (b)]
- (6) Number of bends [see 8.1.2 (3) (a), (b)]
- (7) Mounting of specimen (if specified) (see 4.5)
- (8) Positions of measurement before and after test (if specified) (see 8.1.3)

8.2 Vibration (resistance to vibration) (see Test Fc of JIS C 0040)

8.2.1 Equipment The equipment for this test shall be enough to carry out the test in the specified magnitude and application of vibration, and also satisfy the conditions of the vibration tester specified in 4. of JIS C 0040.

8.2.2 Preparation Prior to the test, the specimen shall be securely fixed to the vibration stand by the aid of mounting device or directly, in accordance with the method specified in the detail specification. Unless otherwise specified, the mounting procedure shall be as follows:

- (1) **Setting of capacitance** The capacitance shall be set to the position of the maximum capacitance. If a rotation stop is provided, the position shall be such that the rotor does not come in contact with it.
- (2) **Mounting** The specimen shall be mounted as follows:
 - (a) Capacitors of screw mounting type are mounted on the mounting jig or mounting plate by clamping the screws.
 - (b) Capacitors of solder mounting type are mounted on the mounting jig by soldering. However, capacitors of printed-circuit board mounting type are mounted on the printed-circuit board by soldering.
 - (c) Capacitors of both screw and solder mounting type are mounted in accordance with (a) and (b).
- (3) **Spindle locking device** For the specimen equipped with spindle locking device, the said device shall be actuated.

8.2.3 Initial measurement The measurements shall be carried out on the capacitance and the items specified in the detail specification.

8.2.4 Test In the test, apply the vibration under one of the conditions shown in Table 13 which is specified in the detail specification.

Carry out the test in 3 directions perpendicular to each other, for 0.5 h or 2 h in each direction (1.5 h or 6 h in total). Unless otherwise specified, employ class A vibration and 0.7 mm or 49 m/s² whichever is the smaller as the peak-to-peak amplitude or the acceleration.

Table 13. Conditions for vibration test

Test conditions		Classification of tests		
		Class A	Class B	Class C
Vibration frequency range	Hz	10 to 55	10 to 500	10 to 2000
Peak-to-peak amplitude or acceleration and test duration	0.7 mm or 49 m/s ² whichever is the smaller	1.5 h	1.5 h	—
	1.5 mm or 98 m/s ² whichever is the smaller	6 h	6 h	6 h
	3.0 mm or 196 m/s ² whichever is the smaller	—	—	6 h
	Rate of sweep	10 to 55 Hz Approximately 5 min	10 to 500 Hz Approximately 11 min	10 to 2000 Hz Approximately 15 min
	Method of sweep	Logarithmic sweep		

8.2.5 Measurement during test The measurement shall be carried out in accordance with the provision, if provided in the detail specification.

8.2.6 Final measurement The measurement shall be carried out on the capacitance and the items specified in the detail specification, and mechanical damages and appearance shall be checked.

8.2.7 Items to be prescribed in detail specification The following items shall be prescribed in the detail specification:

- (1) Equipment (if different from that of 8.2.1)
- (2) Mounting of specimen (see 8.2.2)
- (3) Initial measurement items (see 8.2.3)
- (4) Measuring condition of capacitance (see Table 7)
- (5) Class of test (see 8.2.4)