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Potentiometers for use
in electronic equipment
Part 1 : Generic specification

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

Attention shall be drawn to the possibility that a part of this Standard may conflict with a patent right, application for a patent right after opening to the public, utility model right (including those applied before 1993-12-31) or application for registration of utility model after opening to the public which have technical properties. The Minister of International Trade and Industry and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent right after opened, utility model right or application for registration of utility model after opening to the public which have the technical properties of this kind.

Group standards The following standards form the specifications for the group of element specified in this Standard.

JIS C 5260 *General rules of potentiometers for use in electronic equipment*

JIS C 5260-1 *Potentiometers for use in electronic equipment—Part 1 : Generic specification*

JIS C 5260-2

JIS C 5260-2-1

JIS C 5260-2-2

JIS C 5260-3

JIS C 5260-3-1

JIS C 5260-4 (to be established)

JIS C 5260-4-1

JIS C 5260-4-2

JIS C 5260-5

JIS C 5260-5-1

JIS C 5260-5-2

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Potentiometers for use in electronic equipment Part 1 : Generic specification

Introduction This Japanese Industrial Standard has been prepared based on IEC 60393-1 *Potentiometers for use in electronic equipment Part 1 : Generic specification* published in 1989 as the second edition, and Amendment 1 : 1992 without changing the technical content and structure. Further, the testing method of surface mounting type potentiometer, specification of type form and indication in Annex 1 as Japanese Industrial Standard, and recommended dimensions of control spindle and mounting features in Annex 2 have been added. The Amendments are, however, compiled into the text.

The portions with dotted underlines or sidelines show the matters not specified in the original International Standard. The IEC standard number is based on the new numbering system of IEC standards put in force on January 1st, 1997, and the standards published before the said date are numbered by adding 60000 to the former number. This is only the change in the numbering system and the contents remain unchanged.

Section One—Scope

1 Scope This Japanese Industrial Standard specifies the potentiometers for use in electronic equipment (hereafter referred to as “potentiometers”).

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications for qualification approval and quality assessment systems.

This specification describes on single turn rotary potentiometer with a control spindle, and the terms shall mean as follows for other types of potentiometers:

- (1) The angle of rotation may be number of turns.
- (2) The control spindle shall mean any other actuating device.
- (3) The angle of rotation shall be within the range of mechanical travel of the actuating device in the case of driving mechanism.
- (4) In the case of a linear actuating mechanism, the operating torque shall be operating force.

These alternative prescriptions shall be found in the sectional or detail specification. For 2-terminal potentiometer, the modified part of the standard tests in this specification shall be prescribed in the relevant standard.

Remarks : The corresponding International Standard is as follows:

IEC 60393-1 : 1989 *Potentiometers for use in electronic equipment
Part 1 : Generic specification*
Amendment 1 : 1992

Section Two—General

2 General

2.1 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. If the indication of the year of coming into effect is given to these referred standards, only the edition of indicated year constitutes the provision of this Standard but the revision and amendment made thereafter are not applied.

The normative references without the indication of the year of coming into effect apply limiting only to the most recent edition (including the amendment).

Japanese Industrial Standard

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

Remarks : All provisions cited from IEC 60068-1 : 1978, *Environmental testing Part 1 : General* are equivalent to corresponding provisions of this Standard.

JIS C 0010 : 1993 is identical with IEC 60068-1 : 1988 and Amendment 1 : 1992.

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

Remarks : All provisions cited from IEC 60068-2-1 : 1974, *Environmental testing—Part 2 : Tests. Test A : Cold* and IEC 60068-2-1A First Supplement A : 1976 are equivalent to corresponding provisions of this Standard.

JIS C 0020 : 1995 is identical with IEC 60068-2-1 : 1990, Amendment 1 : 1993 and Amendment 2 : 1994.

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

Remarks : All provisions cited from IEC 60068-2-2 : 1974, *Environmental testing—Part 2 : Tests. Test B : Dry heat* and IEC 60068-2-2A First Supplement A : 1976 are equivalent to corresponding provisions of this Standard.

JIS C 0021 : 1995 is identical with IEC 60068-2-2 : 1974, Amendment 1 : 1993 and Amendment 2 : 1994.

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

Remarks : All provisions cited from IEC 60068-2-3 : 1969, *Environmental testing—Part 2 : Tests. Test Ca : Damp heat, steady state* are equivalent to corresponding provisions of this Standard.

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

Remarks : All provisions cited from IEC 60068-2-14 : 1974, *Environmental testing—Part 2 : Tests. Test N : Change of temperature* are equivalent to corresponding provisions of this Standard.

JIS C 0026 : 1994 *Basic environmental testing procedures Part 2 : Tests—Test Q : Sealing*

Remarks : All provisions cited from IEC 60068-2-17 : 1968, *Environmental testing—Part 2 : Tests—Test Q : Sealing* are equivalent to corresponding provisions of this Standard.

JIS C 0027 : 1988 *Basic environmental testing procedures Part 2 : Tests, Test Db : Damp heat, cyclic (12+12-hour cycle)*

Remarks : All provisions cited from IEC 60068-2-30 : 1980, *Environmental testing—Part 2 : Tests. Test Db and guidance : Damp heat, cyclic (12+12-hour cycle)* are equivalent to corresponding provisions of this Standard.

JIS C 0027 : 1988 is identical with IEC 60068-2-30 : 1980 and Amendment 1 : 1985.

JIS C 0029 : 1989 *Basic environmental testing procedures Part 2 : Tests, Test M : Low air pressure*

Remarks : All provisions cited from IEC 60068-2-13 : 1966, *Environmental testing—Part 2 : Tests. Test M : Low air pressure* are equivalent to corresponding provisions of this Standard.

JIS C 0029 : 1989 is identical with IEC 60068-2-13 : 1983.

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

Remarks : All provisions cited from IEC 60068-2-6 : 1970, *Environmental testing—Part 2 : Tests—Test Fc : Vibration (Sinusoidal)* and Amendment 2 : 1985 are equivalent to corresponding provisions of this Standard.

JIS C 0040 : 1995 is identical with IEC 60068-2-6 : 1982, Amendment 1 : 1983 and Amendment 2 : 1985.

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

Remarks : All provisions cited from IEC 60068-2-27 : 1972, *Environmental testing—Part 2 : Tests. Test Ea : Shock* are equivalent to corresponding provisions of this Standard.

JIS C 0041 : 1995 is identical with IEC 60068-2-27 : 1987.

JIS C 0042 : 1995 *Basic environmental testing procedures Part 2 : Tests Test Eb and guidance : Bump*

Remarks : All provisions cited from IEC 60068-2-29 : 1968, *Environmental testing—Part 2 : Tests. Test Eb and guidance : Bump* are equivalent to corresponding provisions of this Standard.

JIS C 0042 : 1995 is identical with IEC 60068-2-29 : 1987.

JIS C 0050 : 1996 *Basic environmental testing procedures Part 2 : Tests, Test T : Soldering*

Remarks : All provisions cited from IEC 60068-2-20 : 1979, *Environmental testing. Part 2 : Tests. Test T : Soldering* are equivalent to corresponding provisions of this Standard.

JIS C 0050 : 1996 is identical with IEC 60068-2-20 : 1979, Amendment 1 : 1986 and Amendment 2 : 1987.

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

Remarks : All provisions cited from **IEC 60068-2-21 : 1983**, *Environmental testing. Part 2 : Tests. Test U : Robustness of terminations and integral mounting devices* and Amendment 1 : 1985 are equivalent to corresponding provisions of this Standard.

JIS C 0051 : 1994 is identical with **IEC 60068-2-21 : 1983**, Amendment 1 : 1985, Amendment 2 : 1991 and Amendment 3 : 1992.

JIS C 0052 : 1995 *Environmental testing procedures of electronic and electrical resistance to solvents (immersion in cleaning solvents)*

Remarks : All provisions cited from **IEC 60068-2-45 : 1980**, *Environmental testing. Part 2 : Tests. Test XA and guidance : Immersion in cleaning solvents* are equivalent to corresponding provisions of this Standard.

JIS C 0052 : 1995 is identical with **IEC 60068-2-45 : 1980** and Amendment 1 : 1993.

JIS C 0301 *Graphical symbols for electrical apparatus*

Remarks : All provisions cited from **IEC 60117** *Recommended graphical symbols* are equivalent to corresponding provisions of this Standard.

JIS C 5062 *Marking codes for resistors and capacitors*

Remarks : **IEC 60062** *Marking codes for resistors and capacitors*, and Amendment 1 : 1995 are identical with this Standard.

JIS C 5063 *Preferred number series for resistors and capacitors*

Remarks : **IEC 60063** *Preferred number series for resistors and capacitors*, and Amendment 1 : 1967 and Amendment 2 : 1977 are identical with this Standard.

JIS C 6484 *Copper-clad laminates for printed wiring boards—Glass fabric base, epoxy resin*

Remarks : All provisions cited from **IEC 60249-2-5** *Base materials for printed circuits. Part 2 : Specifications. Specification No. 5 : Epoxide woven glass fabric copper-clad laminated sheet of defined flammability (vertical burning test)* are equivalent to corresponding provisions of this Standard.

JIS Z 8202 *Quantity symbols, unit symbols and chemical symbols*

Remarks : All provisions cited from **ISO 1000** *SI Units and recommendations for the use of their multiples and of certain other units* are equivalent to corresponding provisions of this Standard.

JIS Z 8203 *SI units and the use of their multiples and of certain other units*

Remarks : All provisions cited from **ISO 1000** *SI Units and recommendations for the use of their multiples and of certain other units* are equivalent to corresponding provisions of this Standard.

JIS Z 8401 *Rules for rounding off of numerical values*

Remarks : All provisions cited from **ISO 497** *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers* are equivalent to corresponding provisions of this Standard.

JIS Z 8601 *Preferred numbers*

Remarks : All provisions cited from **ISO 3** *Preferred numbers—Series of preferred numbers* are equivalent to corresponding provisions of this Standard.

JIS Z 9015 *Sampling inspection procedures and tables by attributes with severity adjustment (receiving inspection where a consumer can select suppliers)*

Remarks : All provisions cited from **IEC 60410** *Sampling plans and procedures for inspection by attributes* are equivalent to corresponding provisions of this Standard.

IEC standards

IEC 60027-1 *Letter symbols to be used in electrical technology. Part 1 : General*

IEC 60050 *International Electrotechnical Vocabulary (I.E.V)*

IEC 60915 : 1987 *Capacitors and resistors for electronic equipment. Preferred dimensions of spindle ends, bushes and for the mounting of single-hole, bush-mounted, spindle-operated electronic components*

IEC QC 001001 : 1986 *Basic rules of the IEC Quality assessment system for electronic components (IECQ)*
Amendment 2 : 1994

IEC QC 001002 : 1986 *Rules of Procedure of the IEC Quality assessment system for electronic components (IECQ)*
Amendment 2 : 1994

2.2 Units, symbols and terminology

2.2.1 General Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following publications:

JIS C 0301

JIS Z 8202

JIS Z 8203

IEC 60027

IEC 60050

When further items are required they shall be derived in accordance with the principles of the documents listed above.

2.2.2 Type A group of components having similar design features and the similarity of whose manufacturing techniques enables them to be grouped together either for qualification approval or for quality conformance inspection. They are generally covered by a single detail specification.

Remarks 1 Components described in several detail specifications may, in some cases, be considered as belonging to the same type and may therefore be grouped together for qualification approval and for quality conformance inspection.

2 Mounting accessories are ignored provided they have no significant effect upon the test results.

2.2.3 Style A sub-division of a type, generally based on dimensional factors. A style may include several variations, generally based on mechanical construction.

2.2.4 Grade A term to indicate additional general characteristics concerning the intended application e.g. long life applications.

The term "grade" may only be used in combination with one or more words (e.g. long-life grade) and not by a single letter or number. Figures to be added after the term "grade" should be arabic numerals.

2.2.5 Variant A sub-division within a style having specific dimensions for some part of its construction, e.g. terminations, spindle flats or length.

2.2.6 Family (of potentiometers) A group of potentiometers which predominantly displays a particular physical attribute and/or fulfils a determined function.

2.2.7 Sub-family (of potentiometers) A group of potentiometers within a family manufactured by similar technological methods.

2.2.8 Category temperature range The range of ambient temperatures for which a potentiometer has been designed to operate continuously; this is defined by the temperature limits of its appropriate category.

2.2.9 Upper category temperature The maximum ambient temperature for which a potentiometer has been designed to operate continuously at the specified category dissipation (see 2.2.14).

2.2.10 Lower category temperature The minimum ambient temperature at which a potentiometer has been designed to operate continuously.

2.2.11 Critical resistance The resistance value when the rated voltage is equal to the limiting element voltage.

Below the critical resistance the maximum voltage which may be applied across the terminations of a potentiometer is the rated voltage. Above that value the maximum voltage is the limiting element voltage (see 2.2.13, 2.2.15 and 2.2.16).

2.2.12 Rated resistance The rated resistance is the resistance value marked upon the potentiometer.

2.2.13 Rated dissipation The maximum allowable dissipation between terminations a and c (see 2.2.30) of a potentiometer at an ambient temperature of 70 °C. In this case, the rated resistance at 70 °C electrical endurance test shall not greater than the specified value.

Remarks : In practice the dissipation is modified by the following conditions:

- a) Where the resistance value is high and the limiting element voltage (see 2.2.16) limits the rated dissipation being attained.
- b) The dissipation at temperatures other than 70 °C shall be specified in the rating graphs in the relevant detail specification.

- c) Where only terminations a and b or b and c are used and the control spindle is set at an angle less than 100 % of the effective electrical travel.

In this case the limiting moving contact current (see 2.2.18) shall also be taken into account.

2.2.14 Category dissipation The maximum allowable dissipation under continuous load at an ambient temperature equal to the upper category temperature. It shall be normally expressed as a percentage of the rated dissipation.

Remarks : The category dissipation may be zero.

2.2.15 Rated voltage That d.c. or a.c. r.m.s. voltage calculated from the square root of the product of the rated resistance and the rated dissipation.

Remarks : At high values of resistance, the rated voltage may not be applicable because of the size and construction of the potentiometer (see 2.2.11, 2.2.13 and 2.2.16).

2.2.16 Limiting element voltage The maximum d.c. or a.c. r.m.s. voltage which can be applied across the element of a potentiometer.

When the term "a.c. r.m.s. voltage" is used in this specification, the peak voltage shall not exceed 1.42 times of the r.m.s. value.

Remarks : This voltage shall be applied to a potentiometers only when the resistance value is equal to or higher than the critical value.

2.2.17 Isolation voltage The maximum peak voltage under continuous operating conditions which may be applied between the potentiometer terminations and other external conducting parts connected together. The value of the isolation voltage shall be not less than 1.42 times of the limiting element voltage at normal air pressure. Under conditions of low air pressure the value of the isolation voltage will be less and shall be given in the detail specifications.

2.2.18 Limiting moving contact current The maximum current that can be passed between the resistance element and the moving contact.

2.2.19 Variation of resistance with temperature The variation of resistance with temperature can be expressed either as a temperature characteristic or as a temperature coefficient as defined in the next two items.

2.2.19.1 Temperature characteristic of resistance The maximum reversible variation of resistance produced over a given temperature range within the category temperature range. It is expressed normally as a percentage of the resistance related to a reference temperature of 20 °C.

$$\text{Temperature characteristic of resistance} = \frac{\Delta R}{R}$$

where, ΔR : the change in resistance between the two specified ambient temperatures

R : the resistance value at the reference temperature

2.2.19.2 Temperature coefficient of resistance (α_R) The relative variation of resistance between two given temperatures, divided by the difference in temperature producing it (mean coefficient). It shall preferably be expressed in parts per million per °C ($10^{-6}/^{\circ}\text{C}$).

$$\text{Temperature coefficient of resistance } (\alpha_R) = \frac{R_2 - R_1}{R_1 \cdot \Delta\theta}$$

where, $\Delta\theta$: the algebraic difference in degrees Celsius between the reference temperature and the specified ambient temperatures

R_1 : the resistance value at the reference temperature

R_2 : the resistance value at the specified ambient temperature

Remarks: It should be noted that use of the term does not imply any degree of linearity for this coefficient, nor should any be assumed.

2.2.19.3 Temperature coefficient of output voltage ratio (α_0) The relative variation of output voltage ratio between the two given temperatures divided by the difference in temperatures producing it (mean coefficient).

Setting a limiting moving contact at a specified position and apply the specified load. It shall be expressed in parts per million per °C ($10^{-6}/^{\circ}\text{C}$).

$$\text{Temperature coefficient of output voltage ratio } (\alpha_0) = \frac{(U_{ab2}/U_{ac2}) - (U_{ab1}/U_{ac1})}{(U_{ab1}/U_{ac1}) \times \Delta\theta}$$

where, $\Delta\theta$: algebraic difference between specified ambient temperature and reference temperature

U_{ac1} : voltage between terminals a and c at reference temperature

U_{ab1} : voltage between terminals a and b at reference temperature

U_{ac2} : voltage between terminals a and c at specified ambient temperature

U_{ab2} : voltage between terminals a and b at specified ambient temperature

Remarks 1 The value of α_0 may change according to the setting of output voltage ratio.

2 It should be noted that the use of the term does not imply any degree of linearity of this ratio, nor any assumption.

2.2.20 Visible damage Visible damage which reduces the usability of the potentiometer for its intended purpose.

2.2.21 Potentiometer A component for use as a voltage divider with three terminations of which two are connected to the both ends of a resistive element and the third to a moving contact which can be moved mechanically along the resistive element.

2.2.22 Pre-set or trimmer potentiometer A potentiometer designed for relatively infrequent adjustment.

2.2.23 Lead-screw actuated potentiometer A potentiometer having a lead-screw as multi-turn actuating device.

2.2.24 Ganged potentiometers Potentiometers consisting of two or more sections operated by a common spindle. The number of sections is incorporated in the name of potentiometer, such as 2-ganged or 4-ganged potentiometer, etc.

2.2.25 Dual concentric potentiometers Potentiometers consisting of two sections operated independently by concentric spindles.

2.2.26 Spindle sealed potentiometer A potentiometer in which a spindle seal is provided to prevent particles and fluid from passing from the outside of the potentiometer to the inside by way of the spindle bearing (see Fig. 1).

2.2.27 Spindle sealed and panel sealed potentiometer A potentiometer in which a spindle seal and a panel seal is provided to prevent particles and fluid from entering any equipment in which this potentiometer is mounted (see Fig. 2).

2.2.28 Container sealed potentiometer A potentiometer in which a spindle seal is provided and the container housing of the potentiometer is designed to prevent particles and fluid from passing from the outside of the potentiometer to the inside (see Fig. 3).

In some cases a panel seal may additionally be provided. Such a potentiometer is called a "fully sealed potentiometer" (see Fig. 4).

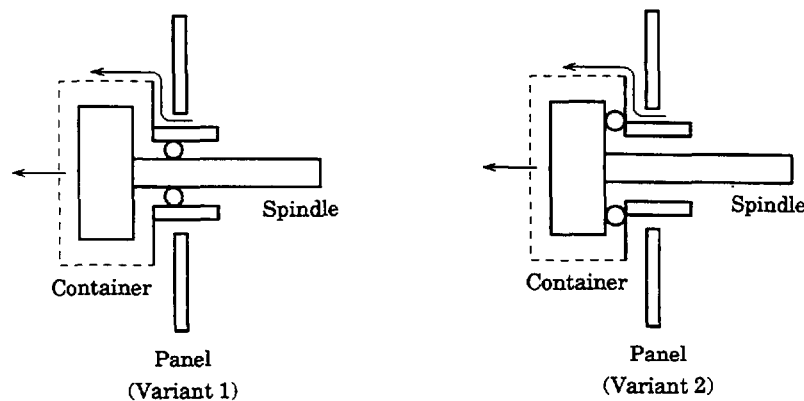


Fig. 1 Spindle sealed potentiometer

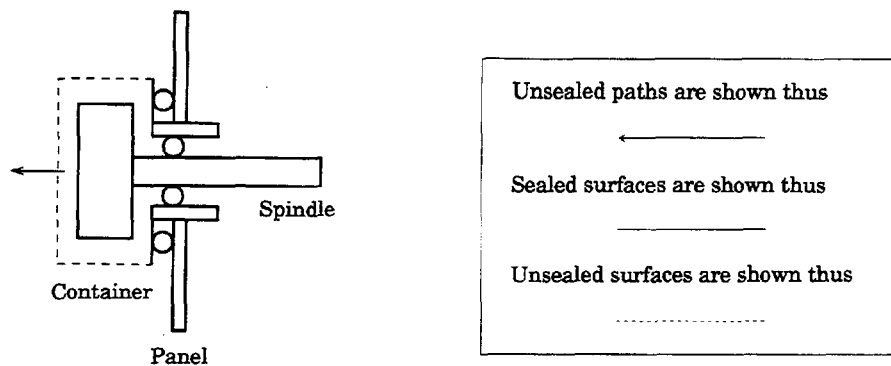


Fig. 2 Spindle and panel sealed potentiometer

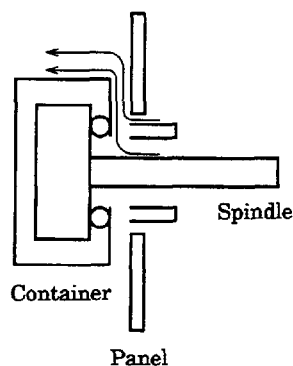


Fig. 3 Container sealed potentiometer

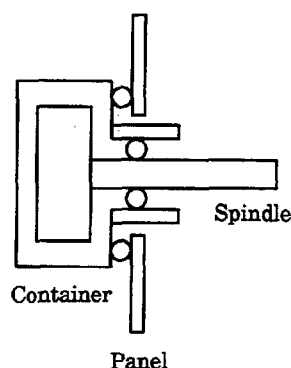


Fig. 4 Fully sealed potentiometer

2.2.29 Direction of rotation Rotation is defined as clockwise or anti-clockwise when viewing the face of the potentiometer which includes the means of actuation. When doubt exists, the reference face shall be marked in accordance with the detail specification.

2.2.30 Designation of terminations The preferred designation of the three terminations of the potentiometer is:

a is the end termination electrically nearest to the moving contact with the spindle set fully anti-clockwise as defined in 2.2.29.

b is the termination of the moving contact.

c is the other end termination.

The numerals 1, 2 and 3 or colours yellow, red and green, may be used as alternatives to a, b and c respectively. When terminations are marked, the marking shall be in accordance with this clause. Additional letters, numbers or colours for other terminations shall be allocated in the relevant specification.

2.2.31 Two-terminal variable resistor A resistor with a permanent contact at one end of the resistive element and a second contact which can be moved along the resistive element for the purpose of changing in resistance.

2.2.32 Moving contact The contact of the potentiometer which moves along the resistive element.

2.2.33 Tap A fixed electrical connection made to the resistive element.

2.2.34 Track The contact path of the moving contact on the resistive element.

2.2.35 Declutching device The device which allows continuous rotation of the actuating device after the moving contact has reached either end of the resistive element.

2.2.36 Number of turns (of an actuating device) The total number of times the actuating device completes (or nearly completes) 360° of movement in covering the total mechanical travel.

2.2.37 Resistance law The relationship of the measured resistance value between terminations a and b or of the output ratio U_{ab}/U_{ac} to the mechanical position of the moving contact.

2.2.37.1 Common potentiometer laws are classified as follows.

- a) Linear law: Law B (Fig. 5)
- b) Logarithmic law: Law A (Fig. 6)
- c) Inverse logarithmic law: Law C (Fig. 7)

The sectional or detail specifications may permit, and prescribe the tolerances for, a rate of change of resistance near to the end of the effective travel less than that required by the prescribed law. It may also permit, and prescribe the tolerances for, approximations to the law of the form shown dotted in Figs. 6 and 7.

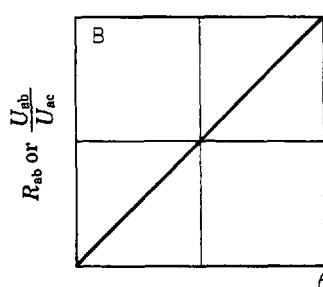


Fig. 5 Linear law

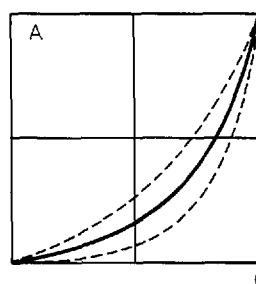


Fig. 6 Logarithmic law

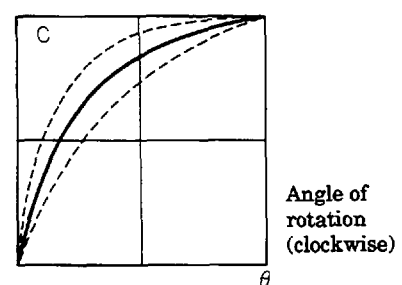


Fig. 7 Inverse logarithmic law

Informative reference : In IEC 60393-1, linear law is called as A and logarithmic law as B. However, in the relevant detail specifications of Japanese Industrial Standard, the above symbols have been used and those shall be used as they are to avoid any inconvenience in business transaction.

2.2.37.2 Laws other than the widely used laws A, B and C listed in **2.2.37.1** (for example sine or co-sine) may be required for special applications (see Annex 1). The law shall then be prescribed in the sectional or detail specification.

2.2.38 Cycle of operation For single and multi-turn potentiometers, one cycle of operation is defined as the travel of the moving contact from one end of the resistive element to the other and back. For continuously rotating potentiometers, one cycle of operation is defined as two revolutions of 360°, in the same direction, of the moving contact.

2.2.39 Shorted-segment A portion of the resistive element over which the output ratio remains constant within specified limits as the moving contact traverses the segment with a specified load resistance.

2.2.40 Terminal resistance Terminal resistance is the minimum resistance which can be obtained between the termination connected to the moving contact b, and any other termination (see **2.2.30**).

2.2.41 Residual resistance The residual resistance is the resistance obtained between the end termination, a or c, and the termination of the moving contact b, when the moving contact is set against the relevant end stop (see **2.2.30**).

Remarks : When there is no sharp change of resistance between the end stop and the point where the minimum effective resistance is observed the residual resistance, the terminal resistance and the minimum effective resistance become the same. The lowest resistance value need not correspond with the mechanical end stop.

2.2.42 Load resistance (R_L) (see Fig. 9) The external resistance to produce the output voltage (connected between the moving contact and either termination a or c).

2.2.43 Total applied voltage (U_{ac}) (see Fig. 8) The voltage applied between input terminations, e.g. the voltage applied between input terminations a and c.

2.2.44 Output voltage (U_{ab}) (see Fig. 8) The voltage between termination b and the specified reference point. Unless otherwise specified, the specified reference point is termination a.

2.2.45 Output ratio (see Fig. 8) The ratio of the output voltage U_{ab} to the total applied voltage U_{ac} .

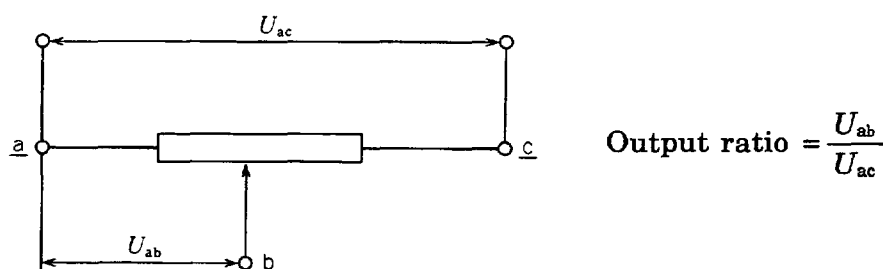


Fig. 8 Output ratio

It is normally expressed as a percentage of the total applied voltage.

2.2.46 Minimum output ratio The ratio of the minimum voltage value which can be obtained between the moving contact termination and one or other of the end terminations to a fixed voltage applied between the end terminations.

2.2.47 Attenuation The reciprocal of the output ratio. It is normally expressed as:

$$20 \log \frac{U_{ac}}{U_{ab}} \text{ dB}$$

2.2.48 Loading error (see Fig. 9) The difference between the output ratio with an infinite load resistance and the output ratio with a specified finite load resistance at any spindle position as long as it is the same position for both output ratio measurements.

Remarks : Minimizing the loading error, by compensating the resistance element to give the desired output voltage with a specified load resistance, is referred to as "load compensation".

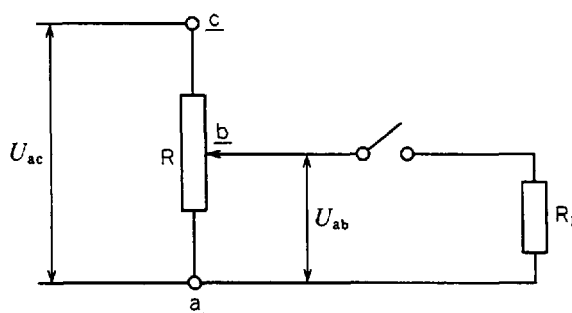


Fig. 9 Loading error

2.2.49 Resistance/travel relationships The following definitions apply to two general constructions:

- Potentiometers fitted with end stops or with declutching devices.
- Single turn rotary potentiometers not fitted with end stops or declutching devices.

The amount of travel may be expressed in degrees, number of turns or millimetres.

For other constructions the detail specification shall redefine the terms or definitions.

Remarks : The alternative terms given in parentheses in 2.2.49.1, 2.2.49.3 and 2.2.49.4 are included for information only.

2.2.49.1 Total mechanical travel (total mechanical rotation) (see Fig. 10) For 2.2.49 a), the total mechanical travel is the value of the movement of the actuating device while the moving contact traverses the whole of its function between the two end stops or, the two positions at which the declutching device operates. In 2.2.49 b), the total mechanical is travel 360°.

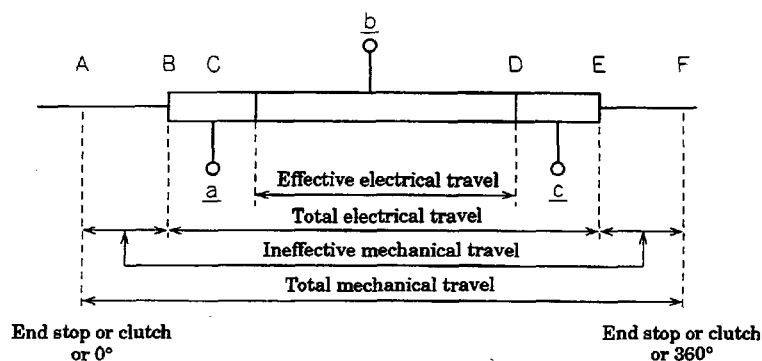


Fig. 10 Travel range

2.2.49.2 Total electrical travel (see Fig. 10) The amount of travel of the actuating device between two end positions during which there should not normally be any interruption in contact between the moving contact and the resistive element.

Remarks : For 2.2.49 a), the end positions usually coincide with the end stops or the positions at which the declutching device operates, and the total electrical travel is therefore the same as the total mechanical travel.

2.2.49.3 Effective electrical travel (angle of effective electrical rotation) The amount of travel of the actuating device necessary to move the moving contact in such a manner that the resistance changes as prescribed by the specified resistance law.

Remarks : For some constructions of potentiometer, the effective electrical travel may be the same as the total electrical travel.

2.2.49.4 Ineffective mechanical travel (angle of ineffective mechanical rotation) (see Fig. 10) The part of the mechanical travel where the continuity between the moving contact and the resistance element cannot be guaranteed. It is equal to the difference between the total mechanical travel and the total electrical travel.

2.2.49.5 Total resistance The total resistance is the resistance between terminations a and c (R_{ac}) when measured as described in 4.6.

2.2.49.6 Effective resistance The portion of the total resistance over which the resistance changes in the manner prescribed by the specified resistance law.

2.2.49.7 Minimum effective resistance The resistance value, at each end of the effective electrical travel, between termination b and the nearer end termination a or c (see 4.4.6), normally expressed as a percentage of the total resistance.

2.2.49.8 Continuity The maintenance of electrical contact between the moving contact and the resistive element as a function of the mechanical travel of the moving contact.

2.2.49.9 Conformity (see Fig. 11) The maximum measured difference between the actual and the specified resistance law when it is expressed as a percentage of total resistance or total voltage applied.

Remarks : Conformity may be expressed in different ways and must be clearly specified in the detail specification. Some methods of expressing conformity are shown in the following item.

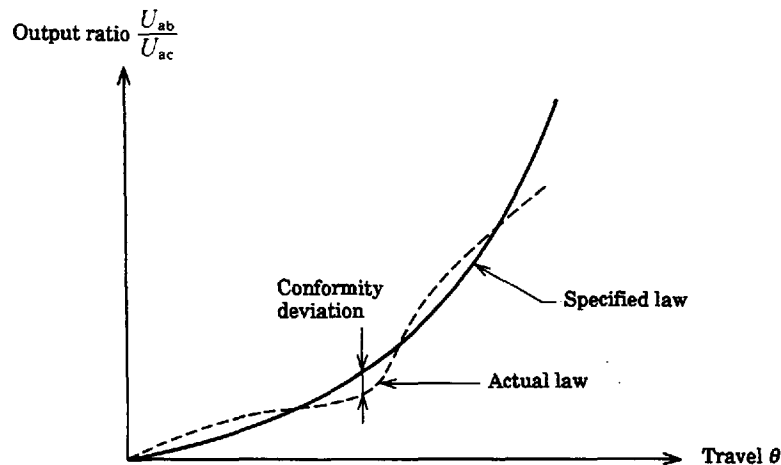


Fig. 11 Conformity

2.2.49.10 Absolute conformity (see Fig. 12) The conformity measured over the specified effective electrical travel and is expressed as the maximum deviation of the actual from the specified resistance law.

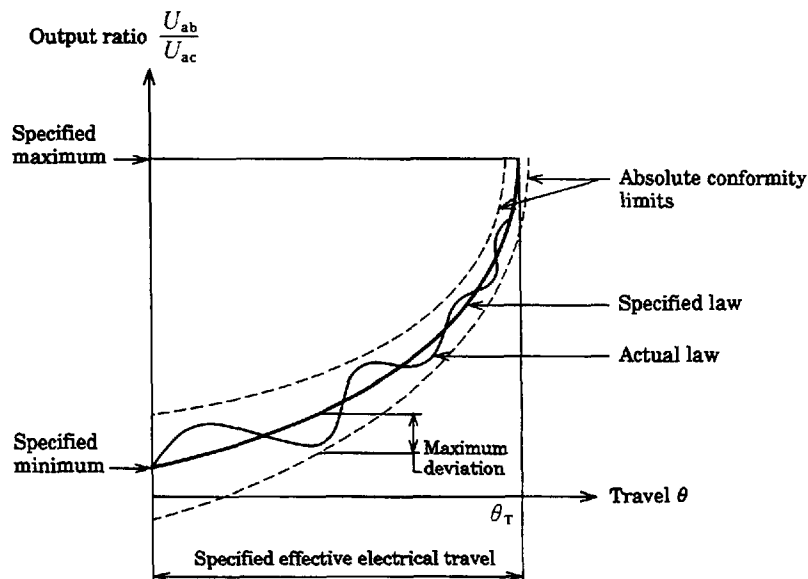


Fig. 12 Absolute conformity

2.2.49.11 Linearity (see Fig. 13) The specific type of conformity when the specified law or output ratio is shown as a straight line.

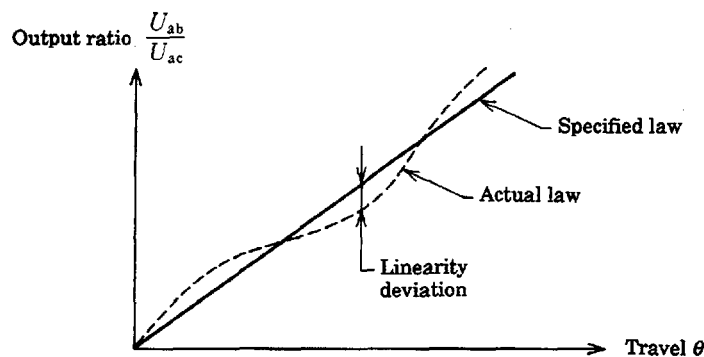


Fig. 13 Linearity

2.2.49.12 Independent linearity (best straight line) (see Fig. 14) The specific type of conformity when the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line with its slope and position is chosen to minimise deviations over the effective electrical travel, or any specified portion thereof.

Remarks : Requirements for minimum and maximum output ratio, when specified, will limit the slope and position of the reference line.

Formula is,

$$\frac{U_{ab}}{U_{ac}} = P\left(\frac{\theta}{\theta_A}\right) + Q \pm C$$

where, P is the unspecified slope, Q is the unspecified intercept at $\theta = 0$, and where P and Q are chosen to minimise C but are limited by the output ratio requirement, and θ_A is the amount of effective electrical travel.

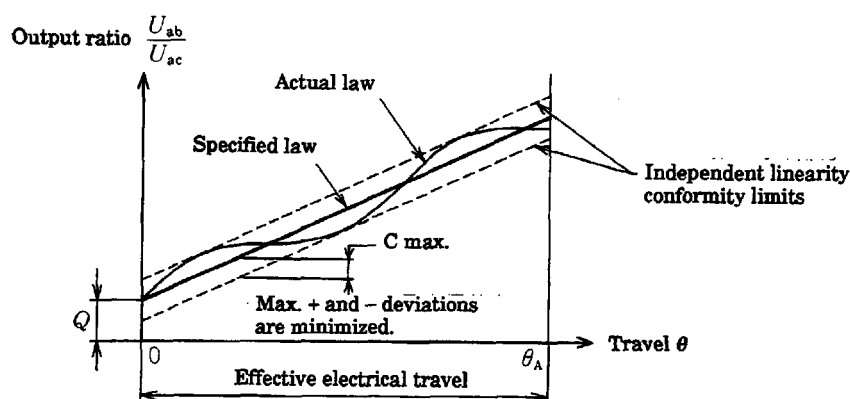


Fig. 14 Independent linearity

2.2.49.13 Zero based linearity (see Fig. 15) (for wirewound potentiometers only) The specific type of conformity when the maximum vertical deviation, expressed as a percentage of total applied voltage, of the actual law from a straight reference line drawn through the specified minimum output ratio extended over the effective electrical travel, with its slope chosen to minimise the maximum deviations.

Any specified requirement for maximum output ratio may limit the possibility to change the slope of the reference line.

Unless otherwise specified, the specified minimum output ratio will be zero.

Formula is,

$$\frac{U_{ab}}{U_{ac}} = P\left(\frac{\theta}{\theta_A}\right) + B \pm C$$

where, P is the unspecified slope limited by the end voltage requirement at the maximum output ratio end; θ_A = amount of effective electrical travel.

Unless otherwise specified: $B = 0$

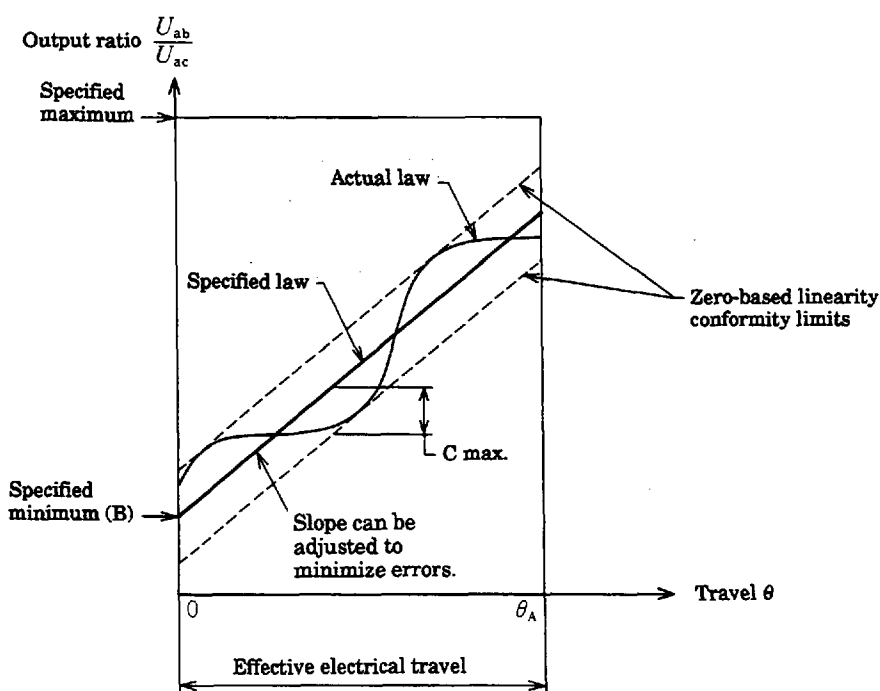


Fig. 15 Zero-based linearity

2.2.49.14 Absolute linearity (see Fig. 16) The specific type of conformity where the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line drawn through the specified minimum and maximum output ratios which are separated by the specified effective electrical travel. Unless otherwise specified, minimum and maximum output ratios are respectively zero and 100 % of the total applied voltage.

Formula is,

$$\frac{U_{ab}}{U_{ac}} = A\left(\frac{\theta}{\theta_T}\right) + B \pm C$$

where, A is the given slope, B is the given intercept and $\theta = 0$; θ_T is the total specified effective electrical travel. Unless otherwise specified $A = 1$ and $B = 0$.

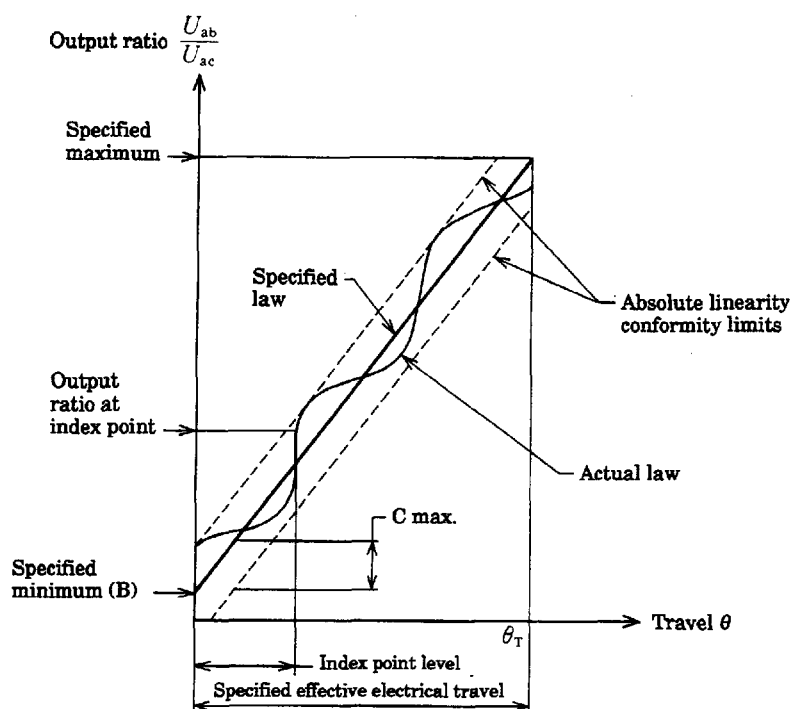


Fig. 16 Absolute linearity

2.2.49.15 Terminal based linearity (see Fig. 17) (for wirewound potentiometers only) The specific type of conformity where the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line drawn through the specified minimum and maximum output ratios which are separated by the effective electrical travel. Unless otherwise specified, minimum and maximum output ratios are respectively, zero and 100 % of total applied voltage.

Formula is,

$$\frac{U_{ab}}{U_{ac}} = A\left(\frac{\theta}{\theta_A}\right) + B \pm C$$

where, A is the given slope; B is the given intercept at $\theta = 0$; θ_A is the amount of effective electrical travel. Unless otherwise specified $A = 1$ and $B = 0$.

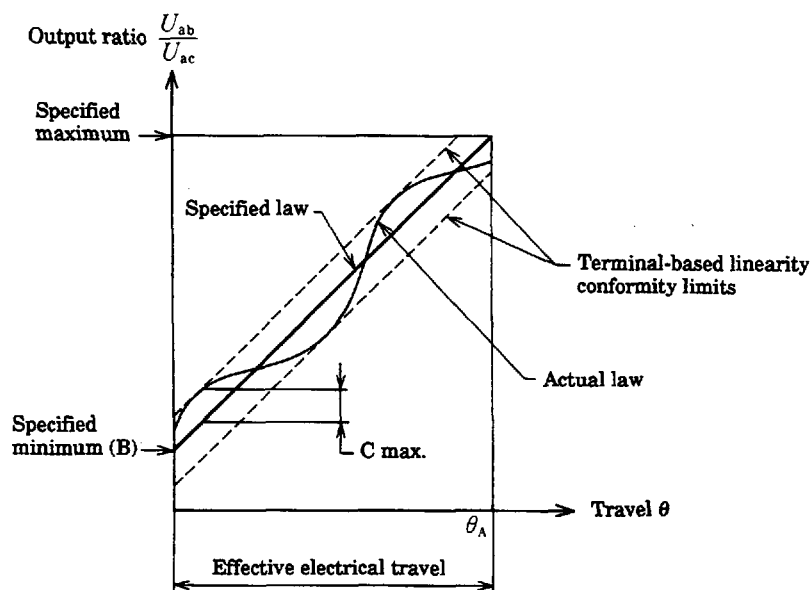


Fig. 17 Terminal based linearity

2.2.49.16 Index point A A point of reference fixing the relationship between a specified actuating device position and the output ratio. It is used to establish an actuating device position reference.

2.2.49.17 Tap location The tap location is the position of a tap relative to some reference.

This is commonly expressed in terms of resistance, output ratio or actuating device position. When an actuating device position is specified, the tap position is the centre of the effective tap width.

2.2.49.18 Effective tap width (see Fig. 18) The effective tap width is the travel of the actuating device, during which the voltages at the moving contact termination b and the tap connection are essentially the same as the moving contact is moved past the tap in one direction.

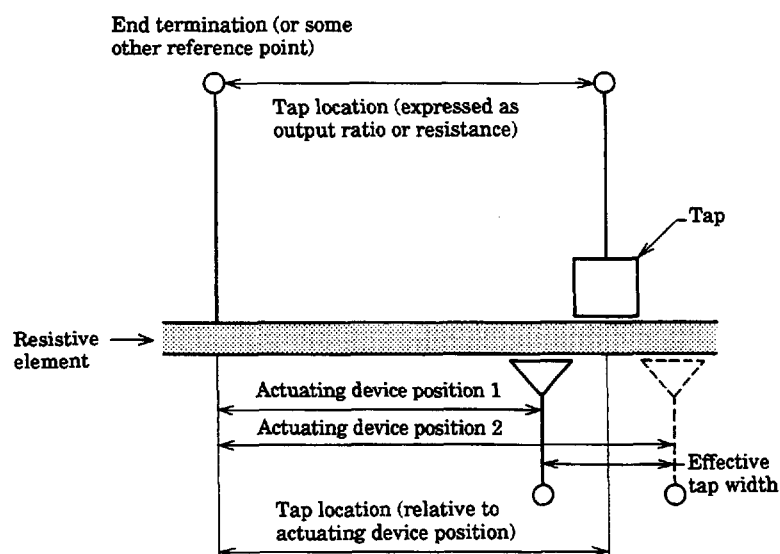


Fig. 18 Effective tap width

2.2.49.19 Phasing The relative alignment of the phasing points of each section of a ganged potentiometer.

2.2.49.20 Phasing point A point of reference on each section to have the relative alignment of the sections of a ganged potentiometer with respect to the position of the moving contacts.

2.2.49.21 Rotational noise Any unwanted variation in the electrical output not present in the input, when moving the moving contact and caused by contact resistance variation and/or track resistance variation.

2.2.49.22 Contact resistance variation (C.R.V.) Change of the resistance between the resistive element and the moving contact when it is moved at a defined speed.

2.2.49.23 Track resistance variation (T.R.V.) Unwanted changes of the output ratio when the moving contact is moved at a defined speed, caused by irregularities of the track.

2.2.49.24 Output smoothness (for non-wirewound types only) Unwanted variation in the electrical output not present in the input. Output smoothness includes effects of contact resistance variations, resolution, and other micro-nonlinearities in the output.

It is expressed as a percentage of the total applied voltage and measured for specified travel increments over the effective electrical travel.

2.2.49.25 Setting ability or resolution (adjustability) The accuracy with which the resistance or output voltage ratio of a potentiometer can be set to a desired value. It is normally expressed as a percentage of the total resistance.

2.2.49.26 Theoretical resolution The reciprocal of the number of turns of the resistance winding in the effective electrical travel and is expressed as a percentage. This term is used in the description of wirewound potentiometers and is a measure of sensitivity to which the output ratio of the potentiometer may be set.

2.2.49.27 Simultaneous conformity phasing The relative alignment of the sections of a ganged potentiometer, from a common reference point, such that the output ratios of all sections fall within their respective conformity limits over the effective electrical travel.

2.2.49.28 Backlash (see Fig. 19) The maximum difference in the actuating device position that occurs when it is moved to the same actual output ratio point from opposite directions.

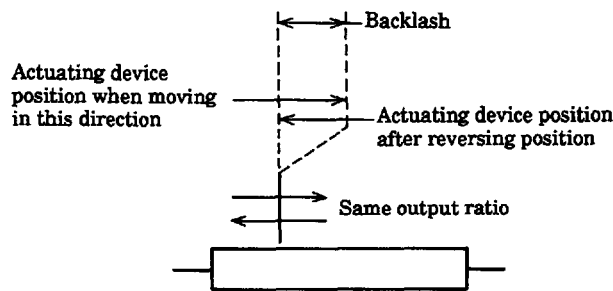


Fig. 19 Backlash

2.2.49.29 Dither A movement of the operating spindle to simulate conditions which may occur in servo systems.

2.2.49.30 Microlinearity The relative change of linearity deviation (see independent linearity) measured for small travel increments and expressed as a percentage of the applied voltage.

2.2.50 Rotary potentiometer (single-turn or multi-turns) Potentiometer actuated by an axial spindle perpendicular to the direction of rotation, and operated frequently to adjust voltage or resistance value.

2.2.51 Power potentiometer Potentiometer having a resistive element designed and constructed for high internal temperature rise and heat transfer capability.

2.2.52 Precision potentiometer Potentiometer of which the output voltage or resistance law meets a precisely defined law as a function of the position of the actuating device.

2.2.53 Slide potentiometer Potentiometer actuated by a rectilinear movement of an actuator and operated frequently to adjust voltage or resistance value.

2.2.53A Surface mounting type potentiometer Small size potentiometer with characteristics and shape suitable for mounting on printed circuit board and hybrid circuit.

2.3 Preferred values

2.3.1 General Each sectional specification shall specify the preferred values appropriate to the sub-family. For rated resistance see also 2.3.2.

2.3.2 Preferred values of rated resistance The preferred values of rated resistance shall be taken from the E series and/or 1, 2, and 5 series specified in JIS C 5063.

2.3.2A Recommended size of a spindle and a mounting device shall be in accordance with Annex 2.

2.4 Marking

2.4.1 General Any marking used on the potentiometers or their packages shall be in conformity with that given in the relevant sectional and detail specifications.

Remarks : When the relevant specifications specify, the marking may comply with Annex 1.

2.4.2 Coding When coding is used for resistance value, tolerance or date of manufacture, the method shall be selected from those given in **JIS C 5062**.

Remarks : When the relevant specifications specify, the coding and marking shall comply with symbols specified in Annex 1.

Section Three—Quality assessment procedures

3 Quality assessment procedures

3.1 Qualification approval/quality assessment systems

3.1.1 When this document is being used for the purposes of a full quality assessment system with qualification approval and quality conformance inspection such as the IEC Quality Assessment System for Electronic Components (IECQ), the procedures in 3.4 and 3.5 shall be applied.

3.1.2 When this document is used for purposes of design proving or type testing other than quality assessment systems as the IECQ system, the procedures and requirements of 3.4.1 and 3.4.2 b) may be used, but the tests and parts of tests shall be applied in the order given in the test schedules.

3.2 Primary stage of manufacture For potentiometers, the primary stage of manufacture is:

- For film types: the deposition of the resistive film on the substrate.
- For carbon composition types: the process which produces the greatest change in polymerisation of the binder.
- For wirewound types: The winding of the resistance wire (or ribbon) on the former.
- For metal composition (thick film): the deposition of the resistive film on the substrate.

3.3 Structurally similar components The grouping of structurally similar components for the purpose of qualification approval and quality conformance inspection shall be prescribed in the sectional specification.

3.4 Qualification approval procedures

3.4.1 The manufacturer shall comply with the followings:

- the general requirements of the rules of procedure governing qualification approval.

- the requirements for the primary stage of manufacture contained in 3.2 of this Standard.

3.4.2 In addition to the requirements of 3.4.1, the procedure a) or b) shall be applied.

- The manufacturer shall produce three lots for lot-by-lot inspection for getting evidence of conformance to the requirements in the specification and one lot for periodic inspection in as short period as possible. No major changes in the manufacturing process shall be made during the period of producing the inspection lots.

The samples shall be taken from the lots in accordance with **JIS Z 9015**. In the case of application of IECQ, Annex B shall be applied.

The samples shall be of the highest and lowest resistance representing the lots. When the critical resistance is less than the highest resistance and more than the lowest resistance, the lots shall contain the products of critical resistance. The highest and lowest resistance values shall be selected from the resistance range for which qualification approval is sought.

The inspection shall be normal inspection, but when the reference number of acceptance is zero defective, number of specimens shall be increased to have one defective for reference of acceptance.

- The manufacturer shall produce test evidence to show conformance with the specified requirements on the fixed sample size test schedule defined in the sectional specification.

The specimens for test shall be picked up at random from the current production or as agreed with the National Supervising Inspectorate (NSI) to receive an approval by IECQ.

3.4.3 Qualification approval obtained as a part of quality assessment system shall be maintained by regular demonstration of compliance with the requirements for quality conformance inspection (see 3.5). For the maintenance of qualification approval in IECQ, the demonstration shall be in compliance with the rules of procedure for IEC Quality Assessment System for Electronic Components, items 11.5.2 and 11.5.3 of 11.5 (Maintenance of qualification approval) of IEC QC 001002.

3.5 Quality conformance inspection The blank detail specification(s) associated with a sectional specification shall prescribe the test schedule for quality conformance inspection. This schedule shall specify the grouping, sampling and period of lot-by-lot inspection, and also period of regular inspection. Inspection level and AQL shall be selected from those given in **JIS Z 9015**. If required, more than one schedule shall be specified.

3.5.1 Certified records of released lots When certified records of released lots are prescribed in the relevant specification and are requested by a purchaser, the following information shall be given as a minimum.

- Information of test results Attributes information (i.e. number of components tested and number of defective components) for the sub-groups covered by periodic inspection without reference to the parameter for which rejection was made.
- Information of the change in resistance after 1 000 h endurance test.

3.5.1.1 Attributes information When the relevant detail specification requires that attributes information shall be recorded, the following procedures shall be used.

- a) When a sub-group comprises a single conditioning test, the total number of rejected potentiometers shall be recorded together with the test in which the failures occurred but without reference to the parameters for which the rejection was made.
- b) When a sub-group comprises a number of conditioning tests, the relevant detail specification shall state whether the results shall be recorded for the individual conditioning test or for a number of them as a group. For the purposes of this specification, the climatic sequence test shall be deemed to form a single conditioning test.

3.5.2 Delayed delivery The lot of potentiometer held for a period exceeding two years (unless otherwise specified in the sectional specification) shall, before delivery, be re-examined for solderability and resistance as specified in group A or B inspection of the detail specification.

When IECQ is applied, the re-examination procedure adopted by the manufacturer's chief inspector shall be approved by the National Supervising Inspectorate (NSI).

Once the "lot" has passed the inspection, its quality is reassured for the specified period.

3.5.3 Release for delivery before the completion of group B tests When the conditions of JIS Z 9015 for changing to reduced severity inspection have been satisfied for all group B tests, the manufacturer is permitted to release components before the completion of such tests.

3.6 Alternative test methods The test and measurement methods given in the relevant specification are not necessarily the only methods which can be used. However, the manufacturer may use alternative methods which will give results equivalent to those obtained by the methods specified. When IECQ is applied, the alternative methods have to be approved by the Japanese Supervising Inspectorate before the inspection. In case of dispute, for referee and reference purposes the specified methods only shall be used.

3.7 Unspecified parameters Those parameters of a component which have been specified in a detail specification are subject to testing and only those parameters of components inspected can be assumed to be within the specified limits.

It should not be assumed that any parameter not specified will valid from one component to another. Should for any reason it be necessary for (a) further parameter(s) to be added, then a new, more extensive, specification should be prepared.

The additional test method(s) shall be fully described with appropriate limits, AQL's and inspection levels.

Section Four—Test and measurement procedures

4 Procedures of test and measurement

4.1 General The sectional and/or blank detail specifications shall contain tables showing the test items to be made, and describe tests to be carried out and measurement items to be made before and after each test or sub-group of tests, and the sequence in which they shall be carried out. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If Japanese specifications for quality assessment system include methods other than those specified above, they shall be fully described.

The issues and amendments of any JIS C 00 series, test, in this Section is given in 2.1 of this Standard.

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing Unless otherwise specified, all tests and measurements shall be made under the standard atmospheric conditions for testing as given in 5.3 (Standard atmospheric conditions) of JIS C 0010.

Temperature: 15 °C to 35 °C

Relative humidity: 25 % to 75 %

Air pressure: 86 kPa to 106 kPa

Before the measurements are made, the potentiometer shall be kept at the measuring temperature for a time sufficient to allow the entire potentiometer to reach this temperature. The same period as is prescribed for recovery at the end of a test is normally sufficient for this purpose.

When measurements are made at a temperature other than the specified temperature, the results shall, when necessary, be corrected to those at specified temperature.

The ambient temperature of the measurement instruments shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (see 4.2.3) and such other conditions as are prescribed in this specification.

When tests are conducted in a sequence, the final measurements of one test may be taken as the initial measurements for the succeeding test.

Remarks : During measurements the potentiometer shall not be exposed to draughts, direct sun-rays or other influences likely to cause error.

4.2.2 Recovery conditions Unless otherwise specified, recovery shall take place under the standard atmospheric conditions for testing (see 4.2.1).

If recovery has to be made under closely controlled conditions, the standard recovery conditions of 5.4.1 (Controlled recovery condition) of JIS C 0010 shall be used.

4.2.3 Referee conditions For referee purpose one of the standard atmospheric conditions for referee tests taken from 5.2 (Referee conditions) of JIS C 0011, as given below, shall be chosen.

Temperature	Relative humidity	Air pressure
(20 ± 1) °C	63 % to 67 %	86 kPa to 106 kPa
(23 ± 1) °C	48 % to 52 %	86 kPa to 106 kPa
(25 ± 1) °C	48 % to 52 %	86 kPa to 106 kPa
(27 ± 1) °C	63 % to 67 %	86 kPa to 106 kPa

4.2.4 Reference conditions For reference purposes the standard atmospheric conditions for reference as below given in 5.1 (Reference conditions) of JIS C 0011 apply.

Temperature: 20 °C

Air pressure: 101.3 kPa

Only temperature may be set as standard condition.

Informative reference : The requirement for relative humidity shall not be specified because compensation by calculation is not generally available.

4.3 Drying When drying is prescribed, the potentiometer shall be conditioned before measurement is made, using procedure I or procedure II as prescribed in the detail specification.

Procedure I: for (24 ± 4) h in an oven at a temperature of (55 ± 2) °C and at a relative humidity not exceeding 20 %.

Procedure II: for (96 ± 4) h in an oven at (100 ± 5) °C.

The potentiometer shall then be cooled in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

4.4 Visual examination and check of dimensions

4.4.1 Visual examination The condition, workmanship and finish shall be checked by visual examination (see 2.2.20).

Marking shall be legible, as checked by visual examination. It shall conform with the requirements of the detail specification.

4.4.2 Dimensions (gauging) The dimensions indicated in the detail specification shall be checked by suitable gauge, and shall comply with the values prescribed in the detail specification.

4.4.3 Dimensions (detail) All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

4.4.4 Total mechanical travel The potentiometer shall be mounted for the measurement of the angular position of the actuating device. The actuating device shall then be set so that the moving contact is at the extreme anti-clockwise end of the total mechanical travel and the angular position (A) shall be recorded. The actuating

device shall then be set so that the moving contact is at the extreme clockwise end of the total mechanical travel, and the angular position (F) shall be recorded (see Fig. 10).

The total mechanical travel is given by: $F - A$

The calculated value shall be within the limits given in the detail specification.

4.4.5 Total electrical travel While mounted for measurement of angular position, a voltage not exceeding the specified value (see 4.6.1) shall be applied between terminals a and c.

The actuating device shall be set at the approximate centre of the total mechanical travel and the electrical continuity shall be monitored as the actuating device is turned slowly anti-clockwise until there is an interruption in contact between the moving contact and the resistance element. The angular position (B) of that interruption shall then be recorded. If no interruption occurs, record the position of the end of the mechanical travel.

The actuating device shall then be set at the approximate centre of the total mechanical travel and the electrical continuity shall be monitored as the actuating device is turned slowly clockwise until there is an interruption in contact between the moving contact and the resistance element. The angular position (E) of that interruption shall then be recorded. If no interruption occurs, record the position of the end of the mechanical travel (see Fig. 10).

The total electrical travel is given by: $E - B$

The value calculated shall be within the limits given in the detail specification.

4.4.6 Effective electrical travel While mounted for measurement of angular position a voltage not exceeding that given in 4.6.1 shall be applied between terminals a and c.

The actuating device shall then be set at the approximate centre of the total electrical travel and then slowly turned anti-clockwise until the output ratio U_{ab}/U_{ac} is within 5 % of the minimum effective resistance when expressed as a percentage of the total resistance. The angular position (C) shall then be recorded.

The actuating device shall then be set at the approximate centre of the total electrical travel and then slowly turned clockwise until the output-ratio U_{bc}/U_{ac} is within 5 % of the minimum effective resistance when expressed as a percentage of the total resistance. The angular position (D) shall then be recorded (see Fig. 10).

Remarks : If a greater accuracy is required, the 5 % tolerance on the output ratio at the minimum effective resistance may be reduced as stated in the detail specification.

The angle of effective electrical travel is given by: $D - C$

The value calculated shall be within the limits given in the detail specification.

The angle of ineffective travel (anti-clockwise) is the amount of travel between position A and position C.

The angle of ineffective travel (clockwise) is the amount of travel between position F and position D.

4.5 Continuity (except for continuously rotating potentiometers)

4.5.1 The potentiometer shall be loaded in such a way that none of its ratings is exceeded throughout the measurement. The resistance variation between terminals a and b is observed whilst the spindle or lead-screw is operated steadily in each direction at a rate of 2 cycles to 5 cycles (see 2.2.38) per minute.

The resistance variation between terminals a and b shall be reasonably smooth and unidirectional when the spindle is rotated slowly (or the moving contact of a lead-screw actuated device is traversed slowly).

Unless otherwise specified there shall be no electrical discontinuity when the moving contact is moved over the total electrical travel.

4.5.2 There shall be no electrical discontinuity when the clutch is acting at each end of the travel of the moving contact of potentiometers fitted with slipping clutches.

4.6 Element resistance

4.6.1 The measurement shall be made with the moving contact having been set at the end of its travel by anti-clockwise rotation of the actuating device (see Remarks in 4.6.2).

The resistance shall be measured using a low direct voltage for as short a time as possible, in order to avoid temperature rise of the resistance element.

In the event of conflicting results, attributable to such test voltages, the voltage specified in the following table shall be used for referee purposes.

Rated resistance R	Measuring voltage V_{-10}^0 %
$R < 10 \Omega$	0.1
$10 \Omega \leq R < 100 \Omega$	0.3
$100 \Omega \leq R < 1 \text{ k}\Omega$	1
$1 \text{ k}\Omega \leq R < 10 \text{ k}\Omega$	3
$10 \text{ k}\Omega \leq R < 100 \text{ k}\Omega$	10
$100 \text{ k}\Omega \leq R < 1 \text{ M}\Omega$	25
$1 \text{ M}\Omega \leq R$	50

Remarks : When a digital resistance meter is used, the values in the table shall be the maximum measuring voltage.

4.6.2 The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the tolerance. When the measurement forms part of a test sequence, it shall be possible to measure a change of resistance with an error not exceeding 10 % of the maximum change permitted for that test.

Remarks : For special types of potentiometer it is necessary to give further information on the measurement procedure, including the setting of the moving contact, in the sectional or detail specification.

4.6.3 The resistance value, at 20 °C, between terminations a and c shall be equal to the rated resistance, taking account of the tolerance.