



IEC 60393-1

Edition 3.0 2008-05

INTERNATIONAL STANDARD

Potentiometers for use in electronic equipment –
Part 1: Generic specification

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**Potentiometers for use in electronic equipment –
Part 1: Generic specification**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POTENTIOMETERS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

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International Standard IEC 60393-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This third edition cancels and replaces the second edition published in 1989 and constitutes a technical revision, including minor revisions related to tables, figures and references.

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

- implementation of Annex H which replaces Section 3 of the previous edition.

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

FDIS	Report on voting
40/1897/FDIS	40/1914/RVD

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

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

A list of all the parts of the IEC 60393 series, under the general title *Potentiometers for use in electronic equipment*, can be found on the IEC web site.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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

POTENTIOMETERS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

1 General

1.1 Scope

This part of IEC 60393 is applicable to all types of resistive potentiometers, including lead-screw actuated types, presets, multi-turn units, etc. to be used in electronic equipment.

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications of electronic components for quality assessment or any other purpose.

It has been mainly written, and the test methods described, to conform to the widely used single-turn rotary potentiometer with an operating shaft.

For other types of potentiometers:

- the angle of rotation may be several turns;
- the reference to an operating shaft shall apply to any other actuating device;
- the angular rotation shall be taken to mean mechanical travel of the actuating device;
- a value for force shall be prescribed instead of a value for torque if the actuating device moves in a linear instead of a rotary manner.

These alternative prescriptions will be found in the sectional or detail specification.

When a component is constructed as a variable resistor, i.e. as a two-terminal device, the detail specification shall prescribe the modifications required in the standard tests.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)*

IEC 60062, *Marking codes for resistors and capacitors*

IEC 60063:1963, *Preferred number series for resistors and capacitors*

Amendment 1 (1967)

Amendment 2 (1977)

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

Amendment 1 (1992)

IEC 60068-2-1:1990, *Environmental testing – Part 2: Tests – Tests A: Cold*

Amendment 1 (1993)

Amendment 2 (1994)

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc : Vibration (sinusoidal)*

IEC 60068-2-13, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14:1994, *Environmental testing – Part 2: Tests – Test N: Change of temperature*
Amendment 1 (1986)

IEC 60068-2-17, *Environmental testing – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Test T: Soldering*
Amendment 2 (1987)

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29, *Environmental testing – Part 2: Tests – Test Eb and guidance: Bump*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test dB : Damp heat, cyclic (12 h + 12 hour cycle)*

IEC 60068-2-45:1980, *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*
Amendment 1 (1993)

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-78, *Environmental testing – Part 2-78 – Test Cab: Damp heat, steady state*

IEC 60410, *Sampling plans and procedures for inspection by attributes*

IEC 60617, *Graphical symbols for diagrams*

IEC 60915, *Capacitors and resistors for use in electronic equipment – Preferred dimensions of shaft ends, bushes and for the mounting of single-hole, bush-mounted, shaft-operated electronic components*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IECQ 001002-3, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of procedure – Part 3: Approval procedures*

IECQ 001005, see www.iecq.org/certificates for relevant information

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units*

ISO 9000, *Quality management systems – Fundamentals and vocabulary*

2 Technical data

2.1 Units and symbols

Units, graphical symbols and letter symbols should, whenever possible, be taken from the following publications:

- IEC 60027-1;
- IEC 60050;
- IEC 60617;
- ISO 1000.

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

2.2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.2.1

type

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

NOTE 1 Components described in several detail specifications may, in some cases, be considered as belonging to the same type and may therefore be grouped for quality assessment purpose.

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

NOTE 3 Ratings are to be given in the detail specification.

2.2.2

style

subdivision of a type, generally based on dimensional factors, which may include several variants, generally of a mechanical order

2.2.3

grade

term indicating additional general characteristics concerning the intended application, for example, long-life applications which may only be used in combination with one or more words (for example, long-life grade) and not by a single letter or number. Figures to be added after the term “grade” should be Arabic numerals

2.2.4

variant

subdivision within a style having specific dimensions for some part of its construction, for example, terminals, shaft flats or length (see Annex F)

2.2.5

family (of electronic components)

group of electronic components which predominantly displays a particular physical attribute and/or fulfils a defined function

2.2.6

subfamily (of electronic components)

group of components within a family manufactured by similar technological methods

2.2.7**category temperature range**

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

2.2.8**upper category temperature**

maximum ambient temperature for which a potentiometer has been designed to operate continuously at that portion of the rated dissipation which is indicated in the category dissipation (see 2.2.13)

2.2.9**lower category temperature**

minimum ambient temperature for which a potentiometer has been designed to operate continuously

2.2.10**critical resistance**

resistance value at which the rated voltage is equal to the limiting element voltage. Below the critical resistance the maximum voltage which may be applied across the terminals of a potentiometer is the rated voltage. Above that value the maximum voltage is the limiting element voltage (see 2.2.12, 2.2.14 and 2.2.15)

2.2.11**nominal total resistance**

resistance value for which the potentiometer has been designed and which is generally marked upon the potentiometer

2.2.12**rated dissipation**

maximum allowable dissipation between terminals a and c (see 2.2.29) of a potentiometer at an ambient temperature of 70 °C under the conditions of the electrical endurance test at 70 °C which will result in a change in resistance not greater than that specified for that test

NOTE 1 In practice, the dissipation is modified by the following conditions.

NOTE 2 For high values of resistance, the limiting element voltage (see 2.2.15) may prevent the rated dissipation being attained

NOTE 3 For the dissipation at temperatures other than 70 °C, reference should be made to the rating graphs in the relevant detail specification

NOTE 4 For situations where only terminals a and b or b and c are being used and the control shaft is set at an angle less than 100 % of the effective electrical travel, the limiting moving contact current (see 2.2.17) should also be taken into account.

2.2.13**category dissipation**

maximum allowable dissipation under continuous load at an ambient temperature equal to the upper category temperature, normally expressed as a percentage of the rated dissipation

NOTE The category dissipation may be zero.

2.2.14**rated voltage**

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

NOTE At high values of resistance, the rated voltage may not be applicable because of the size and construction of the potentiometer (see 2.2.10, 2.2.12 and 2.2.15).

2.2.15**limiting element voltage**

maximum d.c. or a.c. r.m.s. voltage which may be applied across the element of a potentiometer

NOTE 1 When the term “a.c. r.m.s. voltage” is used in this specification, the peak voltage should not exceed 1,42 times the r.m.s. value.

NOTE 2 This voltage should only be applied to potentiometers when the resistance value is equal to, or higher than, the critical value.

2.2.16**insulation voltage**

maximum peak voltage under continuous operating conditions which may be applied between the potentiometer terminals and other external conducting parts connected together

NOTE The value of the insulation voltage should be not less than 1,42 times the limiting element voltage at normal air pressure. Under conditions of low air pressure, the value of the insulation voltage will be less and should be given in the detail specifications.

2.2.17**limiting moving contact current**

maximum current that may be passed between the resistance element and the moving contact

2.2.18**variation of resistance and voltage output ratio with temperature**

can be expressed either as a temperature characteristic or as a temperature coefficient as defined below

2.2.18.1**temperature characteristic of resistance**

maximum reversible variation of resistance produced over a given temperature range within the category temperature range, expressed normally as a percentage of the resistance related to a reference temperature of 20 °C

2.2.18.2**temperature coefficient of resistance (α_r)**

relative variation of resistance between two given temperatures (mean coefficient), divided by the difference in temperature producing it, preferably expressed in parts per million per °C ($10^{-6}/K$)

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

2.2.18.3**temperature coefficient of output ratio (α_o)**

relative variation of voltage output ratio between two given temperatures (mean coefficient) at fixed values of setting and load of the moving contact, divided by the difference in temperature producing it, preferably expressed in parts per million per °C

NOTE 1 The value of α_o may be different for different settings of the output ratio.

NOTE 2 It should be noted that the use of the term does not imply that the function exhibits any degree of linearity, nor should any be assumed.

2.2.19**visible damage**

damage which reduces the usability of the potentiometer for its intended purpose

2.2.20**potentiometer**

component for use as a voltage divider with three terminals of which two are connected to the ends of a resistive element and the third is connected to a moving contact which can be moved mechanically along the resistive element

2.2.21**pre-set or trimmer (or trimming) potentiometer**

potentiometer designed for relatively infrequent adjustment

2.2.22**lead-screw actuated potentiometer**

potentiometer having a lead-screw as multi-turn actuating device

2.2.23**ganged potentiometers**

potentiometers consisting of two or more sections operated by a common operating shaft. The number of sections shall be included in the description, for example, 2-ganged potentiometer or 4-ganged potentiometer

2.2.24**dual concentric potentiometers**

potentiometers consisting of two sections operated independently by concentric operating shafts

2.2.25**shaft-sealed potentiometer**

potentiometer in which a shaft seal is provided to prevent particles and fluid from passing from the exterior of the potentiometer to the interior by way of the shaft bearing (see Figure 1)

2.2.26**shaft-sealed and panel-sealed potentiometer**

potentiometer in which a shaft seal and a panel seal are provided to prevent particles and fluid from entering any equipment in which this potentiometer is mounted (see Figure 2)

2.2.27**fully sealed potentiometer**

potentiometer in which a shaft seal is provided and the housing of the potentiometer is designed to prevent particles and fluid from passing from the exterior of the potentiometer to the interior (see Figure 3)

In some cases a panel seal may additionally be provided.

Such a potentiometer is called a “fully sealed potentiometer” (see Figure 3).

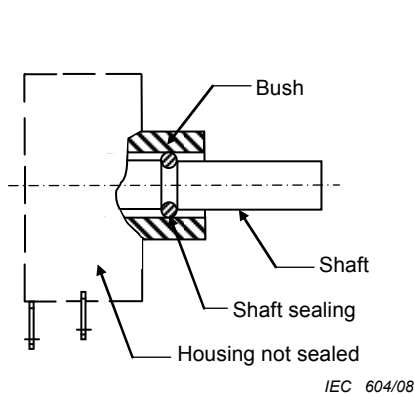


Figure 1 – Shaft-sealed potentiometer

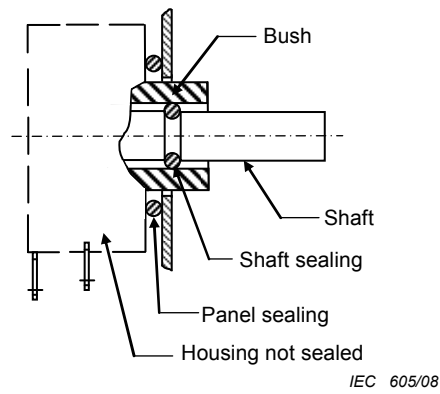


Figure 2 – Shaft- and panel-sealed potentiometer

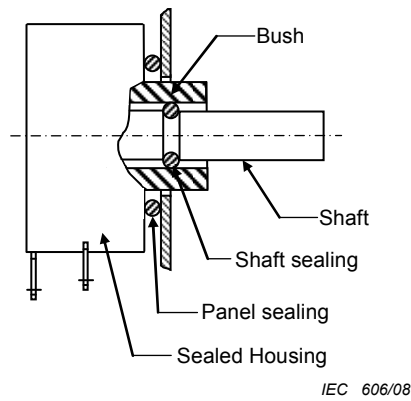


Figure 3 – Fully sealed potentiometer

2.2.28

direction of rotation

defined as clockwise or counter-clockwise when viewing the face of the potentiometer which includes the means of actuation (see Annex G). When doubt exists, the reference face shall be marked in accordance with the detail specification

2.2.29

designation of terminals

preferred designation of the three terminals of the potentiometer is:

- a** is the end terminal electrically nearest to the moving contact with the shaft set fully counter-clockwise as defined in 2.2.28;
- b** is the terminal of the moving contact;
- c** is the other end terminal.

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

2.2.30

variable resistor (two terminals)

variable resistor for use as a current controller with two terminals, one of which being connected to one end of the resistive element and the second to moving contact which can be moved along the resistive element, causing a change in resistance (see 2.2.31)

2.2.31**moving contact (or wiper)**

contact of the potentiometer which moves along the resistive element

2.2.32**tap**

fixed electrical connection made to the resistive element

2.2.32.1**current tap**

electrical connection fixed to the resistive element which is capable of carrying rated element current and may distort the output characteristic

NOTE Current taps on non-wire-wound potentiometers commonly have significant width but low resistance. See 2.2.48.18.

2.2.32.2**voltage tap**

electrical connection fixed to the resistive element which introduces no significant distortion in the output characteristic, usually having significant tap resistance and not being capable of carrying rated element current

NOTE The distinction between current and voltage taps basically applies to taps on non-wire-wound potentiometers. Most taps on wire-wound potentiometers are attached to one turn of wire and can carry rated element current. They do not usually have an effect on resolution or output characteristics.

2.2.33**track**

contact path of the moving contact on the resistive element

2.2.34**stop-clutch device**

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

2.2.35**number of turns** (of an actuating device)

total number of times the actuating device completes (or nearly completes) 360° of movement in covering the total mechanical travel

2.2.36**resistance law**

relationship of measured resistance value between terminals a and b or of the output ratio

$\frac{U_{ab}}{U_{ac}}$ to the mechanical position of the moving contact

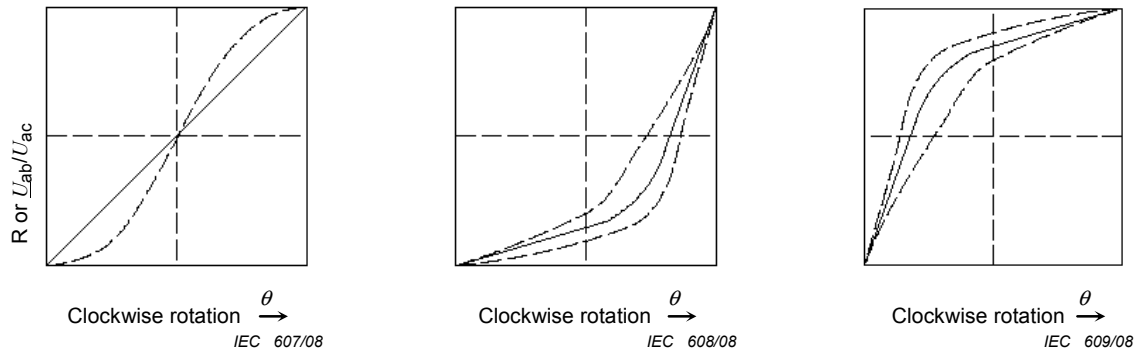
2.2.36.1**common potentiometer laws and classification**

linear resistance law is one having a constant change of resistance or output ratio with angular rotation; non-linear resistance law is one having a variation or lack of constancy in the change of resistance with angular rotation. The resistance law shall conform in general shape to the nominal curves shown in Figure 4 to Figure 6, as applicable

- a) Linear law, see Figure 4;
- b) Logarithmic law, see Figure 5;
- c) Inverse logarithmic law, see Figure 6.

Resistance measurements shall fall within a specified percent of the nominal values shown by the curves at the specified angle of 50 % of electrical rotation.

Examples of common potentiometer law are shown in Annex G of this standard. 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 Figures 4 and 6.



Key

Θ Angle of rotation (clockwise)

Figure 4 – Linear law

Figure 5 – Logarithmic law

Figure 6 – Inverse logarithmic law

2.2.36.2 other potentiometer law

laws other than the widely used laws listed in 2.3.36.1 (for example, sine or cosine) may be required for special applications. The law will then be prescribed in the sectional or detail specification

2.2.37 cycle of operation

cycle of operation, for single and multi-turn potentiometers, which 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, a cycle of operation is defined as two revolutions of 360°, in the same direction, of the moving contact

2.2.38 shorted-segment

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

2.2.39 terminal resistance

minimum resistance which can be obtained between the terminal connected to the moving contact b and any other terminal a or c; see 2.2.29

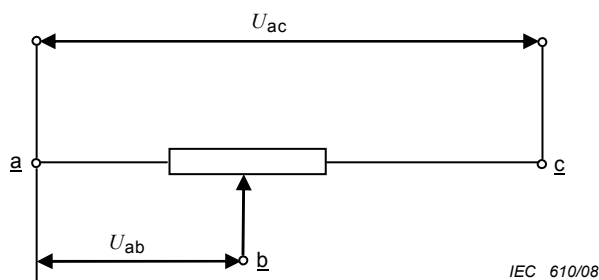
2.2.40 residual resistance

resistance obtained between the end terminal, a or c and the terminal of the moving contact b, when the moving contact is set against the relevant end stop; see 2.2.29

NOTE 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.

2.2.41**load resistance (R_L)** (see Figure 8)external resistance as seen by the output voltage (connected between the moving contact and either terminal a or c)**2.2.42****total applied voltage (U_{ac})** (see Figure 7)voltage applied between input terminals, for example, the voltage applied between input terminations a and c**2.2.43****output voltage (U_{ab})** (see Figure 7)voltage between terminal b and the specified reference point. Unless otherwise specified, the specified reference point is terminal a**2.2.44****output ratio** (see Figure 7)ratio of the output voltage U_{ab} to the total applied voltage U_{ac} normally expressed as a percentage of the total applied voltage

$$\text{Output ratio} = \frac{U_{ab}}{U_{ac}}$$

**Figure 7 – Output ratio****2.2.45****minimum output ratio**

ratio of the minimum voltage value which can be obtained between the moving contact terminal and one or other of the end terminals to a fixed voltage applied between the end terminals

2.2.46**attenuation**

reciprocal of the output ratio normally expressed as:

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

2.2.47**loading error** (see Figure 8)

difference between the output ratio with an infinite load resistance and the output ratio with a specified finite load resistance at any shaft position as long as it is the same position for both output ratio measurements

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

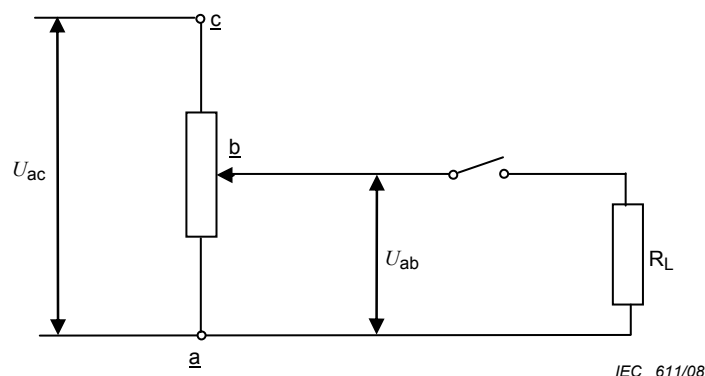


Figure 8 – Loading error

2.2.48 resistance/travel (or angle-of-rotation) relationships
relationships applying to two general constructions:

- a) potentiometers fitted with end stops or with stop-clutch devices;
- b) single-turn rotary potentiometers not fitted with end stops or stop-clutch 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

NOTE The alternative terms given in parentheses in 2.2.48.1, 2.2.48.3 and 2.2.48.4 are included for information only.

2.2.48.1 total mechanical travel (or angle of rotation) (see Figure 9)

in a) above, 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 b) above, the total mechanical travel is 360° (continuous)

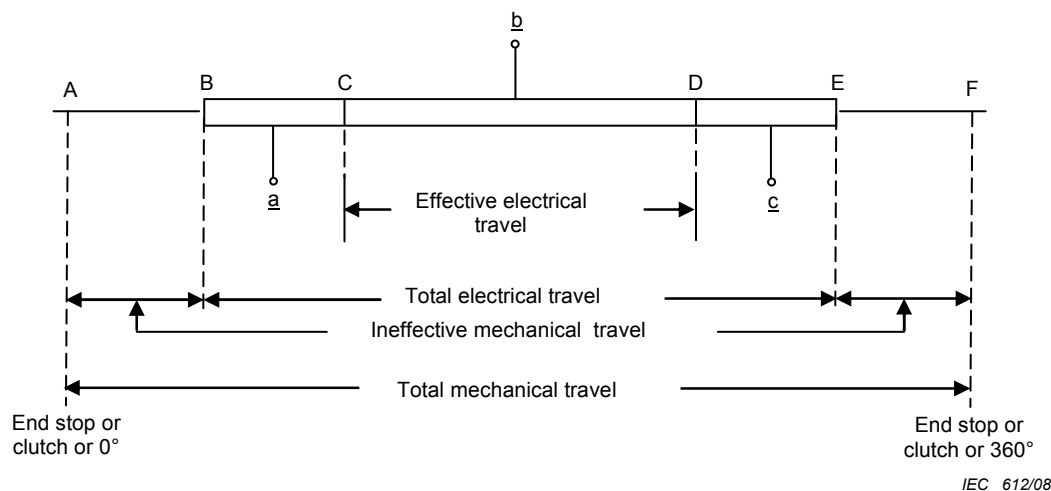


Figure 9 – Total mechanical travel (or angle of rotation)

2.2.48.2**total electrical travel** (see Figure 9)

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

NOTE In a) above, 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.

2.2.48.3**effective electrical travel (angle of rotation)**

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

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

2.2.48.4**ineffective mechanical travel (angle of rotation)** (see Figure 9)

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

2.2.48.5**total resistance**

total resistance is the resistance between terminals a and c (R_{ac}) when measured as described in 4.6

2.2.48.6**effective resistance**

portion of the total resistance over which the resistance changes in the manner prescribed by the specified resistance law

2.2.48.7**minimum effective resistance**

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

2.2.48.8**continuity**

maintenance of electrical contact between the moving contact and the resistive element as a function of the mechanical travel of the moving contact

2.2.48.9**conformity** (see Figure 10)

maximum measured difference between the actual and specified resistance law when it is expressed as a percentage of total resistance or total voltage applied

NOTE Conformity may be expressed in different ways and should be clearly specified in the detail specification. Some methods of expressing conformity are shown in the following subclauses.

Output ratio $\frac{U_{ab}}{U_{ac}}$

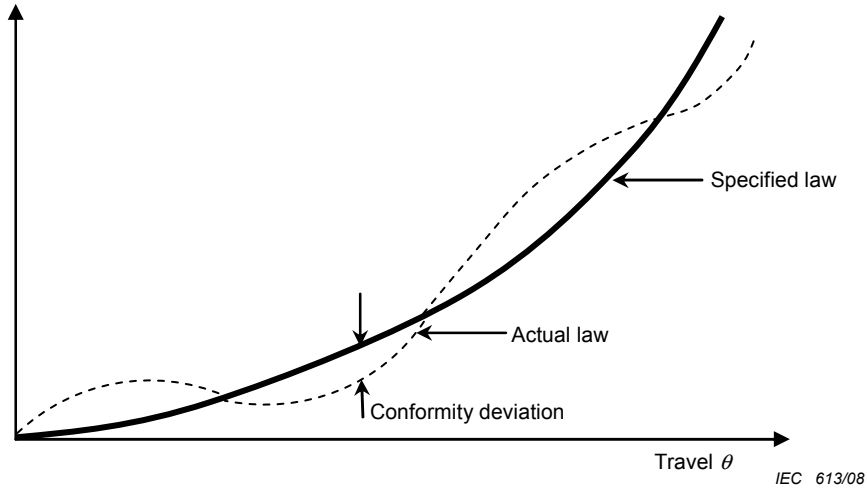


Figure 10 – Conformity

2.2.48.10

absolute conformity (see Figure 11)

conformity measured over the specified effective electrical travel and expressed as the maximum deviation of the actual from the specified resistance law

$$\text{Output ratio } \frac{U_{ab}}{U_{ac}}$$

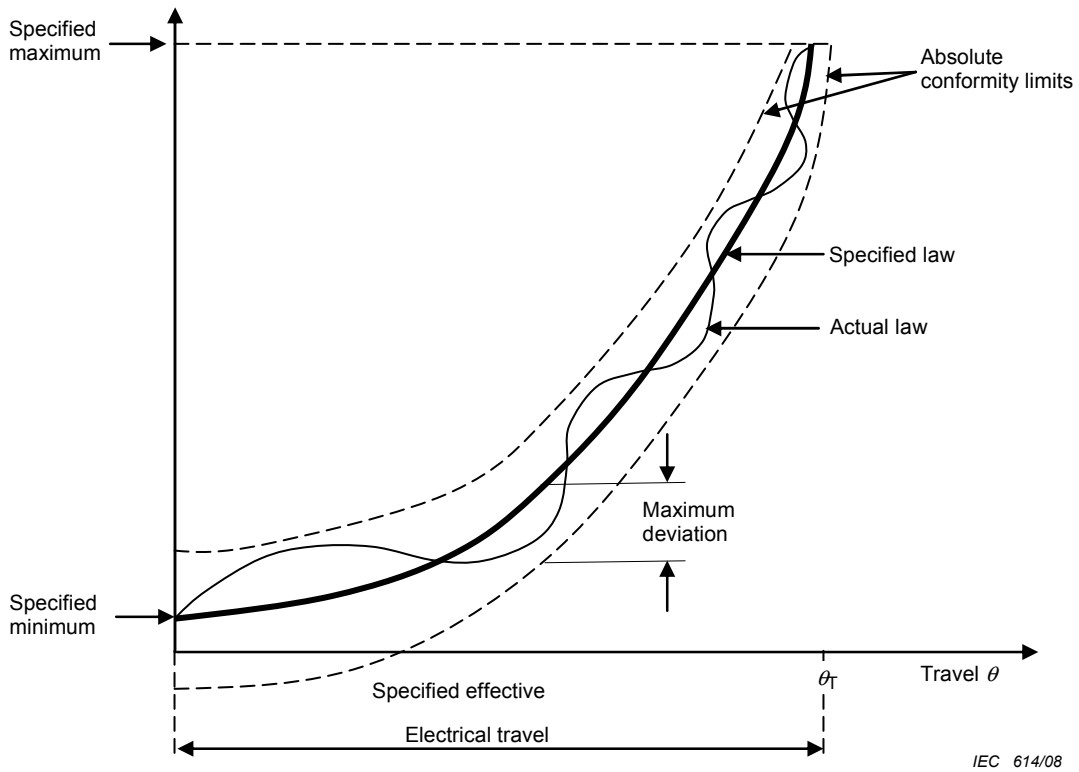


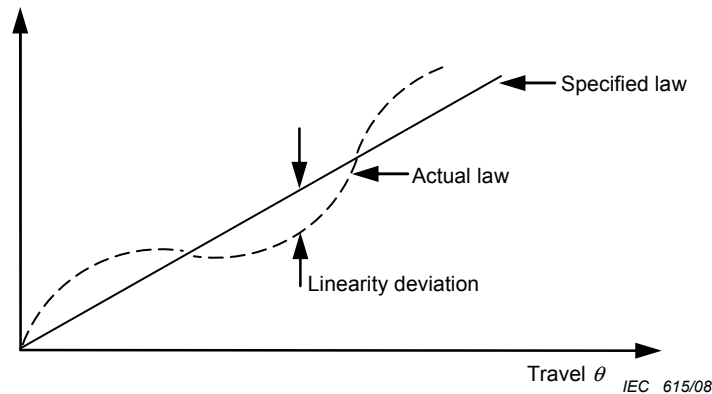
Figure 11 – Absolute conformity

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2.2.48.11**linearity** (see Figure 12)

specific type of conformity when the specified law or output ratio is shown as a straight line

$$\text{Output ratio } \frac{U_{ab}}{U_{ac}}$$

**Figure 12 – Linearity****2.2.48.12****independent linearity (best straight line)** (see Figure 13)

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 minimize deviations over the effective electrical travel or any specified portion thereof

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

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

where

P is the unspecified slope;

Q is the unspecified intercept at $\theta = 0$;

P and Q are chosen to minimize C but are limited by the output ratio requirement;

 θ_A is the amount of effective electrical travel.

$$\text{Output ratio } \frac{U_{ab}}{U_{ac}}$$

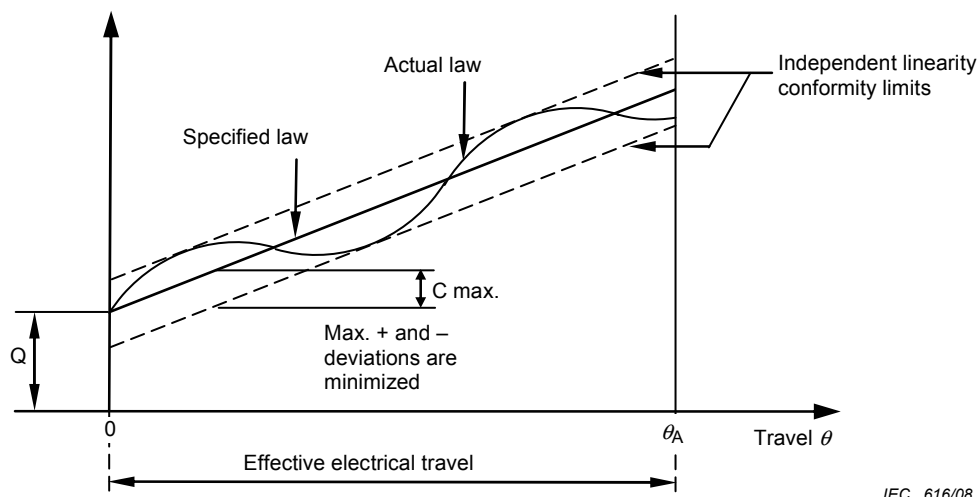


Figure 13 – Independent linearity

2.2.48.13

zero-based linearity (for wirewound potentiometers only) (see Figure 14)

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 minimize 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

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

where

P is the unspecified slope limited by the end voltage requirement at the maximum output ratio end;

θ_A is the amount of effective electrical travel.

Unless otherwise specified B = 0

Output ratio
$$\frac{U_{ab}}{U_{ac}}$$

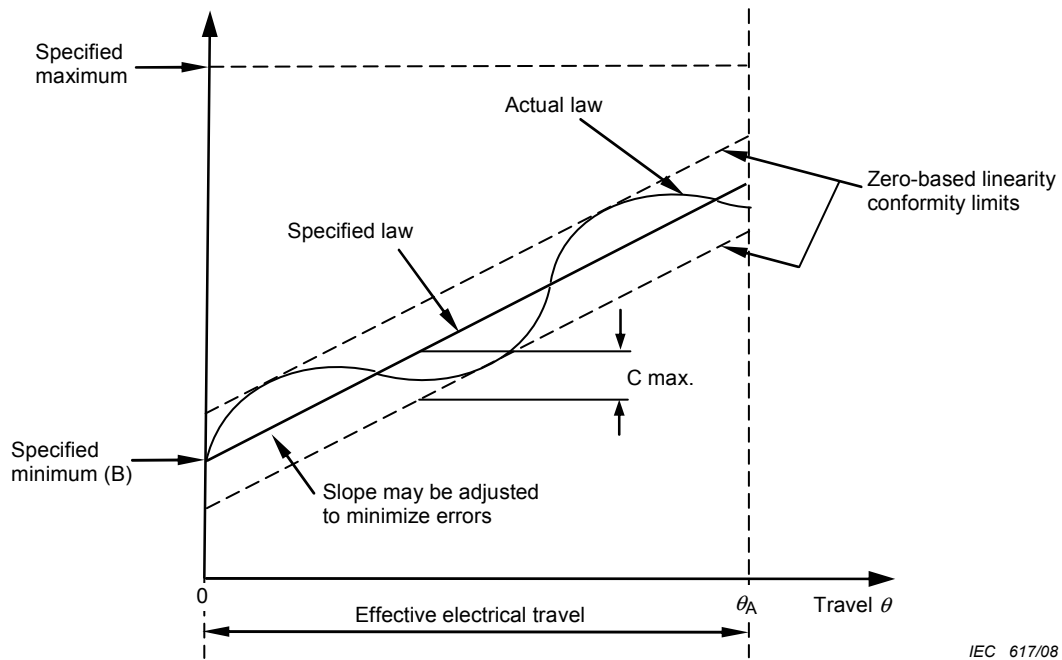


Figure 14 – Zero-based linearity

2.2.48.14

absolute linearity (see Figure 15)

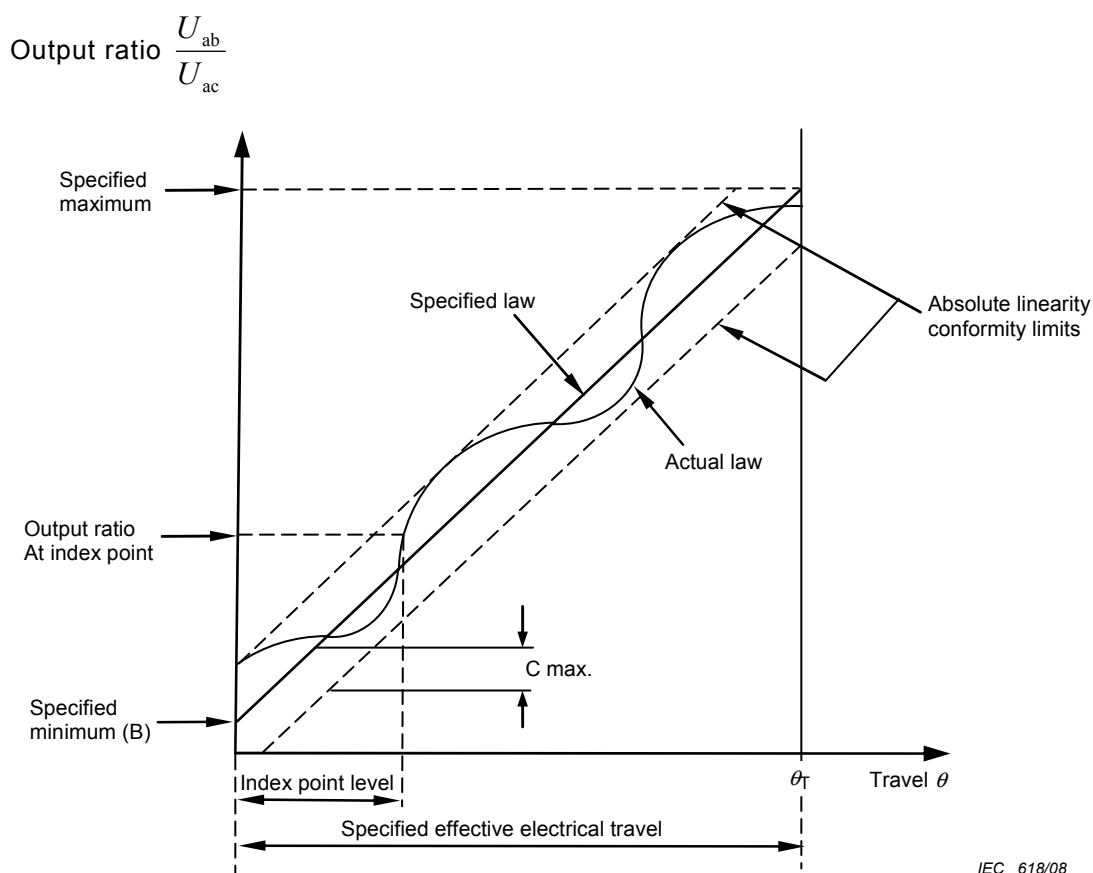
specific type of conformity where the maximum vertical deviation, expressed as a percentage of the total applied voltage, of the actual law from a straight reference line drawn through the specified minimum and maximum output ratios which are separated by the specified effective electrical travel. Unless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

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

where

- A is the given slope;
- B is the given intercept at $\theta = 0$;
- θ_T is the total specified effective electrical travel.

Unless otherwise specified, $A = 1$ and $B = 0$.



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Figure 15 – Absolute linearity

2.2.48.15

terminal based linearity (for wirewound potentiometer only) (see Figure 16)

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

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

where

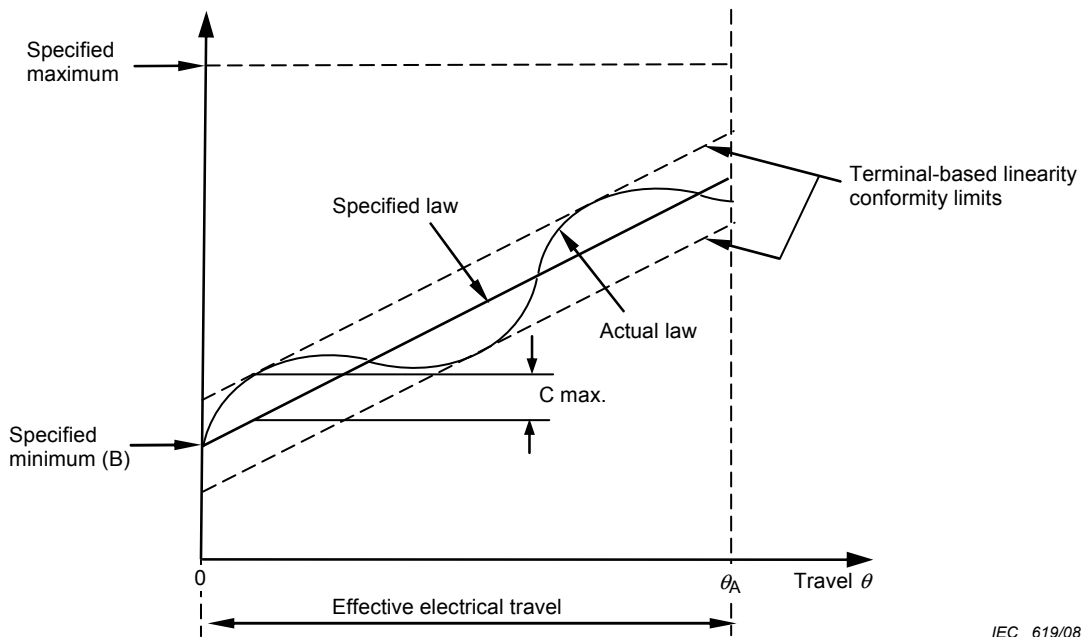
A is the given slope;

B is the given intercept at $\theta = 0$;

θ_A is the amount of effective electrical travel.

Unless otherwise specified $A = 1$ and $B = 0$.

$$\text{Output ratio } \frac{U_{ab}}{U_{ac}}$$



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Figure 16 – Terminal based linearity

2.2.48.16 index point A

point of reference, fixing the relationship between a specified actuating device position and the output ratio, and used to establish an actuating device position reference

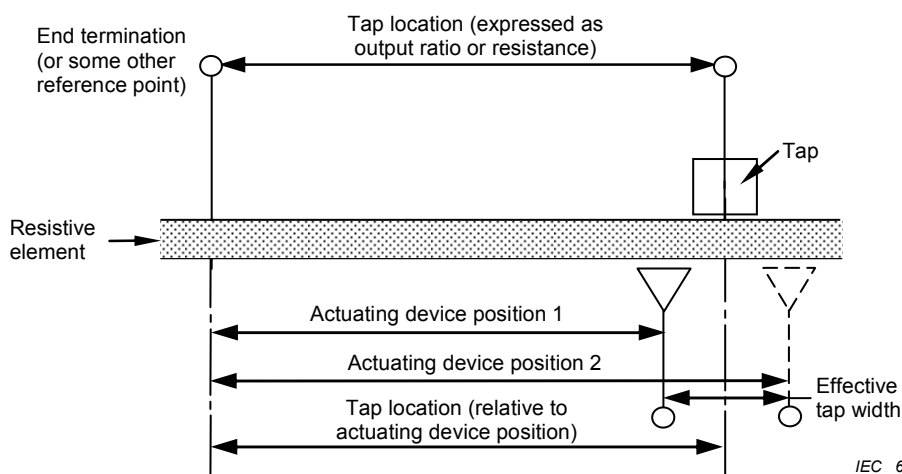
2.2.48.17 tap location

position of a tap relative to some reference

NOTE 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.

2.2.48.18 effective tap width (see Figure 17)

travel of the actuating device, during which the voltages at the moving contact terminal \underline{b} and the tap connection are essentially the same as the moving contact is moved past the tap in one direction



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Figure 17 – Effective tap width

2.2.48.19 (see also 2.2.48.27)**phasing**

relative alignment of the phasing points of each section of a ganged potentiometer

NOTE Unless otherwise specified, phasing requirements apply to a single specified phasing point in each section, and all selections are aligned to the phasing point of the first section.

2.2.48.20**phasing point**

point of reference on each section to describe the relative alignment of the sections of a ganged potentiometer with respect to the position of the moving contacts

2.2.48.21**rotational noise**

any spurious variation in the electrical output not present in the input, when moving the moving contact and caused by contact resistance variation

2.2.48.22**contact resistance variation (CRV)**

change of the resistance between the resistive element and the moving contact when the moving contact is energized with specified current and moved over the adjustment travel in either direction at defined speed

2.2.48.23**equivalent noise resistance (ENR)**

spurious variation in the electrical output not present in the input, defined quantitatively in terms of the equivalent parasitic, transient resistance in ohms, appearing between the moving contact and the resistive element when the operating shaft is rotated or moved

2.2.48.24**output smoothness (for non-wire-wound types only)**

spurious variation in the electrical output not present in the input. Output smoothness includes effects of contact resistance variations, resolution, and other micro-non-linearities 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

2.2.48.25**setting ability or adjustability (including resolution)**

precision with which the resistance or output voltage ratio of a potentiometer can be set to the desired value. It is normally expressed as a percentage of the total resistance.

NOTE A small incremental adjustment in the wire-wound type does not always produce the expected change in output as the moving contact moves off one turn of wire onto another.

2.2.48.26**theoretical resolution (for wire-wound types only)**

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

2.2.48.27**simultaneous conformity phasing**

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

2.2.48.28**backlash** (see Figure 18)

maximum difference in the actuating device position that occurs when it is moved to the same actual output ratio point from opposite directions

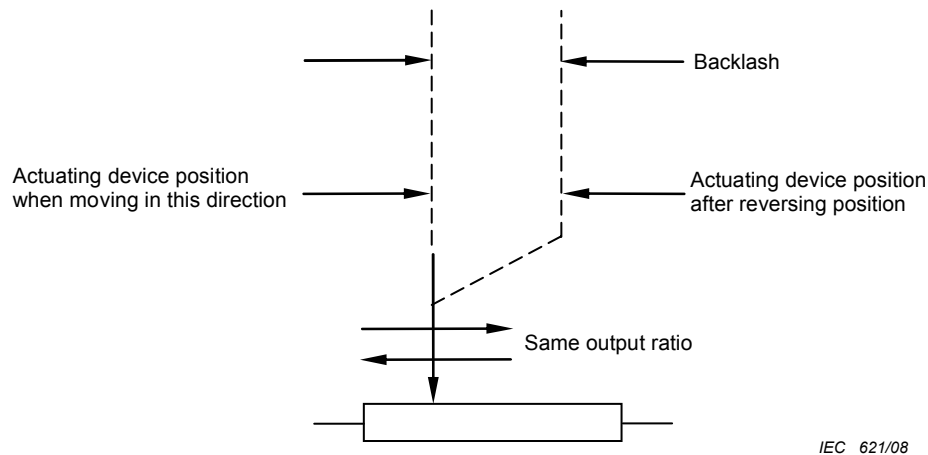


Figure 18 – Backlash

2.2.48.29**dither**

movement of the operating shaft to simulate conditions which may occur in servo systems

2.2.48.30**microlinearity**

relative change of linearity deviation (see 2.2.48.12) measured for small travel increments and expressed as a percentage of the applied voltage

2.2.48.31**setting stability**

refers to the ability of the potentiometer (mainly preset) to remain at the desired setting

NOTE 1 Setting stability may be affected by high temperature exposure, change of temperature, humidity and mechanical shock or vibration.

NOTE 2 The difference of voltage or resistance between the initial measurement made before the environmental test and the measurement made after the test indicates the setting stability in per cent.

2.2.49**rotary potentiometer** (single-turn or multi-turn)

potentiometer which is actuated by an axial shaft perpendicular to the direction of rotation and which may be operated frequently to adjust voltage or resistance values

2.2.50**power potentiometer**

potentiometer having a resistive element which is designed and constructed for high internal temperature rise and heat transfer capability

2.2.51**precision potentiometer**

potentiometer in which the output voltage or resistance law meets a precisely defined law as a function of the position of the actuating device

2.2.52**slide potentiometer**

potentiometer which is actuated by a rectilinear movement of an actuator and may be operated frequently to adjust voltage or resistance values

2.2.53**surface mount potentiometer**

potentiometer whose small dimensions and nature or shape of terminals make it suitable for use in hybrid circuits and on printed boards

2.3 Preferred values**2.3.1 General**

Each sectional specification shall prescribe the preferred values appropriate to the sub-family; for nominal total resistance, see also 2.3.2.

2.3.2 Preferred values of nominal total resistance

The preferred values of nominal total resistance shall be taken from the series specified in IEC 60063 and/or 1, 2, 5 series.

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 specification.

The order of priority for marking small potentiometers shall be specified.

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 IEC 60062.

3 Assessment procedures

When this standard and related standards are used for the purpose of a full quality assessment system such as the IEC Quality Assessment System for Electronic Components (IECQ), the relevant clauses of Annex H apply.

NOTE Section 3 of the previous edition has been moved to Annex H. To maintain reference to the previous editions of this standard, the clause numbers of Section 3 have been converted into the clause numbers of Annex H as shown by the following example:

Clause 3.1 -> Clause H.1
 Clause 3.1.2 -> Subclause H.1.2

4 Test and measurement procedures**4.1 General**

The sectional and/or blank detail specifications shall contain tables showing the tests to be made, which measurements are to be made before and after each test or subgroup 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 national standards within any quality assessment system include methods other than those specified in the above documents, these methods shall be fully described.

The issue and amendment status of any IEC 60068 test in this section is given in 1.2.

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing as given in 5.3 of IEC 60068-1:

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 stored 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 the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in 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.

NOTE During measurements, the potentiometer should not be exposed to draughts, direct sunlight 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 shall be made under closely controlled conditions, the standard recovery conditions of 5.4.1 of IEC 60068-1 shall be used.

4.2.3 Referee conditions

For referee purposes one of the standard atmospheric conditions for referee tests taken from 5.2 of IEC 60068-1, as given in Table 1, shall be chosen.

Table 1 – Standard atmospheric conditions

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

4.2.4 Reference conditions

For reference purposes the standard atmospheric conditions for reference given in 5.1 of IEC 60068-1 apply:

Temperature: 20 °C

Air pressure: 101,3 kPa

4.3 Drying

When drying is prescribed, the potentiometer shall be conditioned before measurement is made using Procedure 1 or Procedure 2 as prescribed in the detail specification.

Procedure 1: for 24 h ± 4 h in an oven at a temperature of 55 °C ± 2 °C and at a relative humidity not exceeding 20 %

Procedure 2: for 96 h ± 4 h in an oven at 100 °C ± 5 °C

The potentiometer shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and it 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 2.2.19.

There shall be no visible damage.

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

4.4.2 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, 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 conform to the values prescribed.

4.4.4 Total mechanical travel (see Figure 9)

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 counter-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.

The total mechanical travel is given by position F – position A.

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

4.4.5 Total electrical travel (see Figure 9)

While mounted for measurement of angular position a voltage not exceeding that given in 4.6.1 shall be applied to terminals a and c.

The actuating device shall be set at the approximate centre of the total mechanical travel and the electrical continuity monitored as the actuating device is turned slowly counter-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 electrical continuity 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.

The total electrical travel is given by position E – position B.

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

4.4.6 Effective electrical travel (see Figure 9)

While mounted for measurement of angular position, a voltage not exceeding that given in 4.6.1 shall be applied to terminals a and c.

The actuating device shall then be set at the approximate centre of the total electrical travel and then slowly turned counter-clockwise until the output ratio $\frac{U_{ab}}{U_{ac}}$ is within 5 % of the value stated in the detail specification for 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 $\frac{U_{bc}}{U_{ac}}$ is within 5 % of the value stated in the detail specification for the minimum effective resistance when expressed as a percentage of the total resistance. The angular position (D) shall then be recorded.

NOTE If a greater accuracy is required, the 5 % tolerance on the output ratio may be reduced as stated in the detail specification.

The angle of the effective electrical travel is given by position D – position C.

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

The angle of ineffective travel (counter-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.

The values calculated shall be less than those given in the detail specification.

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 shaft or lead-screw is operated steadily in each direction at a rate of 2 to 5 cycles (see 2.2.37) per minute.

The resistance variation between terminations a and b shall be reasonably smooth and unidirectional when the shaft 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 of resistance shall be made with the moving contact having been set at the end of its travel by counter-clockwise rotation of the actuating device (see note in 4.6.2).

The resistance shall be measured using a direct voltage of small magnitude applied for as short a time as practicable, in order that the temperature of the resistance element shall not rise appreciably during measurement.

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

Table 2 – Measuring voltages

Nominal total resistance <i>R</i>	Measuring voltage $V \begin{matrix} +0 \\ -10 \end{matrix} \%$
<10 Ω	0,1 (see NOTE 1)
10 to 99 Ω	0,3
100 to 999 Ω	1
1 000 to 9 999 Ω	3
10 000 to 99 999 Ω	10
100 000 to 999 999 Ω	25
≥1 MΩ	50

NOTE 1 When the nominal total resistance is less than 10Ω, the measuring voltage should be so chosen that the potentiometer dissipates less than 10 % of its rated dissipation, but does not exceed 0,1 V.

NOTE 2 When using the digital ohmmeter including multi-meter, the measuring voltages in Table 2 should be maximum value.

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 sequence.

NOTE For special types of potentiometer, it may be 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 terminals a and c shall be equal to the nominal total resistance, taking into account the specified tolerance.

4.7 Terminal resistance

4.7.1 The accuracy of the measuring equipment shall be such that the error does not exceed 5 % and the voltage applied to the potentiometer shall be so chosen that the limiting moving contact current is not exceeded.

4.7.2 The resistance shall be measured as follows.

4.7.2.1 Between terminals a and b with the actuating device rotated in a counter-clockwise direction until a minimum resistance is obtained.

4.7.2.2 Between terminals b and c with the actuating device rotated in a clockwise direction until a minimum resistance is obtained.

4.7.3 The resistance shall not exceed that given in the detail specification.

4.8 Maximum attenuation

Alternative (when specified) to terminal resistance.

4.8.1 Measurement is made

- between terminals a and b, with the operating shaft at the counter-clockwise end of the total electrical travel;
- for potentiometers having inverse non-linear laws between terminals b and c, with the actuating device set at the clockwise end of the total electrical travel.

4.8.2 A supply voltage with frequency of 1,0 kHz \pm 0,2 kHz shall be applied across the terminals a and c of the potentiometer under test. The r.m.s. voltage shall not exceed the d.c. voltages specified in 4.6.1.

The voltage from a to b (or b to c when appropriate) shall be measured by an instrument having an internal impedance of at least 1 M Ω . The ratio of the applied voltage to this voltage is the attenuation.

4.8.3 The maximum attenuation shall be not less than that given in the detail specification.

4.9 Resistance law (conformity)

4.9.1 The potentiometer shall be mounted as for the measurement of angular position of the actuating device.

A constant voltage from a stabilized source not exceeding the voltages given in 4.6.1 shall be applied to terminals a and c of the potentiometer.

4.9.2 The voltage between terminals a and b shall be measured with a high-impedance voltmeter at a number of positions of the actuating device which are spaced at approximately equidistant intervals throughout the effective electrical travel.

At each angular position the output ratio $\frac{U_{ab}}{U_{ac}}$ and the mechanical position of the actuating device shall be recorded.

The measuring method shall be such that the error does not exceed 10 % of the specified tolerance or as otherwise specified in the detail specification.

4.9.3 The number of test points for both qualification approval and for quality conformance testing shall be stated in the detail specification.

At each test angular position, the output ratio $\frac{U_{ab}}{U_{ac}}$ shall be within conformance limits given in the detail specification.

4.10 Matching of the resistance law (for ganged potentiometers only)

When applicable.

NOTE The same procedure may be applied when more than two potentiometers are ganged together.

4.10.1 A voltage not exceeding the voltage given in 4.6.1 shall be applied to the terminals a and c of both potentiometers of the pair.

The voltage across

terminals a and b, and terminals b and c for linear law potentiometers,

or

across terminals a and b for non-linear law potentiometers,

measured on one of the potentiometers shall be compared with the corresponding voltage on the other potentiometer at the identical setting of the actuating device.

4.10.2 The relationship between these two voltages shall be within the limits given in the detail specification.

4.11 Switch contact resistance (when appropriate)

NOTE The tests given in this subclause are quoted from IEC 60512-2-1 and IEC 60512-2-2, except the marked portions with asterisk.

*Marked portions: 1) making the contact; 2) breaking the contact.

These are necessary for a switch fitted on potentiometer.

4.11.1 Contact resistance – Millivolt level method

4.11.1.1 Object

The object of this test is to detail a standard method to measure the electrical resistance across a pair of mated contacts or a contact with a measuring gauge.

4.11.1.2 General measuring requirements

Measurements may be carried out with direct current or alternating current. For a.c. measurements, the frequency shall not exceed 2 kHz. In case of dispute, the d.c. measurement shall govern.

The accuracy of the measuring apparatus shall be such that the total error does not exceed 10 %.

4.11.1.3 Method of measurement

4.11.1.3.1 Measurement details

The contact resistance shall be derived normally from the voltage drop measured between the zones intended for connection of the wiring to the contacts at the points specified in the detail specification.

The contact shall not be operated while the measuring voltage is applied.

Care must be taken during the measurement to avoid exerting abnormal pressure on the contacts under test and to avoid movement of the test cables.

Where the connection points specified in the detail specification are not directly accessible, the resistance of the cable or wire used shall be subtracted from the measured value. The corrected value shall be recorded.

The contacts to be measured shall be chosen in accordance with the detail specification.

4.11.1.3.2 Test current and voltage

The test voltage shall not exceed 20 mV d.c. or a.c. peak, in order to prevent the breakdown of possible insulating film on the contacts..

The test current shall not exceed 100 mA, a.c. or d.c.

4.11.1.4 Measurements

4.11.1.4.1 Measurement with direct current

One measuring cycle consists of

- a) making the contact*;
- b) application of the voltage;
- c) measurement with current flowing in one direction;
- d) measurement with current flowing in the opposite direction;
- e) disconnection of the voltage source;
- f) breaking the contact*.

4.11.1.4.2 Measurement with alternating current

One measuring cycle consists of:

- a) making the contact*;
- b) application of the voltage;
- c) making the measurement;
- d) disconnection of the voltage source;

e) breaking the contact*.

NOTE Unless otherwise specified, the contact(s) made should not be disturbed between the end of the preceding test and the application of the voltage in this test.

4.11.1.5 Requirements

The value of the contact resistance shall not exceed the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Use of the following equation will ensure that the calculated resistance is always correct:

$$R = \frac{ABS \times (V_{mf} + V_{mr})}{(ABS \times (I_f) + ABS \times (I_r))}$$

where

- R is resistance;
- ABS is absolute voltage;
- V_{mf} is measured forward voltage;
- V_{mr} is measured reverse voltage;
- I_f is forward current;
- I_r is reverse current.

NOTE 1 In the equation, it is necessary that the sign of the voltage measurements be included.

NOTE 2 Any deviation from the standard test procedure should be clearly indicated in the test report.

4.11.1.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

- a) the connection point of the measuring wires, their type and size, if applicable;
- b) for mated sets, the contacts to be measured and the number of measuring cycles;
- c) for individual mated contacts, the number of contacts to be measured;
- d) whether contacts are to be operated before the measurements and/or between the measuring cycles;
- e) the permissible limits of contact resistance;
- f) any deviation from the standard test method and/or conditions.

4.11.2 Contact resistance – Specified test current method

4.11.2.1 Object

The object of this test is to detail a standard method to measure the electrical resistance across a pair of mated contacts or a contact with a measuring gauge.

4.11.2.2 General measuring requirements

Measurements may be carried out with direct current or alternating current. For a.c. measurements, the frequency shall not exceed 2 kHz. In case of dispute, the d.c. measurements shall govern.

The accuracy of the measuring apparatus shall be such that the total error does not exceed 10 %.

4.11.2.3 Method of measurement

4.11.2.3.1 Measurement details

The contact resistance shall be derived normally from the voltage drop measured between the zones intended for connection of the wiring to the contacts at the points specified in the detail specification.

The contact shall not be operated while the measuring voltage is applied.

Care must be taken during the measurement to avoid exerting abnormal pressure on the contacts under test and to avoid movement of the test cables.

Where the connection points specified in the detail specification are not directly accessible, the resistance of the cable or wire used shall be subtracted from the measured value.

The corrected value shall be recorded.

The contacts to be measured shall be chosen in accordance with the detail specification.

4.11.2.3.2 Test current and voltage

The contact resistance shall be measured with the rated alternating current or direct current as specified in the detail specification. The e.m.f. of the source shall not exceed 60 V d.c. or a.c. peak but shall be at least 1 V, as specified in the detail specification.

Measurements shall be made on individual contacts within the minute following application of the test current.

4.11.2.4 Measuring cycles

4.11.2.4.1 Measurement with direct current

One measuring cycle consists of

- a) making the contact*;
- b) application of the voltage;
- c) measurement with current flowing in one direction;
- d) measurement with current flowing in the opposite direction;
- e) disconnection of the voltage source;
- f) breaking the contact*.

NOTE Unless otherwise specified, the made contacts should not be disturbed between the end of a preceding test and the application of the voltage in this test, nor between successive measuring cycles.

4.11.2.4.2 Measurement with alternating current

One measuring cycle consists of

- a) making the contact*;
- b) application of the voltage;
- c) making the measurement;
- d) disconnection of the voltage source;
- e) breaking the contact*.

NOTE Unless otherwise specified, the made contacts should not be disturbed between the end of a preceding test and the application of the voltage in this test, nor between successive measuring cycles.

4.11.2.5 Requirements

The value of the contact resistance shall not exceed for any measurement the value specified in the detail specification.

The contact resistance measurement with d.c. shall be the average of the two readings obtained with forward and reverse current.

Use of the equation in 4.11.1.5 will ensure that the calculated resistance is always correct.

NOTE Any deviation from the standard test procedure should be clearly indicated in the test report.

4.11.2.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

- a) the connecting point of the measuring wires, their type and size, if applicable;
- b) for mated sets, the contacts to be measured and the number of measuring cycles;
- c) for individual mated contacts, the number of contacts to be measured;
- d) whether contacts are to be operated before the measurements and/or between the measuring cycles;
- e) the measuring current;
- f) the permissible limits of contact resistance;
- g) any deviation from the standard test method and/or conditions.

4.12 Voltage proof (insulated styles only)

4.12.1 The test shall be performed using one of the following methods, as prescribed in the detail specification.

4.12.1.1 Method for potentiometers with mounting devices

The potentiometers which are designed to be mounted direct onto a metal chassis shall be mounted in the normal manner on a metal plate extending at least 6 mm in all directions beyond the potentiometer at all points.

4.12.1.2 Metal foil method (alternative method for potentiometers without mounting devices)

A metal foil shall be wrapped closely around the whole body of the potentiometer, provided that a minimum space of 1mm between the foil and each terminals can be maintained.

4.12.1.3 Method for surface mount potentiometers

The test shall be performed with the potentiometer mounted as shown in Figure 19 or as prescribed in the relevant detail specification.

The clamping force of the spring shall be $1,0 \text{ N} \pm 0,2 \text{ N}$, unless otherwise specified in the relevant detail specification. The point of contact of the metal block shall be centrally located to ensure good repeatability of the results.

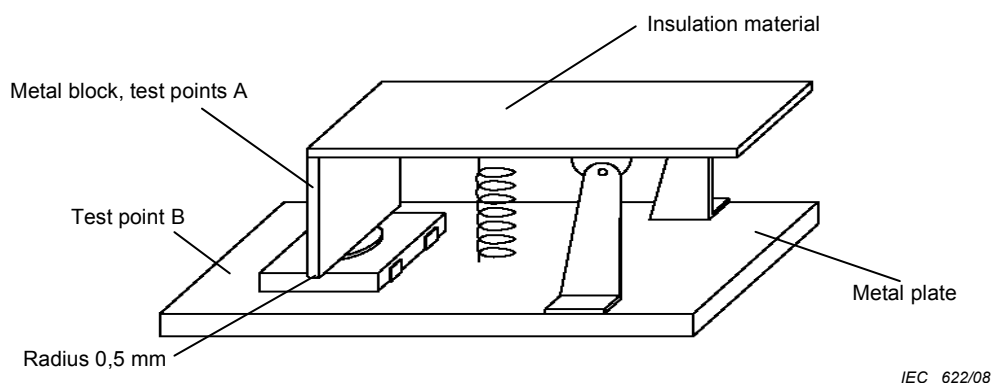


Figure 19 – Example of insulation resistance and voltage proof test jig for surface mount potentiometers

4.12.1.4 For other designs of potentiometer, the method shall be specified in the detail specification.

4.12.2 For all potentiometers except surface mount potentiometers, the test voltage shall be applied between terminals of the potentiometer connected together as one pole, and any other external metal parts and mounting plate connected together or metal foil as the other pole. Test voltage shall be alternating (frequency of 40 Hz to 60 Hz) and shall be increased, at rate of about 100 V/s, zero to peak value of 1,42 times the value of the insulation voltage specified in the detail specification. However, on the instructions of the manufacturer, the voltage may be applied more rapidly. After the specified voltage has been reached, the voltage shall continue to be applied for $60\text{ s} \pm 5\text{ s}$. In addition, in components with insulated actuating devices, the proof voltage shall be applied between all terminals connected together and the actuating device. During the test, the shaft may be operated.

For surface mount potentiometers, an alternating voltage of frequency of 40 Hz to 60 Hz, with a peak value of 1,42 times the insulation voltage, shall be applied for a period of $60\text{ s} \pm 5\text{ s}$ between test points A and B as shown in Figure 19. The voltage shall be applied gradually at a rate of approximately 100 V/s.

4.12.3 When the test is performed at low air pressure, the conditions of 4.12.2 shall be met except that the proof voltage shall be that stated in the detail specification appropriate to the air pressure.

4.12.4 An alternating voltage of a frequency of 40 Hz to 60 Hz with a value of 900 V r.m.s. for switches for supply mains $\leq 120\text{ V}$, and $2U_R + 1\,000\text{ V}$ r.m.s. for switches for supply mains $> 120\text{ V}$, shall be applied gradually at a rate of approximately 100 V/s until the proof voltage is obtained. However, at the discretion of the manufacturer the voltage may be applied more rapidly. The proof voltage shall then be held for $60\text{ s} \pm 5\text{ s}$ between all switch terminals connected together as one pole and the shaft, metal parts of the case and plate connected together as the other pole.

NOTE U_R is the rated voltage of the switch.

4.12.5 The potentiometer and the switch, when fitted, shall withstand this test without breakdown or flashover.

4.13 Insulation resistance (insulated styles only)

4.13.1 The test shall be performed using one of the methods specified in 4.12.1, as prescribed in the relevant specification. The insulation resistance shall be measured between

- a) all potentiometer terminals, connected together, and any other external metal parts together with the actuating device (in components with insulated actuating devices);
- b) all switch contacts, connected together, and any other external metal parts;
- c) open switch contacts.

4.13.2 For all potentiometers except surface mount potentiometers, the insulation resistance shall be measured with a direct voltage of either 100 V \pm 15 V for potentiometers with an insulation voltage <500 V or 500 V \pm 50 V for potentiometers with an insulation voltage \geq 500 V.

The voltage shall be applied for 1 min or for such shorter time as necessary to obtain a stable reading, the insulation resistance being read at the end of that period.

4.13.3 The value of the insulation resistance shall be not less than the value prescribed in the relevant specification.

4.14 Variation of resistance with temperature

4.14.1 The potentiometer shall be dried using either Procedure 1 or Procedure 2 of 4.3 as prescribed in the detail specification.

4.14.2 Unless otherwise specified in the detail specification, the potentiometer shall be maintained at each of the following ambient temperatures in turn:

- a) 20 $\begin{matrix} +5^{\circ}\text{C} \\ -1^{\circ}\text{C} \end{matrix}$;
- b) lower category temperature $\pm 3^{\circ}\text{C}$;
- c) 20 $\begin{matrix} +5^{\circ}\text{C} \\ -1^{\circ}\text{C} \end{matrix}$;
- d) 70 $^{\circ}\text{C} \pm 2^{\circ}\text{C}$;
- e) upper category temperature $\pm 2^{\circ}\text{C}$;
- f) 70 $^{\circ}\text{C} \pm 2^{\circ}\text{C}$;
- g) 20 $\begin{matrix} +5^{\circ}\text{C} \\ -1^{\circ}\text{C} \end{matrix}$.

The temperatures listed in items d) and f) are only applicable to potentiometers having an upper category temperature of 125 $^{\circ}\text{C}$ or higher.

4.14.3 Resistance measurements shall be made at each of the temperatures specified in 4.14.2 after the potentiometer has reached thermal stability.

The condition of thermal stability is deemed to be reached when two readings of resistance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The temperature of the chamber or potentiometer at the time of resistance measurement shall be recorded. The error in the measurement of the temperature shall not exceed 1 $^{\circ}\text{C}$.

4.14.4 Methods of calculation

NOTE The results of one measurement may be used for the calculation of temperature characteristic and the temperature coefficient.

4.14.4.1 Temperature characteristic of resistance

The temperature characteristics of resistance between 20 $^{\circ}\text{C}$ and each of the other temperatures specified in 4.14.2 shall be calculated from the following formula.

$$\text{Temperature characteristic of resistance (in \%)} = A \times \frac{\Delta R}{R}$$

where

A is the difference between the nominal specified temperature divided by the difference between the recorded temperatures;

ΔR is the change in resistance between the two specified ambient temperatures;

R is the resistance value at the reference temperature.

If the resistances recorded in 4.14.3 are designed R_a , R_b , R_c , R_d , R_e , R_f and R_g , respectively, the values of R and ΔR are given in Table 3.

Table 3 – Calculation of resistance value(R) and change in resistance (ΔR)

	Lower category temperature	Upper category temperature	20 °C to 70 °C
R	$\frac{R_a + R_c}{2}$	$\frac{R_c + R_g}{2}$	$\frac{R_c + R_g}{2}$
ΔR	$R_b - R$	$R_e - R$	$\frac{R_d + R_f}{2} - R$

If the temperatures recorded in 4.14.3 are designed T_a , T_b , T_c , T_d , T_e , T_f and T_g , the temperature differences (ΔT) between the recorded temperatures shall be as shown in Table 4.

Table 4 – Calculation of temperature differences (ΔT)

T	Lower category temperature	Upper category temperature	20 °C to 70 °C
ΔT	$\frac{T_b - (T_a + T_c)}{2}$	$\frac{T_e - (T_c + T_g)}{2}$	$\frac{(T_d + T_f)}{2} - \frac{(T_c + T_g)}{2}$

4.14.4.2 Temperature coefficient of resistance (α_R)

The temperature coefficient of resistance (α_R) between 20 °C and each of the other temperatures specified in 4.14.2 shall be calculated from the following formula:

$$\alpha_R = \frac{\Delta R}{R \cdot \Delta T} \times 10^6 \text{ (in } 10^{-6}/\text{K)}$$

where ΔT is the algebraic difference, in Kelvins, between the specified ambient temperature and the reference temperature (for calculation, see 4.14.4.1).

For R , ΔR and ΔT , see 4.14.4.1.

The temperature coefficient of resistance (α_R) is expressed in parts per million per Kelvin.

4.14.4.3 The temperature characteristic of resistance or the temperature coefficient of resistance (α_R), as certain as described above, shall be within the limits prescribed in the detail specification for the appropriate category temperature.

When resistance value is greater than 5 Ω but less than 10 Ω , the temperature characteristic or temperature coefficient of resistance shall not exceed the limits prescribed in the detail specification for values equal to or above 10 Ω by more than a factor of 2.

NOTE The temperature characteristic or temperature coefficient of resistance is not specified for resistance values of less than 5 Ω owing to difficulty of accurate measurement.

4.14.5 Temperature coefficient of output ratio (α_R)

4.14.5.1 The potentiometer shall be dried as specified in 4.14.1. The moving contact shall be set to the position prescribed in the relevant specification and locked in a suitable manner to eliminate changes of setting which may be caused by mechanical and/or thermal influences. The detail specification may specify a load to be applied to the moving contact terminal.

4.14.5.2 The potentiometer shall successively be maintained at each of the temperatures specified according to 4.14.2. The total resistance or a suitable other characteristic shall be monitored in order to judge whether thermal stability has been reached in each step.

4.14.5.3 The output ratio (or, if the input voltage is sufficiently stable, the output voltage) shall be measured at each of the temperatures specified in 4.14.5.2 after the potentiometer has reached thermal stability.

The temperature of the test chamber at the time of output ratio measurement shall be recorded. The error in the measurement of the temperature shall not exceed 1 °C.

The condition of thermal stability may be judged to be reached when two readings of total resistance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

4.14.5.4 The temperature coefficient of output ratio between 20 °C and each of the other temperatures specified in 4.14.5.2 shall be calculated from the following formula:

$$\alpha_R = \frac{\Delta(U_{ab}/U_{ac})}{(U_{ab}/U_{ac}) \cdot \Delta\theta} \times 10^6 \text{ (in } 10^{-6}/\text{K)}$$

Where (U_{ab}/U_{ac}) is the output ratio at the reference temperature and $\Delta(U_{ab}/U_{ac})$ is the algebraic difference of voltage, in volts, between the reference temperature and the specified ambient temperature.

If the values of output ratio recorded in 4.14.5.3 are designated in the same way as the resistance values of 4.14.4, the values of (U_{ab}/U_{ac}) and of $\Delta(U_{ab}/U_{ac})$ correspond to the table in 4.14.4 with R replaced by (U_{ab}/U_{ac}) .

4.15 Rotational noise

For measurement of rotational noise of potentiometers one of the following methods shall be used.

Method A: in cases when the current through the moving contact (I_b) is very low compared to the current passing through the resistive element. The noise output shall be measured with the measuring circuit shown in Figure C.1.

Method B: the contact resistance variation (CRV) shall be measured with the measuring circuit shown in Figure C.2 or its equivalent.

Method C: the peak noise resistance (ENR) shall be measured with the measuring circuit shown in Figure C.3 or its equivalent.

The relevant specification shall state, depending on the type of potentiometer concerned, which method shall be used.

4.15.1 Method A (constant voltage method)

- a) A direct voltage of 20 V, with a source resistance of 1 000 Ω , shall be applied to the end terminations a and c of the potentiometer. The moving contact shall be operated through the angle of total mechanical rotation, excluding the switch, in one direction and back, at 2 to 5 complete cycles per minute.
- b) After three initial cycles, the noise output between terminals a and b (or between terminals b and c when appropriate) shall not exceed that specified in the detail specification.

The noise output shall be measured on a test set such as is described in Annex C.

4.15.2 Method B (constant current method – CRV)

4.15.2.1 Test current (I_b)

A constant current I_b shall be supplied to the potentiometer terminals a and b. The value of the current shall, on the basis of the nominal total resistance (R) of the potentiometer, be selected from Table 5.

Table 5 – Current values (I_b)

R	I_b
$\geq 2,2 \text{ M}\Omega$	0,01 mA
$\geq 100 \text{ k}\Omega < 2,2 \text{ M}\Omega$	0,05 mA
$\geq 10 \text{ k}\Omega < 100 \text{ k}\Omega$	0,1 mA
$\geq 1 \text{ k}\Omega < 10 \text{ k}\Omega$	1 mA
$\geq 100 \Omega < 1 \text{ k}\Omega$	10 mA
$< 100 \Omega$	50 mA

The values of I_b specified in the above table are applicable, provided the limiting current for the moving contact is not exceeded and the dissipation power through the resistive element does not exceed the rated power.

4.15.2.2 Test conditions

Unless otherwise specified in the detail specification, the moving contact shall be operated in both directions through 90 % of the actual effective electrical travel for a total of 6 cycles, the rate of rotation of operating shaft being such that the moving contact completes one cycle in 5 s minimum to 2 min maximum.

For multi-turn potentiometers or lead-screw actuated potentiometers the operating speed shall be limited to a maximum of 3 turns of the shaft per second.

Only the last 3 cycles shall count in determining whether or not a contact resistance variation is observed at least twice in the same location, exclusively of the “roll-on” or “roll-off” points where the moving contact moves from the terminations, on or off, resistance element.

NOTE 1 Roll-on: the abrupt output voltage or resistance change observed as the shaft is displaced from the end of mechanical travel into electrical travel. The same change going from the electrical travel toward the end is called Roll-off.

NOTE 2 CRV should be expressed in percentage of the nominal total resistance of the potentiometer under test.

4.15.2.3 The rotational noise measured between the terminals a and b (or between terminals b and c when appropriate) shall not exceed the limits specified in the detail specification.

4.15.3 Method C (constant current method – ENR)

4.15.3.1 Test current (I_c)

The constant current I_c shall be supplied to the potentiometer terminals a and b. During test, the moving contact energized with a constant current of 1 mA shall make 3 complete cycles and maximum deviations from the reference line on the screen of oscilloscope are noted. Random spikes which are not repetitive shall be disregarded.

4.15.3.2 Test conditions

Unless otherwise specified in the relevant detail specification, the moving contact shall be operated in both directions through 90 % of the actual effective electrical travel for a total of 6 cycles, the rate of rotation of operating shaft shall be such that the moving contact completes 1 cycle in 5 s minimum to 2 min maximum.

For multi-turn potentiometers or lead-screw actuated potentiometers the operating speed shall be limited to a maximum of 3 turns of the shaft per second.

Only the last 3 cycles shall be counted in determining whether or not a noise is observed at least twice in the same location, exclusively of the “roll-on” or “roll-off” points where the moving contact moves from the terminations, on or off, resistive element.

The equivalent noise resistance (ENR) shall be calculated using the following formula:

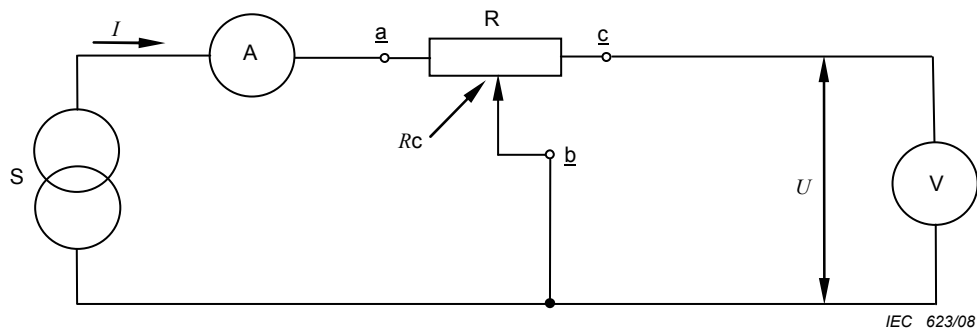
$$\text{Noise (in } \Omega) = \frac{E_{pn}}{0,001}$$

where E_{pn} is the peak-noise signal voltage prescribed on the screen of the oscilloscope.

4.16 Contact resistance at low-voltage levels

4.16.1 The moving contact shall be set between 40 % and 60 % of the effective electrical travel and locked in this position so that during subsequent humidity and endurance tests it cannot be moved.

4.16.2 An adjustable d.c. current source, which has an open circuit voltage of $20 \text{ mV} \pm 2 \text{ mV}$, is connected through an ampere meter to the terminals a and b of the potentiometer as shown in the test circuit in Figure 20. A voltmeter with a high input impedance ($\gg R_N$ of the potentiometer under test) is connected between terminals c and b.

**Key**

- S Adjustable d.c. source
 A Ampere meter
 R Potentiometer under test
 V Voltmeter

Figure 20 – Test circuit contact resistance

4.16.3 The contact resistance R_C is calculated by dividing the measured voltage U by the applied current I .

NOTE 1 Due to thermal e.m.f.s in the test specimen, inaccurate results may be found when very low voltages ($U < 3$ mV) are measured. If this is the case, the measurement is repeated with reversed polarity of the current source. The current is adjusted to the same value in both cases and the contact resistance is then the arithmetic mean of the absolute values of the measured voltage divided by the absolute value of the applied current.

NOTE 2 An a.c. voltage of 20 mV peak may also be used instead of the d.c. source, provided that it does not influence the test result (for example, through auto-transformer action in wire-wound potentiometers). In case of dispute, the d.c. voltage method should be used.

4.16.4 When the detail specification for pre-set potentiometers calls for the measurement of contact resistance at low voltage levels, this measurement is made as part of the following tests.

- Damp heat, steady state.
- Endurance, electrical (at 70 °C): to be applied for that half of the specimens loaded between terminations a and c.
- Endurance, electrical (at upper category temperature): to be applied for that half of the specimens loaded between terminals a and c.

For the above tests an initial contact resistance measurement is made before the tests and final measurements afterwards; all of these measurements with the moving contact in the same position are made according to 4.16.1.

The requirements shall be prescribed in the sectional or detail specification as a maximum resistance variation generally expressed in a percentage of the nominal resistance of the potentiometers.

4.17 Setting ability (adjustability) and setting stability

- a) Setting ability refers to the ease with which a potentiometer can be set accurately to the position that produces the desired circuit condition.
- b) Setting stability refers to ability of the potentiometer to remain at the desired setting position. Stability may be affected by temperature exposure, change of temperature/cycling, humidity, and mechanical shock (or bump) or vibration.

4.17.1 Setting ability (adjustability)

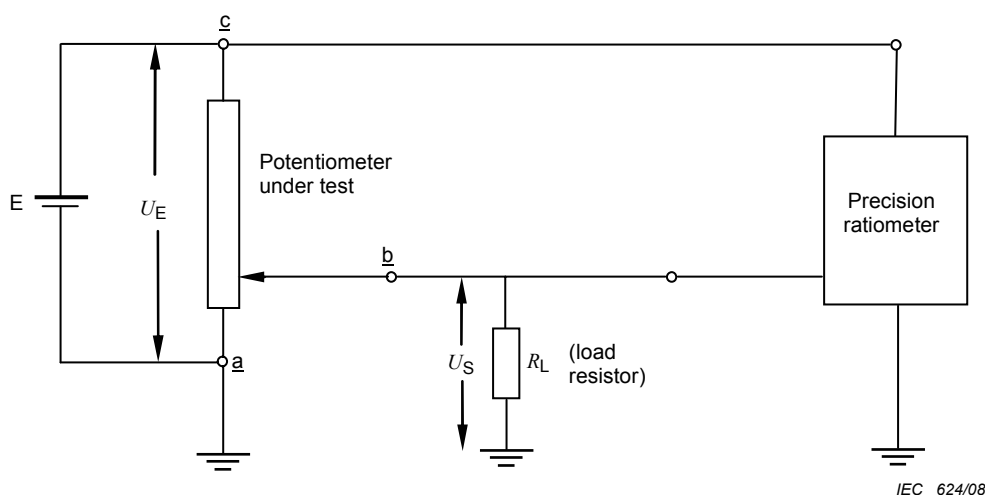
This method verifies at three points of the electrical travel the setting ability properties of the potentiometer.

For wire-wound potentiometers the influence of the resolution shall be taken into consideration when limits for setting ability are fixed.

Two test methods are described; one for potentiometers used as voltage dividers and the other for potentiometers used as current controllers (variable resistors).

NOTE A potentiometer used as a voltage divider has the total applied voltage between the end terminals with negligible current flowing through the moving contact. When a potentiometer used as a current controller (variable resistor), a variable resistor with all current flowing through the moving contact.

4.17.1.1 Method 1: Potentiometer used as voltage divider



Key

U_E 0,1 times the rated voltage or 10 V (whichever is the smaller)

R_L $10 R_N$, where R_N is the nominal total resistance value of the test potentiometer

Figure 21 – Measuring circuit for setting ability (as divider)

The precision ratio meter should have an input impedance of at least 10 MΩ. If a digital or electronic type ratio meter with sufficient accuracy is not available, a precision potentiometer standard in combination with a zero detector may be used.

a) Measuring conditions

1) Adjustment means

Three possibilities for means of adjustment exist:

- i) potentiometers with shaft: unless otherwise specified in the detail specification, for adjustment a knob shall be mounted on the shaft with a diameter between 0,8 and 1,2 times the outside body diameter of the potentiometer unless otherwise specified in the detail specification;
- ii) potentiometers supplied with a specific knob: this knob shall be used;
- iii) preset potentiometers with screw-driver adjustment: the diameter of the screw-driver handle shall be 8 mm ± 1 mm.

2) Accuracy

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement.

3) Setting time

The setting of the potentiometer to specified values shall be completed within a specified time.

b) Measurement

The voltage U_E and the resistance R_L shall be set as specified in Figure 21.

The moving contact of the potentiometer shall be adjusted so that an output voltage near $0,3 U_E$ is obtained, but outside the limit specified in the relevant specification. The test operator shall then begin timing and attempt to adjust the potentiometer under test so that $\frac{U_S}{U_E}$ is as close to $0,3$ as possible, or within the specified limits.

The adjustment shall be completed within 20 s and is judged to be completed when the operator no longer touches the actuating device.

After completion the value of setting ability shall be calculated from the following formula:

$$\text{Setting ability} = \frac{U_{SO}}{U_E} - \frac{U_S}{U_E}$$

where

$\frac{U_{SO}}{U_E}$ is the desired ratio (in this case $0,3$);

$\frac{U_S}{U_E}$ is the ratio measured by the ratio meter.

This test procedure shall be repeated at $0,5 U_E$ and $0,7 U_E$.

For non-linear potentiometers, the detail specification shall prescribe the setting points and the index point.

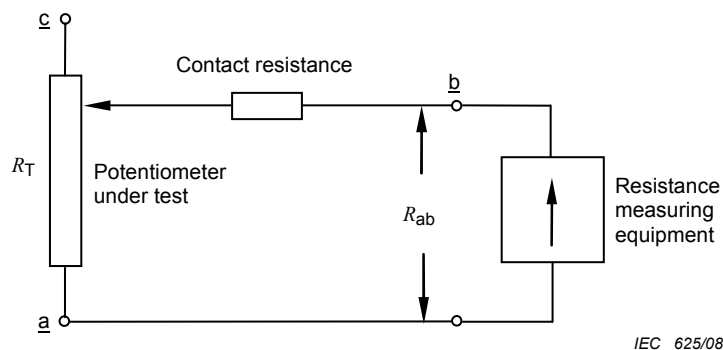
4.17.1.2 Method 2: Potentiometer used as current controller

Figure 22 – Measuring circuit for setting ability (as current controller)

a) Measuring conditions

The same measuring conditions as for Method 1 apply (see 4.17.1.1 a)).

b) Measurement

The moving contact shall be set to obtain a resistance value R_{ab} near $0,3 R_T$ but outside the limit specified in the relevant specification. The test operator shall then begin timing and attempt to adjust the potentiometer under test so that R_{ab} is as close to $0,3 R_T$ ($0,3 R_N$ may be used) as possible, or within the specified limit.

The adjustment shall be completed within 20 s and is judged to be completed when the operator no longer touches the actuating device.

After completion the value of setting ability shall be calculated from the following formula:

$$\text{Setting ability} = \frac{R_{ab} - (R_{ab})_0}{R_T}$$

where

R_T is the total resistance of the potentiometer under test;

$(R_{ab})_0$ is the desired resistance (in this case $0,3 R_T$);

R_{ab} is the resistance value obtained when the adjustment is completed.

This test procedure shall be repeated at $0,5 R_T$ and $0,7 R_T$ (or R_N).

NOTE For referee purposes this procedure should be conducted with suitable equipment so that the current through the contact during adjustment is set at the values specified below.

Table 6 – Moving contact current

Resistance value of test potentiometer R_T	Moving contact current $I_L^a (\pm 20 \%)$
$R_T < 50 \Omega$	30 mA
50 Ω to 499 Ω	10 mA
500 Ω to 99 k Ω	1 mA
100 k Ω to 2 M Ω	100 μA
$R_T > 2 M\Omega$	50 μA

^a Provided it does not exceed the limiting moving contact current.

4.17.1.3 Requirements

The potentiometer shall meet the requirements as prescribed in the detail specification.

4.17.2 Setting stability

Two test method are described, one for the use of voltage and other for the use of resistance. The preset potentiometers shall be subjected to test, either using 4.17.2.1 or 4.17.2.2 as prescribed in the sectional and detail specification.

Unless otherwise specified in the relevant specification, the potentiometers shall be tested as specified in 4.17.2.1.

NOTE Moving contact position: due to the effects of the overlap of termination, the contact resistance is unsuitable at 5 % of total travel of the moving contact. For this reason, it is undesirable to specify a moving contact position of less than 5 % and greater than 95 % of travel for resistance setting stability test.

4.17.2.1 Method 1: Voltage setting stability

The moving contact shall be set at between 40 % and 60 % of the total mechanical travel. A voltage not exceeding the voltage given in 4.6 shall be applied to terminals a and c of the potentiometer. The voltage between terminals a and c, and terminals a and b shall be measured with a high-impedance voltmeter and applied to the following formula:

$$\text{Setting stability (VSS)} = \frac{U_{ab}}{U_{ac}} \times 100 (\%)$$

where

U_{ab} is the voltage across one end terminal and the moving terminal;

U_{ac} is the voltage across the end terminals.

The difference between the initial measurement made before the environmental test and the measurement made after the test indicates the per cent change, a measure of the setting stability.

4.17.2.2 Method 2: Resistance setting stability

Using ohmmeter measure and record total resistance (R_{ac}). Unless otherwise specified, connect the ohmmeter to read output resistance and the moving contact shall be set at between 40 % and 60 % of the total mechanical travel. Measure output resistance and record as $R_{ab(\text{initial})}$. Within 2 h of completion of environmental exposure, re-measure the output resistance and record as $R_{ab(\text{final})}$. Calculate the resistance setting stability (RSS) by

$$\text{Setting stability (RSS)} = \frac{R_{ab(\text{final})} - R_{ab(\text{initial})}}{R_{ac}} \times 100 (\%)$$

NOTE Comparison of voltage setting stability to resistance setting stability.

Voltage setting stability is not sensitive to changes in contact resistance and, therefore, reflects mechanical movement of the moving contact and is symmetrical (for example, $SS_{ab} = SS_{bc}$). Contact resistance is typically positive. Since resistance setting stability is the algebraic sum of voltage setting stability (mechanical movement) and contact resistance shift (increase in contact resistance due to oxidation), resistance setting stability (RSS) will not be symmetrical (for example, RSS_{ab} is not equal to RSS_{bc}). In the case of a positive voltage setting stability shift, the contact resistance contribution to resistance shift will be additive, but for negative voltage setting stability shifts it will reduce the apparent output resistance change. For this reason, it is preferable to require measurement of both RSS_{ab} and RSS_{bc} .

4.17.2.3 Requirements

The potentiometer shall meet the requirements as prescribed in the detail specification.

4.18 Starting torque

When set at a random position away from end stops, or slipping clutch if fitted, the torque necessary to operate the moving contact in either direction shall be as specified in the detail specification.

NOTE When requirements for running torque uniformity exist, they must be as specified in the detail specification.

4.19 Switch torque

The torque necessary to operate the switch shall not exceed that value specified in the detail specification but it shall be at least twice the starting torque as measured in 4.18.

4.20 End stop torque

4.20.1 There shall be no deformation or other apparent damage when the moving contact is set against each end stop in turn and a torque as specified in Table 7 is applied to the operating shaft for 10 s.

Table 7 – End stop torque

Shaft diameter mm	Torque mN.m
>5,5	800
≤5,5	350

NOTE 1 For potentiometers having a body diameter or width equal to, or less than, 14,5 mm, the requirements should be specified in the detail specification.

NOTE 2 When the moving contact or actuating device has been designed for special application, the value of the applied torque should be specified in the detail specification.

4.20.2 When the potentiometer is fitted with a slipping clutch, the moving contact shall be adjusted to each extreme limit of the mechanical travel and a torque shall be applied to the actuating device to force the moving contact to idle for five complete mechanical turns of the actuating device.

During the rotation of the lead-screw a suitable electrical indication device shall be connected between terminal b and the terminal electrically adjacent to the moving contact.

There shall be no discontinuity. After the test, the moving contact shall be capable of operating in its normal manner. The torque required to slip the clutch shall not exceed 5 times the maximum specified starting torque.

4.21 Locking torque

4.21.1 Potentiometers fitted with locking devices shall be mounted on a metal panel by the normal means of mounting and the shaft shall be set on 40 % to 60 % of its total mechanical travel. The locking device shall be tightened using the torque figure prescribed in Table 7 and the value of the output ratio U_{ab}/U_{ac} shall be measured.

Table 8 – Locking torque

Shaft diameter mm	Torque applied for locking mN.m
>5,5	1 100-1 200
≤5,5	900-1 000

4.21.2 The torque of the value prescribed below shall be applied to the shaft of the potentiometer and the value of U_{ab}/U_{ac} shall be measured while the torque is applied to the shaft and shall be compared with the value measured before the torque was applied.

Table 9 – Shaft torque

Shaft diameter mm	Torque applied to the shaft mN.m
>5,5	200-220
≤5,5	130-150

The change in the value $\frac{U_{ab}}{U_{ac}}$ shall not exceed the limit prescribed in the sectional or detail specification.

The locking torque shall be removed and the bushing and threads of the potentiometer examined. There shall be no visible damage.

NOTE For potentiometers having a body diameter or width equal to, or less than, 14,5 mm, the requirements should be specified in the detail specification.

4.22 Thrust and pull on shaft

4.22.1 The potentiometer shall be rigidly mounted by its normal means.

4.22.2 A thrust followed, when applicable, by a pull, as specified below, shall be applied to the operating shaft in the direction along its axis. The continuity shall be checked under these conditions.

In both cases, the requirements for continuity as specified in 4.5 shall be fulfilled.

Table 10 – Thrust and pull

Shaft diameter mm	Thrust / Pull N
>5,5	25
≤5,5	10

4.22.3 The setting stability shall be measured as specified in 4.17.2.1 or 4.17.2.2.

A thrust with the value given in the table of 4.22.2 shall be applied to the operating shaft in the direction along its axis and under these conditions the voltage between terminals a and b shall be measured and the output ratio U_{ab}/U_{ac} shall again be calculated. The test shall be repeated with a pull with the value given in Table 10 in the direction along the axis of the operating shaft and, under these conditions, the voltage between terminals a and b shall be measured and the output ratio U_{ab}/U_{ac} shall again be calculated.

The change in setting stability with respect to that measured before the thrust was applied shall not exceed that prescribed in the relevant specifications.

For precision potentiometers the total axial excursion of the shaft measured at the end of the shaft during the test in 4.22.2 shall not exceed that specified in the detail specification.

4.22.4 The thrust specified below shall be applied to the operating shaft in the direction along its axis for 10 s followed by a pull along the direction of the axis of the operating shaft for 20 s. There shall be no visible damage.

Table 11 – Thrust and pull

Shaft diameter mm	Thrust / Pull N
>5,5	125
≤5,5	50

NOTE For potentiometers having a body diameter or width equal to, or less than, 14,5 mm, the conditions of test should be specified in the detail specification.

4.23 Shaft run-out

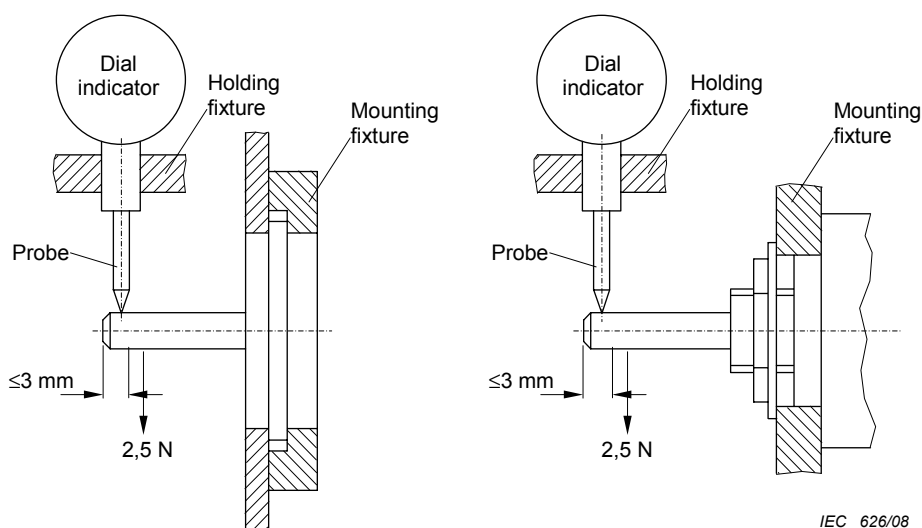
The eccentricity of the shaft diameter with respect to the rotational axis of the shaft shall be as specified in the detail specification. It shall be measured at a specified distance from the end of the shaft when the body of the potentiometer is held and the shaft rotated with a specified load applied radially to the shaft.

The potentiometer shall be mounted firmly with the shaft axis in a horizontal position and held rigidly with respect to the dial indicator (see Figure 23). The dial indicator is positioned so that its probe contacts the shaft within 3 mm from the end of the shaft or the edge of any interruption of the smooth cylindrical surface of the shaft.

When the test is specified for shafts with non-cylindrical surfaces such as flats, slots, or splines, a cylindrical shaft-adaptor shall be used.

The probe is depressed sufficiently to ensure a proper positive and negative indication of the dial during rotation of the shaft.

A force of 25 N is applied radially to the shaft to remove shaft radial play and is positioned as close to the indicator probe as is practicable. For small diameter shafts, the magnitude of the load applied should be reduced so that it never exceeds that which would cause the shaft to deflect more than one-tenth of the shaft run-out limit. The shaft is then rotated slowly through 360° or through its total mechanical travel, whichever is less. The shaft run-out is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, divided by the length of shaft extensions measured from the mounting surface to the point of measurement and shall not exceed the value prescribed in the detail specification.



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Figure 23 – Shaft run-out

4.24 Lateral run-out

The perpendicularity of the mounting surface of the potentiometer with respect to the rotational axis of the shaft shall be as prescribed in the detail specification. It shall be measured on the mounting surface when the shaft is held and the body of the potentiometer is rotated while specified loads are applied radially and axially to the body of the potentiometer.

The potentiometer shall be mounted firmly in the shaft holding fixture with the shaft in a vertical position (see Figure 24). The shaft shall be clamped within 3 mm of the front surface of the potentiometer without interference and held rigidly with respect to the dial indicator. The potentiometer body shall remain free to rotate. Care shall be taken to ensure that the shaft is not distorted in any way by the mode of clamping or the inherent weight of the potentiometer body.

The dial indicator shall be positioned so that its probe contacts the smooth portion of the mounting surface of the potentiometer less than 3 mm from the outside edge of the mounting surface. A 2,0 N force shall be applied normally to the centre line of the shaft axis, on the potentiometer body within 3 mm of the mounting surface.

Simultaneously, a force of 2,5 N shall be applied axially to the centreline of the potentiometer. These loads serve to remove radial play and end play of the shaft. For small diameter shaft, the magnitude of the force applied shall be reduced so that it never exceeds that which would cause the spindle to deflect more than one-tenth of the shaft run-out limit. The probe shall be depressed sufficiently to ensure a proper positive and negative indication during rotation of the potentiometer. The body of the potentiometer shall then be slowly rotated through 360° or through the total mechanical travel, whichever is less. The lateral run-out is the total indicator reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, divided by the mounting surface radius to the point of measurement and shall not exceed the value prescribed in the detail specification.

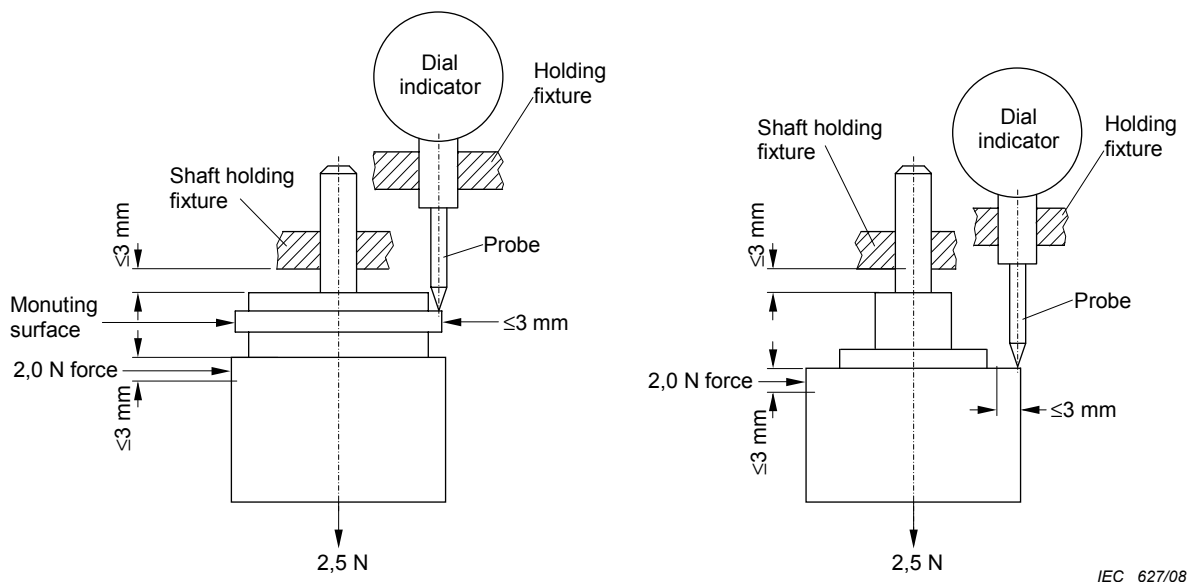


Figure 24 – Lateral run-out

4.25 Pilot (or spigot) diameter run-out

The eccentricity of the pilot diameter with respect to the rotational axis of the shaft shall be as prescribed in the detail specification. It shall be measured on the pilot diameter when the shaft is held and the body of the potentiometer is rotated while a specified load is applied radially to the body of the potentiometer.

The potentiometer shall be mounted firmly in the shaft holding fixture with the shaft axis in a vertical position (see Figure 25). The shaft shall be clamped within 3 mm of the front surface of the potentiometer without interference and shall be held rigidly with respect to the dial indicator.

The potentiometer body shall remain free to rotate. Care should be taken to ensure that the shaft is not distorted in any way by the mode of clamping or the inherent weight of the potentiometer body. The dial indicator shall be positioned so that its probe contacts the periphery of the pilot surface near the midpoint of the surface. A 2,0 N force shall be applied normally to the centre line of the shaft axis on the potentiometer body within 3 mm of the mounting surface to remove the shaft radial play. For small diameter and/or long shafts, the magnitude of the force applied should be reduced so that it never exceeds that which would cause the shaft to deflect more than one-tenth the shaft run-out limit. The probe shall be depressed sufficiently to ensure a proper positive indication of the dial during rotation of the potentiometer.

The body of the potentiometer shall then be slowly rotated through 360° or through the total mechanical travel, whichever is less. The pilot diameter run-out is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, and shall not exceed the value prescribed in the detail specification.

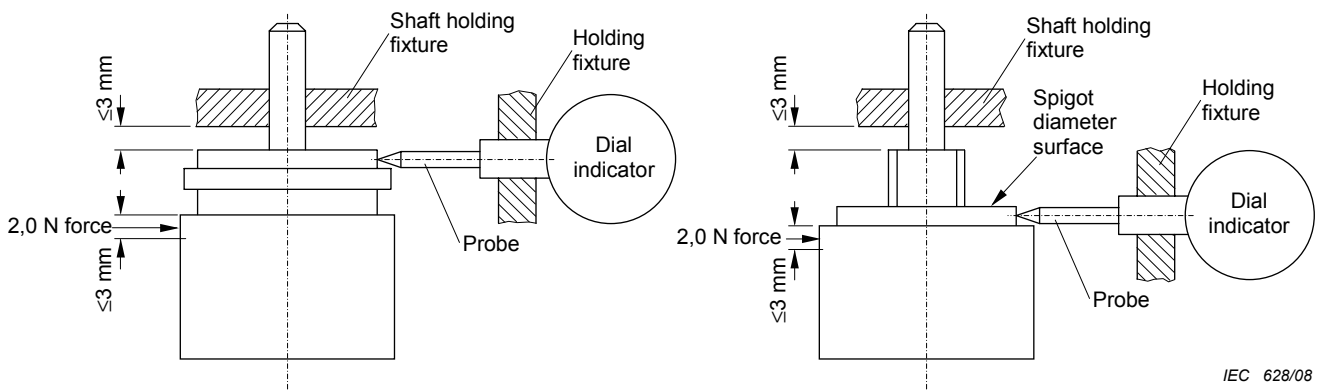


Figure 25 – Pilot (spigot) diameter run-out

4.26 Shaft end play

The total axial excursion of the shaft with respect to the potentiometer body, indicated at the end of the shaft with a specified axial load applied alternately in opposite directions shall be as prescribed in the detail specification.

The potentiometer shall be mounted firmly by its normal means with the shaft axis in a vertical position and held rigidly with respect to the dial indicator, leaving the shaft free to rotate (see Figure 26). The dial indicator shall be positioned with its probe parallel (or normal if pivot pointer indicator is used) to the axis of the shaft on the centre line.

The probe shall be depressed sufficiently to ensure a proper positive and negative indication. A 2,0 N force shall be applied alternately in opposite directions along the axis of the shaft.

The shaft end play is the total indicated reading determined by adding the maximum positive and negative readings, without regard to algebraic signs, and shall not exceed the value prescribed in the detail specification.

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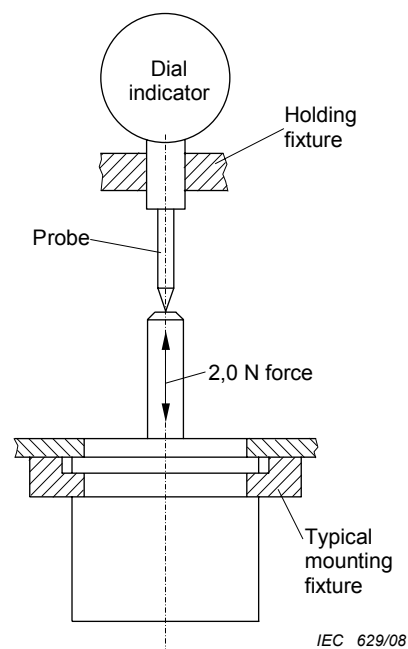


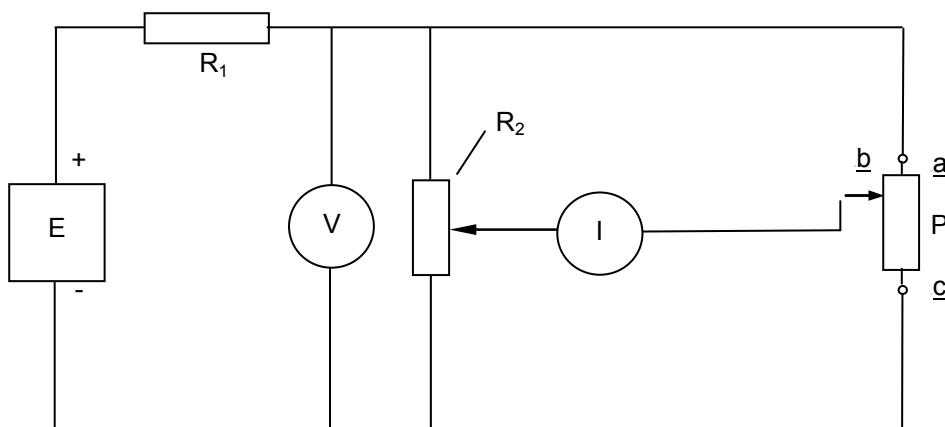
Figure 26 – Shaft end play

4.27 Backlash

4.27.1 The potentiometer shall be mounted for the measurement of the angular position of the actuating device.

A suitable instrument for measuring angular position shall be connected to the operating shaft of the potentiometer.

The actuating device shall be positioned at approximately mid-travel, and the potentiometer connected in the circuit of Figure 27.



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Key

E DC source

I Zero reading galvanometer

P Potentiometer under test

R_1 Resistor limiting the current to a value not exceeding the maximum rated galvanometer current

R_2 Potentiometer (resistance value shall be of the same order as the potentiometer under test)

NOTE R_2 and P comprise a bridge network.

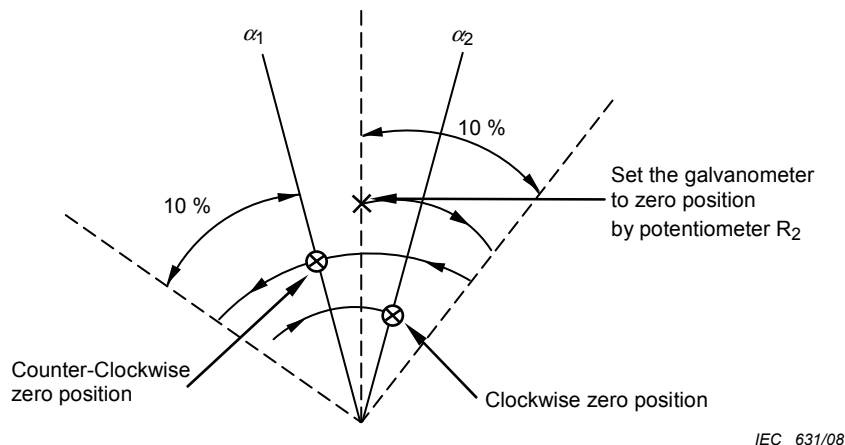
Figure 27 – Test circuit for measurement of backlash

The actuating device of the potentiometer under test shall be set at approximately mid-travel (but not in a tap or shorted area), and the bridge shall be balanced by means of adjustment of potentiometer R_{2B} .

The actuating device shall then be rotated clockwise by about 10 % of the total mechanical travel, followed by an counter-clockwise rotation until the circuit is at balance. The angular position at balance α_1 shall be recorded, after which the rotation shall be continued in an counter-clockwise direction by about 10 % of the total mechanical travel. The actuating device is then rotated clockwise until the circuit is again at balance. This angular position α_2 shall be recorded.

The backlash is the angle included between the angular positions α_1 and α_2 .

NOTE During each rotation, hesitation is permitted, but there should be no momentary reversal of direction.



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Figure 28 – Measurement of backlash

4.27.2 The backlash expressed in degrees shall not exceed the appropriate value in Table 12.

Table 12 – Backlash

Tolerance on conformity %	(α_1, α_2) in degrees	
	Single turn or continuous rotation	Multi-turn
1	0,50	1
0,50	0,25	1
0,25	0,1	1
0,1	0,1	0,4
0,05	0,1	0,1
0,025	0,1	0,1

4.28 Dither

4.28.1 The resistance between terminals a and c shall be measured.

4.28.2 Test method

4.28.2.1 The operating shaft shall be oscillated at the rate of $55 \text{ Hz} \pm 10 \text{ Hz}$ through an angle of between 5° and 10° . The positions of both points of reversal of motion, as given in the detail specification, shall be stable within 1° throughout the test period. The duration of the test shall be related to the number of cycles specified for the mechanical endurance test to the appropriate value in Table 13 or Table 14.

Table 13 – Dither for non-wire wound types

Number of cycles	Duration of test h
$1,25 \times 10^5$	0,5
5×10^5	2,0
$2,5 \times 10^6$	10,0

Table 14 – Dither for wire wound types (under consideration)

When the number of cycles is greater than $2,5 \times 10^6$, the duration of test shall be increased proportionally.

4.28.2.2 When required by the detail specification, the output signal between terminals b and c shall be monitored. The detail specification shall prescribe all necessary requirements.

4.28.3 At the conclusion of this test, the following tests shall be applied.

The potentiometers shall be visually examined. There shall be no visual damage.

The resistance between terminals a and c shall be measured. The change in resistance with respect to the value measured in 4.28.1 shall not exceed the value prescribed in the relevant detail specification.

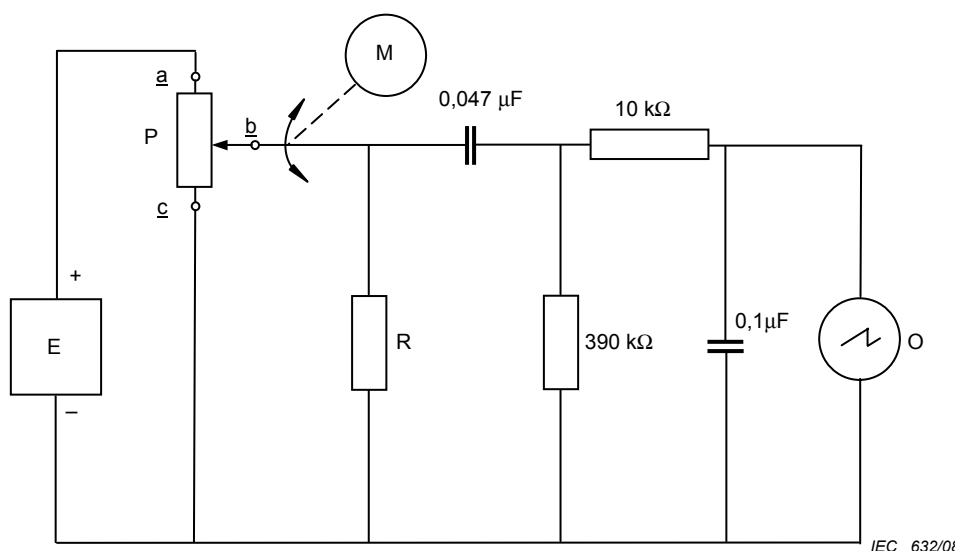
The output smoothness of non-wire-wound types shall be measured and shall not exceed the value prescribed in the detail specification.

4.29 Output smoothness

4.29.1 The potentiometer under test shall be connected as shown in Figure 29.

The output smoothness shall be measured over at least 70 % of the effective electrical travel in increments of angle of 1 % of the effective electrical travel.

4.29.2 The output smoothness, expressed in per cent of the voltage U_{ac} , shall not exceed the value given in the detail specification selected from 0,01 %, 0,025 %, 0,1 %, 0,5 %, 1,0 % and 2,0 %.



Key

- P Potentiometer under test
- E DC source of 10 V or rated voltage (whichever is the less)
- R $100 \times$ nominal total resistance or as specified in the detail specification
- O Oscilloscope having pass band ≥ 1 kHz and input impedance ≥ 1 M Ω
- M rotates the actuating device through not less than 80 % and not greater than 95 % of the effective electrical travel in alternate directions. The speed of rotation shall be between 3 and 5 revolutions per minute and shall be constant for at least 70 % of the duration.

Figure 29 – Test circuit for measurement of output smoothness

4.30 Robustness of terminals

The potentiometers shall be subjected to the procedure of tests Ua1, Ub, or Ud of IEC 60068-2-21, as applicable.

NOTE Test Ub should not be applied if the detail specification describes the terminals as rigid.

4.30.1 The resistance between terminals a and c shall be measured.

4.30.2 Test Ua1 – Tensile

The force applied for 10 s shall be:

- for terminals other than wire end terminals: 20 N;
- for wire terminals; see Table 15.

Table 15 – Tensile force

Nominal cross-sectional area mm ²	Corresponding nominal diameter for circular section wires mm	Force N
$S \leq 0,05$	$d \leq 0,25$	1
$0,05 < S \leq 0,1$	$0,25 < d \leq 0,35$	2,5
$0,1 < S \leq 0,2$	$0,35 < d \leq 0,5$	5
$0,2 < S \leq 0,5$	$0,5 < d \leq 0,8$	10
$0,5 < S \leq 1,2$	$0,8 < d \leq 1,25$	20
$S > 1,2$	$d > 1,25$	40

NOTE For circular section wires, strips or pins, the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification.

For standard wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.

4.30.3 Test Ub – Bending (for wire terminals)

(See note of 4.30).

Method 1: Two consecutive bends shall be applied in each direction.

4.30.4 Test Ub – Bending (for tag terminals)

(See note of 4.30).

Method 1: Two consecutive bends shall be applied in each direction.

4.30.5 Test Ub – Bending (for printed board terminals)

(See note of 4.30).

Printed board terminals which are not described as rigid shall be subjected to the following bending test. The potentiometers shall be firmly clamped and each terminal shall be bent through 90°. The radius of curvature shall be approximately 1 mm. The bending centre shall be 3 mm ± 0,5 mm from the body of the potentiometer for terminals which are 10 mm or longer. For terminals shorter than 10 mm, the bending centre shall be at a point 1,5 mm ± 0,5 mm from the mounting plane of the potentiometers. The terminals shall then be returned to the original position and be bent 90° in the opposite direction with the same radius and the

same bending point. The terminal shall then be returned to the original position. The bends shall be made slowly.

4.30.6 Test Ud – Torque (for terminals with threaded studs or screws)

In accordance with IEC 60068-2-21.

4.30.7 Test Ud – Torque (for integral fixing devices)

In accordance with IEC 60068-2-21.

4.30.8 Final measurements

The following procedure shall be applied:

- After each of these tests, the potentiometers shall be visually examined. There shall be no visible damage.
- At the conclusion of the last of these tests the resistance between terminals a and c shall be measured as specified in 4.6.
- The change of resistance with respect to the value measured in 4.30.1 shall not exceed the value prescribed in the relevant specification.

4.31 Sealing

4.31.1 Static seals (Type A)

Potentiometers fitted with static seals shall be subjected to Test Qa of IEC 60068-2-17.

Unless otherwise specified in the detail specification, the seals shall be tested in each direction at a pressure of 100 kPa to 110 kPa.

4.31.2 Operational seals (Type B)

4.31.2.1 Normal test

Potentiometers fitted with operational seals shall be subjected to Test Qa of IEC 60068-2-17.

Unless otherwise specified in the detail specification, the seals shall be tested at a pressure of 100 kPa to 110 kPa. The rate of operation shall be 5 cycles per min.

The rate of leakage shall not exceed 1 cm³/h.

4.31.3 Container sealing

The potentiometer shall be tested to the following procedure.

The potentiometer's surface shall be cleared of any foreign matter immediately before immersion. The bath shall consist of tap water at a temperature of $85^{+5}_{0}^{\circ}\text{C}$. The potentiometer shall be completely submerged in the bath with no part at a depth of less than 25 mm and shaken for maximum of 5 s, to remove surface air, and shall remain in the bath for a period of 1 min ± 5 s.

During immersion, there shall be no leakage as determined by repetitive any bubbles emerging from the potentiometer.

4.32 Solderability

When the solderability test is followed immediately by the resistance to soldering heat test, a drying procedure as prescribed in 4.3 shall be applied. The detail specification shall describe whether procedure 1 or procedure 2 shall be used.

4.32.1 All potentiometers except surface mount potentiometers shall be subject to test Ta of IEC 60068-2-20, either using the solder bath method (Method 1) or the soldering iron method (Method 2) as prescribed by the detail specification.

4.32.2 When the solder bath method (Method 1) is specified, the following requirements apply.

4.32.2.1 Test conditions

The test shall be carried out under the following conditions.

- a) All potentiometers, except those of b) below:
 - Bath temperature: $235\text{ °C} \pm 5\text{ °C}$ (Sn/Pb) or $245\text{ °C} \pm 5\text{ °C}$ (Sn/Ag/Cu);
 - Immersion time: $2,0\text{ s} \pm 0,5\text{ s}$ (at 235 °C) or $3,0\text{ s} \pm 0,3\text{ s}$ (at 245 °C);
 - Depth of immersion (from the seating plane or component body): $2\text{ }_{-0,5}^0\text{ mm}$, using a thermal insulating screen of $1,5\text{ mm} \pm 0,5\text{ mm}$ thickness.
- b) Potentiometers indicated by detail specification as being not designed for use on printed boards:
 - bath temperature: $235\text{ °C} \pm 5\text{ °C}$ (Sn/Pb) or $245\text{ °C} \pm 5\text{ °C}$ (Sn/Ag/Cu);
 - immersion time: $2,0\text{ s} \pm 0,5\text{ s}$ (at 235 °C) or $3,0\text{ s} \pm 0,3\text{ s}$ (at 245 °C);
 - depth of immersion (from the component body): $3,5\text{ }_{-0,5}^0\text{ mm}$.

4.32.2.2 The terminals shall be examined for poor tinning as evidenced by free flowing of the solder with wetting of the terminals.

4.32.2.3 When the solder bath method is not applicable, the detail specification shall define the test method, test conditions and the requirements.

NOTE When the solder globule method is used, the requirement should include the soldering time.

4.32.2.4 Surface mount potentiometers shall be tested as specified in 4.50.

4.32.3 When the soldering iron method (Method 2) is specified, the following requirements apply.

Temperature of the soldering iron: $350\text{ °C} \pm 10\text{ °C}$ (at start of test);

Bit size: 8 mm (size A) or 3 mm (size B);

Duration : 2 s to 3 s.

4.33 Resistance to soldering heat

4.33.1 When prescribed in the detail specification, the potentiometers shall be dried using either Procedure 1 or Procedure 2 of 4.3.

When the resistance to soldering heat test is to be applied immediately after the solderability test, the drying procedure may be performed prior to the solderability test. The resistance between terminals a or c shall then be measured as specified in 4.6.

4.33.2 Unless otherwise specified in the relevant specification, one of the following tests shall be applied.

- a) For all potentiometers except those of b) and c) below, apply Method 1 of test Tb of IEC 60068-2-20, with the following conditions:
 - temperature of the solder bath: $260\text{ °C} \pm 5\text{ °C}$;
 - depth of immersion from the seating plane: $2\text{ }_{-0,5}^0\text{ mm}$, using a thermal insulating screen of $1,5\text{ mm} \pm 0,5\text{ mm}$ thickness;
 - immersion time: 5 s or 10 s, as specified in the detail specification.
- b) For potentiometers not designed for use on printed boards, as indicated in the detail specification, when the soldering iron method (Method 2) is specified, the following requirements apply:
 - temperature of soldering iron: $350\text{ °C} \pm 10\text{ °C}$ (at start of test);
 - soldering time: 5 s or 10 s;
 - the size of the soldering iron and the point of application shall be specified in the relevant specification.
- c) Surface mount potentiometers shall be tested as specified in 4.51.

4.33.3 The potentiometers shall then remain under the standard atmospheric conditions for recovery for $4\text{ h} \pm 0,5\text{ h}$ (for surface mount potentiometers 1h to 2h) unless it can be demonstrated that stability is reached earlier.

The resistance between terminals a and c shall be measured as specified in 4.6. The change in resistance with respect to the value measured in 4.33.1 shall not exceed the value prescribed in the relevant specification.

The terminal resistance shall be measured as prescribed in 4.7 and shall be less than the limit prescribed in the relevant specification.

4.34 Change of temperature

4.34.1 This test is only applicable to potentiometers having a difference between the upper and lower category temperatures exceeding 95 °C .

4.34.2 The resistance between terminals a and c shall be measured as specified in 4.6.

4.34.3 For preset potentiometers (include surface mount) only, the setting stability shall be measured as specified in 4.17.2.1 or 4.17.2.2.

A voltage not exceeding the voltage given in 4.6 shall be applied to terminals a and c of the potentiometer and the voltage between terminals a and b shall be measured with a high impedance voltmeter.

The output ratio $\frac{U_{ab}}{U_{ac}}$ shall be calculated.

4.34.4 The potentiometers shall be subjected to Test N of IEC 60068-2-14. The low and high temperatures prescribed in Test N shall be the lower and upper category temperatures respectively and the duration of the exposure at these temperatures shall be 30 min.

Potentiometers having a rated dissipation equal to, or less than, 10 W shall be subjected to Test Na, those greater than 10 W shall be subjected to Test Nb.

The rate of change of temperatures in Test Nb shall be 5 °C/min.

4.34.5 After recovery the potentiometers shall be visually examined. There shall be no visible damage

4.34.6 For preset potentiometers (include surface mount) only, after the test, the setting stability shall be re-measured and compared with that measured in 4.34.3, and the change in setting stability shall not exceed that specified in the relevant specification.

4.34.7 The resistance between terminals a and c shall be measured as specified in 4.6. The change in resistance with respect to the value measured in 4.34.2 shall not exceed the limit prescribed in the relevant specification.

4.35 Vibration

The potentiometers shall be mounted as indicated in the relevant specification.

4.35.1 The resistance between terminals a and c shall be measured as specified in 4.6.

4.35.2 For preset potentiometers (include surface mount) only, the setting stability shall be measured as specified in 4.17.2.1 or 4.17.2.2.

A voltage not exceeding the voltage given in 4.6 shall be applied to terminals a and c of the potentiometer and the voltage between terminals a and b shall be measured with a high impedance voltmeter.

The output ratio $\frac{U_{ab}}{U_{ac}}$ shall be calculated.

4.35.3 Unless otherwise prescribed by the relevant specification, the potentiometer shall be subjected to Test Fc of IEC 60068-2-6 using the appropriate degree of severity prescribed in the relevant specification.

4.35.4 Additional requirements during test

4.35.4.1 Potentiometers not fitted with a locking device

The moving contact shall be set between 40 % and 60 % of total mechanical travel unless this operation has been performed as part of the requirements of 4.35.2. Effective continuity between the moving contact and the resistance element shall be checked by oscillographic, or other suitable, means and shall be maintained.

4.35.4.2 Potentiometers fitted with locking device

Those potentiometers fitted with an integral locking device shall have the moving contact set and locked at between 40 % and 60 % of the total mechanical travel, unless this operation has been performed as part of the requirements of 4.35.2.

During the test, any transient resistance changes of the resistance between terminations a and b or, if the resistance between terminals c and b is smaller, between these latter terminals, shall not exceed that specified in the relevant specification.

4.35.5 After the test, the potentiometers shall be visually examined. There shall be no visible damage.

4.35.6 For preset potentiometers (include surface mount), after the test, the setting stability shall be re-measured and compared with that measured in 4.35.2, and the change in setting stability shall not exceed that specified in the relevant specification.

4.35.7 The resistance between terminals a and c shall be measured. The change in resistance with respect to the value measured in 4.35.1 shall not exceed the limit prescribed in the relevant specification.

4.36 Bump

The potentiometers shall be mounted as indicated in the relevant specification.

4.36.1 The resistance between terminals a and c shall be measured as specified in 4.6.

For preset potentiometers (include surface mount) only, the setting stability shall be measured as specified in 4.17.2.1 or 4.17.2.2.

4.36.2 The potentiometers shall be subjected to Test Eb of IEC 60068-2-29, using the appropriate degree of severity.

The relevant specification shall state the degree of severity at which the test shall be performed and the method of mounting to be used.

4.36.3 After the test, the potentiometers shall be visually examined. There shall be no visible damage.

The resistance between terminals a and c shall be measured as specified in 4.6. The change in resistance with respect to the value measured in 4.36.1 shall not exceed the limit prescribed in the relevant specification.

The setting stability shall be re-measured and compared with that measured in 4.36.1, and the change in setting stability shall not exceed that specified in the relevant specification.

4.37 Shock

The potentiometers shall be mounted as indicated in the relevant specification.

4.37.1 The resistance between terminals a and c shall be measured as specified in 4.6.

For preset potentiometers (include surface mount) only, the setting stability shall be measured as specified in 4.17.2.1 or 4.17.2.2.

4.37.2 The potentiometers shall be subjected to test Ea of IEC 60068-2-27, using the mounting method and degree of severity prescribed in the relevant specification. During the test, the potentiometers shall be monitored for electrical discontinuities, of 100 μ s or greater, between the terminals a and b. There shall be no such discontinuities.

4.37.3 After the test, the potentiometers shall be visually examined. There shall be no visible damage.

The resistance between terminals a and c shall be measured as specified in 4.6. The change in resistance with respect to the value measured in 4.37.1 shall not exceed the limit prescribed in the relevant specification.

The setting stability shall be re-measured and compared with that measured in 4.37.1, and the change in setting stability shall not exceed that specified in the relevant specification.

4.38 Climatic sequence

In the climatic sequence, an interval of three days maximum is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period specified for the first cycle of the damp heat, cyclic, test dB.

4.38.1 Initial requirements

The potentiometers shall be dried using either Procedure 1 or Procedure 2 of 4.3 as prescribed for in the relevant specification.

The resistance between terminals a and c shall be measured as specified in 4.6.

4.38.2 Dry heat

4.38.2.1 The potentiometers shall be subjected to Test Ba of IEC 60068-2-2, at the upper category temperature, for a duration of 16 h.

4.38.2.2 After recovery the potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.38.3 Damp heat, cyclic, Test Db, first cycle

The potentiometers shall be subjected to Test Db of IEC 60068-2-30 for one cycle of 24 h, using a temperature of 55 °C (severity b).

After recovery, the potentiometers shall be subjected immediately to the cold test.

4.38.4 Cold

4.38.4.1 The potentiometers shall be subjected to the procedure of Test Aa of IEC 60068-2-1, at the lower category temperature, for a duration of 2 h.

4.38.4.2 While still at the specified low temperature and at the end of the period of low temperature, the starting torque shall be measured, except for potentiometers of category -/-/04.

The starting torque shall be measured, as specified in 4.18 after the moving contact has been operated once over the whole resistive element and back, using a torque not exceeding six times the maximum value specified in the detail specification for starting torque but with an upper limit not exceeding that specified for end stop torque in 4.20.

The starting torque of the potentiometer shall not exceed the value specified in the detail specification.

The operating torque of the switch shall be measured as specified in 4.19 and shall not exceed the value prescribed in the detail specification.

4.38.5 Low air pressure

4.38.5.1 The potentiometers of categories 40/-/- and 55/-/- shall be subjected to the procedure of Test M of IEC 60068-2-13 using the degree of severity prescribed in the relevant specification.

4.38.5.2 The test shall be carried out at a temperature between 15 °C and 35 °C and the duration of the test shall be 1 h.

4.38.5.3 While still at the specified low air pressure and during the last 5 min of the 1 h period, a voltage proof test in accordance with 4.12.3 shall be carried out.

The test voltage shall be in accordance with that given in the detail specification.

During and after this test there shall be no sign of breakdown or flashover.

4.38.6 Damp heat, cyclic, Test dB, remaining cycles

The potentiometer shall be subjected to Test dB, Variant 1, of IEC 60068-2-30 for the following cycles of 24 h as indicated in the table, under the same conditions as used for the first cycle.

Table 16 – Number of cycles

Categories	Number of cycles
- / - / 56	5
- / - / 21	1
- / - / 10	1
- / - / 04	None

4.38.7 DC load (when specified in the detail specification)

At the end of the test, the potentiometers shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At 30 min ± 5 min after removal from the chamber for the damp heat cyclic test, the potentiometers shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller and shall be applied between terminals a and c.

4.38.8 Insulation voltage (to be applied when the d.c. load of 4.38.7 is not specified in the detail specification)

At the end of the conditioning period, the potentiometers shall be removed from the chamber; shaken so as to remove droplets of water and within 15 min the insulation voltage, as specified in the detail specification, shall be applied for 1 min between the terminals connected together and the spindle (when metallic) and/or the mounting plate (see 4.12.1 and 4.12.2).

There shall be no breakdown or flashover.

4.38.9 Recovery

The potentiometers shall then be subjected to the standard atmospheric conditions for testing for not less than 1 h and not more than 2 h.

4.38.10 Final test and measurements

The potentiometers shall then be subjected to such of the following tests and measurements as are prescribed in the detail specification.

After the recovery prescribed in 4.38.9 has been completed, the times for testing shall be:

- 4.38.10.1: to be completed during the first hour;
- 4.38.10.2 and 4.38.10.3: to be completed in not more than 2 h;
- 4.38.10.4 to 4.38.10.7: to be completed in not more than 6 h.

4.38.10.1 After recovery the potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.38.10.2 The resistance between terminals a and c shall be measured as specified in 4.6. The change in resistance with respect to the value measured in 4.37.1 shall not exceed the limit prescribed in the relevant specification.

4.38.10.3 The insulation resistance shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.

4.38.10.4 The switch contact resistance shall be measured as specified in 4.11 and shall not exceed the limit prescribed in the detail specification.

4.38.10.5 The continuity shall be tested as specified in 4.5 and the requirements of the detail specification shall be met.

4.38.10.6 The starting torque shall be measured as specified in 4.18 and shall be within the limits prescribed in the detail specification.

4.38.10.7 The voltage proof test shall be carried out as specified in 4.12. There shall be no breakdown or flashover.

4.39 Damp heat, steady state

4.39.1 The resistance between terminals a and c shall be measured as specified in 4.6.

4.39.2 The potentiometers shall be subjected to Test Ca of IEC 60068-2-78, using the degree of severity corresponding to the climatic category of the potentiometer as indicated in the detail specification.

4.39.2.1 Potentiometers which are designed to be mounted direct onto a metal chassis shall be divided into three groups.

- a) The first group shall be subjected to this test without any voltage applied.
- b) The second group shall be subjected to the test with a direct voltage between terminals a and c. The voltage to be applied shall be selected from the following series:

0 – 4 – 6,3 – 10 – 16 – 25 – 40 – 63 – 100 V

The voltage selected shall be the next lower value to that derived from a calculation of 10 % of the rated voltage or 10 % of the limiting element voltage, whichever is the smaller. Throughout the test period the voltage shall be kept as closely as possible to the specified voltage, a tolerance of $\pm 5\%$ is allowed for mains voltage fluctuations and similar factors.

- c) The third group shall be subjected to the test with a direct voltage of $20\text{ V} \pm 2\text{ V}$ applied between the mounting plate and one of the end terminals. The mounting plate is connected to the negative pole, the terminal to the positive pole of the voltage source. The voltage shall be applied continuously throughout the test.

4.39.2.2 For all other potentiometers, the lot shall be divided into two groups and only the tests in a) and b) of 4.39.2.1 shall be carried out.

4.39.3 DC load (when specified in the detail specification)

At the end of the test, the potentiometers shall be subjected to the standard atmospheric conditions for testing. The time of transfer shall be as short as possible and shall not exceed 5 min. At $30\text{ min} \pm 5\text{ min}$ after removal from the chamber for the damp-heat, steady-state test, the potentiometers shall be subjected to a d.c. voltage for 1 min. The voltage shall be the rated voltage or the limiting element voltage, whichever is the smaller and shall be applied

between terminals a and c. The potentiometers shall then remain in the standard atmospheric conditions for testing for not less than 1 h and not more than 2 h.

4.39.4 Insulation voltage (to be applied when the d.c. load test of 4.39.3 is not specified in the detail specification)

At the end of the conditioning period, the potentiometers shall be removed from the chamber; they shall be shaken so as to remove droplets of water and, within 15 min, the insulation voltage as specified in the detail specification shall be applied for 1 min between the terminals connected together and the shaft (when metallic) and/or the mounting plate (see 4.12.1 and 4.12.2).

There shall be no breakdown or flashover.

4.39.5 Recovery

The potentiometers shall then be subjected to the standard atmospheric conditions for recovery for not less than 1 h and not more than 2 h.

4.39.6 Final tests and measurements

After the recovery prescribed in 4.39.5 has been completed the times for testing shall be:

- | | |
|----------------------|--|
| 4.39.6.1 | to be completed during the first hour; |
| 4.39.6.2 to 4.39.6.3 | to be completed in not more than 2 h; |
| 4.39.6.4 to 4.39.6.8 | to be completed in not more than 6 h. |

4.39.6.1 The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.

4.39.6.2 The resistance between terminals a and c shall be measured. The change in resistance with respect to the value measured in 4.39.1 shall not exceed the limit prescribed in the relevant specification.

4.39.6.3 The insulation resistance shall be measured as specified in 4.13. The value shall be not less than that prescribed in the relevant specification.

4.39.6.4 The switch contact resistance shall be measured as specified in 4.11 and shall not exceed the limit prescribed in the detail specification.

4.39.6.5 The continuity shall be tested as specified in 4.5 and the requirements of the detail specification shall be met.

4.39.6.6 The starting torque shall be measured as specified in 4.18 and shall be within the limits prescribed in the detail specification.

4.39.6.7 The rotational noise shall be measured as specified in 4.15.2 or 4.16.2, whichever is applicable, and shall not exceed the limit prescribed in the detail specification.

4.39.6.8 The voltage proof test shall be carried out as specified in 4.12 or as stated in the detail specification. There shall be no breakdown or flashover.

4.40 Mechanical endurance (potentiometers)

4.40.1 The resistance between terminals a and c shall be measured as specified in 4.6.

4.40.2 Half the specimens shall be loaded between terminals a and c and the other half shall be unloaded. (When a special requirement exists for loading through the moving contact, the detail specification shall specify the conditions to be used.)

For potentiometers not exceeding 10 W rated dissipation the use of a d.c. voltage, provided the ripple does not exceed 5 %, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers exceeding 10 W rated dissipation an a.c. voltage shall be applied. The applied voltage shall be the rated voltage or the limiting element voltage, whichever is the lesser.

4.40.3 Unless otherwise specified, the potentiometers shall be mounted as specified in 4.43.1.5. The potentiometers shall be subjected to this test in such a manner that the temperature of any one potentiometer shall not appreciably influence the temperature of any other potentiometer. There shall be no undue draught over the potentiometers.

4.40.4 A suitable driving mechanism shall be fixed to the operating shaft and arranged to operate cyclicly so that the mechanical travel is according to one of the following methods.

Method 1: greater than 90 % of the total mechanical travel. (This method is to be used unless otherwise specified in the relevant specification.)

Method 2: 50 % \pm 5 % of the effective electrical travel. (This method is preferred for precision potentiometers and shall be specified in the relevant specification.)

The torque of the driving mechanism shall not be more than 200 mN.m for potentiometers with a rated dissipation not exceeding 10 W and not more than 714 mN.m for potentiometers exceeding 10 W rated dissipation.

4.40.5 Unless otherwise specified in the detail specification, the number of cycles of operation and the rate of operation for single turn rotary potentiometers shall be as given in Table 17.

Table 17 – Number of cycles

Potentiometer type	Number of cycles of operation	Rate cycles/min
Non-wire-wound	25 000 or 10 000 as specified in the detail specification	10 to 17
Wire-wound	5 000	5 to 10
Preset and surface mount	20, 50, 100, 200 or 500 as specified in the detail specification	5 to 10

NOTE 1 A cycle of operation is defined as the travel of the moving contact from one end of the resistance element to the other and back. And when a switch is fitted, this includes the operation of the switch.

NOTE 2 For other constructions of potentiometers, for example, multi-turn helical, continuous rotation, lead-screw actuated, etc., the detail specification should specify the number of operations and the rate of operation. It also must define the cycle of operation.

4.40.6 After the test the potentiometers shall be allowed to remain under standard atmospheric conditions for test for 1 h to 2 h. After this period such of the following tests, prescribed in the detail specification, shall be made.

a) The potentiometer shall be visually examined. There shall be no visible damage.

- b) The resistance shall be measured between terminals a and c and the change in resistance compared with the value measured in 4.40.1 shall not exceed the limit specified in the relevant specification.
- c) The terminal resistance shall be measured as specified in 4.7 and shall be less than the limit prescribed in the detail specification.
- d) The insulation resistance shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.
- e) The starting torque shall be measured as specified in 4.18 and shall be within the limits prescribed in the detail specification.
- f) The continuity shall be tested as specified in 4.5 and the requirements of the detail specification shall be met.
- g) The thrust and pull on the shaft shall be tested as specified in 4.22.2 and 4.22.3 and the requirements of the detail specification shall be met.
- h) The voltage proof test shall be carried out as specified in 4.12. There shall be no breakdown or flashover.
- i) The rotational noise shall be measured as specified in 4.15 and shall not exceed the limit prescribed in the detail specification.
- j) When applicable, the sealing test shall be performed as specified in 4.31 and the requirements of the detail specification shall be met.
- k) When continuous monitoring of the contact resistance is specified during the mechanical endurance test, the following procedure shall be used.

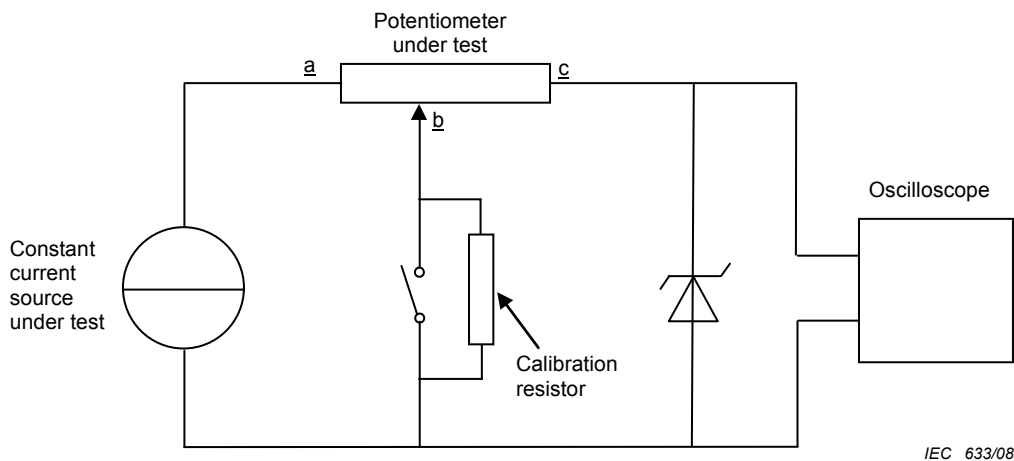


Figure 30 – The circuit for continuous monitoring of the contact resistance

A constant current of $(0,01 \text{ V/nominal total resistance}) \pm 5 \%$, or as specified in the detail specification, shall be applied between terminals b and c. The signal on the moving contact shall be mounted during mechanical cycling for continuity throughout the test. Discontinuity shall be considered to have occurred if the resistance of the moving contact rises to more than 10 times the rated total resistance for more than 0,1 % of the distance specified in Methods 1 or 2 of 4.40.4 as applicable, unless otherwise specified in the detail specification.

- l) The conformity (linearity or other specified law) shall be tested as specified in 4.9 and shall meet the requirements of the detail specification.

4.41 AC endurance testing of mains switches on capacitive loads

This test, when required in the detail specification, shall be used to assess the electrical operation of mains switches used to switch from 45 Hz to 65 Hz a.c. current capacitive load.

4.41.1 Preparation of specimen

The test specimen shall be wired as specified in the detail specification and connected to the test circuit.

4.41.2 Test method

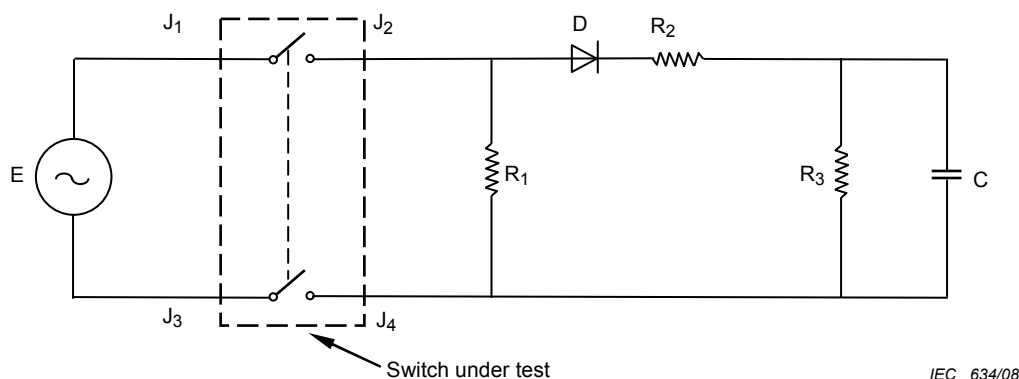
When specified in the detail specification, a load circuit as described below shall be used for endurance tests for each pole pair in the case of a multiple switch. The correct electrical operation of each switch contact of multiple switches during the switch-off part of the operation cycle shall be monitored. Single-pole switches should break the circuit between point J_1 and J_2 of the test circuit (see Figure 31).

The switch shall be subjected to a total of 10 000 cycles of operation, unless otherwise specified in the detail specification. The duty cycle shall be approximately 50 %. The rate of cycling shall be 7 cycles to 12 cycles per minute.

In order to obtain random load conditions the switch closure shall not be synchronized to the supply frequency.

4.41.3 Test circuit

The test circuit shall be as given in Figure 31.



Key

- E r.m.s. voltage of the test source (45 Hz to 65 Hz)
- R_1 100 Ω or E/I where the rated current is specified
- R_2 4,7 Ω
- R_3 390 Ω
- C 390 μF
- D Silicon diode having appropriate characteristics

Figure 31 – Test circuit a.c. endurance testing

When the surge current rating of the switch is specified, the following values shall be used:

R_1 is E/I , where E is the r.m.s. voltage of the test source and I is the rated r.m.s. current;

R_2 is $\frac{R_1 \cdot \sqrt{2}}{X}$, where X is the ratio of the rated peak surge current to the rated r.m.s. current;

R_3 is $\frac{800}{X} R_1$;

$R_2 C$ 2 500 $\times 10^{-6}\text{s}$.

The load circuit components shall be such that the load current shall be within $\pm 10\%$ of its specified value.

The impedance of the source shall be sufficiently low in order to not affect the test results.

4.41.4 Initial and final measurements

The contact resistance and temperature shall be measured before commencement of the test and on completion of the test.

Insulation resistance and voltage proof shall be measured on completion of the test.

4.41.5 Requirements

Contact resistance, insulation resistance and temperature rise shall be within specified limits.

There shall be no breakdown or flashover during application of the specified proof voltage.

4.41.6 Details to be specified

When this test is required by the detail specification, the following details shall be specified:

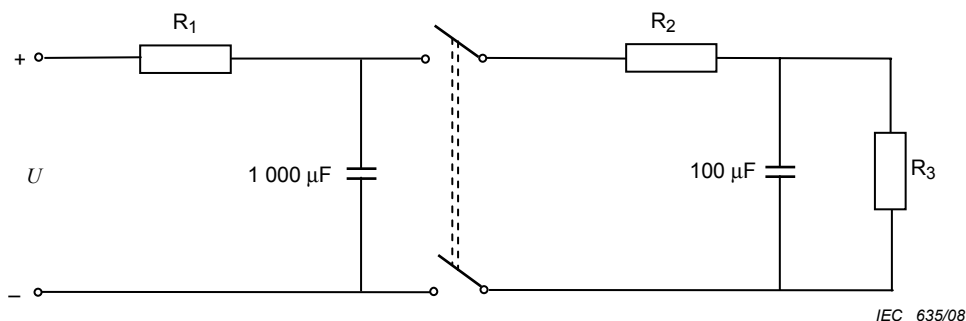
- preparation of specimen;
- voltage E to be applied;
- test current (shall not be greater than the normal current rating of the specimen);
- surge current (where known);
- required number of cycles, if other than 10 000;
- requirements for initial and final measurements;
- additional requirements, if any.

4.42 DC endurance testing of switches

4.42.1 The switch shall be subjected to 5 000 operations at 10 cycles to 17 cycles per minute, on/off, being loaded as given in Figure 32 and to further 5 000 operations without load.

During the 'off' part of the switching sequence, the switch contacts shall remain open for a period equal to, or greater than, 1 s.

After 10 000 operations (see 4.42.2), the switch shall be allowed to continue to operate up to the 25 000 operations required for the test of 4.40, but no further checks shall be made.



NOTE When a single-pole switch is tested, it must be connected in the positive line (between R_1 and R_2).

Figure 32 – Test circuit d.c. endurance testing

Table 18 – Number of operations

Switch application	Test voltage V d.c.	R_1 Ω	R_2 Ω	R_3 Ω
Power supply a.c.	225	≤ 225	15	4 700
Power supply a.c./d.c.	225	≤ 225	15	210
<34 V	34	≤ 34	6,8	33

NOTE Resistor R_1 should be so chosen that the 1 000 μF capacitor should be fully charged between each cycle of operation of the switch. The charging current should be not greater than 1 A. A cycle of operation is the closing of the switch contacts followed by their opening.

4.42.2 After 10 000 operations the following tests shall be made.

4.42.2.1 The switch shall be visually examined. There shall be no visible damage.

4.42.2.2 The torque required to operate the switch shall be measured as specified in 4.19 and shall not be greater than that specified in the detail specification.

4.42.2.3 The insulation resistance of the switch shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.

4.42.2.4 The switch contact resistance shall be measured as specified in 4.11 and shall be less than the limit specified in the detail specification. The switch shall be operated with a load for between 5 and 10 operations and the correct electrical operation of each switch contact shall be monitored.

4.42.2.5 The voltage proof test shall be carried out on the switch as specified in 4.12. There shall be no breakdown or flashover.

4.43 Electrical endurance

The rated dissipation shall always be given with reference to an ambient temperature of 70 °C and shall be verified by means of the endurance test at 70 °C or, in the case of certain power potentiometers, the endurance test at room temperature using the correction factor given in 4.43.1.3.

When changes in the slope of the derating curve occur at temperatures other than 70 °C, one of the following procedures shall apply in addition to 4.43.1 or 4.43.2.

a) At temperatures lower than 70 °C (for example, when a potentiometer is derated linearly from 20 °C, through 70 °C, to zero dissipation at the upper category temperature or a potentiometer has a constant dissipation of 20 °C to 40 °C and then derates linearly from 40 °C, through 70 °C, to zero dissipation at the upper category temperature), the potentiometers shall be subjected to the conditions specified in 4.43.2 (electrical endurance at 70 °C), except that

- 1) the test temperature shall be that at which the change in the slope of the derating curve occurs;
- 2) the voltage to be applied shall be the rated voltage multiplied by the correction factor, or it shall be the limiting element voltage, whichever is the smaller.

This correction factor is:

$$\sqrt{\frac{\text{upper category temperature} - T}{\text{upper category temperature} - 70\text{ °C}}}$$

b) At temperatures higher than 70 °C (for example, when a potentiometer maintains its rated dissipation constant from 20 °C, through 70 °C, to (say) 125 °C and then derates linearly to either zero dissipation or the category dissipation at the upper category temperature), the potentiometers shall be subjected to the conditions specified in 4.43.2 (electrical endurance at 70 °C) except that the test temperature shall be the temperature at which the change in the slope of the derating curve occurs.

The requirements for intermediate and final measurements in a) or b) above shall be the same as those specified in the relevant specification for the endurance test used to verify the rated dissipation.

4.43.1 Electrical endurance at room temperature

4.43.1.1 The resistance between terminals a and c shall be measured as specified in 4.6. For those specimens which according to the relevant specification are to be loaded between

terminals a and b or b and c the resistance shall also be measured between these terminals (see 4.43.1.4).

4.43.1.2 The potentiometer shall be subjected to an electrical endurance test of 42 days (1 000 h) at an ambient temperature between 15 °C and 35 °C.

4.43.1.3 For potentiometers with a rated dissipation ≤ 10 W, the use of a d.c. voltage, provided the ripple voltage does not exceed 5 %, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers having a rated dissipation of > 10 W, an a.c. voltage shall be used.

The voltage to be applied for the purpose of this test shall be the voltage calculated from the nominal total resistance and 95 % of the rated dissipation at 70 °C multiplied by the correction factor, or it shall be the limiting element voltage, whichever is the lesser.

The correction factor is :

$$\sqrt{\frac{\text{Zero dissipation temperature} - T}{\text{Zero dissipation temperature} - 70\text{ °C}}}$$

The zero dissipation temperature shall be obtained from the derating curves in the relevant specification.

The applied voltage shall be within ± 5 % of the calculated voltage.

4.43.1.4 During the test, the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to half the specimens, between terminals a and c. For the remaining specimens, the moving contact shall be set at 95 % (or 5 % for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to terminals a and b or b and c when appropriate.

NOTE The 0,5 h “off” periods are included in the total test duration specified in 4.43.1.2.

4.43.1.5 Unless otherwise specified (see note), each potentiometer shall be mounted on a 1,5 mm thick steel panel having the dimensions given in Table 19 and placed in such a manner that the mounting point of any potentiometer is spaced, in any direction, from the mounting point of any other potentiometer by four times the diameter of the potentiometer.

The mounting point shall be the centre of the hole cut in the panel to accommodate the bush of the potentiometer.

Table 19 – Panel size

Rated dissipation	Panel size in mm
Up to and including 4 W	50 × 50
Greater than 4 W up to and including 63 W	100 × 100
Greater than 63 W	300 × 300

NOTE Those potentiometers which are designed to be mounted by their terminations on printed boards should be so mounted during this test on a 1,6 mm thick glass base epoxy-laminate board.

4.43.1.6 After approximately 48 h, 168h, 500 h and 1 000 h, the potentiometers shall be removed from the chamber and allowed to cool(recover) under standard atmospheric conditions for testing for not less than 1 h and not more than 4 h.

After intermediate measurements the potentiometer shall be returned to the chamber. The interval between the removal of any potentiometer from the chamber and the return to the chamber shall not exceed 12 h.

The potentiometers shall then be subjected to such of the following tests as are prescribed in the detail specification.

- a) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.
- b) The resistance shall be measured between terminals a and c and a and b or b and c as appropriate. The change in resistance with respect to the value measured in 4.43.1.1 shall not exceed the value prescribed in the relevant specification.
- c) The insulation resistance shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.
- d) The rotational noise shall be measured as specified in 4.15 and shall not exceed the limit prescribed in the detail specification.
- e) The continuity shall be tested as specified in 4.5 and the requirements of the detail specification shall be met.
- f) When applicable, the sealing test shall be performed as specified in 4.31 and the requirements of the detail specification shall be met.

4.43.2 Electrical endurance at 70 °C

4.43.2.1 The resistance between terminals a and c shall be measured as specified in 4.6. For those specimens which, according to the relevant specification, shall be loaded between terminals a and b (or b and c) the resistance shall also be measured between these terminals (see 4.43.2.4).

4.43.2.2 The potentiometers shall be subjected to an electrical endurance test of 42 days (1 000 h) at an ambient temperature of 70 °C ± 3 °C.

4.43.2.3 For potentiometers with a rated dissipation of ≤10 W, the use of a d.c. voltage, provided the ripple voltage does not exceed 5 %, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of test, an a.c. voltage may be used. For potentiometers having a rated dissipation of >10 W, an a.c. voltage shall be used.

The voltage to be applied for the purpose of this test shall be the rated voltage or the limiting element voltage, whichever is the lesser.

At all times during the test the applied voltage shall be within ± 5 % of the calculated voltage.

4.43.2.4 During the test, the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to half the specimens between terminals a and c. For the remaining specimens, the moving contact shall be set at 95 % (or 5 % for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to terminals a and b or b and c when appropriate.

NOTE The 0,5 h “off” periods are included in the total test duration specified in 4.43.2.2.

4.43.2.5 Unless otherwise specified, the potentiometers shall be mounted as specified in 4.43.1.5.

The potentiometers shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than ±3 °C from the nominal temperature of the chamber, at any point where potentiometers are placed.

4.43.2.6 After approximately 48 h, 168 h, 500 h and 1 000 h, the potentiometers shall be removed from the chamber and allowed to cool under standard atmospheric conditions for testing for not less than 1 h and not more than 4 h.

After intermediate tests, the potentiometers shall be returned to the test chamber. The interval between the removal of any potentiometer from the chamber and its return to the conditions of test shall not exceed 12 h.

The potentiometers shall then be subjected to such of the following tests as are prescribed in the detail specification.

- a) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.
- b) The resistance shall be measured between terminals a and c, a and b or b and c as appropriate. The change of resistance with respect to the value measured in 4.43.2.1 shall not exceed the value prescribed in the relevant specification.
- c) The insulation resistance shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.
- d) The rotational noise shall be measured as specified in 4.15 and shall not exceed the limit prescribed in the detail specification.
- e) The continuity shall be tested as specified in 4.5 and the requirements of the detail specification shall be met.
- f) When applicable, the sealing test shall be performed as specified in 4.31 and the requirements of the detail specification shall be met.

4.43.3 Electrical endurance at upper category temperature

4.43.3.1 This test is not applicable to potentiometers having an upper category temperature of 70 °C.

4.43.3.2 The resistance between terminals a and c shall be measured as specified in 4.6. For those specimens which, according to the relevant specification, are to be loaded between terminals a and b or b and c the resistance shall also be measured between these terminals (see 4.43.3.5).

4.43.3.3 The potentiometers shall be subjected to an electrical endurance test of 42 days (1 000 h) at an ambient temperature equal to the upper category temperature ± 3 °C given in the relevant specification.

4.43.3.4 For those potentiometers derating to zero at their upper category temperature, the test shall be performed at zero dissipation. For other potentiometers the test shall be performed with their category dissipation. For potentiometers having a rated dissipation ≤ 10 W the use of a d.c. voltage, provided the ripple does not exceed 5 %, shall be the preferred method. If, however, it can be demonstrated that there will be no relaxation in the severity of the test, an a.c. voltage may be used. For potentiometers having a rated dissipation > 10 W an a.c. voltage shall be used.

The voltage shall be the limiting element voltage or that voltage calculated from the category dissipation and the nominal total resistance, whichever is the lesser.

At all times during the test the applied voltage shall be within ± 5 % of the calculated voltage.

4.43.3.5 During the test, the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to half the specimens between terminals a and c. For the remaining specimens, the moving contact shall be set at 95 % (or 5 % for potentiometers having inverse non-linear laws) of the total electrical travel and the voltage shall be applied in cycles of 1,5 h “on” and 0,5 h “off” to terminals a and b or b and c when appropriate.

NOTE The 0,5 h “off” periods are included in the total test duration specified in 4.43.3.3.

4.43.3.6 Unless otherwise specified, the potentiometers shall be mounted as specified in 4.43.1.5.

The potentiometers shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than ± 3 °C from the nominal temperature of the chamber, at any point where potentiometers are placed.

4.43.3.7 After approximately 48 h, 168h, 500 h and 1 000 h, the potentiometers shall be removed from the chamber and allowed to cool under standard atmospheric conditions for testing for not less than one hour and not more than four hours.

After intermediate measurements the potentiometers shall be returned to the test chamber. The interval between the removal of any potentiometer from the chamber and its return to the chamber shall not exceed 12 h.

The potentiometer shall then be subjected to such of the following tests as are prescribed in the detail specification.

- a) The potentiometers shall be visually examined. There shall be no visible damage and the marking shall be legible.
- b) The resistance shall be measured between terminals a and c, a and b or b and c as appropriate. The change in resistance with respect to the value measured in 4.43.3.2 shall not exceed the value prescribed in the relevant specification.
- c) The insulation resistance shall be measured as specified in 4.13. The value shall not be less than that prescribed in the relevant specification.

4.44 Component solvent resistance

4.44.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.44.2 The components shall be subjected to Test XA of IEC 60068-2-45, with the following details.

- a) Solvent to be used: See 3.1.2 of IEC 60068-2-45
- b) Solvent temperature: 23 °C \pm 5 °C, unless otherwise specified in the detail specification
- c) Conditioning: Method 2 (without rubbing)
- d) Recovery time: 48 h, unless otherwise specified in the detail specification

4.44.3 The measurements prescribed in the relevant specification shall then be made and the specified requirements be met

4.45 Solvent resistance of the marking

4.45.1 The components shall be subjected to Test XA of IEC 60068-2-45, with the following details.

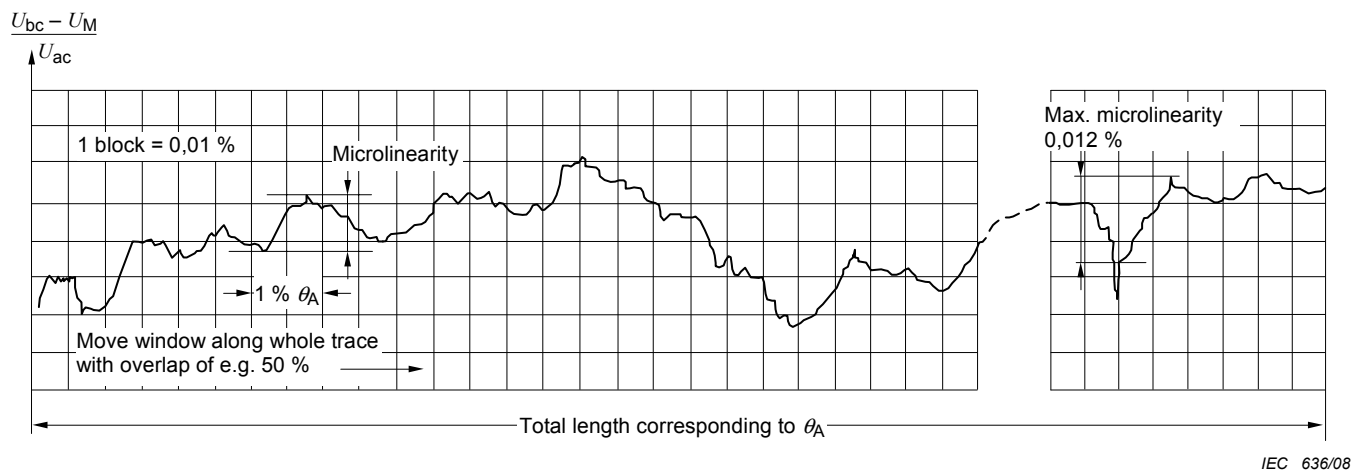
- a) Solvent to be used: See 3.1.2 of IEC 60068-2-45
- b) Solvent temperature: 23 °C \pm 5 °C
- c) Conditioning: Method 1 (with rubbing)
- d) Rubbing material: Cotton wool
- e) Recovery time: Not applicable, unless otherwise stated in the detail specification

4.45.2 After the test the marking shall be legible.

4.46 Microlinearity

4.46.1 Microlinearity shall be measured with a maximum load of $1 \mu\text{A}$ on the moving contact terminal b of the potentiometer under test. Effects of non-uniform speed of travel shall be excluded.

The value of microlinearity is equal to the change of linearity along the travel increment at any measured position (see Figure 33). The measurement increments shall have an overlap of not less than 50 %. The measurement principle is given in Figure 34.



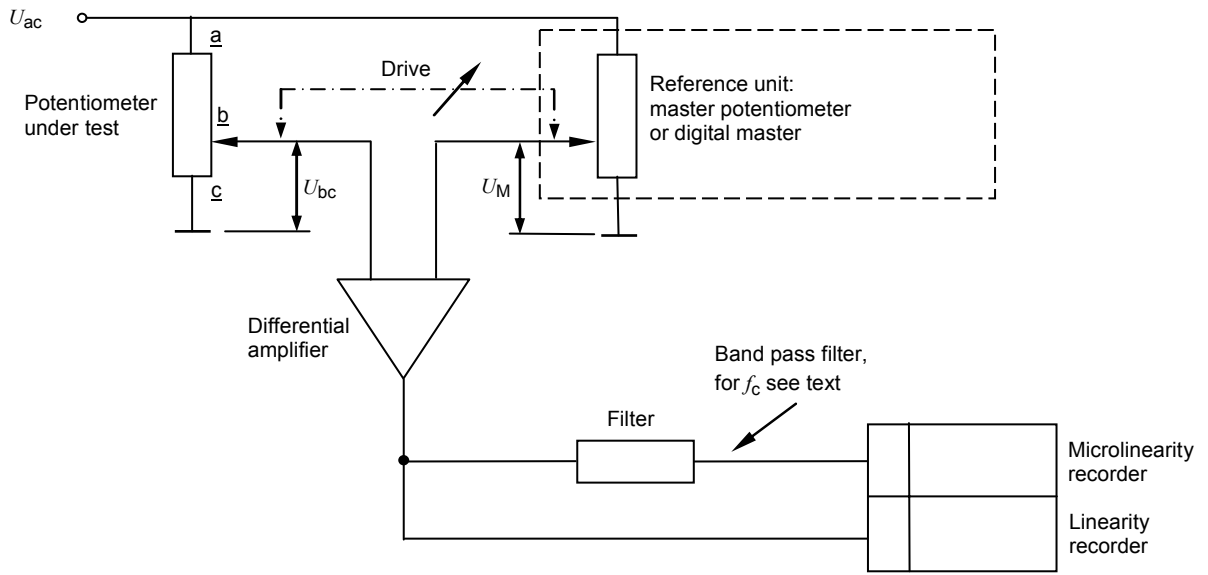
θ_A Effective electrical travel

Figure 33 – Example of microlinearity measurement

4.46.2 The detail specification shall specify

- the increment if different from 1 % of the effective electrical travel;
- the part of the electrical travel to be covered, if different from the effective electrical travel;
- the requirement of microlinearity. The requirement may differ for different parts of the electrical travel.

A practical example of a test circuit and results is given in Figure 34.



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NOTE For the digital reference unit, the basic description is given in Annex E.

Figure 34 – Block diagram of a circuit for evaluation of microlinearity

The filter shown in Figure 34 is a band pass filter which shall pass all frequencies from the lower cut-off frequency f_c to $100 f_c$. The purpose of the filter is to remove slow voltage variations caused by the potentiometer law and by voltage instability.

f_c shall be calculated as follows:

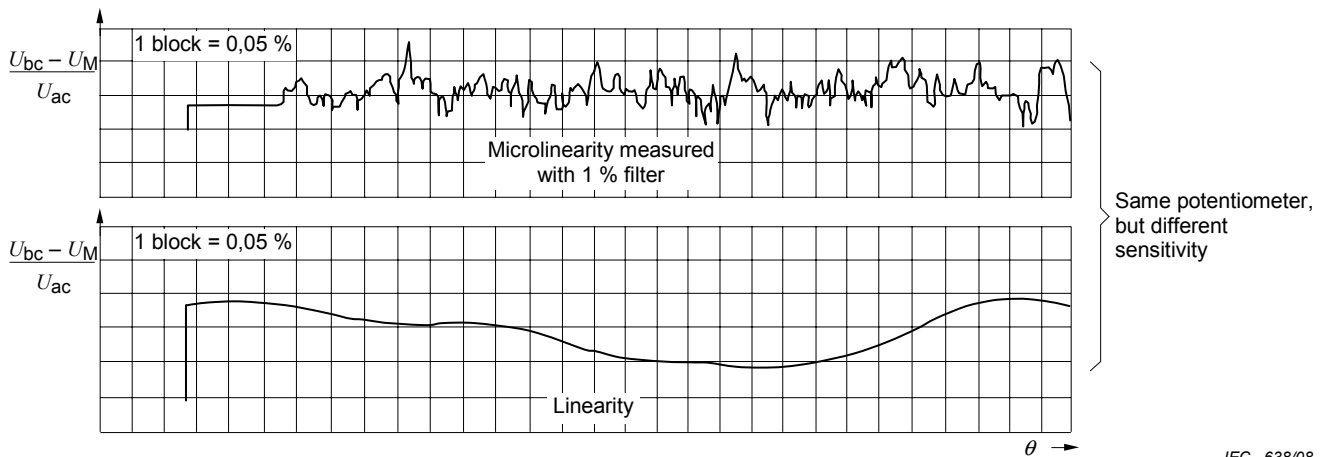
$$f_c = m / (i \times t_m)$$

where

i is the increment, in mm;

m is the effective electrical travel, in mm;

t_m is the time for traverse of m , in s.



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Figure 35 – Example of simultaneous evaluation of linearity and microlinearity

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4.47 Mounting (for surface mount potentiometers)

4.47.1 Surface mount potentiometers shall be mounted on a suitable substrate, the method of mounting depending on the potentiometer construction. The substrate material shall normally be a 1,6 mm thick epoxide woven glass fabric laminated printed board (as defined in IEC 61249-2-7, reference 61249-2-7IEC-GC-Cu) or a 0,635 mm alumina substrate, and it shall not affect the result of any test or requirement. The detail specification shall indicate which material is to be used for electrical measurements.

The substrate shall have metallized land areas of proper spacing to permit mounting of surface mount potentiometers and it shall provide electrical connection to the surface mount potentiometer terminals. The details shall be specified in the detail specification.

Examples of test substrate for mechanical and electrical tests are shown in Figure 36 and Figure 37, respectively. If another mounting method applies, the method should be clearly described in the detail specification.

4.47.2 When the detail specification specifies wave soldering, a suitable glue, details of which may be specified in the detail specification, shall be used to fasten the component to the substrate before soldering is performed.

Small dots of glue shall be applied between the conductors of the substrate by means of suitable device securing repeatable results.

The surface mount potentiometers shall be placed on the dots using tweezers. In order to ensure that no glue is applied to the conductors, the surface mount potentiometers shall not be moved about.

The substrate with the surface mount potentiometers shall be heat-treated in the oven at 100 °C for 15 min.

The substrate shall be soldered in a suitable soldering apparatus. The apparatus shall be adjusted to have a pre-heating temperature of 80 °C to 100 °C, a soldering temperature at 260 °C ± 5 °C, and a soldering time of 5 s ± 0,5 s.

The soldering operation shall be repeated a second time (two cycles in total).

The substrate shall be cleaned for 3 min in a suitable solvent (see 3.1.2 of IEC 60068-2-45).

4.47.3 When the detail specification specifies reflow soldering, the following mounting procedure applies.

- a) The solder used, in preform or paste form, shall be silver bearing (2 % minimum) eutectic Sn/Pb solder together with a flux, as stated in Test T of IEC 60068-2-20. Alternative solders, such as 60/40 or 63/37 may be used on surface mounts whose construction includes solder leach barriers. The Pb-free solder used in perform or paste form shall be Sn96,5Ag3,0Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58.
- b) The surface mount potentiometer shall then be placed across the metallized land areas of the tests substrate so as to make contact between surface mount and substrate land areas.
- c) The substrate shall then be placed in or on a substrate heating system (molten solder, hot plate, tunnel oven, etc.). The temperature of the unit shall be maintained between 215 °C and 260 °C, until the solder melts and reflows forming a homogeneous solder bond, but for not longer than 10 s.

NOTE 1 The flux is removed by a suitable solvent (see 3.1.2 of IEC 60068-2-45). All subsequent handling is such as to avoid contamination. Care is taken to maintain cleanliness in the test chambers and during post test measurements.

NOTE 2 The detail specification may require a more restricted temperature range.

NOTE 3 If vapour phase soldering is applied, the same method may be used with the temperature adapted.

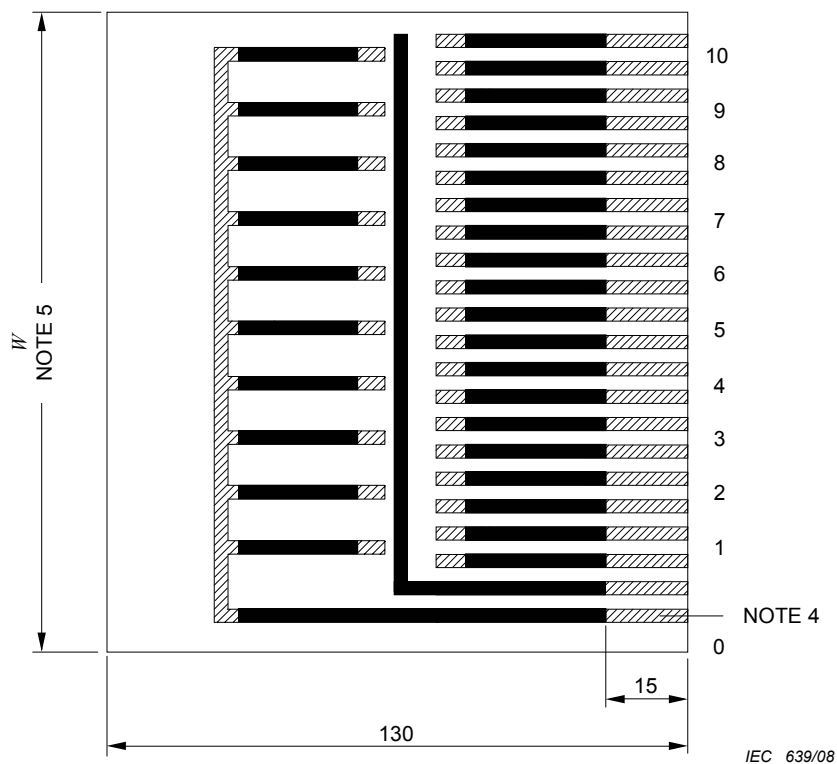


Figure 36 – Suitable substrate for mechanical and electrical tests
(may not be suitable for impedance measurements)

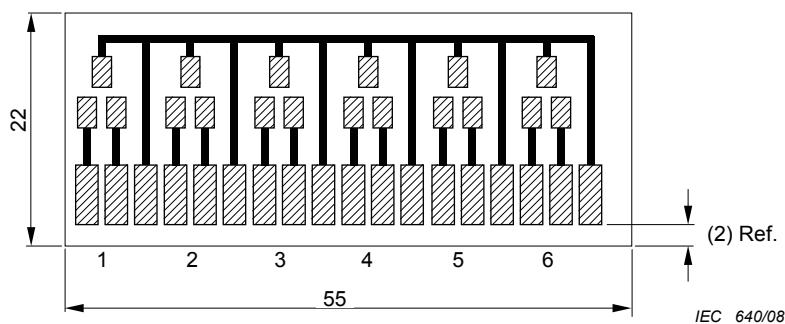




Figure 37 – Suitable substrate for electrical tests

Notes to Figures 36 and 37:

- NOTE 1  solderable areas
 areas which shall not be solderable (covered with non-solderable lacquer)

NOTE 2 All dimensions are in millimetres.

NOTE 3 Material: Figure 36: epoxide woven glass
 thickness: 1,6 mm ± 0,1 mm

Figure 37: 90 % to 98 % alumina
 thickness: 0,635 mm ± 0,05 mm

NOTE 4 This conductor may be omitted or used as a guard electrode.

NOTE 5 Dimension *W* is dependent on the design of the test equipment.

Dimensions not given should be chosen according to the design and size of the specimens to be tested.

4.48 Shear (adhesion) test

4.48.1 Test conditions

The surface mount potentiometers shall be mounted as described in 4.47.

4.48.2 The potentiometers shall be subjected to Test Ue3 of IEC 60068-2-21, under the following condition.

A force of 5 N shall be applied to the surface mount potentiometer body progressively, without shock, and shall be maintained for a period of $10\text{ s} \pm 1\text{ s}$.

4.48.3 Requirements

The surface mount potentiometers shall be visually examined in the mounted state. There shall be no visible damage.

4.49 Substrate bending test (formerly bond strength of the end face plating)

4.49.1 The surface mount potentiometer shall be mounted on an epoxide woven glass printed board, as described in 4.47.

4.49.2 The resistance of the surface mount potentiometer shall be measured as specified in 4.6.

4.49.3 The potentiometer shall be subjected to Test Ue1 of IEC 60068-2-21 using the conditions as prescribed in the relevant specification for deflection D and number of bends.

4.49.4 The resistance of the surface mount potentiometers shall be measured as specified in 4.6, with the board in the bent position. The change of resistance compared with that measured in 4.49.2 shall not exceed the limit specified in the detail specification.

4.49.5 The printed board shall be allowed to recover from the bent position and then removed from test jig.

4.49.6 Final inspection and requirements

The surface mount potentiometers shall be visually examined and there shall be no visible damage.

4.50 Solderability (for surface mount potentiometers)

Surface mount potentiometers shall be tested in accordance with Test Td of IEC 60068-2-58. The relevant specification shall prescribe the severity and method to be used so that wetting, dewetting or resistance to dissolution or metallization is consistent with the surface mounting classification.²

4.51 Resistance to soldering heat (for surface mount potentiometers)

Surface mount potentiometers shall be tested in accordance with test Td of IEC 60068-2-58. The relevant specification shall prescribe the severity and method to be used for the resistance to soldering heat to be consistent with the surface mounting classification¹.

¹ Under consideration.

Annex A (normative)

Rules for the preparation of detail specifications for capacitors and resistors for electronic equipment

A.1 The drafting of a complete detail specification by IEC technical committee 40, if required, shall begin only when all the following conditions have been met.

- a) The generic specification has been approved.
- b) The sectional specification, when appropriate, has been circulated for approval as a FDIS.
- c) The associated blank detail specification has been circulated for approval as a FDIS.
- d) There is evidence that at least three National Committees have formally approved, as their own national standard, specifications covering a component of closely similar performance.

Where a National Committee formally asserts that substantial or significant use is made within its country of a part described by some other national standard, this assertion may count towards the foregoing requirement.

A.2 Detail specifications prepared under the responsibility of technical committee 40, shall use the standard or preferred values, rating and characteristics, and severities for environmental tests, etc., which are given in the appropriate generic or sectional specifications.

An exception to this rule may only be granted for a specification when agreed by technical committee 40.

A.3 The detail specification should not be circulated as a FDIS until the sectional and blank detail specifications have been approved for publication.

Annex B (normative)

Interpretation of sampling plans and procedures as described in IEC 60410 for use within the IEC Quality Assessment System for Electronic Components

When using IEC 60410 for inspection by attributes, the following interpretations of the clauses and subclauses of IEC 60410 indicated below apply for the purpose of this specification.

- 1.1 The responsible authority is the National Authorized Institution implementing the Basic Rules and Rules of Procedure.
- 1.5 The unit of product is the electronic component defined in a detail specification.
- 2 Only the following definitions from this clause are required:
 - a defect is any nonconformance of the unit of product to specified requirements,
 - a defective is a unit of product which contains one or more defects.
- 3.1 The extent of nonconformance of product shall be expressed in terms of per cent defective.
- 3.3 Not applicable.
- 4.5 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional document.
- 5.4 The responsible authority is the Chief Inspector, acting in accordance with the procedures prescribed in the document describing the inspection department of the approved manufacturer and approved by the National Supervising Inspectorate.
- 6.2 The responsible authority is the Chief Inspector.
- 6.3 Not applicable.
- 6.4 The responsible authority is the Chief Inspector.
- 8.1 Normal inspection shall always be used at the start of inspection.
- 8.3.3 (d) The responsible authority is the Chief Inspector.
- 8.4 The responsible authority is National Supervising Inspectorate.
- 9.2 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional document.
- 9.4 (Fourth sentence only). Not applicable.

(Fifth sentence only). The responsible authority is the Chief Inspector.
- 10.2 Not applicable.

Annex C (normative)

Measuring methods for rotational noise

C.1 Method A (constant voltage method)

The circuit of apparatus for measuring the rotational noise of potentiometers is shown in Figure C.1.

Basically, the apparatus is an audio amplifier of adjustable gain feeding a diode rectifier which controls a coloured lamp. When the signal input reaches some pre-determined level, the coloured lamp is illuminated.

This is used to indicate that the noise output of a potentiometer is above or below some pre-set limit level. The apparatus is arranged to provide 20 V d.c. with a source resistance of 1 000 ohms to apply to the potentiometer.

The following data are given on the response of the amplifier:

- 6 dB below zero level at 60 Hz and 20 kHz;
 - 20 dB below zero level at 20 Hz and 45 kHz;
 - 30 dB or more below zero at 80 kHz and all higher frequencies;
- zero level is taken at 1 000 Hz.

The preset input levels at approximately 1 000 Hz which operate the red lamp are:

4,7 – 6,8 – 10 – 15 – 22 – 33 – 47 – 68 – 100 – 150 and 220 mV r.m.s.

If the amplifier has an over-extended bass response, it is possible that, when testing logarithmic law A and inverse logarithmic law C potentiometers, harmonics of the 0,5 Hz operating frequency may give rise to appreciable error in the noise reading on very low-noise potentiometers. To avoid this, the amplifier shall be designed so that it cuts off rapidly below 50 Hz.

The circuit shall ensure that short noise durations will cause the red lamp to operate long enough to be observed.

A second circuit operates at about one-tenth of the preset level and illuminates a green light. Since it is unlikely that potentiometers will be found with a noise level less than one-tenth of the limit, the green lamp will operate on good potentiometers and the red lamp on reject potentiometers.

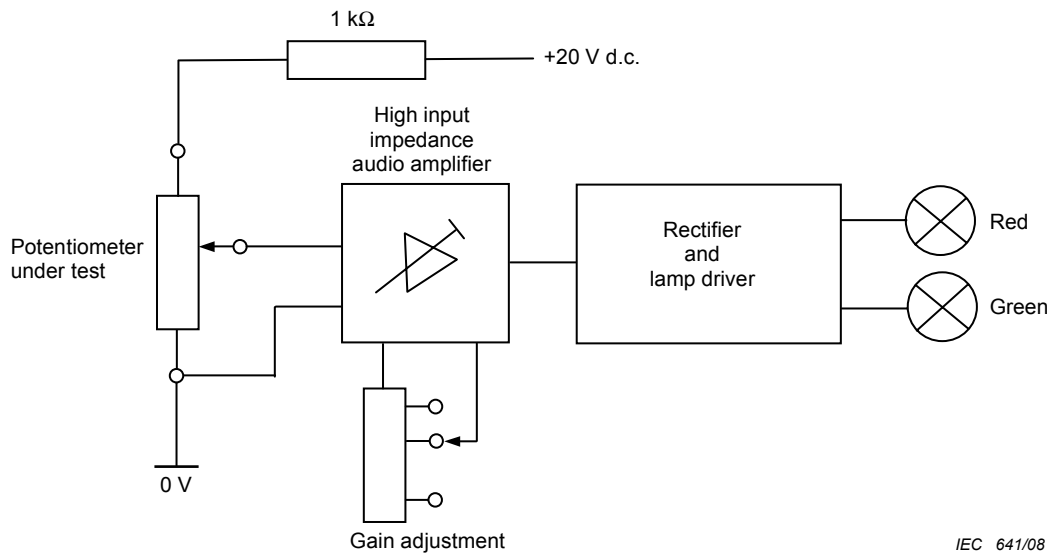
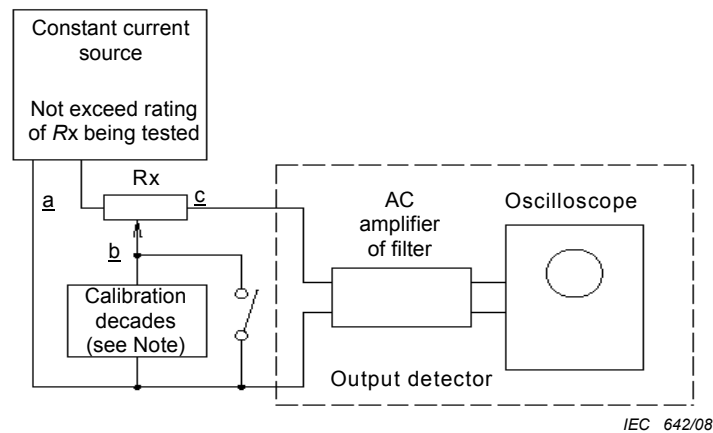


Figure C.1 – Measuring circuit for method A, rotational noise

C.2 Method B (constant current method – CRV)

The circuit of apparatus for measuring the rotational noise of potentiometers is shown in Figure C.2.



Key

R_x test specimen

The oscilloscope bandwidth is 100 Hz to 50 kHz.

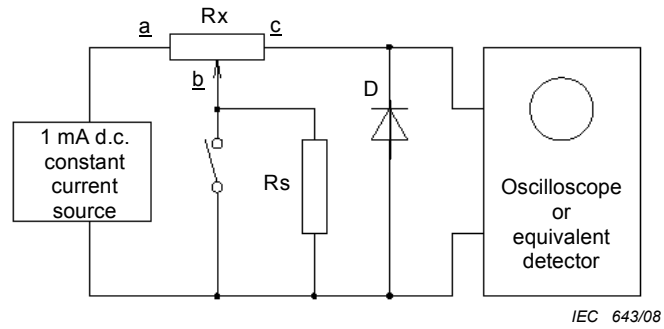
The minimum input impedance is at least 10 times the nominal resistance being tested.

NOTE At the calibration of the decade, terminals a and b should be coincident. The calibration decade should be set for the contact-resistance-variation (CRV) level of the specified nominal resistance being tested.

Figure C.2 – Measuring circuit for CRV

C.3 Method C (constant current method – ENR)

The circuit of apparatus for measuring the rotational noise of potentiometers is shown in Figure C.3.



Key

Rx test specimen

Rs calibration resistor

D zener diode (6V)

The oscilloscope bandwidth is d.c. to 50 kHz.

The minimum input impedance is at least 10 times the nominal resistance being tested.

Figure C.3 – Measuring circuit for ENR

Annex D (normative)

Apparatus for measuring mechanical accuracy

D.1 Dial indicator

The minimum dial division shall be equal to, or less than, 10 % of the specified tolerance and shall have a readability to 1 μm for measurements of less than 25 μm . The indicator should not be used over a range of more than a third of the total travel of the probe without error correction. If a dial indicator is used with a pivot type pointer, the longitudinal centre line of the stylus shall remain normal to the relevant part of the potentiometer during measurement or the applicable correction factor shall be used.

The dial indicator holding the fixture shall hold the dial indicator rigidly maintaining its proper attitude to the work piece during measurement. In addition, it should provide for a gradual movement of the indicator position so that it is not damaged as the probe approaches the potentiometer.

D.2 Cylindrical shaft adaptor

An adaptor with a smooth cylindrical surface and which, when mounted on the potentiometer spindle, adds eccentricity no greater than 10 % of the specified run-out tolerance.

D.3 Potentiometer mounting fixture

A fixture to hold the test specimen rigidly by the normal mounting means leaving the shaft free to move.

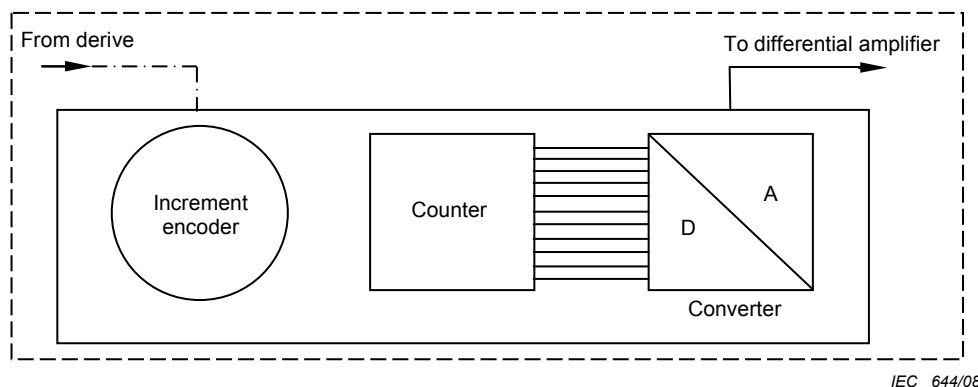
D.4 Potentiometer shaft holding fixture

A fixture to hold the test specimen by the shaft in either a horizontal or vertical position, leaving the potentiometer body free to move.

Annex E
(normative)

Measuring method for microlinearity

Basic description of a digital reference unit (synthetic high precision master unit) and measuring method for microlinearity.



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Figure E.1 – Block diagram of a digital reference unit (synthetic high-precision master)

When selecting a suitable DA converter for the synthetic master reference unit of Figure E.1, the following basic details should be considered.

E.1 Resolution bits

The minimum number of bits (*b*) which should be covered by the DA converter shall be the greater of *b_v* and *b_i* calculated as below.

The number *b_v* of bits required for voltage accuracy is

$$B_v = (1/\ln 2) \times \ln (5/\mu_{max})$$

where

μ_{max} is the maximum allowed microlinearity (1 % = 0,01);

$$1/\ln 2 = 1,433.$$

The number of bits *b_i* required by the relative travel increment width as specified for the measurement is:

$$b_i = (1/\ln 2) \times \ln(30mi)$$

where

i is the width of increment;
m is the effective electrical travel } in identical units
 1/ln 2 = 1,433.

E.2 Accuracy of the DA converter output

Minimum requirement 1/2 last significant bit (LSB). With b chosen as under E.1 above, the resulting digital synthetic master will have a voltage setting accuracy of ten times better, as is required for the measurement.

E.3 Maximum measuring speed

The measuring speed shall consider the setting time of the DA converter and should at least allow for twice the sum of all setting times involved. Hence, the minimum time t_m required for one measuring travel becomes:

$$t_m = 2 b \times 2 t_s$$

where

- t_s is the setting time of the DA converter;
- b is the number of bits covered by travel.

Example

Requirement for:

voltage accuracy:	0,03 %
relative increment I/m :	1 %

Result: $b_v = 1,443 \times \ln(5/0,0003) = 14,03$; $b_v = 14$ bit

$b_i = 1,433 \times \ln(30/0,01) = 11,55$; $b_i = 12$ bit

The voltage bit figure is the higher one; for example, the DA converter shall be at least of a 14-bit type, able to simulate a master potentiometer with the usual ten times better accuracy as compared to the deviations to be measured.

Annex F (normative)

Preferred dimensions of shaft ends, bushes and for the mounting hole, bush-mounted, shaft-operated electronic components

The referred dimensions of shaft ends contained in this standard have, in principle, been selected from IEC 60915. Dimensions of shaft ends for manually operated electronic components. Where sizes are required which are not contained in this annex, they should be chosen from those remaining in the IEC 60915.

Unless otherwise specified in the relevant specification and/or the detail specification, the following shall be applied.

F.1 Shaft ends and dimensions

- a) Rounded shaft: as given in Figure 1 and Table 1 of IEC 60915.
- b) Flatted shaft: as given in Figure 2 and Table 2 of IEC 60915.
- c) Slotted shaft: as given in Figure 3 and Table 3 of IEC 60915.
- d) Concentric shaft: as given in Figure 4 and Table 4 of IEC 60915.

F.2 Bushes, mounting holes, lug (non-turn devices) and dimensions

- a) Single-hole bush mounting with anti-rotation lug (non-turn devices) on mounting face: as given in Figure 5, Figure 6 and Table 5 of IEC 60915.
- b) Single and double flatted bush mounting: as given in Figure 7, Figure 8 and Table 6 of IEC 60915.
- c) Single-hole bush mounting with anti-rotation lug (non-turn devices) on bush: as given in Figure 9, Figure 10 and Table 7 of IEC 60915.

F.3 Mounting nuts and dimensions

- a) Mounting nut: as given in Figure 11 and Table 8 of IEC 60915.

F.4 Mounting washers (flat, spring and internal tooth) and dimensions

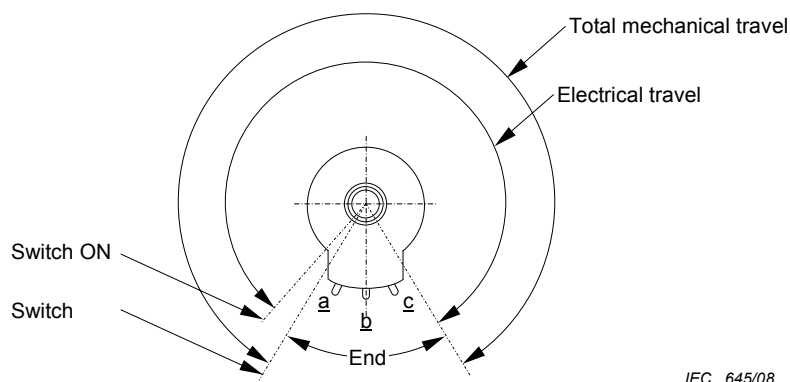
Under consideration. If necessary, mounting washers and dimensions are specified in the detail specification.

Annex G (informative)

Example of common potentiometer's law

G.1 Rotation

The total mechanical rotation and the electrical rotation of potentiometers shall be as defined on Figure G.1. The electrical rotation of potentiometers with switches shall be equal to the rotation from the stop at the end opposite the switch to the point where the members engage to actuate the switch to the "off" position.



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Figure G.1 – Definition of rotation (shaft-end view)

G.2 Resistance law and code letter

Table G.1 – Resistance law and code letter

Code letter	Percent total nominal resistance			Centre tap	Resistance law
	Percent electrical travel				
	20 ^a	50	80 ^a		
0B	-	40 to 60	-		See Figure G.2
2B	2 to 10	40 to 60	90 to 98		
3B	1 to 7	40 to 60	93 to 99		
0BM	-	^b	-	with	See Figure G.3
2BM	-	^b	-		
3BM	-	^b	-		
10A	-	6 to 15	-	-	See Figure G.4
15A	-	10 to 25	-	with	See Figure G.5
10AM	-	^b	-		
15AM	-	^b	-	-	See Figure G.6
10C	-	6 to 15	-		
15C	-	10 to 25	-		
15CM	-	^b	-	with	See Figure G.7

^a These are the target values on design at each points.

^b 30 % of nominal tap resistance.

G.3 Clockwise law(linear law B and logarithmic law A)

A clockwise law is a resistance law in which the resistance varies approximately as shown in Figure G.2 to Figure G.5, increasing as the rotation angle increases in clockwise(CW) direction as viewed from the operating shaft, and measured between terminals a and b.

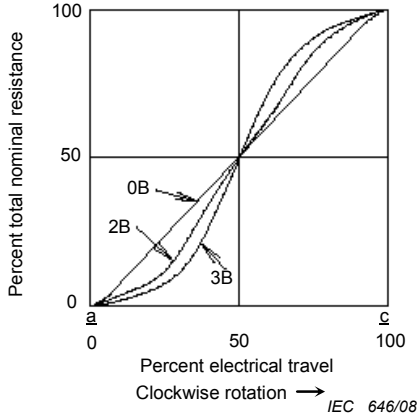


Figure G.2 – Linear law, without centre tap

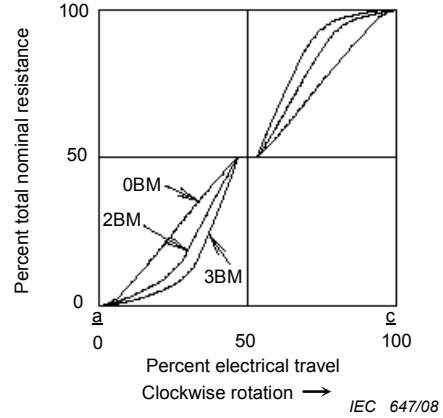


Figure G.3 – Linear law, with centre tap

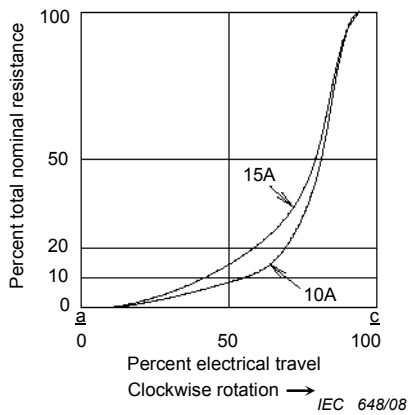


Figure G.4 – Logarithmic law, without tap

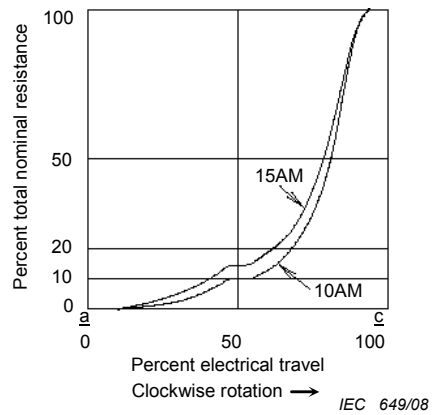


Figure G.5 – Logarithmic law, with tap

G.4 Counter-clockwise law (inverse logarithmic law C)

A counter-clockwise (CCW) law is resistance law in which the resistance varies approximately as shown in Figure G.6 and Figure G.7, increasing as the rotation angle in a counter-clockwise direction as viewed from the operating shaft, and measured between terminals b and c.

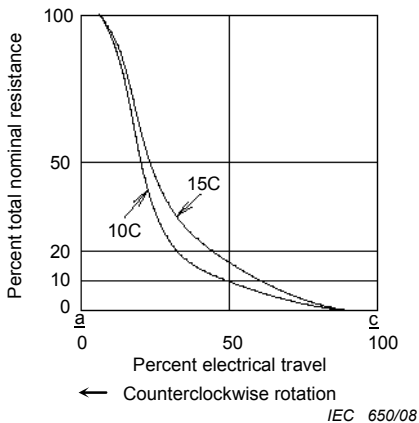


Figure G.6 – Inverse logarithmic law without tap

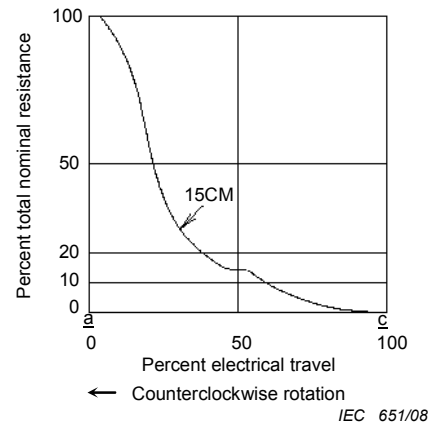


Figure G.7 – Inverse logarithmic law with tap

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Annex H (normative)

Quality assessment procedures

H.1 General

When this standard, and any related standards are used for the purpose of a full quality assessment system such as the IEC Quality Assessment System for Electronic Components (IECQ), compliance with Clauses H.5, H.6 or H.14 is required.

When such standards are used outside quality assessment systems for purposes such as design proving or type testing, the procedures and requirements of H.5.1 and H.5.3b) may be used, but, if used, the tests and parts of tests shall be applied in the order given in the test schedules.

Before components can be qualified according to the procedures of this clause, the manufacturer shall obtain the approval of his organization in accordance with the provisions of IEC QC 001002-3.

The methods that are available for the approval of components of assessed quality and which are covered by the following subclauses, are:

- qualification approval according to the provisions of IEC QC 001002-3, Clause 3;
- capability approval according to the provisions of IEC QC 001002-3, Clause 4;
- technology approval according to the provisions of IEC QC 001002-3, Clause 6.

For a given subfamily of components, separate sectional specifications for qualification approval and capability approval are necessary and capability approval is therefore available only when a relevant sectional specification has been published.

H.1.1 Applicability of qualification approval

Qualification approval is appropriate for a standard range of components manufactured to similar design and production processes and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and performance levels applies directly to the component range to be qualified, as prescribed in Clause H.5 and the relevant sectional specification.

H.1.2 Applicability of capability approval

Capability approval is appropriate when components based on common design rules are fabricated by a group of common processes. It is particularly appropriate when components are manufactured to a user's specific requirements.

Under capability approval, detail specifications fall into the following three categories.

H.1.2.1 Capability qualifying components (CQCs), including process validation test vehicles

A detail specification shall be prepared for each CQC as agreed with the national supervising inspectorate (NSI). It shall identify the purpose of the CQC and include all relevant test severities and limits.

H.1.2.2 Standard catalogue components

When the manufacturer requires a component approved under the capability approval procedure to be listed in the IECQ register of approvals, a capability approval detail specification complying with the blank detail specification shall be written. Such specifications shall be registered by the IECQ and the component shall be listed in IEC QC 001005² approved under the IECQ system, including ISO 9000.

H.1.2.3 Customer specific components

The content of the detail specification (often known as a customer detail specification (CDS)) shall be by agreement between the manufacturer and customer in accordance with IEC QC 001002-3, 4.4.3.

Further information on these detail specifications is given in the relevant sectional specification.

Approval is given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures and the results of tests on capability qualifying components, including any process validation test vehicles. See Clause H.6 and the relevant sectional specification for further information.

H.1.3 Applicability of technology approval

Technology approval is appropriate when the complete technological process (design, process realization, product manufacture, test and shipment) covers the qualification aspects common to all components determined by the technology.

H.2 Primary stage of manufacture

The primary stage of manufacture shall be specified in the sectional specification.

H.3 Subcontracting

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed it shall be in accordance with IEC QC 001002-3, 4.2.2.

The sectional specification may restrict subcontracting in accordance with of IEC QC 001002-3, 4.2.2.2.

H.4 Structurally similar components

The grouping of structurally similar components for qualification approval testing or for quality conformance testing under qualification approval, capability approval or technology approval shall be prescribed in the relevant sectional specification.

H.5 Qualification approval procedures

H.5.1 Eligibility for qualification approval

The manufacturer shall comply with IEC QC 001002-3, 3.1.1.

² IEC QC 001005 has been withdrawn; see www.iecq.org/certificates for relevant information.

H.5.2 Application for qualification approval

The manufacturer shall comply with IEC QC 001002-3, 3.1.3.

H.5.3 Test procedure for qualification approval

One of the following procedures shall be used.

- a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible, and on one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

Samples shall be taken from the lots in accordance with IEC 60410 (see Annex A). Normal inspection shall be used, but if the sample size gives acceptance on zero non-conformances, additional specimens shall be taken to meet the sample size requirements to give acceptance on one nonconforming item.

- b) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the sectional specification.

The specimens taken to form the sample shall be selected at random from current production or as agreed with the NSI.

For the two procedures, the sample sizes and the number of permissible non-conformances shall be of comparable order. The test conditions and requirements shall be the same.

H.5.4 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with IEC QC 001002-3, 3.1.4 have been completed satisfactorily.

H.5.5 Maintenance of qualification approval

Qualification approval shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see H.5.6).

H.5.6 Quality conformance inspection

The blank detail specification(s) associated with the sectional specification shall prescribe the test schedule for quality conformance inspection. This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection.

Operation of the switching rule for reduced inspection in Group C is permitted in all subgroups except endurance.

Sampling plans and inspection levels shall be selected from those given in IEC 60410 or IEC 61193-2.

If required, more than one schedule may be specified.

H.6 Capability approval procedures

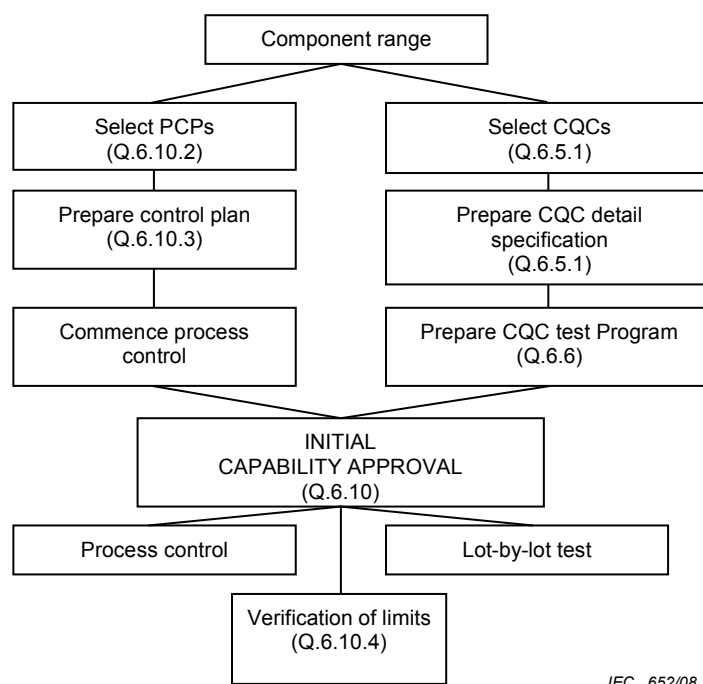
H.6.1 General

Capability approval covers

- the complete design, material preparation and manufacturing techniques, including control procedures and tests;
- the performance limits claimed for the processes and products, that is, those specified for the capability qualifying components (CQCs) and process control parameters (PCPs);

- the range of mechanical structures for which approval is granted.

For a general overview of capability approval see Figure H.1.



IEC 652/08

Figure H.1 – General scheme for capability approval

H.6.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of IEC QC 001002-3, 4.2.1.

H.6.3 Application for capability approval

The manufacturer shall comply with the requirements of IEC QC 001002-3, 4.2.4, and with the requirements of the relevant sectional specification.

H.6.4 Description of capability

The capability shall be described in a capability manual in accordance with IEC QC 001002-3, 4.2.5, and the requirements of the relevant sectional specification. The manual shall include or make reference to the following as a minimum:

- a general introduction and description of the technologies involved;
- aspects of customer liaison including provisions of design rules (if appropriate) and assistance to customers in the formulation of their requirements;
- a detailed description of the design rules to be used;
- the procedure for checking that the design rules are complied with for the relevant component technology manufactured to a detail specification;
- a list of all materials used, with reference to the corresponding purchasing specifications and goods inward inspection specifications;
- a flow chart for the total process, showing quality control points and permitted rework loops and containing references to all process and quality control procedures;
- a declaration of processes for which approval has been sought in accordance with the requirements of the relevant sectional specification;
- a declaration of limits for which approval has been sought in accordance with the requirements of the relevant sectional specification;

- a list of CQCs used to assess the capability, with a general description of each, supported by a detailed table showing where the declared limits of capability are demonstrated by a particular CQC design;
- detail specification for each CQC;
- a detailed control plan including PCPs used to control processes, with a general description of each PCP and showing the relation between a given PCP and the related properties and performance of the finished component;
- guidance on the application of structural similarity in sampling for quality conformance testing.

The NSI shall treat the capability manual as a confidential document. The manufacturer may, if he so wishes, disclose part or all of it to a third party.

H.6.5 Demonstration and verification of capability

The manufacturer shall demonstrate and verify the capability in accordance with IEC QC 001002-3, 4.2.6, and the requirements of the relevant sectional specification with the following details:

H.6.5.1 CQCs for demonstrating capability

The manufacturer shall agree with the NSI the process qualifying parameters and the range of capability qualifying components which are necessary to demonstrate the capability range specified in the capability manual.

The demonstration shall be made by testing the agreed range of CQCs, which shall be designed, manufactured and the process parameters controlled in accordance with the capability manual. The CQCs shall comply with the following requirements:

- a) The range of CQCs used shall represent all the limits of the declared capability. The CQCs shall be chosen to demonstrate mutually attainable combinations of limits.
- b) The CQCs shall be one of the following:
 - components specially designed to demonstrate a combination of limits of capability, or
 - components of designs used in general production, or
 - a combination of both of these, provided the requirements of a) are met.

When CQCs are designed and produced solely for capability approval, the manufacturer shall use the same design rules, materials and manufacturing processes as those applied to released products.

A detail specification shall be prepared for each CQC and shall have a front page format in accordance with Annex C. The detail specification shall identify the purpose of the CQC and shall include all relevant stress levels and test limits. It may refer to internal control documentation which specifies production testing and recording in order to demonstrate control and maintenance of processes and limits of capability.

H.6.5.2 Limits of capability

The limits of capability shall be described in the relevant sectional specification.

H.6.6 Programme for capability approval

In accordance with IEC QC 001001-3, 4.2.6, the manufacturer shall prepare a programme for the assessment of the declared capability. This programme shall be so designed that each declared limit of capability is verified by an appropriate CQC.

The programme shall include the following:

- a bar chart or other means of showing the proposed timetable for the approval exercise;
- details of all the CQCs to be used with references to their detail specifications;
- a chart showing the features to be demonstrated by each CQC;
- reference to the control plans to be used for process control.

H.6.7 Capability approval test report

In accordance with IEC QC 001002-3, 4.2.6.3, a capability approval test report shall be issued. The report shall meet the specific requirements of Annex D of this specification and shall contain the following information:

- the issue number and date of the capability manual;
- the programme for capability approval in accordance with H.6.6;
- all the test results obtained during the performance of the programme;
- the test methods used;
- reports on actions taken in the event of failure (see H.6.10.1).

The report shall be signed by the designated management representative (DMR) as a true statement of the results obtained and submitted to the body, designated in the national rules, which is responsible for the granting of capability approval.

H.6.8 Abstract of description of capability

The abstract is intended for formal publication in IEC QC 001005 after capability approval has been granted.

The abstract shall include a concise description of the manufacturer's capability and give sufficient information on the technology, methods of construction and range of products for which the manufacturer has been approved.

H.6.9 Modifications likely to affect the capability approval

Any modifications likely to affect the capability approval shall satisfy the requirements of IEC QC 001002-3, 4.2.11.

H.6.10 Initial capability approval

The approval is granted when

- the selected range of CQCs has collectively satisfied the assessment requirements of the CQC detail specifications, with no nonconforming item allowed;
- the control plan has been fully implemented in the process control system.

H.6.10.1 Procedure in the event of failure

See IEC QC 001002-3, 4.2.10, with the following details.

In the event of the failure of the specimens to meet the test requirements, the manufacturer shall notify the NSI and shall state his intention to follow one of the actions described in a) and b) below.

- a) to modify the proposed scope of his capability.
- b) to conduct an investigation to establish the cause of failure as being either
 - failure of the test itself, for example, test equipment failure or operator error;
 - or
 - design or process failure.

If the cause of failure is established as a failure of the test itself, then either the specimen which apparently failed or a new one, if appropriate, shall be returned to the test schedule after the necessary corrective action has been taken. If a new specimen is to be used, it shall be subjected to all of the tests in the given sequence of the test schedule(s) appropriate to the apparently failed specimen.

If the cause of failure is established as a design or process failure, a test programme shall be carried out to demonstrate that the cause of failure has been eradicated and that all corrective measures, including documentation, have been carried out. When this has been accomplished, the test sequences in which the failure has occurred shall be repeated in full using new CQCs.

After the action is complete the manufacturer shall send a report to the NSI, and shall include a copy in the capability approval test report (see H.6.7).

H.6.10.2 General plan for the selection of PCPs and CQCs

Each manufacturer shall prepare a process flow chart, based on the example given in the relevant sectional specification. For all the process steps included in his flow chart, the manufacturer shall include the corresponding process controls.

Controls shall be denoted by the manufacturer as shown in the example in the relevant sectional specification.

H.6.10.3 Process control test plans

The test plans shall form part of the process control system used by the manufacturer. When statistical process control (SPC) is used, implementation shall be in accordance with SPC basic requirements. The SPC plans represent mandatory controls at process nodes.

For each process step where production equipment is employed, the manufacturer shall monitor the process parameters at regular intervals and compare the readings to the control and action limits which he will establish.

H.6.10.4 Test plans for CQCs demonstrating limits of capability

Test plans for CQCs for the demonstration of limits of capability shall be prescribed in the relevant sectional specification.

H.6.11 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with IEC QC 001002-3, 4.2.6, have been completed satisfactorily and the requirements of the relevant sectional specification have been met.

H.6.12 Maintenance of capability approval

Capability approval shall be maintained by complying with the requirements of IEC QC 001002-3, 4.2.9, and with the requirements declared in the capability manual following the schedule of maintenance given in the relevant sectional specification.

Additionally, the following details apply.

- a) Capability approval remains valid without retesting for two years.
- b) the programme for the retesting of CQCs shall be defined by the manufacturer. For process control, the manufacturer shall establish a control system. An example of a control programme chart may be given in the sectional specification. For verifying limits of capability, the manufacturer shall ensure that all the test plans of H.6.10.4 which are relevant to his capability approval are repeated at least every two years.

- c) quality conformance inspection of components for delivery may be used to support the maintenance of capability approval where relevant. In particular, where the manufacturer holds qualification approval for a range of components which are manufactured by the same processes and which also fall within the limits of capability for which he holds capability approval, process control test results and periodic quality conformance test results arising from the qualification approval may be used to support the maintenance of capability approval.
- d) the manufacturer shall ensure that the range of CQCs remains representative of the products released and in accordance with the requirements of the relevant sectional specification.
- e) The manufacturer shall maintain production, so that
- the processes specified in the capability manual, with the exception of any additions or deletions agreed with the NSI following the procedure of H.6.9, remain unchanged;
 - no change has occurred in the place of manufacture, and final test;
 - no break exceeding six months has occurred in the manufacturer's production under capability approval.
- f) The manufacturer shall maintain a record of the progress of the maintenance of capability programme so that at any time the limits of capability which have been verified and those which are awaiting verification in the specified period can be established.

H.6.13 Extension of capability approval

The manufacturer may extend the limits of his capability approval by carrying out the test plan from H.6.10.4, which relates to the type of limit to be extended. If the proposed extension refers to a different type of limit from those described in H.6.10.4, the manufacturer shall propose the sampling and tests to be used and these shall be approved by the NSI. The manufacturer shall also establish process control over any new processes needed for manufacture to the new limits.

An application for an extension of capability shall be made in the same way as for the original approval.

H.6.14 Quality conformance inspection

The quality conformance test requirements are given in the detail specification and shall be carried out in accordance with IEC QC 001002-3, 4.3.1.

H.7 Rework and repair

H.7.1 Rework

Rework as defined in IEC QC 001002-3, 4.1.4, shall not be carried out if prohibited by the relevant sectional specification. The relevant sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection in accordance with the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the DMR. Rework shall not be subcontracted.

H.7.2 Repair

Components which have been repaired as defined in IEC QC 001002-3, 4.1.5, shall not be released under the IECQ system.

H.8 Release for delivery

Components shall be released for delivery according to H.2.6 and IEC QC 001002-3, 4.3.2, after the quality conformance inspection prescribed in the detail specification has been carried out.

H.8.1 Release for delivery under qualification approval before the completion of Group B tests

When the conditions of IEC 60410 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

H.9 Certified test records of released lots

When certified test records are requested by a purchaser, they shall be specified in the detail specification.

NOTE For capability approval, the certified test records refer only to tests carried out on capability qualifying components.

H.10 Delayed delivery

Components held for a period exceeding two years (unless otherwise specified in the sectional specification) following the release of the lot shall, before delivery, be re-examined for solderability and electrical characteristics as specified in the detail specification.

The re-examination procedure adopted by the manufacturer's DMR shall be approved by the NSI.

Once a lot has been satisfactorily re-inspected, its quality is reassured for the specified period.

H.11 Alternative test methods

See IEC QC 001002-3, 3.2.3.7, with the following details.

In case of dispute, for referee and reference purposes, only the specified methods shall be used.

H.12 Manufacture outside the geographical limits of IECQ NSIs

A manufacturer may have his approval extended to cover partial or complete manufacture of components in a factory of his company located in a country which does not have an NSI for the technical area concerned, whether this country is a IECQ member country or not, provided that the requirements of IEC QC 001002-3, 2.5.1.3, are met.

H.13 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing shall be assumed to be within the specified limits. It cannot be assumed that any unspecified parameter will remain unchanged from one component to another. If it is necessary, for any reason, to control one or more additional parameters, then a new, more extensive specification shall be used.

The additional test method(s) shall be fully described and appropriate limits, sampling plans and inspection levels specified.

H.14 Technology approval procedures

H.14.1 General

Technology approval of components covers the complete technological process. It extends the existing concepts – qualification and capability approval – by adding as mandatory

- a) the use of in-process control methods, for example, SPC;
- b) continuous quality improvement strategy;
- c) monitoring the overall technologies and operations;
- d) procedural flexibility due to the quality assurance management system and market sector requirements;
- e) the acceptance of a manufacturer's operational documentation to provide means for rapid approval or extension of approval.

H.14.2 Eligibility for technology approval

The manufacturer shall comply with QC 001002-3, 6.2.1.

H.14.3 Application of technology approval

The manufacturer shall comply with QC 001002-3, 6.2.2.

H.14.4 Description of technology

The technology shall be described in a Technology Approval Declaration Document (TADD) and a Technology Approval Schedule (TAS) in accordance with QC 001002-3, 6.4.

H.14.5 Demonstration and verification of the technology

The manufacturer shall demonstrate and verify the technology in accordance with QC 001002-3, 6.4 and 6.5.

H.14.6 Granting of technology approval

Technology approval shall be granted when the procedures in accordance with QC 001002-3, 6.7.3 have been completely satisfied.

H.14.7 Maintenance of technology approval

Technology approval shall be maintained by complying with the requirements of QC 001002-3, 6.7.5.

H.14.8 Quality conformance inspection

The quality conformance test and requirements shall be carried out in accordance with the relevant detail specification and technology approval schedules.

H.14.9 Failure rate level determination

The determination of failure rate level and certification shall be described in the relevant specification.

H.14.10 Outgoing quality level

The definition shall be agreed between customer and manufacturer.

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