

## Potentiometers and Trimmers

These application notes are valid unless otherwise specified in the datasheets.

### 1. GENERAL DEFINITIONS

#### 1.1 - Potentiometer

A potentiometer is a mechanically actuated variable resistor with three terminals. Two of the terminals are linked to the ends of the resistive element and the third is connected to a mobile contact moving over the resistive track. The output voltage becomes a function of the position of this contact. Potentiometer is advised to be used as a voltage divider.

#### 1.2 - Trimming potentiometer (trimmer)

A potentiometer designed for relatively infrequent adjustments

#### 1.3 - Multi-ganged potentiometer

A potentiometer with two or more sections, each electrically independent, operated by a common spindle.

#### 1.4 - Multi-turn potentiometer

A potentiometer with a shaft rotation of more than 360° from one end of the resistive element to the other. Multi-turn types are usually trimming or precision potentiometers.

#### 1.5 - Sealed potentiometers

Two levels of sealing are usually recognized. The less severe one provides protection only against dust and cleaning processes (solvent splashes and vapors). For definition of sealing, see table "Protection Levels" at the end of these Application Notes. Hermetic sealing is more rigorous and protects the product against environmental pressure. (Not applicable for trimmers and potentiometers)

#### 1.6 - Panel seal

This is used to seal the cut-out hole through which the potentiometer is mounted.

#### 1.7 - Spindle seal

One or more O-rings are used to seal the spindle/case joint.

### 2. MECHANICAL DEFINITIONS

#### 2.1 - Mechanical travel

The full extent of travel between the end stops of the spindle (Fig. 1). In potentiometers fitted with a slipping clutch, the position of the end stops is defined as those points where the clutch starts to slip at each end of the travel of the moving contact.

#### 2.2 - Actual electrical travel

The angle of rotation of the spindle throughout which the resistance changes in the manner prescribed by the specified resistance law. (Fig. 1)

#### 2.3 - End stop torque

The maximum torque that may be applied to the spindle when set against either end stop without causing any damage.

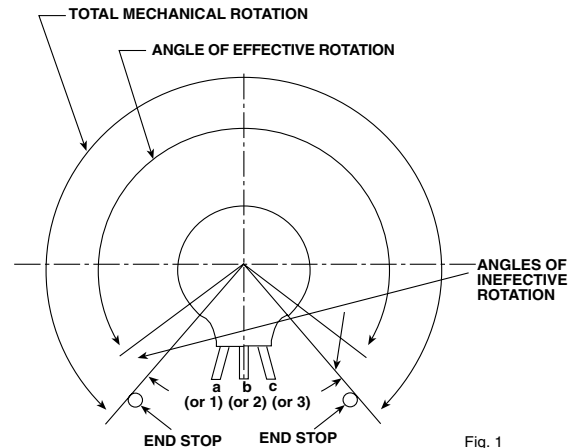


Fig. 1

#### 2.4 - Operating torque

The necessary torque to move the contact in either direction from a random position away from end stops.

#### 2.5 - Locking torque

The torque that may be applied to the shaft of a potentiometer fitted with a locking device without causing shaft rotation.

#### 2.6 - Rotational life

The minimum number of cycles of operations obtainable under specified operating conditions while performance parameters (e.g., resistance rotational noise, torque, etc.) remain within specifications. A cycle is defined as the travel of the moving contact from end to end of the resistance element, and back.

#### 2.7 - Direction of rotation

Rotation is defined as clockwise or counter-clockwise when viewing the surface of the potentiometer which includes the means of actuation.

#### 2.8 - Adjustment shaft

The mechanical input member of a potentiometer which, when rotated, causes the wiper to travel the resistance element resulting in a change in output voltage or resistance.

##### 2.8.2 - Single-turn Adjustment

Requires 360° or less mechanical input to cause the wiper to travel the total resistance element.

##### 2.8.2 - Multi-turn Adjustment

Requires more than 360° mechanical input to cause the wiper to travel the total resistance element.

**2.9 - Terminal**

An external contact that provides electrical connection to the resistance element and wiper.

**2.9.1 - Printed Circuit Terminal**

Rigid non-insulated electrical conductor suitable for printed circuit board

**2.9.2 - Solder Lug Terminal**

Rigid non-insulated electrical conductor suitable for external lead attachment

**2.9.3 - Leadwire Type**

Flexible insulated conductor

**2.10 - Stop clutch**

A device that allows the wiper to idle at the ends of the resistance element while the adjustment shaft continues to be actuated in the same direction. We recommend to not exceed 10 screw turns at clutch position to not damage internal mechanism.

**2.11 - Stop**

A positive limit to mechanical and electrical adjustment.

**3. INPUT AND OUTPUT TERMS**

**3.1 Input terms**

**3.1.1 - Total Applied Voltage**

(E) The total voltage applied between the designated input terminals.

**Note:** When plus (+) and minus (-) voltages are applied to the potentiometer, the total applied voltage (commonly called peak-to-peak applied voltage) is equal to the sum of the two voltages. Each individual voltage is referred to as zero-to-peak applied voltage.

**3.2 - Output terms**

**3.2.1 - Output Voltage**

(e) The voltage between the wiper terminal and the designated reference points. Unless otherwise specified, the designated reference point is the counter-clockwise (CCW) terminal.

**3.2.2 - Output Voltage Adjustment Ratio**

(e/E) The ratio of the output voltage to the designated input reference voltage. Unless otherwise specified the reference voltage is the total applied voltage.

**3.2.3 - Output Resistance**

The resistance measured between the wiper terminal and the designated reference point. Unless otherwise specified, the designated reference point is the CCW terminal.

**3.3 - Load terms**

**3.3.1 - Load Resistance**

(RL) The external resistance as seen by the output voltage (connected between the wiper terminal and the designated reference point).

**Notes:** No load means an infinite load resistance. In case of unspecified conditions of use or test, this load resistance shall be at least 100 times higher than the total potentiometer nominal resistance value.

**4. ELECTRICAL DEFINITIONS**

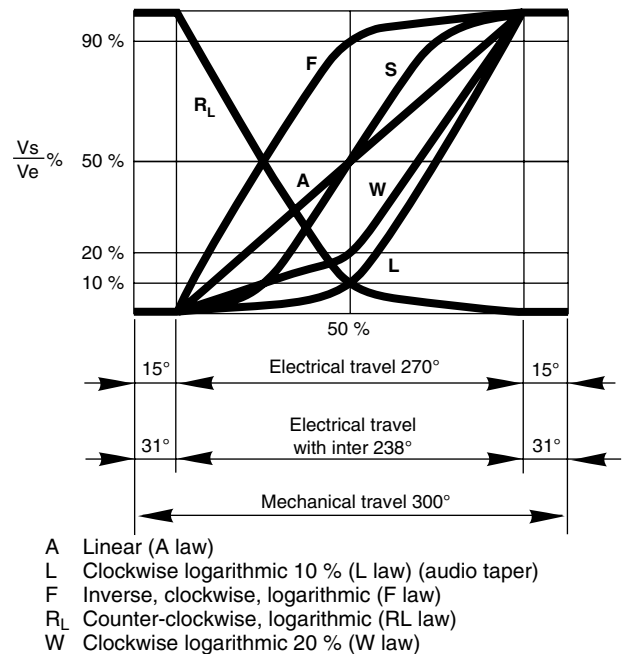
**4.1 - Power rating**

The maximum power that can be dissipated across the total resistance element, i.e., between terminals a (or 1) and c (or 3), at the specified ambient temperature. In practice this dissipation is modified by the following conditions:

- 4.1.1 - For ambient temperatures higher than that specified, reference should be made to the derating curve.
- 4.1.2 - For high values of resistance, the limiting element voltage may prevent the maximum power rating from being obtained.
- 4.1.3 - For situations when the power is dissipated in only part of the resistance element, the maximum current capacity of the element will prohibit maximum total power dissipation.

**4.2 - Resistance law**

The relationship between the mechanical position of the moving contact and the resistance value across terminals a and b. (This may also be expressed as the relationship between the position of the moving contact and the ratio  $V_{ab}/V_{ac}$ ). Typical available laws are indicated in Figure 2.



**4.3 - Conformity**

This is a measure of the maximum deviation of the actual to the correspondant theoretical voltage expressed as percent of the total applied voltage.

**4.4 - Independent linearity (best straight line)**

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.

#### 4.5 - Total resistance

The resistance value of the resistive element measured between connections a and c or 1 and 3 in conditions defined by CECC 41000:

Temperature: + 20 °C ± 1 °C

Relative humidity: 65 % ± 2 %

This value has to be included between limits of resistance nominal value according to tolerance.

##### 4.5.1 - Minimum Effective Resistance

The resistance value at each end of the effective rotation between termination b (or 2) and the nearest end termination, a or c (1 or 3).

#### 4.6 - Effective resistance

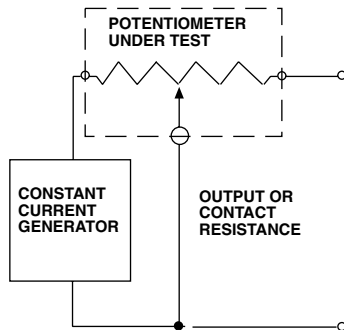
The portion of the total resistance over which the resistance changes in accordance with the declared resistance law. It is the total resistance minus the sum of the two minimum effective resistance values.

#### 4.7 - End resistance

The resistance measured between termination a or c and termination b when the moving contact is positioned at the corresponding end of mechanical travel.

#### 4.8 - Contact resistance

The resistance appearing between the contact and the resistive element when the shaft is rotated or translated. The wiper of the potentiometer is excited by a specific current and moved at a specified speed over a specified portion of the actual electrical travel.



#### 4.9 - Continuity

Continuity is the maintenance of continuous electrical contact between the wiper and the resistive element over the total mechanical travel in both directions.

#### 4.10 - Setting stability

For a fixed setting of the adjustment shaft, the amount of change in the output voltage due to the effects of an environmental condition, (expressed as a percentage of the total applied voltage).

#### 4.11 - Setting ability

A measure of the ability for the user to adjust the wiper to any particular voltage ratio or resistance output.

#### 4.12 - Resolution

This term is used in the description of wirewound potentiometers and is a measure of the sensitivity to which the output ratio of the potentiometer may be set. The theoretical resolution is the reciprocal of the number of turns of the resistance winding in the actual electrical travel multiplied by 100 i.e., (expressed as a percentage).

#### 4.13 - Limiting element voltage

The maximum voltage that may be applied across the element of a potentiometer, provided that the power rating is not exceeded.

#### 4.14 - Insulation voltage

The maximum voltage which may be applied under continuous operating conditions between any potentiometer termination and other external conductive parts connected together. The insulation voltage is not less than 1.4 times the limiting element voltage.

#### 4.15 - Dielectric strength (voltage proof)

The maximum voltage which may be applied under 1 ATM pressure for 60 s between any potentiometer termination and any external conductive part without breakdown occurring. Dielectric strength is not less than 1.4 times the insulation voltage.

#### 4.16 - Insulation resistance

The resistance measured between the terminals and other external conductive parts (e.g., shaft, housing, or mounting), when a specified D.C. voltage is applied.

#### 4.17 - Temperature coefficient of resistance (TCR)

The unit change in resistance per °C change from a reference temperature, expressed in parts per million per °C as follows:

$$TC = \frac{R_2 - R_1}{(T_2 - T_1)R_1} \times 10^6$$

Where :

R<sub>1</sub> = Resistance in ohms, at reference temperature

R<sub>2</sub> = Resistance in ohms, at test temperature

T<sub>1</sub> = Reference temperature in °C

T<sub>2</sub> = Test temperature in °C

#### 4.18 - Hysteresis

Average of the voltage deviation between clockwise and counter clockwise for specified travel increments over the theoretical electrical travel, expressed as a percentage of the total applied voltage.

## 5. ENVIRONMENTAL DEFINITIONS

### 5.1 - Climatic category

The climatic category is defined in terms of the temperature extremes (hot and cold) and number of days exposure to dampness, heat, and steady-state conditions that the component is designed to withstand.

The category is indicated by a series of three sets of digits, separated by oblique strokes, as follows:

- First set: Two digits denoting the minimum ambient temperature of operation (cold test).
- Second set: Three digits denoting the upper category temperature (at that temperature the allowed dissipation is at least 25 %).  
The maximum allowable temperature with zero dissipation is higher than the upper category temperature.
- Third set: Two digits denoting the number of days used for the "dampness, heat, and steady-state" test.

Example: P13: 55/100/56

Cold: - 55 °C

Upper category temperature: + 100 °C

(maximum allowable temperature: + 125 °C)

Damp heat: 56 days.

### 5.2 - Classify materials

Plastic materials used are UL94 class VO and/or our products are compliant with the flammability test of STD UL746C § 17 and 52.

### 6. STORAGE RECOMMENDATIONS

Careful attention must be paid when the components are stored. Because high and very low environmental temperature, high humidity, corrosive gases, etc. might affect the solderability of the terminals and the function of the package. Listed below are notes to be observed:

- The recommended storage conditions are in between + 10 °C and 25 °C (room temperature) at a relative humidity in between 35 % and 75 %.
- Do not store them within the vicinity of any corrosive gases such as hydrogen sulphide, sulphurous acid, chlorine or ammonium. The oxidation of the metals caused by such toxic gases may affect solderability as well as the electrical and mechanical performance of these products.
- Exposure to the direct sunlight and dust must be avoided
- Handle carefully to avoid deformation of terminals
- Keep parts in the original packages until just before use, and unpack only the quantity needed. Always seal any opened packages to protect them from oxidation and contaminants.
- Moisture Sensitive Level (MSL) for applicable SMD components, following storage conditions should be applied.

MSL LEVEL	FLOOR LIFE	
	TIME	CONDITIONS
1	Unlimited	≤ 30 °C/85 % RH
2	1 year	≤ 30 °C/60 % RH
2A	4 weeks	≤ 30 °C/60 % RH
3	168 hours	≤ 30 °C/60 % RH
4	72 hours	≤ 30 °C/60 % RH
5	48 hours	≤ 30 °C/60 % RH
5A	24 hours	≤ 30 °C/60 % RH
6	Time on label (TOL)	≤ 30 °C/60 % RH

If any special storage conditions are applied (outside those recommendations), it is the user's responsibility.

### 7. SMD AND THROUGH HOLE COMPONENTS, SOLDER AND CLEANING RECOMMENDATIONS

VISHAY Trimmers sealed surface mount components are designed to withstand the processes related to Infrared, Hot Air, Vapour Phase Reflow and Dual Wave soldering. They are sealed against flux by means of an O-ring seal or press fit and can withstand exposure to all commonly used defluxing solvents. It is important to note before pre-heating and soldering trimmers, make sure the position of the wiper is not in contact with the end terminals (beginning or end of the wiper mechanical travel) to avoid malfunction of trimmers.

#### 7.1 - Adhesive application (for SMD only)

When an assembly has to be wave soldered, an adhesive is essential to bond the SMDs to the substrate. Under normal conditions reflow, soldered substrates do not need adhesive to maintain trimmer orientation, since the solder paste does it. The amount of adhesive, the curing time and temperature to use should be in accordance with adhesive manufacturer's recommendations. Otherwise, the adhesive polymerization time & temperature have to also respect trimmers soldering recommendations. (§3)

**Caution:** The height and the volume of adhesive dots applied are critical for two reasons: the dot must be high enough to reach the SMD, and there must not be any excess adhesive, since this can pollute the solder land and prevent the formation of a good soldered joint.

#### 7.2 - Flux and solder recommendations

SMD & Through hole components can be used with R & RA (Rosin & Rosin Activated) type flux to OA (Organic Acid). It is always advisable not to use a flux of an activity level greater than that necessary to achieve optimum yields for solder wetting. Fluxes of RA and OA activity levels are corrosive and therefore must be removed. It is advisable that all types of fluxes be removed by cleaning due to the possibility of corrosion.

**Caution:** Avoid highly activated fluxes. Consult factory before using OA.

Suggested Solder composition is:

- Tin Lead solder: Sn63/Pb37
  - Lead (Pb)-free solder: Sn96.5/Ag3/Cu0.5
- } Typical solder paste print thickness would be 0.8 to 1 mm thick

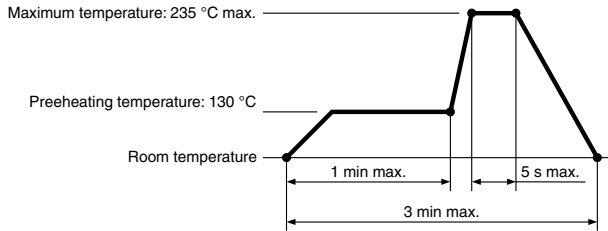
#### 7.3 - Soldering recommendations

Normal preheating is required to activate flux and minimize thermal shock to components. The maximum recommended temperature for flow and reflow soldering profiles are specified below. It is important to note temperature of those profiles corresponds to parts temperature (and not PCB temperature). The use of leaded solder process or lead (Pb)-free solder process is specified under each series of SMD or through hole products.

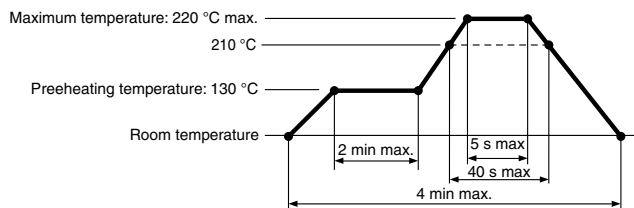
**General Caution:** User must always test and verify pre-heating and soldering processes as well as other production line assembly before final production.

## Leaded solder process

### Wave soldering (1 time max.)

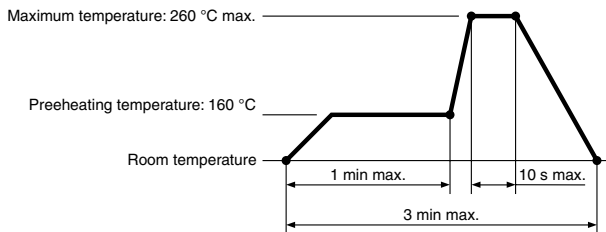


### Infrared or Hot Air reflow soldering (2 times max.) (for SMD only)

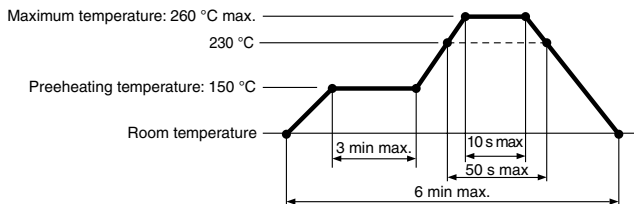


## Lead (Pb)-free solder process

### Wave soldering (1 time max.)



### Infrared or Hot Air reflow soldering (2 times max.) (for SMD only)



**Vapor phase reflow:** Vapour with 215 °C condensation temperature for a period not more than 2 minutes

**Soldering iron caution:** Use the appropriate soldering iron size, shape and heat capacity for soldering SMD trimmers. Do not exceed the maximum time and temperature parameters specified: 3 s at 350 °C. Never touch the body of the trimmer or potentiometer with the soldering iron.

**Infrared soldering caution:** If the infrared radiation is the heat source, the temperature increase of the SMD trimmers should be carefully checked because the radiation absorption rate depends on the color and the structure of the material of trimmers.

## 7.4 - Washing recommendations (refer to protection level of the component)

Cooling down time after soldering and before exposure to defluxing solvents is required. The component body temperature when exposed to cleaning should not exceed 60 °C. Cleaning spray rinse is recommended with pressures of not greater than 60 psi (5.5 kg-cm<sup>2</sup>) for a period not to exceed 15 - 20 seconds.

Appropriate defluxing solvent/Aqueous:

- Aqueous detergent solutions
- Terpene based semiaqueous
- Ester/Ether based solvents
- Methanol
- HAS - HCFC

**Caution:** • Avoid using cleaning solvents such as Trichloroethane or Freon which endanger the environment

- Ultrasonic may cause component damage or failure

## 7.5 - Reworking recommendations

- General: Excessive and/or repeated high temperature heat exposure may affect component performance and reliability
- Recommended: Hot air reflow technique is the safest method for SMD component
- Caution: Avoid use of a soldering iron or wave soldering as a rework technique

## 7.6 - Adjustment recommendations

Adjustment of components should be done only after part has reached ambient temperature and cleaning solvent has evaporated (10 minutes).



<b>DEGREES OF PROTECTION PROVIDED BY ENCLOSURES - IP CODES DEFINITIONS</b>		
<b>FIRST CHARACTERISTIC NUMERAL</b>	<b>DEGREE OF PROTECTION</b>	
	<b>BRIEF DESCRIPTION</b>	<b>DEFINITION</b>
<b>0</b>	Non-protected	-
<b>1</b>	Protected against solid foreign object of 50 mm diameter and greater	The object probe, sphere 50 mm diameter shall not fully penetrate <sup>(1)</sup>
<b>2</b>	Protected against solid foreign object of 12.5 mm diameter and greater	The object probe, sphere 12.5 mm diameter shall not fully penetrate <sup>(1)</sup>
<b>3</b>	Protected against solid foreign object of 2.5 mm diameter and greater	The object probe, sphere 2.5 mm diameter shall not fully penetrate <sup>(1)</sup>
<b>4</b>	Protected against solid foreign object of 1 mm diameter and greater	The object probe, sphere 1 mm diameter shall not fully penetrate <sup>(1)</sup>
<b>5</b>	Dust-protected	Ingress of dust is totally prevented but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
<b>6</b>	Dust-tight	No ingress of dust
<b>SECOND CHARACTERISTIC NUMERAL</b>	<b>DEGREE OF PROTECTION</b>	
	<b>BRIEF DESCRIPTION</b>	<b>DEFINITION</b>
<b>0</b>	Non-protected	-
<b>1</b>	Protected against vertically falling water drops	Vertically falling water drops shall have no harmful effect
<b>2</b>	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling water drops shall have no harmful effect drops when the enclosure is tilted at any angle up to 15° on either of the vertical
<b>3</b>	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effect
<b>4</b>	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect
<b>5</b>	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effect
<b>6</b>	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effect
<b>7</b>	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under stabilized conditions of pressure and time
<b>8</b>	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7

**Note:**

<sup>(1)</sup> The full diameter of the object probe shall not pass through an opening enclosure.