

# IEEE Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components

IEEE Power and Energy Society

Sponsored by the  
Surge Protective Devices Committee

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(Revision of IEEE Std C62.33-1982)

# **IEEE Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components**

Sponsor

**Surge Protective Devices Committee**  
of the  
**IEEE Power and Energy Society**

Approved 7 December 2016

**IEEE-SA Standards Board**

**Abstract:** Test methods and preferred values for metal-oxide varistor (MOV) surge protective components are covered in this standard and have the following main parameter ranges: packaging (leaded disc-type or surface mount), nominal varistor voltage (5 V to 1200 V), 8/20 surge current rating (10 A to 70 kA), and 8/20 clamping voltage (10 V to 3 kV). With appropriate component selection, these components could be used for the overvoltage protection of power and signal systems having continuous ac voltages (2.5 V rms to 750 V rms), steady-state dc voltages (3.3 V to 1000 V), and peak signal feed voltages (3.5 V to 850 V). Information is given on manufacturer type testing used to determine environmental performance and rated values.

**Keywords:** clamping voltage, ESD, IEEE C62.33™, leaded, MCOV, metal-oxide varistor, MOV, nominal voltage, surface mount, surge current rating, TOV, varistor

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## Introduction

This introduction is not part of IEEE Std C62.33-2016, IEEE Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components.

This test method document has been developed for the purpose of testing and comparing metal-oxide varistor (MOV) surge protective components.

An MOV is a surge diverter used for limiting transient overvoltages in power and communications circuits.

The interest in low-voltage varistors has grown with the trend to highly sophisticated electrical and electronic devices that are exposed to surges from the environment. Initially, there were no standard terms or tests to define or compare these devices. The IEEE Surge Protection Devices Committee formed its Low Voltage Surge Protection Devices Working Group in 1970 to define these parameters.

Experts were drawn from many fields in communications and power utilities, electronic manufacturers and users, test equipment manufacturers and laboratories, and producers of varistors themselves. The requirements, experiences, and vocabularies of these representatives were melded to produce this document as a guide to potential users of varistor surge protective devices.

## Contents

|                                                                    |    |
|--------------------------------------------------------------------|----|
| 1. Overview .....                                                  | 9  |
| 1.1 Scope .....                                                    | 9  |
| 2. Normative references .....                                      | 9  |
| 3. Definitions, acronyms, and abbreviations .....                  | 10 |
| 3.1 Definitions .....                                              | 10 |
| 3.2 Acronyms and abbreviations .....                               | 12 |
| 4. Environments .....                                              | 13 |
| 4.1 Test conditions .....                                          | 13 |
| 5. Electrical characteristics .....                                | 13 |
| 5.1 General .....                                                  | 13 |
| 5.2 Varistor voltage .....                                         | 13 |
| 5.3 Leakage current dc .....                                       | 14 |
| 5.4 Capacitance .....                                              | 14 |
| 5.5 Clamping voltage .....                                         | 15 |
| 6. Electrical ratings .....                                        | 15 |
| 6.1 General .....                                                  | 15 |
| 6.2 Maximum ac (dc) continuous operating voltage .....             | 16 |
| 6.3 ESD test (for SMD type MOV only) .....                         | 18 |
| 6.4 Rated impulse energy .....                                     | 19 |
| 6.5 Nominal discharge current, $I_n$ .....                         | 19 |
| 6.6 Endurance at maximum operating temperature .....               | 22 |
| 6.7 TOV withstand .....                                            | 23 |
| 6.8 Thermal overload .....                                         | 25 |
| Annex A (informative) Environment tests .....                      | 28 |
| Annex B (normative) Identification and procurement .....           | 34 |
| Annex C (informative) Informative parameters .....                 | 35 |
| Annex D (normative) Impulses used in this standard .....           | 37 |
| Annex E (informative) IEC thermally protected MOV evaluation ..... | 41 |
| Annex F (informative) Bibliography .....                           | 43 |

# IEEE Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components

## 1. Scope

This standard covers test methods and performance values for metal-oxide varistor (MOV) surge protective components (SPCs) with the following main parameter ranges:

- Packaging: Leaded disc-type or surface mount
- Nominal varistor voltage: 5 V to 1200 V
- 8/20 surge current rating: 10 A to 70 kA
- 8/20 clamping voltage: 10 V to 3 kV

With appropriate component selection, these components could be used for the overvoltage protection of power and signal systems having the following:

- Continuous ac voltages: 2.5 V rms to 750 V rms
- Steady-state dc voltages: 3.3 V to 1000 V
- Peak signal feed voltages: 3.5 V to 850 V

Information is given on manufacturer type testing used to determine environmental performance and rated values.

## 2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 60060-2:2010, High voltage test techniques – Part 2: Measuring systems.<sup>1</sup>

IEC 61000-4-2:2001, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test.

<sup>1</sup>IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

### 3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.<sup>2</sup>

#### 3.1 Definitions

This standard defines the following terms:

**clamping voltage ( $V_C$ ):** Maximum peak voltage across the metal-oxide varistor (MOV) measured under conditions of a specified waveform impulse with current peak  $I_p$ . If there is both a front peak and rear peak on the voltage waveform, the rear peak voltage is defined as the clamping voltage.

NOTE—ITU-T K.77 (01/2009) [B24] recommends that each MOV has its peak voltage measured in both polarities and the larger value of the two be taken as the MOV clamping voltage.<sup>3, 4</sup>

**clamping voltage current ( $I_C$ ):** Crest value of the current through the varistor for clamping voltage measurement having a current wave shape of 8/20.

**combination wave generator:** Generator with 1.2/50 open-circuit voltage waveform and 8/20 short-circuit current waveform.

**current peak de-rating curve:** Curves expressing the relationship of the three variables of  $I_p$ ,  $n$ ,  $\tau$ , where  $I_p$  is the impulse current peak,  $\tau$  is the impulse width, and  $n$  is the average application number of the impulse that the metal-oxide varistor (MOV) can withstand in terms of specified pass criterion.

NOTE 1—The current  $I_g$ , the  $I_p$  value with increasing  $n$  or  $\tau$ , can be represented by Equation (1) and Equation (2).

$$\text{LOG } I_g = A - a \text{ LOG } n \text{ (for a constant value of } \tau) \quad (1)$$

$$\text{LOG } I_g = B - b \text{ LOG } \tau \text{ (for a constant value of } n) \quad (2)$$

where

$A, a, B, b$  are four constants which depend on the type and manufacturing of the MOV  
 $A$  and  $a$  depend on  $\tau$  values and  $B$  and  $b$  depend on  $n$  values

NOTE 2—Equation (1) and Equation (2) agree well with the actual characteristics of an MOV when  $n \geq 10$ , but become inaccurate for when  $n < 10$ .

**endurance at maximum operating temperature:** Property to operate at maximum operating temperature and maximum continuous operating voltage for 1000 h.

NOTE—Unless otherwise specified, the maximum operating temperature can be taken as 85 °C.

**front peak voltage ( $V_F$ ):** Maximum voltage across the metal-oxide varistor occurring at the initial time of an applied impulse current of specified waveform and peak value.

<sup>2</sup>The *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

<sup>3</sup>Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

<sup>4</sup>Numbers in brackets correspond to those of the bibliography in Annex F.

**impulse:** Unidirectional wave of voltage or current that, without appreciable oscillations, rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, excursions of opposite polarity, with defining parameters being polarity, peak value, front time and time to half-value on the tail. (IEC 60099-9 [B16])

**impulse current peak [IP ( $n$ ,  $\tau$ )]:** Repetitive impulse current peak that can be applied for a specified number of applications,  $n$ , with a specified impulse width  $\tau$ .

**impulse width ( $\tau$ ):** Normalized impulse duration that is the ratio of the waveform area to the impulse peak, by means of  $\tau$  any waveform of impulse can be converted into an equivalent rectangular wave.

**leakage current dc ( $I_{Ld}$ ):** Current passing through the metal oxide varistor with the maximum dc voltage  $V_{DC}$  applied on it, and at a specified temperature.

**maximum continuous operating voltage (MCOV) [ $V_{AC}$  ( $V_{DC}$ )]:** Maximum ac rms voltage  $V_{AC}$  or maximum dc voltage  $V_{DC}$  that can be applied continuously at a temperature of 25 °C.  $V_{AC}$  shall be a substantially sinusoidal voltage (less than 5% total harmonic distortion).

**multilayer varistor (MLV):** Varistors made using multiple, fine grain ceramic layers that are connected in parallel.

NOTE—MLVs are generally surface mount components used for electrostatic discharge protection of electronic circuits.

**metal-oxide varistor (MOV):** Component made of zinc oxide (ZnO) and a few additives whose conductance, at a given temperature, increases rapidly with the voltage increasing over a certain voltage range.

NOTE—An MOV is also known as a voltage-dependent resistor (VDR) or a varistor.

**nominal discharge current ( $I_n$ ):** Maximum value of the repetitive current through the varistor having a current wave shape of 8/20.

NOTE—Unless otherwise specified, 15 pulses are used for qualification.

**nominal varistor voltage ( $V_N$ ):** Voltage, at specified dc, used as a reference point in the component characteristic.

NOTE—Unless otherwise specified, a dc of 1 mA is used.

**rated impulse energy ( $W_{tm}$ ):** Maximum single impulse energy that can be absorbed by the metal-oxide varistor for a specified waveform.

NOTE—ITU-T K.77 (01/2009) [B24] recommends that either a 2 ms rectangular current impulse or a 10/1000 current impulse be used as the characterization waveform.

**rated peak single pulse transient current (varistor),  $I_{TM}$ :** Maximum peak current that may be applied for a single 8/20 impulse, with rated line voltage also applied, without causing device failure.

**surge protective component (SPC):** Component specifically included in a device or equipment for the mitigation of the onward propagation of overvoltages or overcurrents, or both. (ITU-T K.96 (02/2014) [B25])

**surge protective device (SPD):** Device that restricts the voltage of a designated port or ports, caused by a surge, when it exceeds a predetermined level. (IEC 61643-21:2009-04 [B20])

NOTE 1—Secondary functions may be incorporated, such as a current-limiting device to restrict a terminal current.

NOTE 2—Typically, the protective circuit has at least one non-linear voltage-limiting surge protective component.

NOTE 3—An SPD is a combination of a protection circuit and any holder.

**temperature de-rating curve:** Graphical representation of parameters de-rating against temperature.

NOTE—Typical parameters are maximum continuous operating voltage  $V_C$  ( $V_{DC}$ ), nominal discharge current  $I_n$ , impulse current peak  $I_p$  ( $n$ ,  $\tau$ ), and rated impulse energy,  $W_m$ .

**temporary overvoltage (TOV) ( $V_T$ ):** AC voltage rms or dc voltage that the metal-oxide varistor can withstand;  $V_T$  exceeds the maximum continuous operating voltage  $V_C$  or  $V_{DC}$ .

**thermal equilibrium:** State reached when the temperature of the parts of a component or equipment operating in a given environment no longer varies faster than a specified limit. (IEC 60050-151 [B2])

**varistor:** Resistor the resistance of which is strongly varying with the applied voltage. (IEC 60050-151 [B2])

**wave shape designation (of an impulse):** (A) The wave shape of an impulse (other than rectangular) of a current or voltage is designated by a combination of two numbers. The first, an index of the wave front, is the virtual duration of the wave front in microseconds. The second, an index of the wave tail, is the time in microseconds from virtual zero to the instant at which one-half of the crest value is reached on the wave tail. Examples are 1.2/50 and 8/20 waves. (B) The wave shape of a rectangular impulse of current or voltage is designated by two numbers. The first designates the minimum value of current or voltage that is sustained for the time in microseconds designated by the second number. An example is the 75 A 1000  $\mu$ s wave. (IEEE Std C62.11-2012 [B23])

## 3.2 Acronyms and abbreviations

This standard uses the following abbreviations and acronyms:

|      |                                      |
|------|--------------------------------------|
| AQL  | acceptable quality level             |
| ESD  | electrostatic discharge              |
| HMM  | human metal model                    |
| MCOV | maximum continuous operating voltage |
| MLV  | multilayer varistor                  |
| MOV  | metal-oxide varistor                 |
| PS   | power source                         |
| SMD  | surface mount device                 |
| SPC  | surge protective component           |
| SPD  | surge protective device              |
| TOV  | temporary overvoltage                |
| VDR  | voltage-dependent resistor           |

## 4. Environments

### 4.1 Test conditions

In the absence of specified environmental standards, the following test conditions are to be used for these tests:

|                    |                   |
|--------------------|-------------------|
| Temperature:       | 25 °C ± 10 K      |
| Relative humidity: | 25% to 75%        |
| Air pressure:      | 86 kPa to 106 kPa |

The waveform of the impulses used in this standard shall meet the requirements of [Annex D](#).

When tests are conducted, the MOVs of leaded disc type shall be mounted as for normal use, while the MOVs of surface mount device (SMD) types shall be mounted on the substrate. Unless otherwise specified, the substrate shall be as described in [Annex A](#).

## 5. Electrical characteristics

### 5.1 General

MOVs of various types should have the characteristics listed in [Table 1](#) when tested as specified.

For the tests for electrical characteristics, a statistically significant number of samples should be chosen. Generally, “statistically significant” is 30 samples, but guidance such as acceptable quality level (AQL) tables or customer requests may apply.

### 5.2 Varistor voltage

#### 5.2.1 Preferred voltage values

When tested according to [5.2.2](#), varistor voltage should be within the specified limits. [Table 2](#) and [Table 3](#) show the nominal varistor voltages of high voltage and low voltage disc types that are commonly used; their allowable tolerances are ±10%. Components with voltages higher than [Table 2](#) are less commonly used and individual suppliers should be contacted to find the voltages available.

The nominal varistor voltages and tolerances listed in [Table 4](#) are typical for SMD types.

#### 5.2.2 Test method

A power supply of constant current source of 1 mA dc ± 10% shall be used. The voltage across the tested MOV should rise from a lower value than that of the varistor voltage measured, rather than declining from the maximum voltage of the current source. The ripple of dc voltage shall be no more than 1%. The time of applied test current 1 mA shall be within 20 ms to 100 ms prior to taking the voltage reading. The accuracy of the voltmeter shall be ±0.5%. The voltage shall be measured for positive and negative polarities of the test current.

NOTE—Two successive measurements may give slightly different outcomes, usually the first is less than the second. Unless otherwise specified, the first is taken.