



IEEE Guide for the Application of Surge-Protective Components in Surge-Protective Devices and Equipment Ports—Part 2: Metal- Oxide Varistors (MOVs)

IEEE Power and Energy Society

Developed by the
Surge Protective Devices Committee

IEEE Std C62.42.2™-2022

STANDARDS

IEEE Guide for the Application of Surge-Protective Components in Surge-Protective Devices and Equipment Ports—Part 2: Metal-Oxide Varistors (MOVs)

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Abstract: Surge protective components (SPCs) used in power and telecom surge-protective devices (SPDs) and equipment ports are covered by the C62.42 guide series. Component construction, characteristics, ratings, and application examples are covered in this part on metal-oxide varistor (MOV) technology SPCs.

Keywords: clamping voltage, electrostatic discharge, ESD, leaded, maximum continuous operating voltage, MCOV, metal-oxide varistor, MOV, nominal voltage, IEEE C62.42.2™, surface mount, surge current rating, temporary overvoltage, TOV, varistor

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Introduction

This introduction is not part of IEEE Std C62.42.2-2022, IEEE Guide for the Application of Surge-Protective Components in Surge-Protective Devices and Equipment Ports—Part 2: Metal-Oxide Varistors (MOVs).

This application guide on metal-oxide varistors, or MOVs, explains MOV characteristics and ratings. Using these parameters, design procedures are given for ac mains protection, protection configurations, circuit modeling, and tolerancing.

Much of the material in this guide appeared in IEEE Std C62.42™-2005 [B32]⁶. The extracted material has been updated to represent modern-day approaches.

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IEEE Guide for the Application of Surge-Protective Components in Surge-Protective Devices and Equipment Ports—Part 2: Metal-Oxide Varistors (MOVs)

1. Overview

1.1 Scope

The IEEE Std C62.42™ guide series covers surge-protective components (SPCs) used in power and telecom surge-protective devices (SPDs) and equipment ports. This part on metal-oxide varistor (MOV) technology SPCs covers:

- Component construction
- Characteristics
- Ratings
- Application examples

NOTE—This edition of IEEE Std C62.42.2 uses materials extracted from IEEE Std C62.42-2005. Unused figures from IEEE Std C62.42-2005 are shown in [Annex E](#).

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{7,8}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

⁷The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁸The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

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.

IEEE C62.33™, IEEE Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components.^{9,10}

3. Definitions, acronyms, and abbreviations

3.1 Definitions

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.¹¹

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

NOTE—The quotient of peak open-circuit voltage and peak short-circuit current is normally $2\Omega \pm 10\%$.

category temperature range: Range of ambient temperatures for which a component, a device, or equipment has been designed to operate continuously.

NOTE—The range is given by the lower and upper category temperatures.¹²

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 .

NOTE 1—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 2—ITU-T K.77 (01/2009) [B42] 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.

clamping voltage, V_{CLP} (class current): Limiting voltage under standard atmospheric conditions when passing an 8/20 class current pulse (IEC 61051-1 [B25])¹³.

⁹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<https://standards.ieee.org/>).

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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.

class current (I_{CLS}): Peak value of current, which is 1/10 of the maximum peak current for 100 pulses for the 8/20 current pulse with a time interval of 30 s (IEC 61051-1 [B25]).¹⁴

component capacitance (C): Capacitance between the component terminals measured at a specific frequency and bias.

current peak derating curve: Curves expressing the relationship of the three variables of I_p , n , and τ , where I_p is the impulse current peak, τ 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 τ , can be represented by Equation (1) and Equation (2).

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

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

where

A , a , B , b are four constants which depend on the type and manufacturing of the MOV
 A and a depend on τ values
 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 $n < 10$.

electrostatic discharge, ESD (low-voltage SMD varistors): Transfer of electric charge between bodies of different electrostatic potential in proximity or through direct contact (IEC 60050-161 [B5])¹⁵.

NOTE—There are two ESD test methods, as follows:

- Contact discharge method: a method of testing in which the electrode of the ESD pulse generator is held in contact with the component, and the discharge is actuated by the discharge switch within the generator.
- Air discharge method: a method of testing in which the electrode of the ESD pulse generator is brought close to the component, and the discharge is actuated by a spark to the component (IEC 61051-1 [B25])¹⁶.

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.

equivalent rectangular pulse duration ($\square$): Normalized unidirectional pulse duration that is equal to the ratio of the area of the pulse wave to the pulse peak.

¹⁴See Footnote 13.

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¹⁶See Footnote 13.

ESD clamping voltage (low-voltage SMD varistors): Peak voltage developed across the varistor terminations measured at 30 ns after initiation of impulse of 30 A/8 kV (IEC 61051-1 [B25])¹⁷.

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.

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 [B19]).¹⁸

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

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

isolation voltage, V_{ISO} (insulated components): Maximum peak voltage that can be applied under continuous operating conditions between the component terminations and the component body insulation.

NOTE—Also known as proof voltage or withstand voltage.

lead component: A component having solid or stranded wires—or formed conductors—that extends from the body to serve as a mechanical or electrical connector or both (IEC 61051-1 [B25]).¹⁹

leakage current (dc) I_{LD} : Current passing through the component with the specified dc voltage applied on it and at a specified temperature.

limiting voltage: Value of the voltage, which appears at the terminations of the component, when a specified current pulse is applied to it.

lower category temperature: Minimum ambient temperature at which a component, a device, or equipment has been designed to operate continuously.

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).

maximum peak current (I_{PM}): Maximum current per pulse that can be passed by a varistor at an ambient temperature of 25 °C for a given number of pulses (IEC 61051-1 [B25])²⁰.

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): Nonlinear resistor made of a sintered mixture of zinc and other metal oxides whose conductance, at a given temperature and within a given current range, increases rapidly with current.

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

¹⁷See Footnote 13.

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¹⁹See Footnote 13.

²⁰See Footnote 13.

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 a specified dc, used as a reference point in the component V - I characteristic.

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

rated impulse energy (E_M): Maximum single impulse energy that can be absorbed by the component for a specified waveform.

NOTE—ITU-T K.77 (01/2009) [B42] recommends that either a 2-ms rectangular current impulse or a 10/1000 current impulse be used as the characterization waveform.

rated average dissipation power (P_M): Maximum average dissipation power of repetitive pulses allowed to be applied to the varistors at an ambient temperature of 25 °C.

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 component failure.

style: Subdivision of a type, generally based on dimensional factors that can include several variants, generally of a mechanical order (IEC 61051-1 [B25])²¹.

surface mounting device/component (SMD): Component designed for mounting onto terminal pads or conducting tracks on the surface of substrate (IEC 61051-1 [B25])²².

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) [B43]).

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 [B27])²³.

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

NOTE 2—Typically, the protective circuit has at least one nonlinear voltage-limiting surge-protective component (SPC).

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

temperature derating curve: Graphical representation of parameters derating 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 , τ), and rated impulse energy, E_M .

temporary overvoltage (TOV) withstanding capability (V_T): Specified TOV stress that a component should be capable of withstanding, evaluated by the energy absorbed by the component and initial temperature.

NOTE 1—The TOV stress can be expressed as a specified voltage and a rated time duration or as a specified time and a rated voltage. Normally, TOV stress will have a specified source impedance.

NOTE 2—This capability is intended to match the operation of thermal disconnectors of the surge-protective devices (SPDs) that use the MOV.

²¹See Footnote 13.

²²See Footnote 13.

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