

# **SIOV metal oxide varistors**

## General technical information

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## 1 General technical information

### 1.1 Introduction

Despite its many benefits, one of the few drawbacks of semiconductor technology is the vulnerability of solid-state devices to overvoltages. Even voltage pulses of very low energy can produce interference and damage, sometimes with far-reaching consequences. So, as electronics makes its way into more and more applications, optimum overvoltage or transient suppression becomes a design factor of decisive importance.

SIOV<sup>® 1)</sup> varistors have been proven to be excellent protective devices because of their application flexibility and high reliability. The metal oxide varistor, with its extremely attractive price/performance ratio, is an ideal component for limiting surge voltage and current as well as for absorbing energy.

The EPCOS product range includes radial-leaded disks, block varistors and strap varistors for power distribution applications. Special types for automotive electrical systems and for telecom applications round off the product range.

Overvoltage protection devices like SIOV varistors are often referred to in international publications as a TVSS (transient voltage surge suppressor).

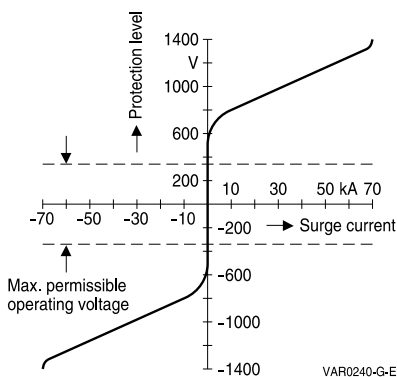
### 1.2 Definition

Varistors (**variable resistors**) are voltage-dependent resistors with a symmetrical V/I characteristic curve (figure 2) whose resistance decreases with increasing voltage. Connected in parallel with the electronic device or circuit that is to be guarded, they form a low-resistance shunt when voltage increases and thus prevent any further rise in the surge overvoltage.



**Figure 1**

Circuit diagram symbol for a varistor



**Figure 2**

Typical V/I characteristic curve of a metal oxide varistor on a linear scale, using the SIOV-B60K250 as an example

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The voltage dependence of varistors or VDRs (voltage dependent resistors) may be approximately characterized by the formula

$$I = K \cdot V^\alpha,$$

where  $\alpha$  denotes the “nonlinearity” exponent and in this way  $\alpha$  may be interpreted as a measure of the “steepness” of the V/I characteristic (more details will follow in section 1.6). In metal oxide varistors it has been possible to produce  $\alpha$  figures of more than 30. This puts their protection levels in the same region as those of zener diodes and suppressor diodes. Exceptional current handling capability combined with response times of < 25 ns make them an almost perfect protective device. The principle of overvoltage protection by varistors is explained in chapter “Selection procedure” in section 1.2.

### 1.3 Microstructure and conduction mechanism

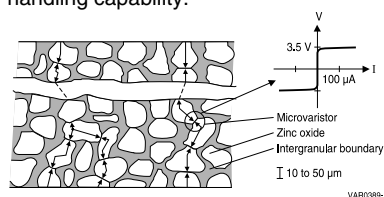
Sintering zinc oxide together with other metal oxide additives under specific conditions produces a polycrystalline ceramic whose resistance exhibits a pronounced dependence on voltage. This phenomenon is called the varistor effect.

Figure 3 shows the conduction mechanism in a varistor element in simplified form. The zinc oxide grains themselves are highly conductive, while the intergranular boundary formed of other oxides is highly resistive. Only at those points where zinc oxide grains meet does sintering produce “microvaristors”, comparable to symmetrical zener diodes (protection level approx. 3.5 V). The electrical behavior of the metal oxide varistor, as indicated by figure 3, results from the number of microvaristors connected in series or in parallel.

This implies that the electrical properties are controlled by the physical dimensions of the varistor:

- Twice the ceramic thickness produces twice the protection level because then twice the number of microvaristors are arranged in series.
- Twice the area produces twice the current handling capability because then twice the number of current paths are arranged in parallel.
- Twice the volume produces almost twice the energy absorption capability because then there are twice as many absorbers in the form of zinc oxide grains.

The series and parallel connection of the individual microvaristors in the sintered body of a SIOV also explains its high electrical load capacity compared to semiconductors. While the power in semiconductors is dissipated almost entirely in one thin p-n junction area, in a SIOV it is distributed over all the microvaristors, i.e. uniformly throughout the component’s volume. Each microvaristor is provided with energy absorbers in the form of zinc oxide grains with optimum thermal contact. This permits high absorption of energy and thus exceptionally high surge current handling capability.



**Figure 3** Conduction mechanism in a varistor element

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### Grain size

For matching very different levels of protection to ceramic thicknesses that are suitable for fabrication, SIOV varistors have to be produced from ceramics with different voltage gradients. The variation of raw materials and sintering process influence the growth of grain size (grain diameter approx. 10 to 100  $\mu\text{m}$ ) and thus produce the required specific ceramic voltage (approx. 30 to 250 V/mm). The V/I characteristic of the individual microvaristors is not affected by this.

Ceramics with a small specific voltage (low-voltage types  $\leq 40$  V) cannot handle the same current density as high-voltage types. That explains the differences in surge current, energy absorption and mechanical dimensions within the various type series. The effect of the different grain sizes is most apparent between the voltage classes K40 and K50. For example, the maximum permissible surge current is:

SIOV-S07K40	$i_{\text{max}} = 250$ A
SIOV-S07K50	$i_{\text{max}} = 1200$ A

## 1.4 Construction

Sintered metal oxide ceramics are processed on different production lines:

### Disk types

Here the varistor disk is fitted with leads of tinned copper wire and then the ceramic body is coated with epoxy resin in a fluidized bed.

### Disk varistors in housing

Here the disk varistors are fitted into a housing for special overvoltage fields application.

#### ■ ThermoFuse (ETFV or T) types

These are designed for self-protection under abnormal overvoltage conditions.

### Block types

The large electromagnetic forces involved in handling currents between 10 kA and 100 kA call for solid contacting with special electrodes and potting in a plastic housing. Block varistors are electrically and mechanically connected by screw terminals.

### Strap types

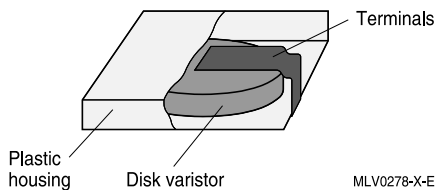
After contacting of the varistor ceramics with special bolt-holed electrodes, these components are coated with epoxy resin in a fluidized bed.

For photos of all constructions see "Overview of types".

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### SMD types

#### Monolithic ceramic body



**Figur 4** Construction of SMD components

The SMD disk varistor series (CU) are disk varistor elements encapsulated with a UL 94 V-O flame-retardant thermoplast for SMD soldering process.

#### ■ Termination of CU varistors

The tinned copper alloy terminals are suitable for SnPb and lead-free wave and reflow soldering.

#### ■ Marking of CU varistors

For further information please refer to the corresponding data sheet.

## 1.5 Equivalent circuits

Figure 5 shows the simplified equivalent circuit of a metal oxide varistor. From this the behavior of the varistor can be interpreted for different current ranges.

**Leakage current region ( $< 10^{-4}$  A)**

In the leakage current region the resistance of an ideal varistor goes towards  $\infty$ , so it can be ignored as the resistance of the intergranular boundary will predominate. Therefore  $R_B \ll R_{IG}$ . This produces the equivalent circuit in figure 6:

The ohmic resistance  $R_{IG}$  determines behavior at low currents, the  $V/I$  curve goes from exponential to linear (downturn region).

$R_{IG}$  shows a distinct temperature dependence, so a marked increase in leakage current must be expected as temperature increases.

**Normal operating region ( $10^{-5}$  to  $10^3$  A)**

With  $R_V \ll R_{IG}$  and  $R_B \ll R_V$ ,  $R_V$  determines the electrical behavior (figure 7). The  $V/I$  curve (figure 13) follows to a good approximation the simple mathematical description by an exponential function (equation 3 in 1.6.1) where  $\alpha > 30$ , i.e. the curve appears more or less as a straight line on a log-log scale.

**High-current region ( $> 10^3$  A)**

Here the resistance of the ideal varistor approaches zero. This means that  $R_V \ll R_{IG}$  and  $R_V < R_B$  (figure 8). The ohmic bulk resistance of ZnO causes the  $V/I$  curve to resume a linear characteristic (upturn region).

**Capacitance**

Equivalent circuits 4 and 5 indicate the capacitance of metal oxide varistors (see product specifications for typical values).

In terms of overvoltage suppression, a high capacitance is desirable because, with its lowpass characteristic, it smooths steep surge voltage edges and consequently improves the protection level.

**Lead inductance**

The response time of the actual varistor ceramics is in the picosecond region. In the case of leaded varistors, the inductance of the connecting leads causes the response time to increase to values of several nanoseconds. For this reason, all attempts must be made to achieve a mounting method with the lowest possible inductance i.e. shortest possible leads.

Equivalent circuits

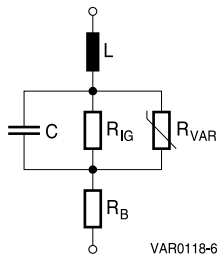


Figure 5

VAR0118-6

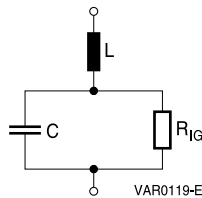


Figure 6

VAR0119-E

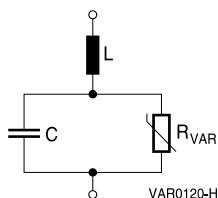


Figure 7

VAR0120-H

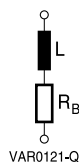


Figure 8

VAR0121-Q

- L Lead inductance ( $\approx 1$  nH/mm)
- C Capacitance
- $R_{IG}$  Resistance of intergranular boundary ( $\rho \approx 10^{12}$  to  $10^{13}$   $\Omega$ cm)
- $R_{VAR}$  Ideal varistor (0 to  $\infty$   $\Omega$ )
- $R_B$  Bulk resistance of ZnO ( $\rho \approx 1$  to 10  $\Omega$ cm)

## 1.6 V/I characteristics

### 1.6.1 Forms of presentation

The V/I characteristics of metal oxide varistors are similar to those of power functions (odd exponents), so it is fairly obvious that the latter should be used to describe them. As the curves are symmetrical, only one quadrant is generally shown for reasons of simplification (figure 9).

$$I = KV^\alpha \quad \alpha > 1 \quad (\text{equ. 1})$$

I	Current through varistor
K	Ceramic constant (depending on varistor type)
V	Voltage across varistor
$\alpha$	Nonlinearity exponent (measure of nonlinearity of curve)

Another possible interpretation of the physical principle underlying these curves is that of a voltage-dependent resistance value, and particularly its rapid change at a predetermined voltage. This phenomenon is the basis of the CTVS protection principle (figure 10).

$$R = \frac{V}{I} = \frac{V}{KV^\alpha} = \frac{1}{K} V^{1-\alpha} \quad (\text{equ. 2})$$

Equations 1 and 2 can be shown particularly clearly on a log-log scale, because power functions then appear as straight lines:

$$\log I = \log K + \alpha \log V \quad (\text{equ. 3})$$

$$\log R = \log \left( \frac{1}{K} \right) + (1 - \alpha) \log V \quad (\text{equ. 4})$$

This is virtually the only form of presentation used for CTVS characteristics (figures 11 and 12). A further advantage of the log-log format is the possibility of showing the wide range of the V/I curve (more than ten powers of 10).

It is evident that the simplified equations 1 to 4 cannot cover the downturn and upturn regions as described in section 1.5. Here, a mathematical description as shown in equation 21 in chapter "Application notes" is required.

Determining the nonlinearity exponent  $\alpha$

Two pairs of voltage/current values ( $V_1/I_1$  and  $V_2/I_2$ ) are read from the V/I characteristic of the varistor and inserted into equation 3, solved for  $\alpha$ :

$$\alpha = \frac{\log I_2 - \log I_1}{\log V_2 - \log V_1} \quad (\text{equ. 5})$$



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### Presentation of the V/I characteristics

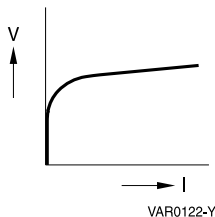


Figure 9

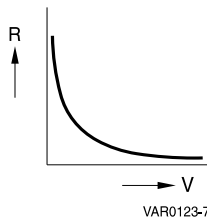


Figure 10

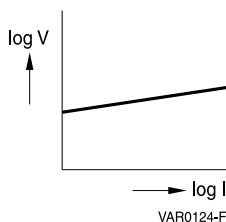


Figure 11

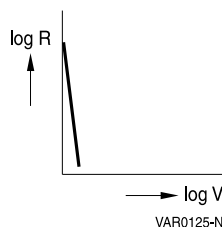


Figure 12

### 1.6.2 Real V/I characteristic and ohmic resistance

Figure 13 shows a typical V/I characteristic with SIOV-B60K250 taken as an example.

The downturn and upturn regions according to equivalent circuits 5 and 7 are easy to make out.

Calculating nonlinearity exponent  $\alpha$

Normally  $\alpha$  is determined according to equation 5 from the pairs of values for 1 A and 1 mA of the V/I characteristic. For figure 13 this means:

$$\alpha = \frac{\log I_2 - \log I_1}{\log V_2 - \log V_1} = \frac{\log 1 - \log 10^{-3}}{\log 470 - \log 390} = \frac{0 - (-3)}{2.67 - 2.59} = \frac{3}{0.08} \approx 38$$

The V/I curve of figure 13 is virtually a straight line between  $10^{-4}$  and  $10^3$  A, so it is described over a wide range to a good approximation by equation 3. The downturn and upturn regions may be adapted by inserting correction components in equation 3.

Another type of characteristic curve approximation is described in chapter “Application notes”, section 1.9.1.

Derived from figure 13, figure 14 shows the change in static resistance  $R = V/I$  for SIOV-B60K250. The resistance is  $> 1 \text{ M}\Omega$  in the range of the permissible operating voltage, whereas it can drop by as many as ten powers of 10 in case of overvoltage.

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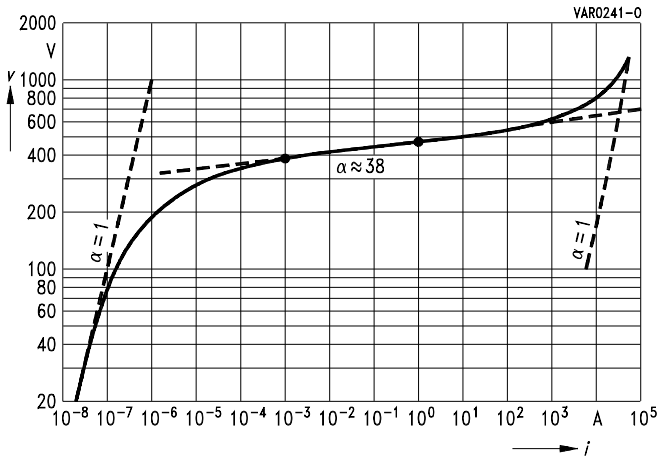


Figure 13 Real V/I characteristic of a metal oxide varistor as exemplified by SIOV-B60K250

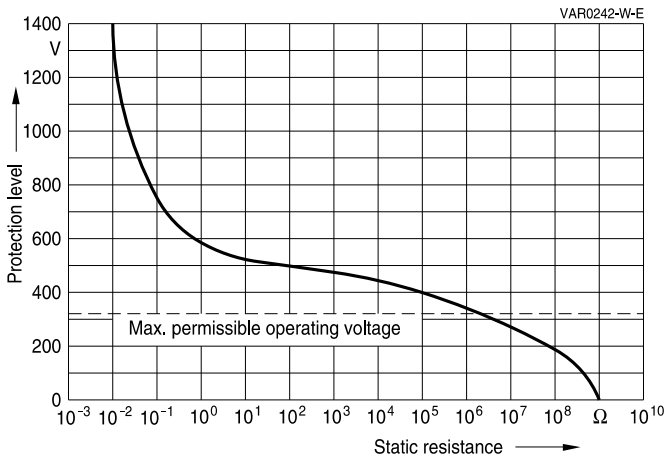


Figure 14 Static resistance of a metal oxide varistor versus protection level as exemplified by SIOV-B60K250

### 1.6.3 Presentation of tolerance band

The real V/I characteristic of individual varistors is subject to a certain deviation, which is primarily due to minor fluctuations in manufacturing and assembly process parameters. For varistors belonging to a certain type, their V/I curves are required to lie entirely within a well defined tolerance band. The tolerance band shown in figure 15 illustrates this in the case of SIOV-S14K14.

Varistors are operated at one of two conditions: If the circuit is operated at normal operating voltage, the varistor will be highly resistive. In an overvoltage event, it will be highly conductive.

These conditions concern two different segments of the V/I curve:

**Lefthand part of curve (< 1 mA):** This part of the curve refers to the “high-resistance” mode, where circuit designers may generally want to know about the largest possible leakage current at given operating voltage. Therefore the lower limit of the tolerance band is shown.

**Righthand part of the curve (> 1 mA):** This segment covers the “low-resistance” mode in an overvoltage event, where the circuit designer’s primary concern is the worst-case voltage drop across the varistor. The upper limit of the tolerance band is shown.

The 1 mA “dividing line” between the two segments does not really have any electrophysical significance but it is generally used as a standard reference (varistor voltage – refer to section 1.7.5 for explanations).

Related branches are identified by the same maximum AC operating voltage (here “14”).

V/I characteristic 1 in figure 15 shows the mean value of the tolerance band between the limits indicated by dashed lines. The mean at 1 mA represents the varistor voltage, in this case 22 V. The tolerance  $K \triangleq \pm 10\%$  refers to this value, so at this point the tolerance band ranges from 19.8 to 24.2 V.

**Leakage current at operating voltage:**

A maximum permissible operating voltage of 18 V<sub>DC</sub> is specified for SIOV-S14K14. For this, depending on where the varistor is in the tolerance band (figure 15), you can derive a leakage current between  $6 \cdot 10^{-6}$  A and  $2 \cdot 10^{-4}$  A (region 2). If the varistor is operated at a lower voltage, the figure for the maximum possible leakage current also drops (e.g. to max.  $2 \cdot 10^{-6}$  A at 10 V<sub>DC</sub>).

In the worst case, the peak value of the maximum permissible AC operating voltage ( $v = \sqrt{2} \cdot 14 \text{ V} = 19.8 \text{ V}$ )

will result in an ohmic peak leakage current of 1 mA (see figure 15, point 3).

**Protection level:**

Assuming a surge current of 100 A, the voltage across SIOV-S14K14 will increase to between 35 V and 60 V (region 4), depending on where the varistor is in the tolerance band.

### 1.6.4 Overlapping V/I characteristics

As explained earlier (section 1.3) the differences in nonlinearity between voltage classes up to K40 and K50 and above lead to overlapping V/I curves.

In particular with SIOV disk varistors, before selecting voltage rating K40 you should always check whether K50 is not a more favorable solution. Firstly, the protection level is lower for higher surge currents, and secondly, the load capability of K50 is considerably higher for varistors of the same diameter.

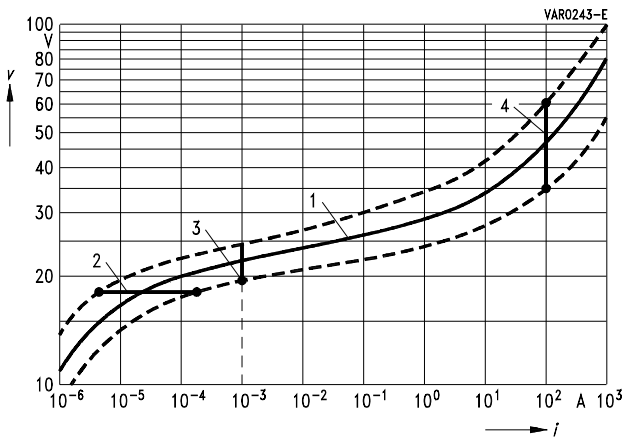


Figure 15 Tolerance limits of a metal oxide varistor as exemplified by SIOV-S14K14

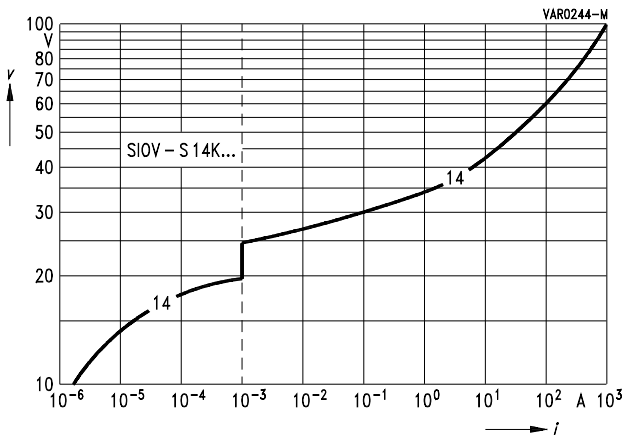


Figure 16 Tolerance limits of a metal oxide varistor as exemplified by SIOV-S14K14

## 1.7 Terms and descriptions

### 1.7.1 Operating voltage

The product tables specify maximum AC and DC operating voltages. These figures should only be exceeded by transients. Automotive types, however, are rated to withstand excessive voltage (jump start) for up to 5 minutes.

The leakage current at specified operating voltage is negligible.

The maximum permissible AC operating voltage is used to classify the individual voltage ratings within the type series.

In most applications the operating voltage is a given parameter, so the varistors in the product tables are arranged according to maximum permissible operating voltage to facilitate comparison between the individual varistor sizes.

### 1.7.2 Surge current, transient

Short-term current flow – especially when caused by overvoltage – is referred to as surge current or transient.

The maximum surge current that can be handled by a metal oxide varistor depends on amplitude, pulse duration and number of pulses applied over device lifetime. The ability of a varistor to withstand a single pulse of defined shape is characterized by the maximum non-repetitive surge current specified in the product tables (single pulse,  $t_r \leq 20 \mu\text{s}$ ).

If pulses of longer duration or multiple pulses are applied, the surge current must be derated as described in section 1.8.

#### *Maximum surge current*

The maximum non-repetitive surge current is defined by an 8/20  $\mu\text{s}$  waveform (rise time 8  $\mu\text{s}$ /decay time to half value 20  $\mu\text{s}$ ) according to IEC 60060 as shown in figure 17. This waveform approximates a rectangular wave of 20  $\mu\text{s}$ . The derating curves of the surge current, defined for rectangular waveforms, consequently show a knee between horizontal branch and slope at 20  $\mu\text{s}$ .

### 1.7.3 Energy absorption

The energy absorption of a varistor is correlated with the surge current by

$$W = \int_{t_0}^{t_1} v(t) i(t) dt \quad (\text{equ. 6})$$

where  $v(t)$  is the voltage drop across the varistor during current flow.

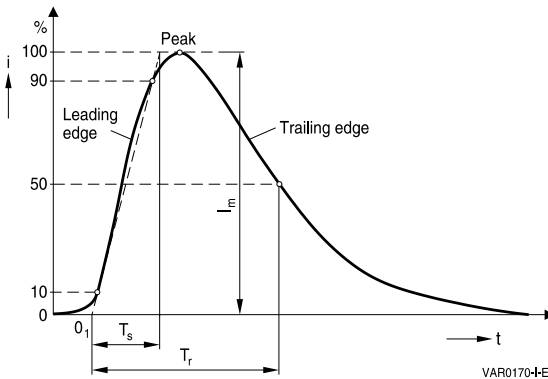
Figure 13 in chapter “Application notes” illustrates the electrical performance for the absorption of 100 J in the case of SIOV-S20K14AUTO.

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*Maximum energy absorption*

Surge currents of relatively long duration are required for testing maximum energy absorption capability. A rectangular wave of 2 ms according to IEC 60060 (figure 18) is commonly used for this test.

In the product tables the maximum energy absorption is consequently defined for a surge current of 2 ms.

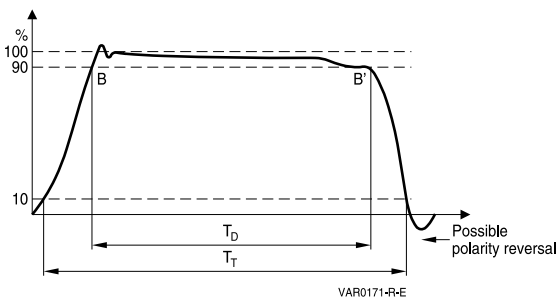


- $T_S$  Rise time in  $\mu s$
- $T_R$  Decay time to half value in  $\mu s$
- $O_1$  Nominal start
- $I_m$  Peak value

Frequently used  $T_S/T_R$  ratios:

Surge currents	Surge voltages
4/10 $\mu s$	1.2/50 $\mu s$
8/20 $\mu s$	10/700 $\mu s$
10/350 $\mu s$	
10/1000 $\mu s$	

**Figure 17** Waveform to IEC 60060 standard



- $T_D$  Duration of peak value ( $\approx 2$  ms)
- $T_T$  Total duration

**Figure 18** Waveform to IEC 60060 standard

#### 1.7.4 Average power dissipation

If metal oxide varistors are selected in terms of maximum permissible operating voltage, the resulting power dissipation will be negligible.

However, the rated maximum power dissipation must be taken into account if the varistor has not enough time to cool down between a number of pulses occurring within a specified isolated time period.

The examples in chapter "Calculation examples" show the calculation of the minimum time interval in periodic application of energy.

#### 1.7.5 Varistor voltage

The varistor voltage is the voltage drop across the varistor when a current of 1 mA is applied to the device. It has no particular electrophysical significance but is often used as a practical standard reference in specifying varistors.

#### 1.7.6 Tolerance

Tolerance figures refer to the varistor voltage at 25 °C. As shown in figure 15 the tolerance band for other current values can be larger.

**Note:**

When the tolerance is examined, the current of 1 mA must only be applied briefly so that the results are not corrupted by warming of the varistor (see temperature coefficient). The current should only flow for 0.2 up to 2.0 s, typical is a duration of 1 s.

#### 1.7.7 Protection level (clamping voltage)

The protection level is the voltage drop across the varistor for surge currents > 1 mA.

The V/I characteristics show the maximum protection level as a function of surge current (8/20 μs waveform).

In the product tables the protection level for surge currents according to the R10 series (ISO 497) is additionally specified. This is also referred to as clamping voltage.

#### 1.7.8 Capacitance

The product tables specify typical capacitance figures for 1 kHz.

The tabulated values show that metal oxide varistors behave like capacitors with a ZnO dielectric. The capacitance rises in proportion to disk area (and thus to current handling capability) and drops in proportion to the spacing of the electrodes, i.e. it decreases with increasing protection level.

Capacitance values are not subject to outgoing inspection.

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### 1.7.9 Response behavior, response time

The response time of metal oxide varistor ceramics to transients is in the subnanosecond region, i.e. varistors are fast enough to handle even ESD transients with the extreme steep current rise of up to 50 A/ns.

You can find similar results for the silicon chip used in semiconductor protective devices like suppressor diodes.

However, when the chip is mounted in its package, the response time increases due to the series inductance of its package to values  $> 1$  ns.

The varistors specified in this data book have response times  $< 25$  ns.

Comparing the protection behavior of varistors with semiconductors, higher figures of protection level may be found for varistors. This cannot be explained by a higher response time of varistors – which definitely is not true – but rather it is due to slightly less nonlinearity of the V/I characteristics.

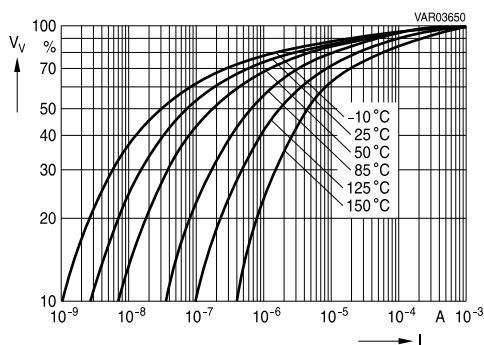
The V/I characteristics in this data book have been measured at currents  $> 1$  mA with the standard 8/20  $\mu$ s waveform (figure 17). So they allow for the inductive voltage drop across the varistor for the particular di/dt.

If surge currents with steep edges are to be handled, one should always design the circuit layout for as low an inductance as possible.

### 1.7.10 Temperature coefficient

Metal oxide varistors show a negative temperature coefficient of voltage. Figure 19 shows the typical varistor behavior.

The temperature coefficient value drops markedly with rising currents and is completely negligible from roughly 1 mA upwards.



**Figure 19** Typical temperature dependence of the V/I characteristic taking SIOV-S20K275 as an example.

( $V_V$  = applied DC voltage in percentage of varistor voltage at +25 °C)



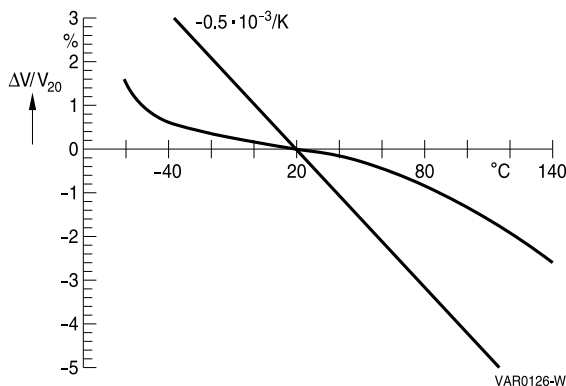
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An increase in leakage current is consequently noticeable at higher temperatures, especially in the  $\mu\text{A}$  region.

Equation 7 describes the TC of varistor voltage (at 1 mA):

$$|TC| < 0.5 \cdot 10^{-3}/K = 0.05\%/K = 1\%/\Delta 20K \quad (\text{equ. 7})$$

Figure 20 shows results for SIOV-S20K275 as an example.



**Figure 20** Temperature coefficient of voltage at 1 mA for SIOV-S20K275

## 1.8 Derating

Derating is the intentional reduction of maximum ratings in the application of a device. With metal oxide varistors derating is of particular interest under the following conditions:

- Derating for repetitive surge current and energy absorption
- Derating at increased operating temperatures

### 1.8.1 Derating for repetitive surge current

A typical feature of metal oxide varistors is the dependence of the maximum permissible ratings for surge current, and thus for energy absorption, on the pulse shape, pulse duration, and the number of times this load is repeated during the overall lifetime of the varistor.

The derating for a particular maximum permissible surge current can be derived from the curves for a type series in repetition figures graded  $10^x$ . The surge derating curve is mainly dependent on the varistor size but also voltage rating. Such derating curves can be found for all individual varistors in this data book.

The maximum permissible energy absorption can also be calculated from the derating curves by

$$W_{\max} = V_{\max} i_{\max} t_{r,\max}$$

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### 1.8.2 Derating at increased operating temperatures

For operating temperatures exceeding 85 °C or 125 °C the following operating conditions of varistors have to be derated according to figure 21:

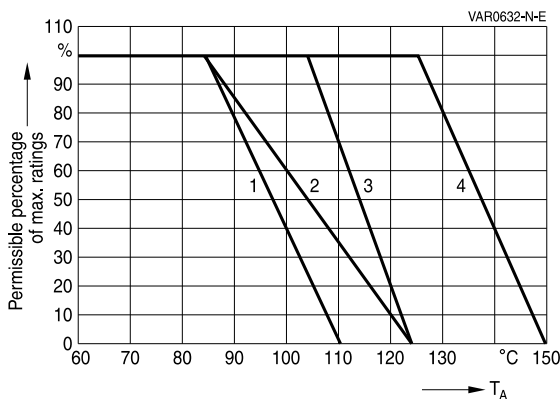
- Voltage
- Surge current
- Energy absorption
- Average power dissipation

### 1.9 Operating and storage temperature

The upper limits of the operating and storage temperature ranges for the individual type series can be deduced from the 100% and 0% values in figure 21, respectively. For lower ratings, refer to the product tables.

### 1.10 Climatic categories

The limit temperatures according to IEC 60068 are stated in the product tables as LCT (lower category temperature) and UCT (upper category temperature).



Derating curve 1	Derating curve 2	Derating curve 3	Derating curve 4
SIOV- B LS	SIOV- CU or S ... (AUTO) T or ETFV types	SIOV- S ... (E2) (E3) (E4) Q	SIOV- S ... AUTOD1 SNF

**Figure 21** Temperature derating for operating voltage, surge current, energy absorption and average power dissipation

## General technical information

### 1.11 Overload response

#### 1.11.1 Moderate overload

Surge currents or continuous overload of up to approx. one and a half times the specified figures can lead to a change in varistor voltage by more than  $\pm 10\%$ . In most cases the varistor will not be destroyed, but there may be an irreversible change in its electrical properties. The thermal fuse in EPCOS ETFV may open in such a condition.

#### 1.11.2 Heavy overload

Surge currents far beyond the specified ratings will puncture the varistor element. In extreme cases the varistor will burst.

Excessive steady-state overload fuses the ZnO grains and conducting paths are formed with the bulk resistance of ZnO, which is considerably lower than the resistance of the original varistor. The overload can overheat the varistor ceramic with the result that it becomes unsoldered from the electrodes.

### 1.12 Design notes

If steep surge current edges are to be expected, you must make sure that your design is as low inductive as possible (cf 1.7.9).

#### 1.12.1 Physical protection, fuses

Due to the unpredictable nature of transients a varistor may be overloaded although it was carefully selected. Overload may result in package rupture and expulsion of hot material. For this reason the varistor should be physically shielded from adjacent components, e.g. by a suitable metal case.

Fuse protection of varistors against excessive surge current is usually not possible because standard fuses are unable to quench surge currents. But fuses can offer protection against damage caused by follow-on currents. Such follow-on currents flow when a damaged varistor is in low resistance mode and still connected to power.

When varistors are operated on standard line impedances, nominal fuse currents and varistor type series should be matched as follows:

Type	S05	S/SNF07	S/SNF10	S/SNF14	S/SNF20/ Q14	S25/ Q20
Nominal fuse current [A]	$\leq 1$	$\leq 3$	$\leq 6$	$\leq 10$	$\leq 16$	$\leq 25$

Type	T14	T20	ETFV25
Nominal fuse current [A]	$\leq 10$	$\leq 16$	$\leq 25$

Type	B32	B40/LS40/ LS41	B60/LS50	B80
Nominal fuse current [A]	$\leq 50$	$\leq 80$	$\leq 125$	$\leq 160$

## General technical information

In applications where the conditions deviate from standard power line impedances, better fuse protection of the varistor can be obtained using thermo-fuses. These thermo-fuses should be in direct thermal contact with the varistor. Better protection can be achieved with a thermal fuse or EPCOS ThermoFuse varistors series ETFV/ T where the thermal coupling is matched with the varistors.

### 1.12.2 Potting and sealing, adhesion

Potting, sealing or adhesive compounds can produce chemical reactions in the varistor ceramic that will degrade its electrical characteristics. Information about this is available on inquiry.

### 1.12.3 Prior damage

The values specified only apply to varistors that have not been subjected to prior electrical, mechanical or thermal damage.

### 1.12.4 Environmental conditions

SIOV varistors are designed for indoor applications. On all accounts, prevent exposure to:

- Direct sunlight
- Rain or condensation
- Steam, saline spray
- Corrosive gases
- Atmospheres with reduced oxygen content

### 1.12.5 Mechanical strength of wire leads of disk-type varistors

The wire leads comply with the requirements of IEC 60068-2-2. They may only be bent at a minimum distance of 4 mm from the enamel coating end. When bending leads to shape, the lead-component junction must be supported. The minimum bend radius should be 0.75 mm.

## 1.13 Designation system

Varistor = **variable resistor**

SIOV<sup>®</sup> = registered tradename for EPCOS varistors

**Table 1**

SIOV	Design	Rated dimension	Tolerance	Max. AC oper. volt.	Additional specifications	Additional specifications
Design	<b>B</b>					
	<b>ETFV/ T</b>					
	<b>LS ... P</b>					
	<b>LS ... PK2</b>					
	<b>LS ... QP</b>					

## General technical information

**Table 1** (continued)

Design	<b>LS ... QPK2</b>	Strap type, square, epoxy coating, straight straps (HighE series)
	<b>Q</b>	Disk type, square, leaded (EnergetiQ series)
	<b>S/ SNF</b>	Disk type, round, leaded
	<b>CU</b>	Encapsulated chip

Rated diameters/length of disk varistors 5 up to 80 mm.

Tolerance of varistor voltage (1 mA)	K	±10%
	L	±15%
	M	±20%
	S...A/B/C	Special tolerance A, B, or C
Max. permissible AC operating voltage	11 ... 1100 V <sub>RMS, max</sub>	
Taping	G	Tape / reel
	GA	Tape / Ammo pack
	G.S.	Tape / reel, crimp style S, S2, S3, S4, S5 (see chapter "Taping, packaging and lead configuration")
Appendix	AUTO	Additional load dump and jump start specification
	AUTO ... D1	Additional load dump, jump start and high-temperature specification
	E2	Advanced series
	E3	SuperioR series
	E4	SuperioR series
	K1	Multiple pulse (MP) series
	K2	Suffix to define modifications
	M	Customer specific trimmed lead length (in mm)
	P	Standard coating (epoxy)
	Q	Square shape
R5	$\square e$ = 5.0 mm, lead spacing differs from standard	
R7	$\square e$ = 7.5 mm, lead spacing differs from standard	

Production code: all coated varistors are marked with year/week code.

Example: 17 29 = 29th week of year 2017

MOV	metal oxide varistor
ZnO	zinc oxide varistor
VDR	voltage-dependent resistor

Abbreviation for overvoltage protection elements in general:

TVSS	transient voltage surge suppressor
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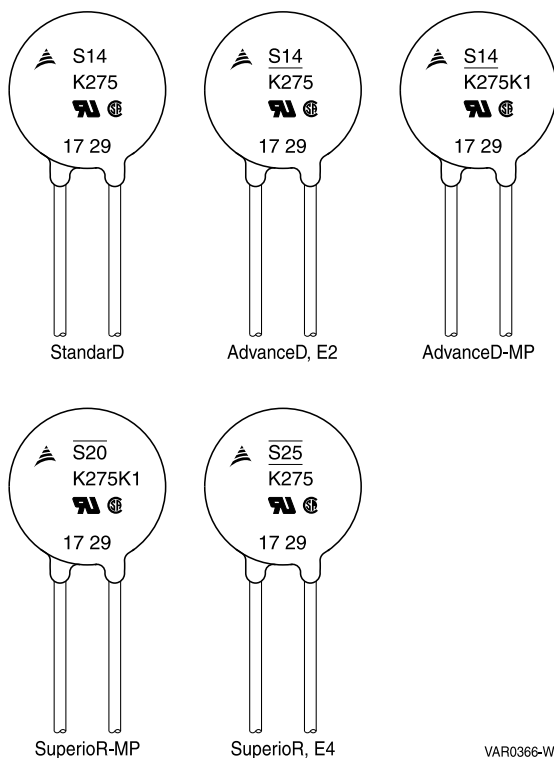
## General technical information

### 1.14 Marking of disk varistors

Disk-type varistors have printed markings as shown in figure . They are distinguished as follows:

- no underline under the “S/ SNF”: S/SNF (Standard types)
- an additional underline under the “S/ SNF”: S/SNF (for AdvanceD types, E2)
- or a line above the “S/ SNF”: S/SNF (for SuperioR types, E3)
- or a line above and under the “S/ SNF”: S/SNF... (for SuperioR types, E4)

The lower section of the marking area contains the date code yy ww.



**Figure 22** Various forms of printed markings of disk-type varistor series Standard, AdvanceD and SuperioR, using S14K275, S20K275 and S25K275 as an example.

Date code 17 29  $\triangle$  yy ww  $\triangle$  29th week of year 2017  
 S/ SNF05, S/ SNF07: UL/ CSA marking is not printed.