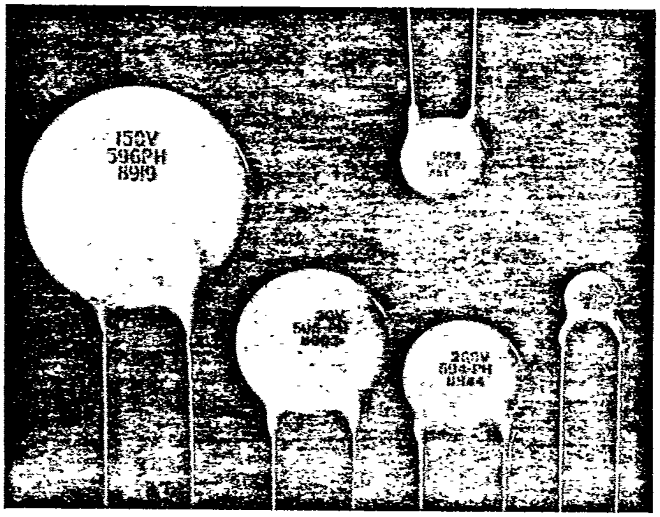
METAL OXIDE VARISTORS

Zinc Oxide Voltage Dependent Resistor

U.L. File #E98144 VDE File #14480-4790-1001/A1F



DESCRIPTION

GENERAL

V(oltage) D(ependent) R(esistor)—varistors—have a high degree of non-linearity between resistance value and applied voltage. This characteristic is created by non-homogeneous metal oxide materials selected for rectifying action at the interface of two crystals. The electrical characteristic of the component is the product of a large number of these interstitial junctions, forming a complex network of series and parallel rectifying junctions.

The Philips Components product line uses ZnO (with doping) as the element material. ZnO offers much sharper V-I curves than other commonly used materials.

PHYSICAL

A disc of low beta metal oxide ceramic with two solid tinned copper wires. ZnO's are epoxy coated.

ELECTRICAL DATA, see also Table 1 and subsequent curves.

Climatic category	40/125/56
Insulation voltage	2500 V
Temperature coefficient of voltage at 1 mA	–0.065%/°C
Derating (see Fig. 31.)	

Mounting

Series 592 thru 595 available on	Tape & Reel.
Series 592 and 593 available on	Ammo Pack

Soldering

Solderability	max. 240°C, max. 4s
Resistance to heat	max. 265°C, max. 11s

Impact

free fall	39.4" (1000 mm)

Termination Strength

Tensile strength	2.25 lb (10 N)
Bending	1.12 lb (5 N)
Flammability	Nonflammable

METAL OXIDE VARISTORS

INTRODUCTION TO METAL OXIDE VARISTORS

Metal Oxide Varistors, also called V(oltage) D(ependent) R(esistors), show a high degree of non-linearity between their resistance value and the applied voltage. They are made of non-homogeneous material giving a rectifying action at the contact of two particles. The electrical characteristic of the conglomeration is determined by a large number of crystal contacts which form a complicated network of series and parallel rectifying contacts.

These resistors have found a diversity of applications in the different sectors of electronics. They offer an inexpensive and reliable solution for protection of electronic circuits, semiconductor components, collectors of motors, relay contacts, etc. against over-voltages and their consequences.

MANUFACTURING PROCESS

Crystals of metal oxides, with the right electrical and dimensional properties are pressed together with a ceramic binder to the shape of discs. After a drying period the varistors are sintered at a high temperature. Firing time, temperature and gaseous atmosphere have an important influence on the electrical characteristics. The contacts are metallized with silver enabling good electrical contact. After leads have been soldered to the contacts the varistors are epoxied and laser marked.

During and after the manufacturing process the electrical properties are controlled not only to ensure that the varistors are within the specification but also to control stability and reliability.

METAL OXIDE VARISTORS

ELECTRICAL PROPERTIES

Direct Current

The relation between voltage and current of a varistor can be approximated by:

$$V = C\, I^{\beta}$$

where V is the voltage in volts, I the current in amperes and C and β are constants. This equation is illustrated in Fig. 1. In principle the same characteristic is plotted for a specific type on a double logarithmic scale in Fig. 2. For not too small values of current this relation is a straight line which follows directly from the equation $\log V = \log C + \beta \log I$. In this case β is the directional coefficient of the straight line.

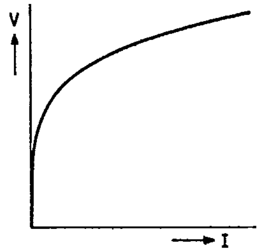


Fig. 1 Shape of the voltage/current characteristic of a varistor when plotted on a linear scale.

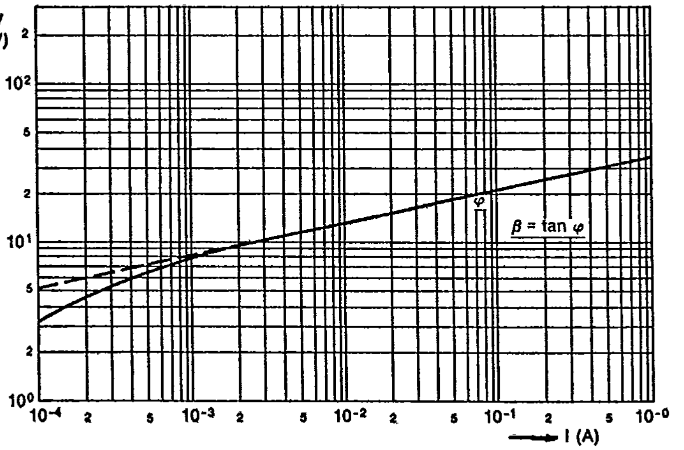


Fig. 2 Voltage/current characteristic of a varistor plotted on a logarithmic scale.

In order to determine the exact values of the constants C and β it is necessary to measure three points of the characteristic. Only when these are on a straight line when plotted on a double logarithmic scale, is extrapolation permitted (only to higher values). Equation (1) may also be written:

$$I = \left(\frac{V}{C}\right)^{\alpha} \qquad (2)$$

in which:

$$\alpha = 1/\beta \qquad (3a)$$

and

$$K = \frac{1}{C^{1/\beta}} = \frac{1}{C^{\alpha}} \qquad (3b)$$

The varistors do not have a polar effect; this means that when the voltage is changed from positive to negative, the current changes its direction, but retains its value. Strictly speaking, Eqs (1) and (2) are valid only when the absolute values are taken for I and V. In a.c. calculations this may be very important. For practical design, reference is made to the voltage/current characteristics given in the data sheets of the relevant varistor types.

Practical values and specification

The C and β-values of varistors depend on the composition of the material and on the method used in the processing; furthermore, the C-value depends on the shape and the dimensions of the varistor. Practical β-values are β = 0.02 to 0.035.

It is inherent to the material properties that the β-value of a varistor with a low C-value will always be higher than that of a varistor with a high C-value. Practical C-values range from 14 to a few thousand. As the method of fabrication compels a minimum thickness and, as will be seen further, enlarging of the surface area gives little change in the C-value, the latter has for practical reasons a limited lowest value.

According to Eq. (1) it is possible to specify the electrical characteristics of a varistor by giving its C and β-values. The advantage of this specification is that only two parameters are used. The disadvantage is, however, that due to the inevitable tolerances on the β-values, the spread in voltages at low currents (in the working area) becomes very large. It is for this reason that the method of specifying by the C-value defined at 1 A is abandoned and we now specify the voltage across the varistor at currents which lie in the working area (1, 10 or 100 mA instead of 1 A). In this way it is possible to supply varistors which have much closer tolerances in the area where they are used, see Fig. 5.

METAL OXIDE VARISTORS

Varistors in series

For each varistor we can write the equation:

$$V = CI^{\beta}. \qquad (1)$$

When n equal elements are connected in series and a voltage of n times the original voltage is applied, the current will be the same as for V volts over one varistor. Consequently we may write for a series circuit of n varistors:

$$nV = C'\,I^{\beta}. \qquad (4)$$

From Eqs (1) and (4) it is evident that,

$$C' = nC, \qquad (5)$$

which means that the C-value of a varistor can be increased by series connection.

Varistors in parallel

For one varistor again we have:

$$V = CI^{\beta}. \qquad (1)$$

When n of these varistors are connected in parallel and the same voltage V is applied, the current in each varistor will still be the same. The total current in the circuit will be nI. This gives the following equation:

$$V = C''(nI)^{\beta}. \qquad (6)$$

From Eqs (1) and (6) it follows:

$$C'' = \frac{C}{n^{\beta}} \qquad (7)$$

As varistors have a β-value from 0.02 to 0.40, it is clear that the C-value will decrease very little by connecting two or more elements in parallel. When, e.g. $\beta = 0.20$, 32 varistors are needed for a 50% reduction of the C-value. It is important that in parallel circuits all varistors have about the same β and C-values, otherwise the current division will very much depend on the voltage across the circuit.

Note: On no occasion may a varistor be connected in parallel with the aim of obtaining higher power dissipation.

Resistance value

When defining R as usual as the quotient of voltage and current, we find:

$$R = \frac{V}{I} = \frac{CI^{\beta}}{I} = \frac{C}{I^{1-\beta}} \qquad (8)$$

or when starting from the form $I = \left(\frac{V}{C}\right)^{\alpha}$:

$$R = \frac{V}{I} = \frac{V}{\frac{V^{\alpha}}{C^{\alpha}}} = \frac{C^{\alpha}}{V^{\alpha-1}} \qquad (9)$$

From these equations it is once more evident that the resistance value is not a constant one, but is very much dependent on the values of voltage and current.

Dissipated power

The power dissipated in a varistor is equal to the product of voltage and current, so it may be written:

$$W = I\,V = \left(\frac{V}{C}\right)^{\alpha} \cdot V = \frac{V^{\alpha+1}}{C^{\alpha}} \qquad (10)$$

When the coefficient $\alpha = 5$, the power dissipated by the varistor is proportional to the 6th power of the voltage. A voltage increase of only 12% will, in this case, double the dissipated power. Consequently it is very important that the applied voltage does not rise above a certain maximum value, as otherwise the permissible rating will be exceeded.

In addition, since varistors have a negative temperature coefficient, at higher dissipation (and accordingly higher temperature) the resistance value will decrease and the dissipated power will increase still more.

Temperature coefficient

In the foregoing formulae no temperature effects have been taken into account. These, however, may not always be neglected, as the C-value has an appreciable negative temperature coefficient. The β-value is practically independent of the temperature. With good approximation it may be written:

$$C_t = C_0\,(1 + at), \qquad (11)$$

in which:

C_t = C-value of the varistor at t °C;
C_0 = C-value of the varistor at 0 °C;
a = temperature coefficient.

For different materials the value of a lies between −0.0010 and −0.0018. Thus, for circuits where the current is constant, the temperature coefficient on voltage lies between −0.10 and −0.18% per degree C.

For circuits where the voltage is constant the temperature coefficient on current lies between +0.4 and +0.8% per degree C, depending on the β-value.

High frequency alternating current

For low frequencies the small capacitance of the varistor does not affect the voltage dependency of the resistance. For high frequencies, however, this parallel capacitance may not be neglected. For low voltages and currents they may even determine the impedance of the varistor. At high voltages, the influence of the capacitance is less serious; because in that case the resistance over which this capacitance is shunted has decreased. In general the effect of the capacitance in h.f. circuits will be an apparent increase of β. Furthermore the voltage/current graph on a logarithmic scale will no longer by a straight line.

A number of curves demonstrating this effect are given in Fig. 3.

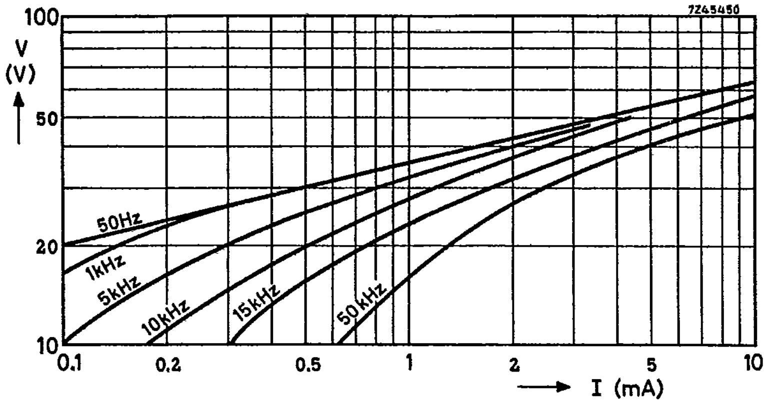


Fig. 3 Voltage/current relation for different frequencies.

PERMISSIBLE DISSIPATION

The temperature which a varistor will reach is determined by the dissipated power, the heat conductivity of the material, the contact with, and the nature of, the surrounding medium and by the ambient temperature. As already explained the dissipated power will increase rapidly with increasing voltage.

The cooling per degree Celsius, though increasing slightly with temperature, depends mainly on the total surface area of the varistor.

For most varistor types the maximum permissible body temperature is 125°C.

METAL OXIDE VARISTORS

ZINC-OXIDE VOLTAGE DEPENDENT RESISTORS

Unlike SiC types, the ZnO varistors are mainly intended for applications requiring intermittent power dissipation, i.e. transient suppression and contact arc prevention. In their transient suppression role, the symmetrical mode of operation allows them to be connected directly across a.c. power lines carrying r.m.s. voltages. They are capable of withstanding voltage or current pulses with a high peak energy level. A typical β for this type of varistor is 0.03. This means that, if the current through the varistor increases by a factor of 10 within the straight-line portion of the characteristic, the voltage across it increases by a factor of 1.07.

A typical V/I characteristic for one of these varistors is shown in Fig. 4. The upward turn of the characteristic (decreasing non-linearity) is due to the increasing influence of the linear series resistance of the component as its non-linear resistance falls to very low values at extreme currents. A good approximation of the relationship between the voltage and the current in the curved portion of the characteristics is given by the expression:

$$V = CI^{\beta} + IR_S,$$

where R_S is the series resistance of the varistor.

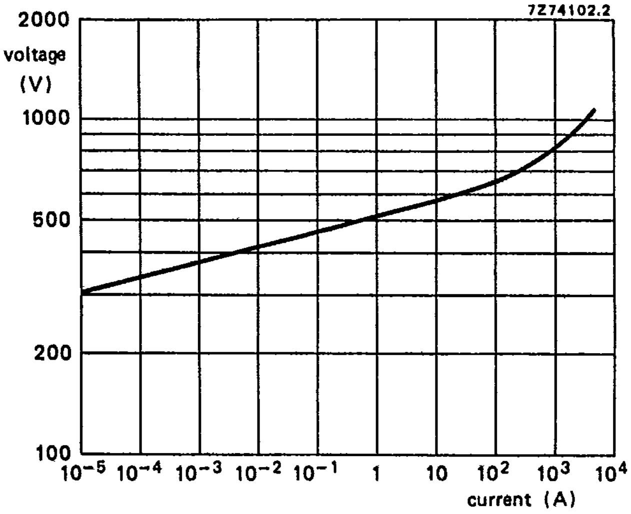


Fig. 4 Typical V/I characteristic of ZnO varistor 2322 595 52516 for 220 V mains supply.

Normal operating conditions of the ZnO varistor

Owing to the extreme nonlinearity of the voltage/current characteristic of ZnO varistors, and the necessity to allow a margin for the extra dissipation during a transient, ensure that the maximum voltage applied across the varistor during normal operation never attains such a value that the specified average dissipation limit of the varistor is approached. This will never be a problem if the varistor is selected according to the figures for max. r.m.s. voltage in the data sheet. The peak value of the sinusoidal voltage applied to the varistor must always be less than the minimum voltage specified at 1 mA. If the applied voltage is other than sinusoidal, the varistor should be selected on the basis of the specified maximum peak working voltage.

METAL OXIDE VARISTORS

HOW TO MEASURE VARISTORS

The following points have to be considered when measuring varistors.

1. Use only d.c. voltage.
2. Keep the measuring time as short as possible. Self-heating effects may influence the measurements due to the negative temperature coefficient of the varistors.
3. When the varistors are specified at a voltage and current which is above the maximum dissipation, pulses should be used. For instance all zinc oxide types, which are for spike/transient suppression are measured under pulse-conditions. These types are measured with a standard pulse current 8/20 μs as defined in IEC 60-2, section 6.
4. The β-value measurement needs some explanation. As mentioned earlier the β-value is not always constant but depends on the voltage and current. The β-values of our discs are measured between 0.3 I and 3 I, where I is the current at which the varistor is specified. For example:

$$\beta = \log \frac{V_2}{V_1}; \text{ with } V_2 = \text{voltage at } 3\,I, \quad V_1 = \text{voltage at } 0{,}3\,I.$$

TOLERANCES

Standard varistors are specified with a certain tolerance on voltage and a spread on β-value. It can be seen in Fig. 5 that due to the spread in β-value the tolerance on voltage may increase at currents other than the specified current at which the varistor is measured.

For some applications, where tolerances have to be kept as low as possible, the varistors are measured at a current or voltage which lies near to its working point in the circuit. For other applications, especially spark suppression, it is often important to specify the varistor at two points: a point at low current or low voltage and a point at high current or high voltage.

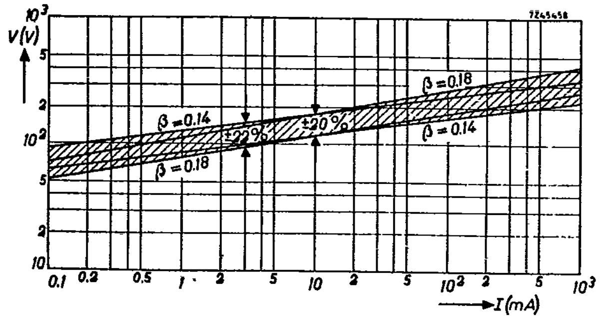


Fig. 5 Spread of voltage/current characteristic due to β-tolerance.

METAL OXIDE VARISTORS

Table 1. Metal Oxide Varistor Performance Characteristics

Maximum Continuous Voltage		Voltage at 1 mA		Part Number *See Table 6	Maximum Clamping Voltage at Current (8 x 20 µS)		Maximum Energy (10 x 1000 µS)	Maximum Non-Repetitive Surge Current (8 x 20 µS)	Typical Capacitance at 1 KHz
V(RMS)	V(DC)	V(MIN)	V(MAX)		V	A	Joules	A	pF
14	18	20	24	2322-592-51406	48	1.0	0.5	100	1300
				2322-593-51406	43	2.5	1.7	250	2800
				2322-594-51406	43	5.0	4.3	500	6000
				2322-595-51406	43	10.0	5.4	1000	15000
				2322-596-51406	43	20.0	16.0	2000	17000
17	22	24	30	2322-592-51706	60	1.0	0.7	100	1050
				2322-593-51706	53	2.5	2.0	250	2000
				2322-594-51706	53	5.0	5.3	500	4000
				2322-595-51706	53	10.0	6.9	1000	10000
				2322-596-51706	50	20.0	17.0	2000	16000
20	26	30	36	2322-592-52006	73	1.0	0.8	100	900
				2322-593-52006	65	2.5	2.5	250	1500
				2322-594-52006	65	5.0	6.5	500	3000
				2322-595-52006	65	10.0	8.8	1000	7500
				2322-596-52006	58	20.0	22.0	2000	15000
25	31	35	43	2322-592-52506	86	1.0	0.9	100	500
				2322-593-52506	77	2.5	3.0	250	1350
				2322-594-52506	77	5.0	7.7	500	2600
				2322-595-52506	77	10.0	9.4	1000	6500
				2322-596-52506	77	20.0	26.0	2000	14000
30	38	42	52	2322-592-53006	96	1.0	1.1	100	700
				2322-593-53006	93	2.5	3.6	250	1600
				2322-594-53006	93	5.0	9.2	500	2700
				2322-595-53006	90	10.0	12.0	1000	6000
				2322-596-53006	93	20.0	30.0	2000	13000
35	45	50	62	2322-592-53506	123	1.0	1.4	100	560
				2322-593-53506	115	2.5	4.4	250	1300
				2322-594-53506	110	5.0	11.0	500	2200
				2322-595-53506	105	10.0	14.0	1000	4800
				2322-596-53506	110	20.0	35.0	2000	11000
40	56	61	75	2322-592-54006	145	1.0	1.6	100	460
				2322-593-54006	135	2.5	5.2	250	1000
				2322-594-54006	130	5.0	13.0	500	1800
				2322-595-54006	130	10.0	17.0	1000	3800
				2322-596-54006	135	20.0	40.0	2000	7000
50	65	74	90	2322-592-55006	145	5.0	2.6	400	370
				2322-593-55006	140	10.0	7.0	1200	900
				2322-594-55006	140	25.0	12.0	2500	1500
				2322-595-55006	140	50.0	21.0	4500	3100
				2322-596-55006	135	100.0	27.0	6500	5500
60	85	90	110	2322-592-56006	165	5.0	2.8	400	290
				2322-593-56006	165	10.0	8.3	1200	700
				2322-594-56006	165	25.0	15.0	2500	1200
				2322-595-56006	165	50.0	24.0	4500	2300
				2322-596-56006	165	100.0	30.0	6500	4800
75	100	108	132	2322-592-57506	190	5.0	3.4	400	240
				2322-593-57506	200	10.0	10.0	1200	530
				2322-594-57506	200	25.0	18.0	2500	1000
				2322-595-57506	200	50.0	29.0	4500	1900
				2322-596-57506	200	100.0	40.0	6500	3800
95	125	135	165	2322-592-59506	230	5.0	4.1	400	180
				2322-593-59506	250	10.0	13.0	1200	450
				2322-594-59506	250	25.0	22.0	2500	800
				2322-595-59506	250	50.0	37.0	4500	1500
				2322-596-59506	250	100.0	50.0	6500	3000
130	170	185	225	2322-592-51316	310	5.0	5.5	400	130
				2322-593-51316	340	10.0	17.0	1200	320
				2322-594-51316	340	25.0	30.0	2500	580
				2322-595-51316	340	50.0	56.0	4500	1050
				2322-596-51316	325	100.0	70.0	6500	3000
140	180	192	242	2322-592-51416	350	5.0	7.1	400	110
				2322-593-51416	370	10.0	20.0	1200	270
				2322-594-51416	370	25.0	36.0	2500	490
				2322-595-51416	370	50.0	59.0	4500	850
				2322-596-51416	370	100.0	75.0	6500	1800
150	200	216	264	2322-592-51516	395	5.0	7.1	400	110
				2322-593-51516	400	10.0	20.0	1200	270
				2322-594-51516	400	25.0	36.0	2500	490
				2322-595-51516	400	50.0	59.0	4500	850
				2322-596-51516	360	100.0	80.0	6500	1600
175	225	247	303	2322-592-51716	410	5.0	7.3	400	90
				2322-593-51716	455	10.0	23.0	1200	230
				2322-594-51716	455	25.0	41.0	2500	430
				2322-595-51716	455	50.0	67.0	4500	750
				2322-596-51716	455	100.0	90.0	6500	1600
230	300	324	396	2322-592-52316	560	5.0	10.0	400	70
				2322-593-52316	600	10.0	30.0	1200	170
				2322-594-52316	600	25.0	54.0	2500	320
				2322-595-52316	600	50.0	88.0	4500	540
				2322-596-52316	595	100.0	120.0	6500	1200
250	320	351	429	2322-592-52516	600	5.0	11.0	400	60
				2322-593-52516	650	10.0	33.0	1200	160
				2322-594-52516	650	25.0	58.0	2500	300
				2322-595-52516	650	50.0	96.0	4500	480
				2322-596-52516	650	100.0	130.0	6500	1000
275	350	387	473	2322-592-52716	695	5.0	12.0	400	55
				2322-593-52716	710	10.0	36.0	1200	140
				2322-594-52716	710	25.0	63.0	2500	270
				2322-595-52716	710	50.0	104.0	4500	440
				2322-596-52716	680	100.0	140.0	6500	900
300	385	423	517	2322-592-53016	750	5.0	13.0	400	50
				2322-593-53016	800	10.0	40.0	1200	130
				2322-594-53016	800	25.0	71.0	2500	240
				2322-595-53016	800	50.0	117.0	4500	400
				2322-596-53016	775	100.0	150.0	6500	900
320	420	462	565	2322-592-53216	800	5.0	15.0	400	45
				2322-593-53216	850	10.0	46.0	1200	115
				2322-594-53216	850	25.0	69.0	2500	210
				2322-595-53216	850	50.0	90.0	4500	380
				2322-596-53216	810	100.0	160.0	6500	750
385	505	558	682	2322-592-53816	1000	5.0	18.0	400	40
				2322-593-53816	1025	10.0	51.0	1200	95
				2322-594-53816	1025	25.0	67.0	2500	180
				2322-595-53816	1025	50.0	110.0	4500	280
				2322-596-53816	950	100.0	155.0	6500	750
420	560	612	748	2322-592-54216	1100	5.0	20.0	400	35
				2322-593-54216	1120	10.0	56.0	1200	85
				2322-594-54216	1120	25.0	73.0	2500	165
				2322-595-54216	1120	50.0	120.0	4500	250
				2322-596-54216	1060	100.0	160.0	6500	600
460	615	675	825	2322-592-54616	1200	5.0	21.0	400	30
				2322-593-54616	1240	10.0	63.0	1200	75
				2322-594-54616	1240	25.0	82.0	2500	150
				2322-595-54616	1240	50.0	135.0	4500	225
				2322-596-54616	1240	100.0	175.0	6500	420
510	670	738	902	2322-594-55116	1335	25.0	89.0	2500	135
				2322-595-55116	1335	50.0	145.0	4500	220
				2322-596-55116	1280	100.0	190.0	6500	500
550	745	819	1001	2322-594-55516	1500	25.0	98.0	2500	120
				2322-595-55516	1500	50.0	160.0	4500	180
				2322-596-55516	1500	100.0	215.0	6500	350

*For composition of the catalogue number, see Table 6

METAL OXIDE VARISTORS

Electrical characteristics

Varistor characteristics are measured at high currents and high energy levels using an exponentially decaying waveform, as shown in Fig. 6, representative of lightning surges and the discharge of stored energy in reactive circuits. Based on CECC recommendations, the standard waveform used for current and voltage rating measurements has a virtual front duration of 8μs and an impulse duration of 20 μs. It is therefore called the 8/20 μ waveform.

For energy rating measurements, a longer duration waveform (the 10/1000 μs waveform) having exactly the same format as Fig. 6 is used.

Voltage-current characteristics for each varistor series are shown in Figs. 7 to 20.

t_1	t_2
8μs	20μs
10μs	1000μs

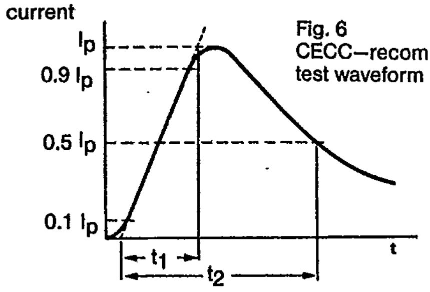


Fig. 6
CECC–recommended test waveform

592 SERIES (A)

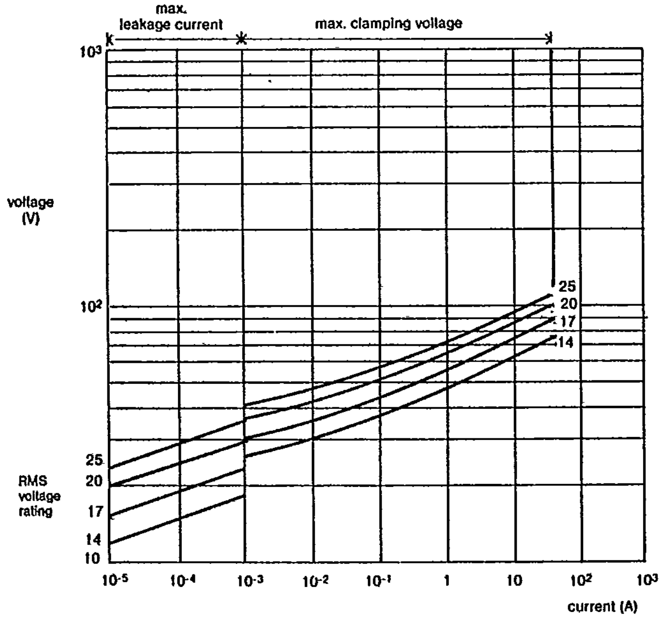


Fig. 7
V-I characteristics, 592 series, 14 to 25 V

592 SERIES (B)

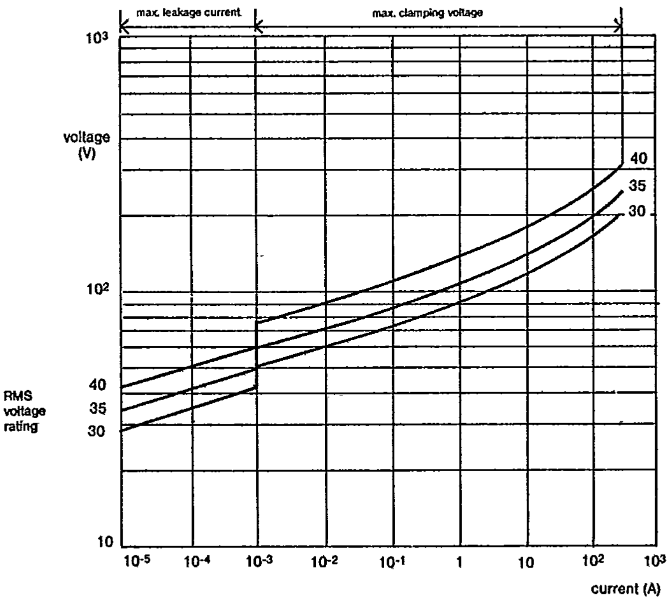


Fig. 8
V-I characteristics, 592 series, 30 to 40 V

METAL OXIDE VARISTORS

Zinc Oxide Disc

592 SERIES (C)

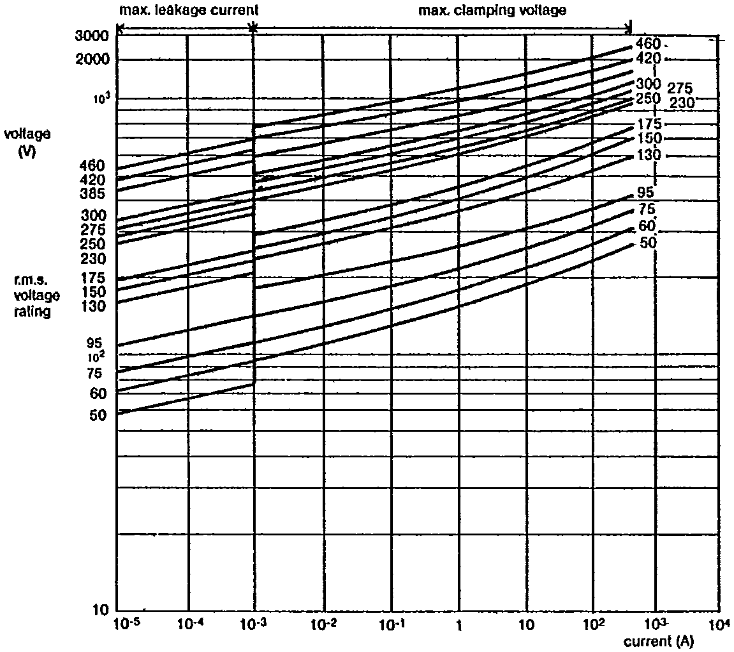


Fig. 9
V-I characteristics, 592 series, 50 to 460 V

593 SERIES (A)

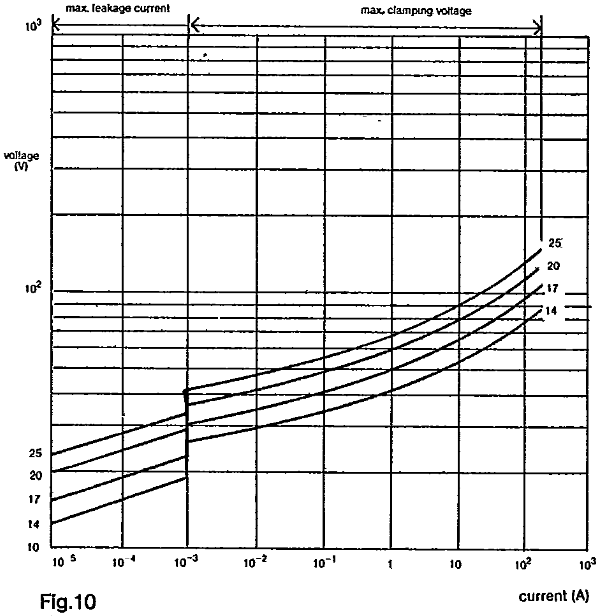


Fig.10
V-I characteristics, 593 series, 14 to 25 V

593 SERIES (B)

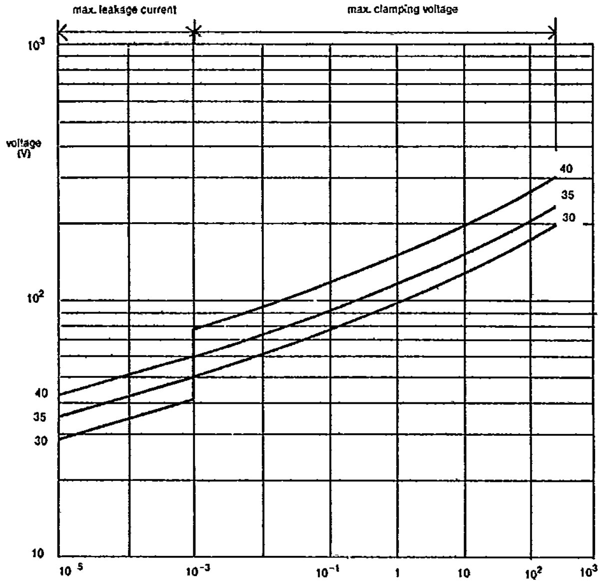


Fig. 11
V-I characteristics, 593 series, 30 to 40 V

593 SERIES (C)

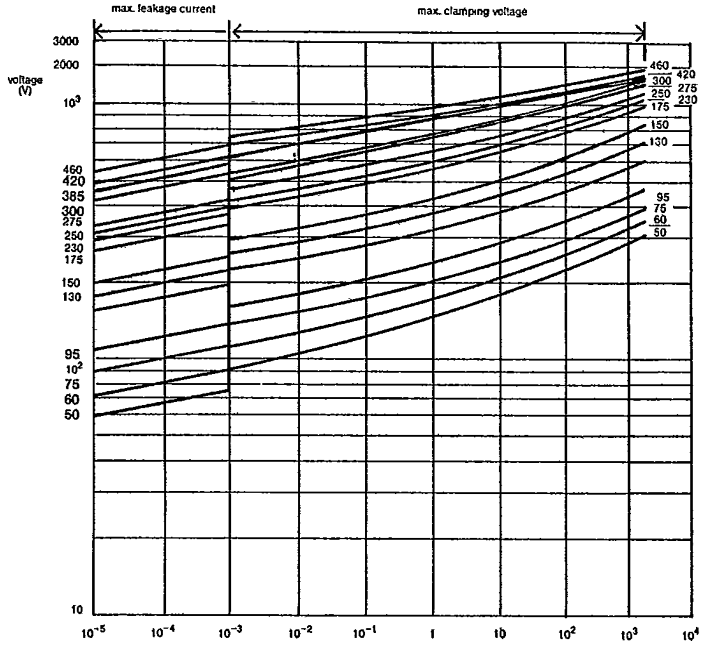


Fig. 12
V-I characteristics, 593 series, 50 to 460 V

METAL OXIDE VARISTORS

Zinc Oxide Disc

594 SERIES (A)

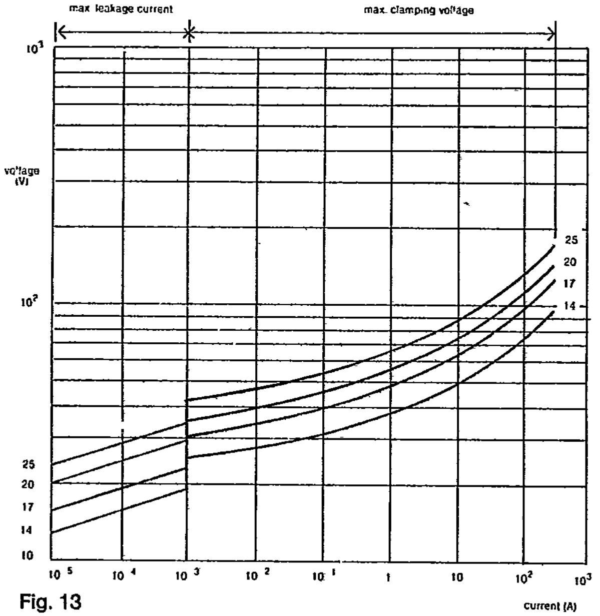


Fig. 13
V-I characteristics, 594 series, 14 to 25 V

594 SERIES (B)

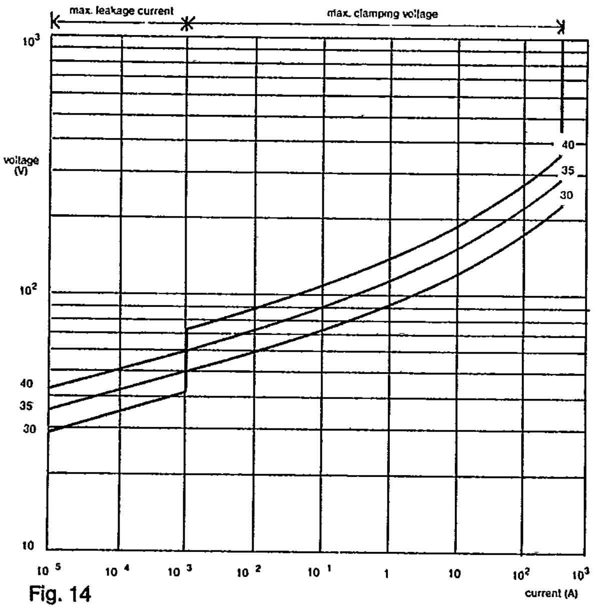


Fig. 14
V-I characteristics, 594 series, 30 to 40 V

594 SERIES (C)

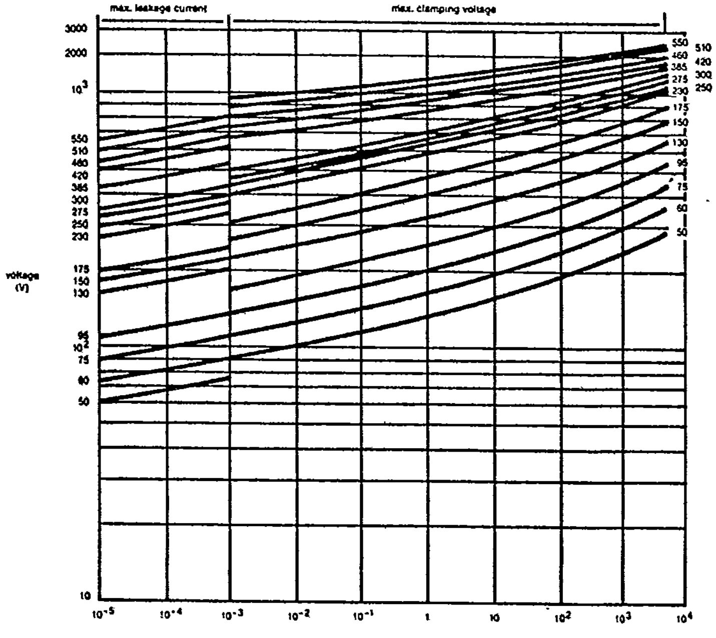


Fig. 15
V-I characteristics, 594 series, 50 to 550 V

595 SERIES (A)

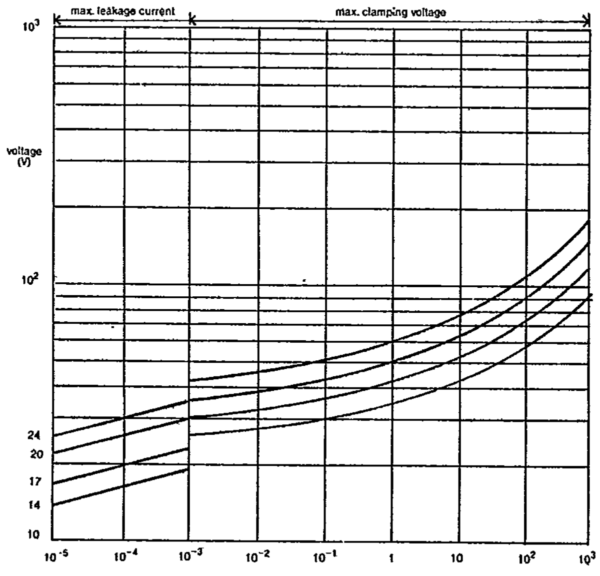


Fig. 16
V-I characteristics, 595 series, 14 to 25 V

8

Non-Linear Resistors

METAL OXIDE VARISTORS

Zinc Oxide Disc

595 SERIES (B)

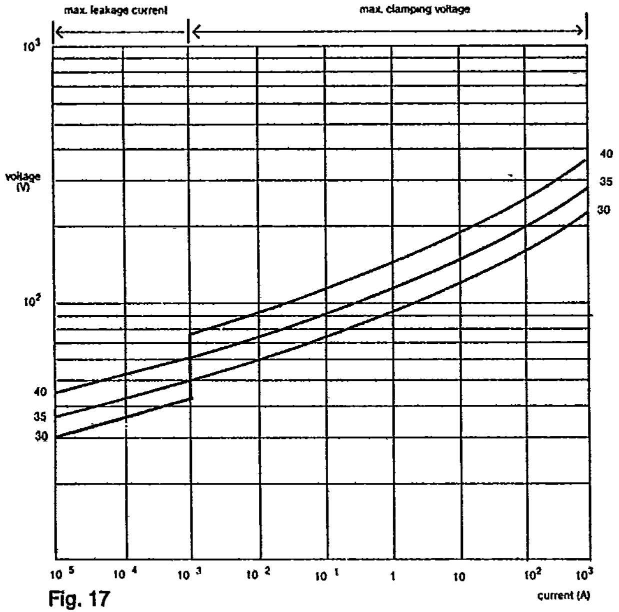


Fig. 17
V-I characteristics, 595 series, 30 to 40 V

595 SERIES (C)

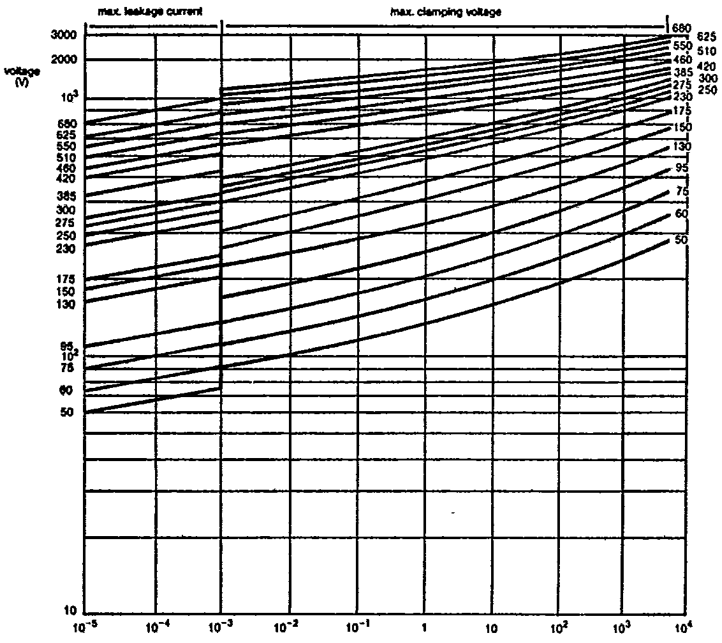


Fig. 18
V-I characteristics, 595 series, 50 to 550 V

596 SERIES (B)

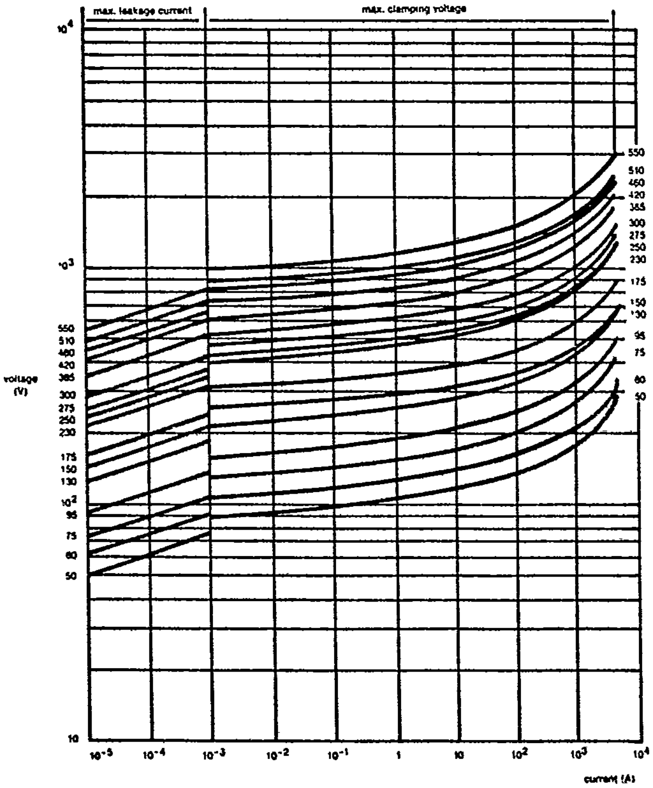


Fig. 20
V-I characteristics, 596 series, 50 to 550 V

596 SERIES (A)

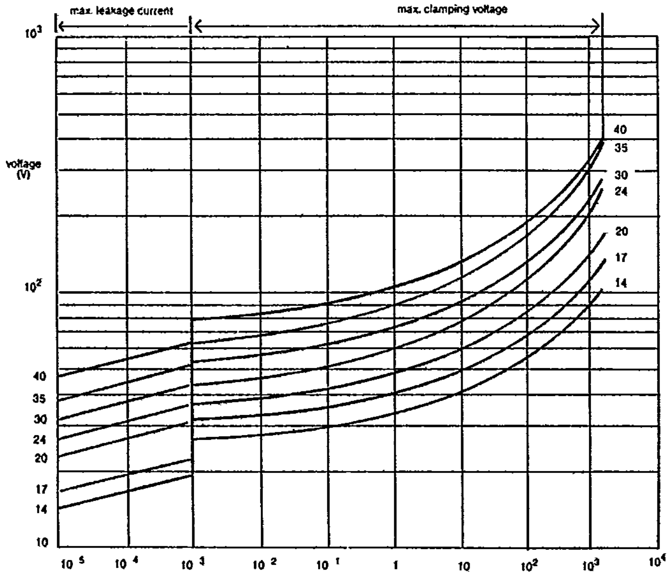


Fig. 19
V-I characteristics, 596 series, 14 to 40 V

METAL OXIDE VARISTORS

Zinc Oxide Disc

MAX. APPLICABLE TRANSIENT CURRENT AS A FUNCTION OF IMPULSE DURATION

592 SERIES (A)

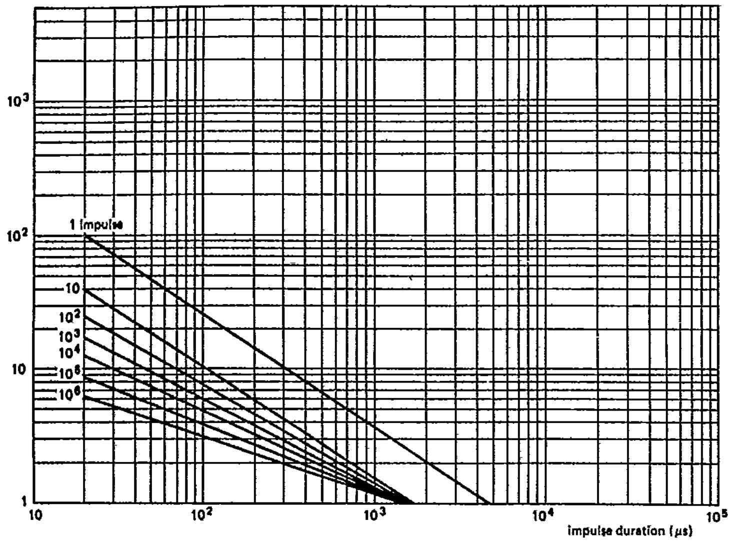


Fig. 21 Max. applicable transient current as a function of impulse duration, 592 series, 14 to 40 V

592 SERIES (B)

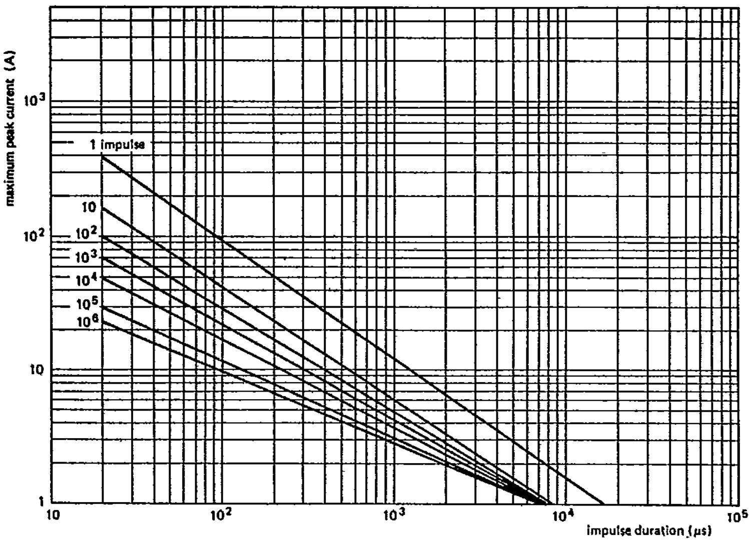


Fig. 22 Max. applicable transient current as a function of impulse duration, 592 series, 50 to 460 V

593 SERIES (A)

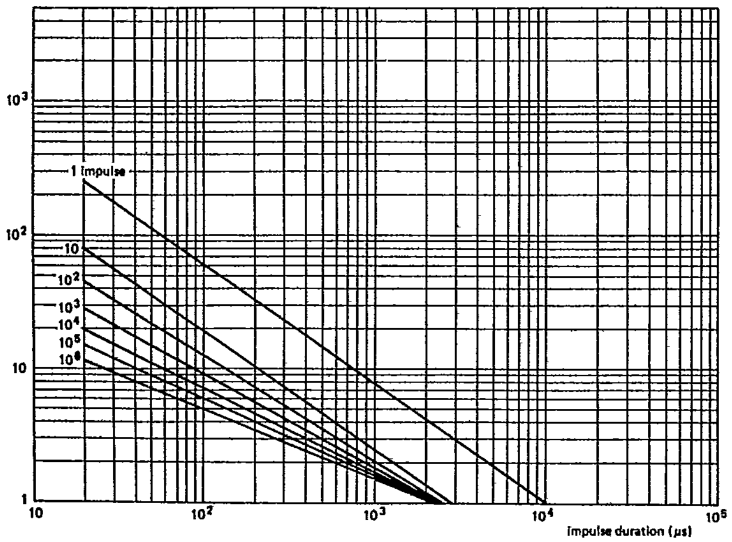


Fig. 23 Max. applicable transient current as a function of impulse duration, 593 series, 14 to 40 V

593 SERIES (B)

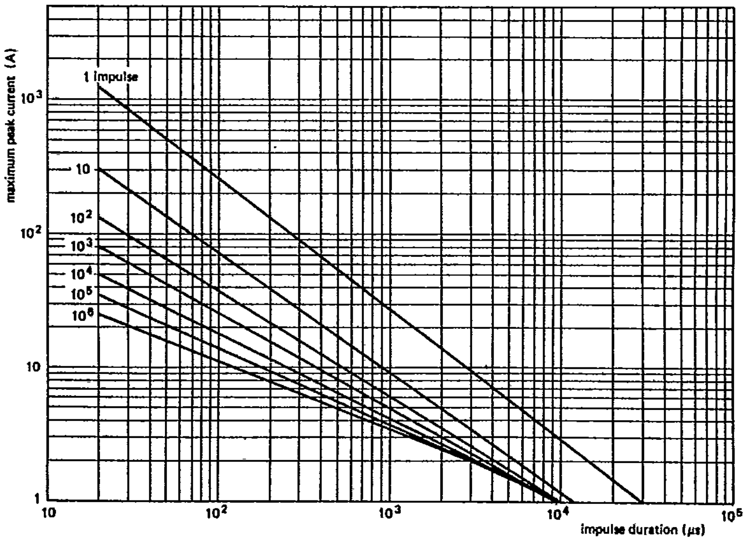


Fig. 24 Max. applicable transient current as a function of impulse duration, 593 series, 50 to 460 V

METAL OXIDE VARISTORS

Zinc Oxide Disc

MAX. APPLICABLE TRANSIENT CURRENT AS A FUNCTION OF IMPULSE DURATION

594 SERIES (A)

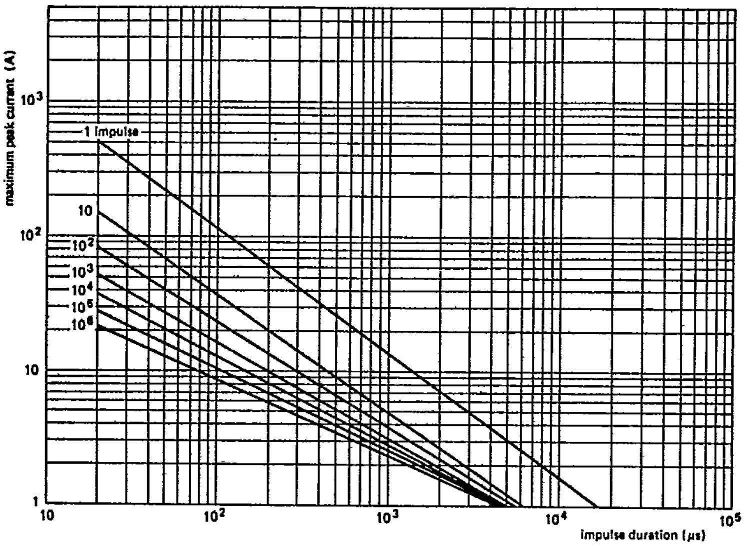


Fig. 25 Max. applicable transient current as a function of impulse duration, 594 series, 14 to 40 V

594 SERIES (B)

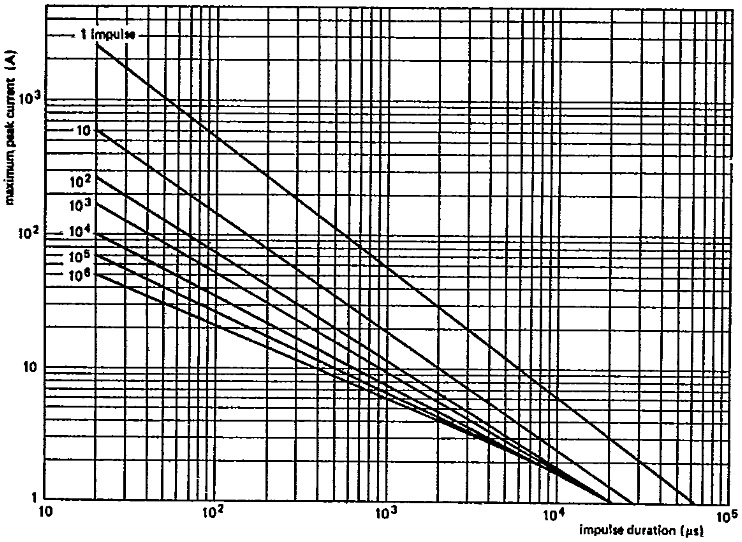


Fig. 26 Max. applicable transient current as a function of impulse duration, 594 series, 50 to 550 V

METAL OXIDE VARISTORS

Zinc Oxide Disc

MAX. APPLICABLE TRANSIENT CURRENT AS A FUNCTION OF IMPULSE DURATION

595 SERIES (A)

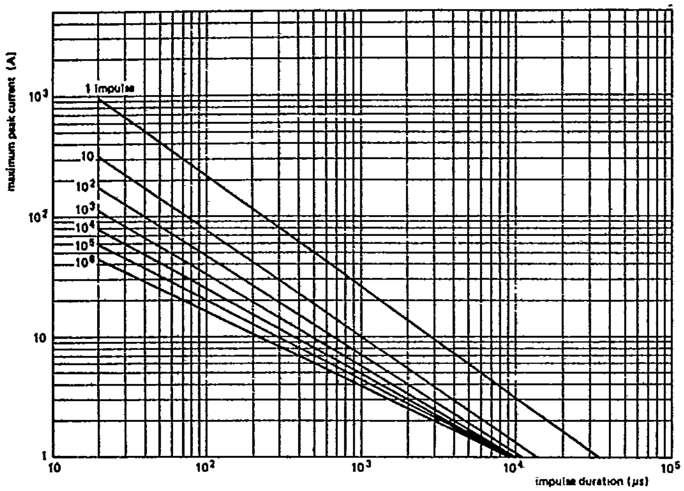


Fig. 27 Max. applicable transient current as a function of impulse duration, 595 series, 14 to 40 V

595 SERIES (B)

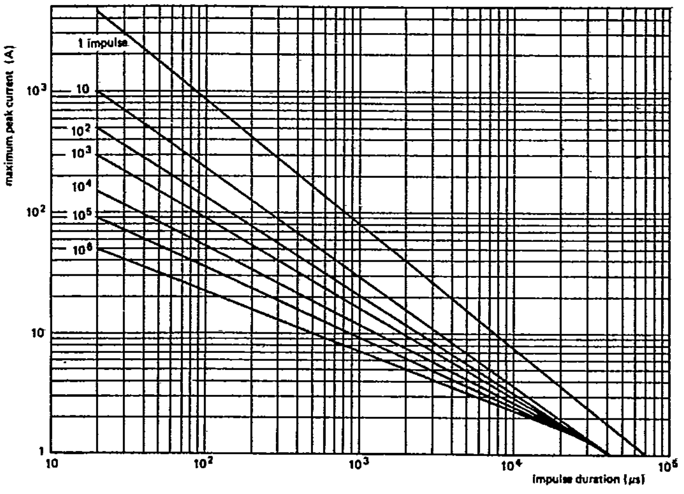


Fig. 28 Max. applicable transient current as a function of impulse duration, 595 series, 50 to 550 V

596 SERIES (A)

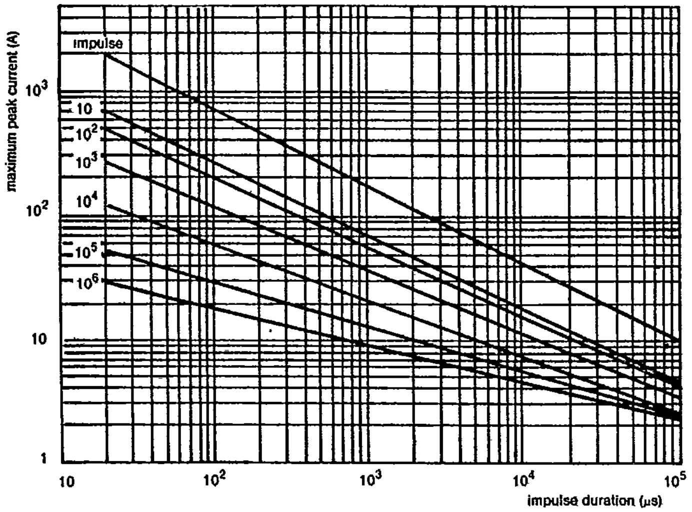


Fig. 29 Max. applicable transient current as a function of impulse duration, 596 series, 14 to 40V

596 SERIES (B)

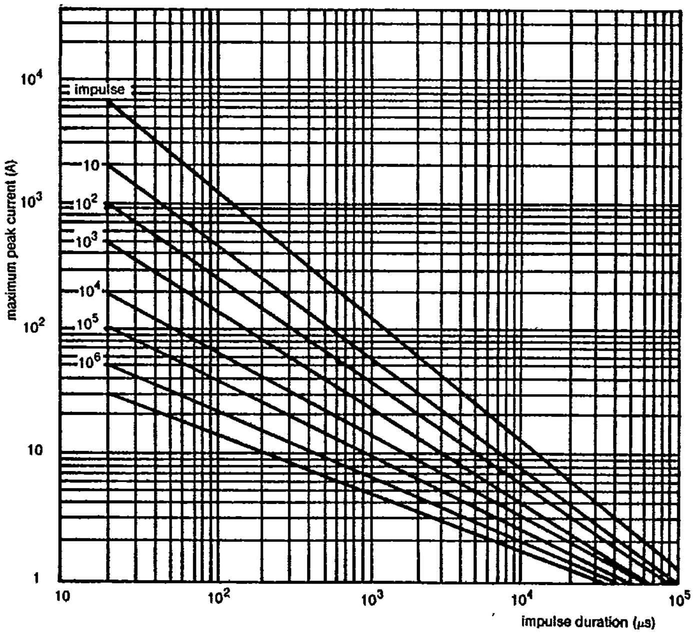


Fig. 30 Max. applicable transient current as a function of impulse duration, 596 series, 50 to 550V

METAL OXIDE VARISTORS

Zinc Oxide Disc

VOLTAGE

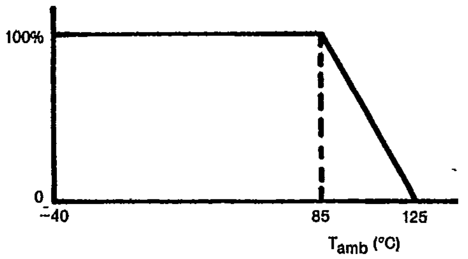


Fig. 31 Derating of max. DC or RMS working voltage with temperature.

MECHANICAL DIMENSIONS:

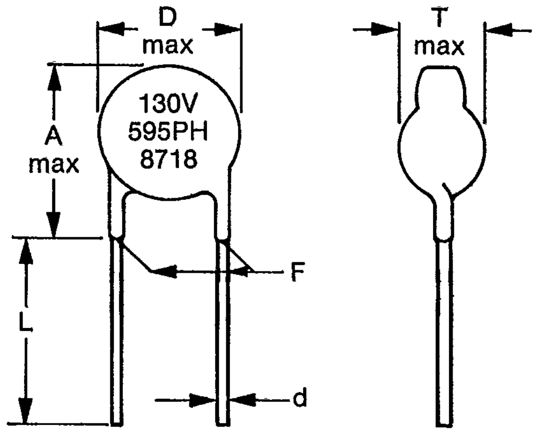


Figure 32A Straight Lead

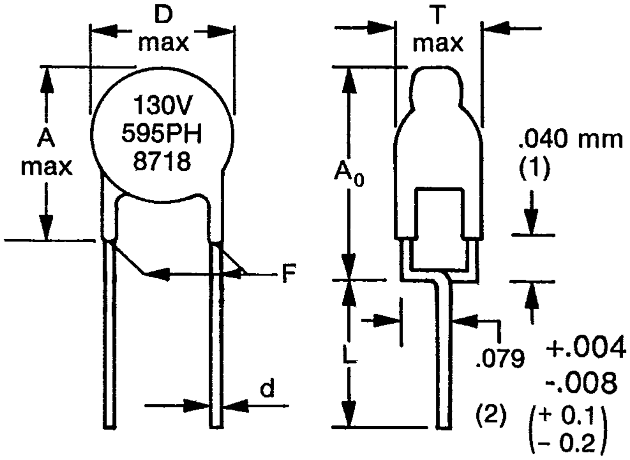


Figure 32B Kinked Lead

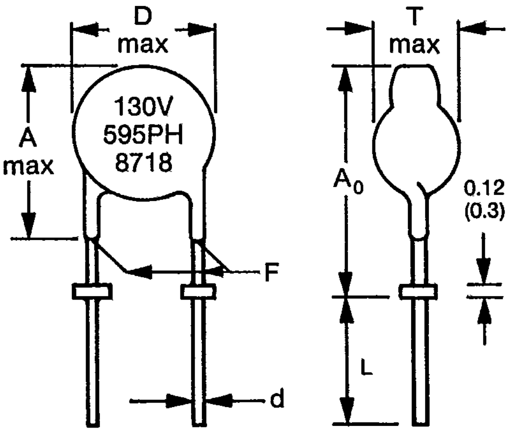


Figure 32C Flanged Lead

Table 3 Maximum thickness (T) in inches (mm) from Table 2

RMS VOLTAGE	SERIES 592, 593	SERIES 594, 595, 596
14-95	0.162 (4.1)	0.173 (4.4)
130	0.165 (4.2)	0.181 (4.6)
140-150	0.173 (4.4)	0.189 (4.8)
175	0.181 (4.6)	0.197 (5.0)
230-275	0.193 (4.9)	0.213 (5.4)
300	0.209 (5.3)	0.232 (5.9)
320-385	0.228 (5.8)	0.260 (6.6)
420	0.232 (5.9)	0.260 (6.6)
460	0.236 (6.0)	0.260 (6.6)
510	–	0.272 (6.9)
550	–	0.276 (7.0)

Table 2 Dimensions in inches (mm) for Figures 32A, B, C

SERIES	D (MAX)	T (MAX)	A (MAX)	L (MIN)	D (±10%)	F	A (MAX)
592	0.276 (7)	0.236 (6.0)	0.355 (9)	0.787 (20)	0.024 (0.6)	0.197 +0.315 −0.008 (5) (+0.8) (−0.2)	0.433 (11)
593	0.354 (9)	0.236 (6.0)	0.433 (11)	0.748 (19)	0.024 (0.6)	0.197 +0.315 −0.008 (5) (+0.8) (−0.2)	0.512 (13)
594	0.531 (13.5)	0.276 (7.0)	0.610 (15.5)	0.669 (17)	0.032 (0.8)	0.300 ±0.039 (7.62) (±1)	–
595	0.669 (17)	0.276 (7.0)	0.748 (19)	0.630 (16)	0.032 (0.8)	0.300 ±0.039 (7.62) (±1)	–
596	0.945 (24)	0.276 (7.0)	1.004 (25.5)	1.000 (25.4)	0.032 (0.8)	0.300 ±0.039 (7.62) (±1)	–

Dimension 'T' dependent on RMS Voltage rating (see Table 3)

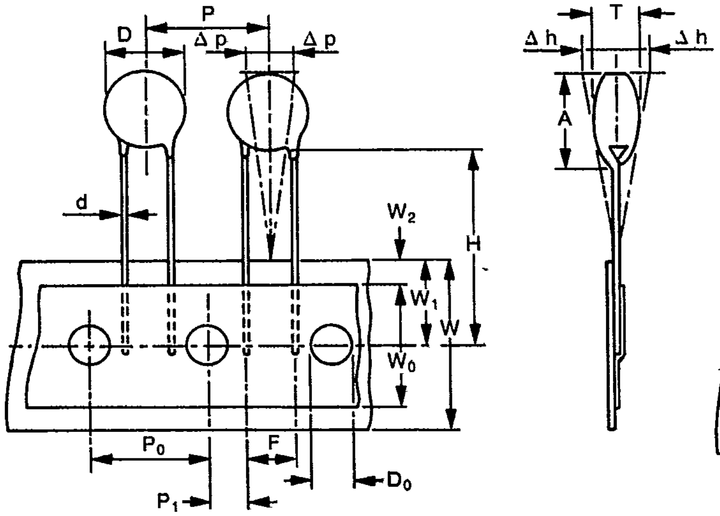


Fig. 33 Straight Lead

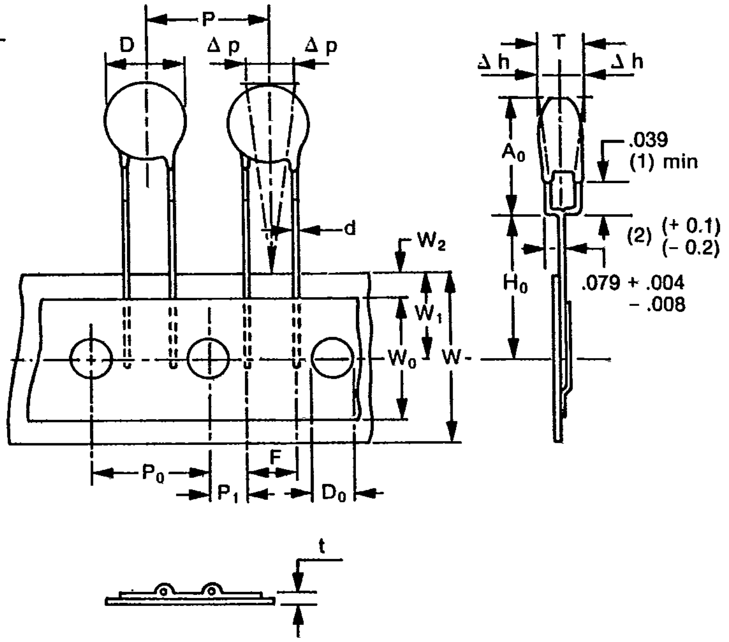


Fig. 33B Kinked Lead

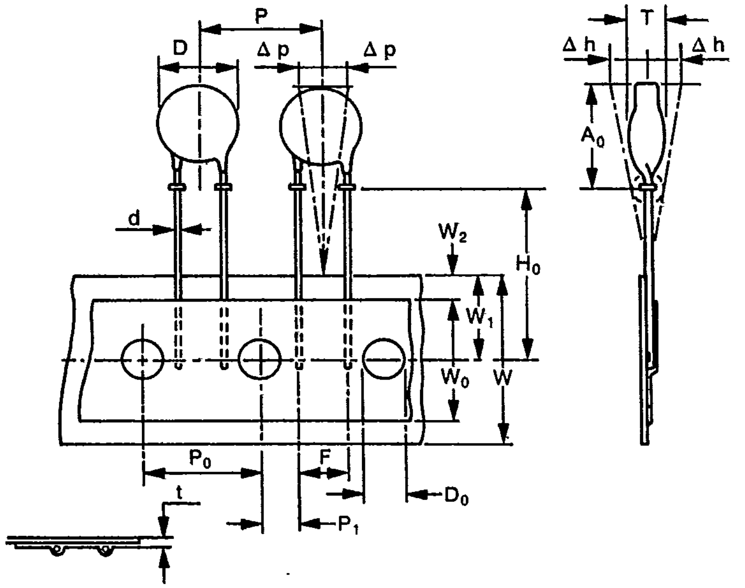


Fig. 33C Flanged Lead

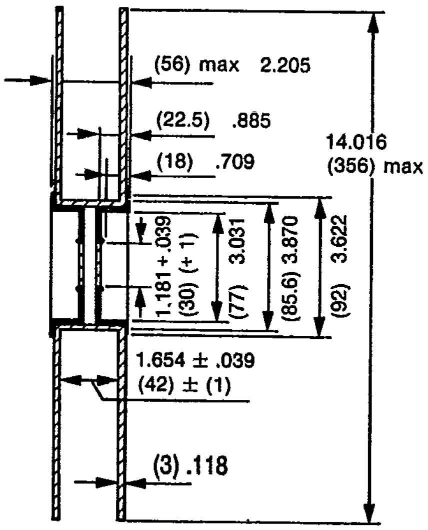


Fig. 33D Reel Dimensions

METAL OXIDE VARISTORS

Table 4. Dimensions in inches (mm) for Figures 33A, B, C

Dimensional Data				
Details	Symbol	Dimensions Nominal	Tolerance	Remarks
Body diameter	D	see table 2		
Total thickness	T	see table 3		
Mounting height	A_0-A	see table 2		
Lead wire diameter	d	see table 2		
Pitch of components	P	(12.7) .500	(±1) ±.040	
Feed hole pitch	P_0	(12.7) .500	(±0.3) ±.012	cumulative pitch error (±1 mm) 20 pitches
Feed hole centre to lead centre	P_1	(3.81) .150	(±0.7) ±.028	guaranteed between component and tape
Component alignment	Δp	0	(±1.3) ±.051	
Lead to lead distance	F	see table 2		guaranteed between component and tape
Component alignment	Δh	(0) 0	(±2) ±.079	
Tape width	W	(18) .709	(+1/−0.5) +.039/−.020	
Hold down tape width	W_0	.492 (12.5) min.		
Hole position	W_1	(9) .354	(±0.5) ±.079	
Hold down tape position	W_2	.118 (3) max.		
Distance component to tape centre	H	(20) .787	(+2) ±.079	
Lead wire clinch height	H_0	(18.25 or 16) .719 or .630	(±0.5) ±.020	see table 5
Free hole diameter	D_0	(4) .157	(±0.2) ±.008	
Total tape thickness	t	(0.9 max.) .035		with cardboarded tape (0.5±0.1) .020±.004
AQL: mechanical Level II			1%	

METAL OXIDE VARISTORS

Table 5. Packaging Configurations

Code number 2322		Packing quntity	Packing	H inches (mm) See table 4	Outline
592-	0...6 1...6	1500 1500	reel reel	.630 (16)	fig. 33A fig. 33C
	2...6 3...6	1500 1500	reel reel	.719 (18.25)	fig. 33C fig. 33B
	5...6	500	bulk	–	fig. 32A
	6...6 7...6	500 250	bulk bulk	–	fig. 32B fig. 32C
	8...6	1500	reel	.630 (16)	fig. 33B
593-	0...6 1...6	1500 1500	reel reel	– .630 (16)	fig. 33A fig. 33C
	2...6 3...6	1500 1500	reel reel	.719 (18.25)	fig. 33C fig. 33B
	5...6	500	bulk	–	fig. 32A
	6...6 7...6	500 250	bulk bulk	–	fig. 32B fig. 32C
	8...6	1500	reel	.630 (16)	fig. 33B
594-	0...6 5...6	7501 250	reel bulk	–	fig. 33A fig. 32A
595-	03006 to 01716 53006 to 51716	7501 250	reel bulk	–	fig. 33A fig. 32A
	02316 to 05516 52316 to 55516	7501 100	reel bulk	–	fig. 33A fig. 32A
596-	5...6	50	bulk	–	fig. 33A

Table 6. Metal Oxide Varistor Part Number Definition

2322

Philips Product

592

Varistor Disc Size

592 = 5 mm
593 = 7 mm
594 = 10 mm
595 = 14 mm
596 = 20 mm

5

***Packaging/Lead Type**

0 = T & R/Straight
1,2 = T & R/Flange†
3,8 = T & R/Kinked†
5 = Bulk/Straight
6 = Bulk/Kinked
7 = Bulk/Flange

* Series 594, 595 are only available as type 0 and 5
*Series 596 only available as type 5
†See Tape and Reel Dimensions

750

Maximum Continuous RMS Voltage

140 = 14V
170 = 17V
200 = 20V
250 = 25V
300 = 30V
350 = 35V
400 = 40V
500 = 50V
600 = 60V
750 = 75V
950 = 95V
131 = 130V
141 = 140V
151 = 150V
171 = 175V
231 = 230V
251 = 250V
271 = 275V
301 = 300V
321 = 320V
381 = 385V
421 = 420V
461 = 460V
511 = 510V
551 = 550V

6

Ochre Epoxy Coating

6 = Ochre Epoxy Coating
**7 = Ammo Pack Tape & Ochre Epoxy Coating

**Only available for 592 & 593 Series

METAL OXIDE VARISTORS

Table 7. Test Results

Notes 1. Clause numbers of tests and performance requirements refer to CECC 42000
2. Inspection levels and AQL's are selected from IEC Publication 410.
3. In this table: p = periodicity (in months)
n = sample size
c = acceptance criterion (permitted number of defectives)
D = destructive
ND = non-destructive
4. The varistors shall be mounted by their normal means in such a manner that there shall be no parasitic vibration.

Clause number and test	**D or ND**	**Conditions of test**	**IL**	**AQL**	**Performance requirements**
(see note 1)		**(see note 1)**	**(see note 2)**		**(see note 1)**
GROUP A INSPECTION (lot-by-lot)					
Sub-Group A1	ND			1.0%	
4.2.1. Visual examination					As in 4.2.1.
4.2.2. Marking					As in 4.2.2.
Sub-Group A2	ND			0.65%	
B2.6 Protection level		At class current given in table 2			As specified in table 2
4.3. Voltage		At 1 mA			Values given in table 2
Sub-Group A3	ND			1.0%	
4.2.3. Dimensions (gauging)		D and T			As specified in tables 1 and 2
GROUP B INSPECTION (lot-by-lot)					
Sub-Group B1	D			2.5%	
4.11. Robustness of terminations		Test Ua and Ub of IEC 68-2-21 Visual examination Voltage at 1 mA			As in 4.11.6. Within the values given in table 2
4.10.1. Solderability		Solder bath method: 235±5°C			The terminations shall be uniformly tinned
x.x. Solvent resistance of coating and marking		Visual examination IEC 68-2-45 (1980) Test Xa Solvent: 3.1.1. Temperature: 23±5°C			No visual damage Legible marking
Sub-Group B2	D			1.0%	
4.7. Voltage proof		Method: metal balls (4.7.1.2.) 2500 V			As in 4.7.3.

METAL OXIDE VARISTORS

Clause number and test (see note 1)	D or ND	Conditions of test (see note 1)	Sample size and criterion of acceptability (see note 3)			Performance requirements (see note 1)
			p	n	c	
GROUP C INSPECTION (periodic)						
Sub-Group C1	D		6	13	1	
x.y. Maximum surge current		100 pulses 8/20 μs at 2 per min in one direction				
		Visual examination				No visible damage
		Voltage at 1 mA				Δ V/V: ± 10% max.
Sub-Group C2	D		12	13	1	
x.z. Maximum peak current		100 pulses 10/1000 μs in one direction, 1 every 2 min				
		Visual examination				No visible damage
		Voltage at 1 mA				Δ V/V: ± 10% max.
Sub-Group C3	D		12	13	1	
		7 specimens				
4.6. Capacitance		f = 1 kHz				
		Signal level 1 V max				As given in table 2
		Zero bias				with ± 50%
4.10.2. Resistance to soldering heat		Method Tb of IEC 68-2-20A				
		Visual examination				As in 4.10.2.4.
		Voltage at 1 mA				Δ V/V: ± 5% max.
4.12. Rapid change of temperature		Test Na of IEC 68-2-14				
		Ta: Lower category temp.: −40°C				
		Tb: Upper category temp.: 125°C				
		Visual examination				As in 4.12.4
		Voltage at 1 mA				Δ V/V: ± 5% max.
		6 specimens				
4.14. Shock		Pulse shape: half sine				
		Acceleration: 490 m/s^2				
		Pulse duration: 11 ms				
		3 x 6 shocks				
		Visual examination				As in 4.14.3
		Voltage at 1 mA				Δ V/V: ± 5% max.
		All specimens				
4.17. Climatic sequence – Dry heat – Damp heat, cyclic, first cycle – Cold – Damp heat, cyclic, remaining cycles – Final measurement		Visual examination				As in 4.16.9.1
		Voltage at 1 mA				Δ V/V: ± 5% max.
		Voltage proof				As in 4.7.3.

METAL OXIDE VARISTORS

Clause number and test (see note 1)	D or ND	Conditions of test (see note 1)	Sample size and criterion of acceptability (see note 3)			Performance requirements (see note 1)
			p	n	c	
Sub-Group C4 4.20. Endurance at upper category temperature	D	1000 h at 85°C and at max. r.m.s. voltage	12	13	1	
		Examination at 48 h, 500 h and 1000 h				
		Visual examination				As in 4.20.5.1.
		Voltage at 1 mA				△ V/V: ± 5% max.
		Examination at 1000 h				
		Voltage at class current				1,1 x the initial limits
		Voltage proof				As in 4.7.3.
GROUP D INSPECTION (periodic) **Sub-Group D1** 4.17. Damp heat, steady state	D	**4 specimens** No applied voltage	24	8	1	
		Other 4 specimens Applied voltage: 10% of the max. d.c. voltage				
		Visual examination				As in 4.17.3.1.
		Voltage at 1 mA				△ V/V: ± 5% max.
		Voltage proof				As in 4.7.3.
Sub-Group D2 4.2. Dimensions (detail)	ND		24	8	1	As specified in table 1 and 2
4.5. Temperature coefficient of voltage		At 1 mA				−0.065%/°C
Sub-Group D3 4.18. Inflammability Needle flame test	D	Test IEC 695-2-2 10 s—vertical	24	5	0	5 s max.