PASSIVE COMPONENTS

DATA HANDBOOK

Varistors, Thermistors and Sensors

BOOK PA02 1992

Philips Components

PHILIPS

QUALITY ASSURED

Our quality system focuses on the continuing high quality of our components and the best possible service for our customers. We have a three-sided quality strategy: we apply a system of total quality control and assurance; we operate customer-oriented dynamic improvement programmes; and we promote a partnering relationship with our customers and suppliers.

PRODUCT SAFETY

In striving for state-of-the-art perfection, we continuously improve components and processes with respect to environmental demands. Our components offer no hazard to the environment in normal use when operated or stored within the limits specified in the data sheet.

Some components unavoidably contain substances that, if exposed by accident or misuse, are potentially hazardous to health. Users of these components are informed of the danger by warning notices in the data sheets supporting the components. Where necessary the warning notices also indicate safety precautions to be taken and disposal instructions to be followed. Obviously users of these components, in general the set-making industry, assume responsibility towards the consumer with respect to safety matters and environmental demands.

All used or obsolete components should be disposed of according to the regulations applying at the disposal location. Depending on the location, electronic components are considered to be 'chemical', 'special' or sometimes 'industrial' waste. Disposal as domestic waste is usually not permitted.

Contents list

For easy reference, (code) catalogue numbers (12 digits) are at the top of each page. Orders should always state the 12 figure (code) catalogue number. All dimensions on drawings are in mm unless otherwise indicated. According to the S.I. units the symbol K (Kelvin) is used instead of °C in combinations such as K/W. Also ΔT is in K. Atmospheric pressure is given in kPa instead of millibars, mm Hg, etc. 1000 mbar = 100 kPa.

Varistors, Thermistors and Sensors

Contents list

DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

SELECTION GUIDE

POSITIVE TEMPERATURE COEFFICIENT (PTC) THERMISTORS

PRODUCT FUNCTION	RANGE	OUTLINE	CODE NUMBERS	PAGE
Degaussing (dual)	145 V; 7.2 A_{pp} min.	Plastic housing	2322 662 96026	41
	145 V; 19 A_{pp} min.	Plastic housing	2322 662 96125	41
	145 V; 25 A_{pp} min.	Plastic housing	2322 662 96013	41
	245 V; 16.2 A_{pp} min.	Plastic housing	2322 662 96123	41
	265 V; 11.6 A_{pp} min.	Plastic housing (PN)	2322 662 96012	41
	265 V; 10 A_{pp} min.	Plastic housing	2322 662 96024	41
	265 V; 12 A_{pp} min.	Plastic housing	2322 662 96009	41
	265 V; 12 A_{pp} min.	Plastic housing	2322 662 96022	41
	265 V; 15 A_{pp} min.	Plastic housing	2322 662 96016	41
	265 V; 15 A_{pp} min.	Plastic housing	2322 662 96116	41
	265 V; 17 A_{pp} min.	Plastic housing	2322 662 96011	41
	265 V; 17 A_{pp} min.	Plastic housing	2322 662 96111	41
	270 V; 24 A_{pp} min.	Plastic housing	2322 662 96124	41
	270 V; 24 A_{pp} min.	Plastic housing	2322 662 96126	41
Temperature protection	T_n = 60 °C to 170 °C	Chip size 1.5 x 1.5 mm	2322 671 91052 to 91067	49
	T_n = 60 °C to 170 °C	Chip size 1.7 x 1.7 mm	2322 671 91002 to 91017	49
		Leaded	2322 671 91102 to 91114	49
	T_n = 80 °C to 150 °C	Insulated long leads	2322 672 92045 to 92053	59
Overload protection	60 V (DC), T_s = 140 °C	Naked disc	2322 66. 4...1	73
		Leaded, bulk	2322 66. 5...1	73
		Leaded on tape	2322 66. 6...1	73
	145 V_{rms}, T_s = 140 °C	Naked disc	2322 66. 4...2	73
		Leaded, bulk	2322 66. 5...2	73
		Leaded on tape	2322 66. 6...2	73
	265 V_{rms}, T_s = 140 °C	Naked disc	2322 66. 4...3	73
		Leaded, bulk	2322 66. 5...3	73
		Leaded on tape	2322 66. 6...3	73
	56 V (DC), T_s = 120 °C	Naked disc	2322 66. 0...1	99
		Leaded, bulk	2322 66. 1...1	99
	265 V_{rms}, T_s = 120 °C	Naked disc	2322 66. 0...3	117
		Leaded, bulk	2322 66. 1...3	117

NEGATIVE TEMPERATURE COEFFICIENT (NTC) THERMISTORS

PRODUCT FUNCTION	RANGE	OUTLINE	CODE NUMBERS	PAGE
Temperature sensing and control	Basic	Radial leads	2322 640 5....	165
		Radial leads	2322 640 6....	169
		Radial leads	2322 642 6....	289
		Radial leads	2322 645 series	211
	Special accuracy	Radial leads	2322 640 10...	189
		Radial leads	2322 640 90012	203
		Moulded	2322 640 90013	206
		Moulded with metal strip	2322 640 98013	206
		Radial leads	2322 645 90001	217
		Moulded with metal strip	2322 645 98001	220
		Screw	2322 645 97001	220
		Moulded	2322 645 96001	220
		Radial leads	2322 645 90015	221
		Radial leads	2322 645 90022	225
	Assembly	Moulded	2322 640 90004	193
		Moulded with metal strip	2322 640 98004	193
		Moulded	2322 640 90005	197
		Moulded with metal strip	2322 640 98005	197
		Screw 2.2 kΩ to 470 kΩ	2322 640 7....	207
		Screw 3.3 Ω to 1.5 kΩ	2322 642 7....	207
		Long radial leads	2322 645 90028	229
	High temperature	SOD27	2322 633 72224	239
		SOD27	2322 633 73224	239
		SOD27, SOD80	2322 633 5..../8....	243
	Miniature	Glass encapsulated bead with radial leads	2322 626 1....	249
		Glass encapsulated bead with radial leads	2322 626 2....	253
		Bead with axial leads	2322 633 0....	231
		Bead with radial leads	2322 633 1....	231
		Glass encapsulated bead with axial leads	2322 633 2....	235
	Naked disc	Disc	2322 611 9....	257

PRODUCT FUNCTION	RANGE	OUTLINE	CODE NUMBERS	PAGE
Surge current limiting	1 Watt	Radial leads	2322 610 1...	263
	High current	Radial leads	2322 644 90005 to 90025	267
	Disc without leads	Disc	2322 644 90012	273
	Disc with leads	Disc	2322 653/4/5/6	275
Temperature compensation	Basic	Radial leads	2322 642 6....	289
		Radial leads	2322 645 series	211

VARISTORS (VDR)

PRODUCT FUNCTION	RANGE	OUTLINE	CODE NUMBERS	PAGE
Transient suppression	Basic	Available in:	2322 592 series	325
		Straight leads	2322 593 series	325
		Kinked leads	2322 594 series	325
		Flanged leads	2322 595 series	325
		On tape (reel)		
		In ammopack		
		Bulk		

HUMIDITY SENSOR

PRODUCT FUNCTION	RANGE	OUTLINE	CODE NUMBER	PAGE
Sensing	Basic	Housing	2322 691 90001	351

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Varistors, Thermistors and Sensors (V, T and S) are part of our extensive range of Passive Components. We have been making these non-linear resistors for more than 20 years and gained an enviable reputation for our advanced ceramic technology, high quality and value for money solutions.

V, T and S products are used as sensing and protection devices in all kinds of electronic applications.

This data handbook contains our broad range of standard products, but our major strength is the capability to offer customized products which have to be application specific.

DEVICE	FUNCTION	APPLICATION
PTC thermistor	degaussing	colour televisions monitors
	temperature protection	industrial electronics power supplies electronic data processing
	overload protection	telecommunications automotive systems industrial electronics consumer electronics electronic data processing
NTC thermistor	temperature sensing	domestic appliances automotive systems industrial electronics medical electronics
	surge inrush current limiting	power supplies lighting electronic data processing
	temperature compensation	consumer electronics industrial electronics electronic data processing
Varistor (VDR)	transient suppression	telecommunications automotive systems industrial electronics consumer electronics electronic data processing
Humidity sensors	humidity sensing	industrial electronics

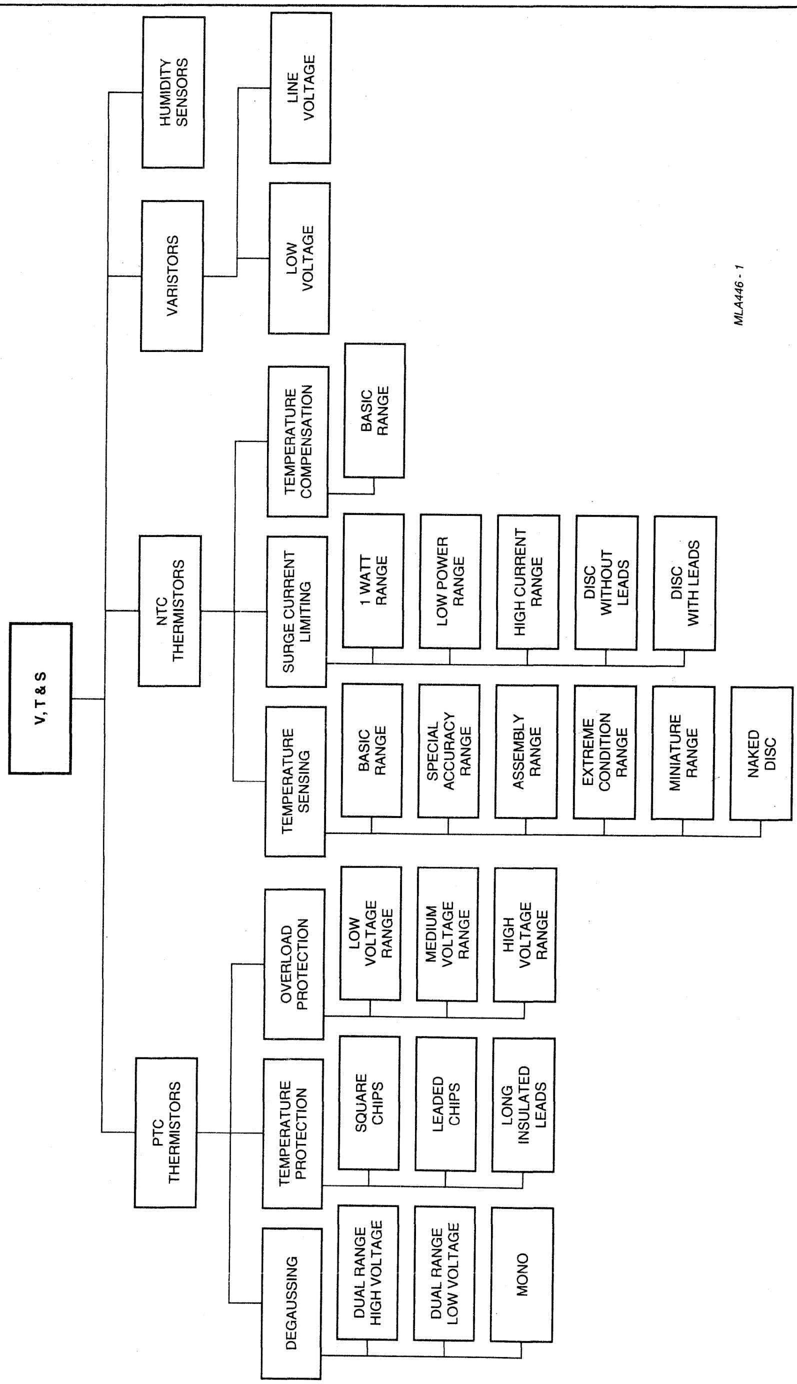


Fig.1 General introduction.

APPLICATIONS

V, T and S APPLICATIONS

APPLICATION	PTC			NTC			VARISTORS	HUMISTORS
	DEGAUSSING	TEMPERATURE PROTECTION	OVERLOAD PROTECTION	TEMPERATURE SENSING	SURGE CURRENT LIMITING	TEMPERATURE COMPENSATION	TRANSIENT PROTECTION	HUMIDITY SENSING
Telecommunications			X				X	
Automotive		X	X	X			X	
Small domestic appliances				X			X	
Large domestic appliances (white goods)			X	X	X		X	
Colour television, monitors	X				X		X	
Other consumer equipment			X			X	X	
EDP		X	X		X	X	X	
Lighting			X				X	
General industrial		X	X	X	X	X	X	X
Medical				X				
SMPS		X	X		X			

POSITIVE TEMPERATURE COEFFICIENT (PTC) THERMISTORS

INTRODUCTION

1. GENERAL

Positive Temperature Coefficient (PTC) thermistors exhibit a high positive temperature coefficient of resistance. They differ from Negative Temperature Coefficient (NTC) thermistors in the following manner:

1. The temperature coefficient of a PTC is positive only between certain temperatures. Outside this range, the temperature coefficient is either zero or negative.
2. The absolute value of the temperature coefficient of PTC thermistors is much higher than that of NTC thermistors.

PTC thermistors are used in a variety of applications, including current limiting, temperature sensing, degaussing and for protection against overheating in equipment such as electric motors. They may also be used in level indicators, time delay devices, thermostats, and as compensation resistors. For further details, refer to the 'Applications' section.

2. ELECTRICAL COMPOSITION

PTC thermistors are prepared from $BaTiO_3$, by a similar method to that used in the preparation of NTC thermistors, using solid solutions of $BaTiO_3$. Extra electrons on the Ti ions are created by introducing foreign ions having a different valency. Use of these compounds allows two alternatives for preparation:

1. Substitution of trivalent ions such as La^{3+} or Bi^{3+} for Ba^{3+}, or
2. Substitution of pentavalent ions such as Sb^{5+} or Nb^{5+} for Ti.

Both methods give identical results. If prepared in the absence of oxygen, these semiconductors exhibit a weak temperature coefficient of resistance. A strong positive coefficient is obtained by firing the ceramic samples in an oxygen rich atmosphere. This is achieved by penetrating the pores and crystal boundaries with oxygen during the cooling period following the firing process. The oxygen atoms, which have been absorbed on the crystal surfaces, attract electrons from a thin zone of the semiconducting crystals. This forms electrical potential barriers consisting of a negative surface charge with, on both sides, thin layers having a positive space charge resulting from the now, uncompensated, foreign ions. These barriers cause an extra resistance in the thermistor, exhibited by the formula:

$$R_b \,\alpha\, \frac{1}{a}\, e^{eV_b/kT} \qquad (\alpha = \text{directly proportional to})$$

where, 'a' represents the size of the crystallites, thus 1/a is the number of barriers per unit length of the thermistor, and V_b represents the potential of the barriers. Since V_b is inversely proportional to the value of the dielectric constant of the crystals, R_b is extremely sensitive to variations in the dielectric constant. Such variation in the dielectric constant is a special property of materials having a ferroelectric nature as can be found in the compound $BaTiO_3$ and its solid solutions. If their ferroelectric Curie temperature (θ) is exceeded, the relative dielectric constant decreases with the temperature increase in accordance with the relationship shown overleaf:

$$\epsilon_r = \frac{C}{T - \theta}$$

where C has an approximate value of 10^5 K. As a result, the resistivity increases sharply just above the Curie temperature. Below the Curie temperature, the barriers are weak or absent, partly as a result of the high effective dielectric constant of $BaTiO_3$ in strong fields, and partly as a result of the spontaneous polarisation of the crystals which may compensate the boundary changes.

The electrons are captured at the boundaries and gradually liberated in proportion with the increase in body temperature of the PTC with respect to its switching temperature, causing the potential barriers to decrease in strength. This means that the PTC loses its properties and may eventually respond in a similar fashion to a NTC if the temperature becomes too high. The applications of a PTC are, therefore, restricted by a certain temperature limit.

Since the PTC effect is caused by crystal boundary barriers, the extra resistance R_b is shunted by a high parallel capacitance C_b. This leads to frequency dependence of an extra impedance Z_b up to 5 MHz. The characteristic properties described in the following paragraphs are thus restricted to this frequency range.

3. ELECTRICAL PROPERTIES

Resistance/temperature characteristics

Figure 1 shows a comparison of typical resistance/temperature characteristic curves for PTC and NTC thermistors.

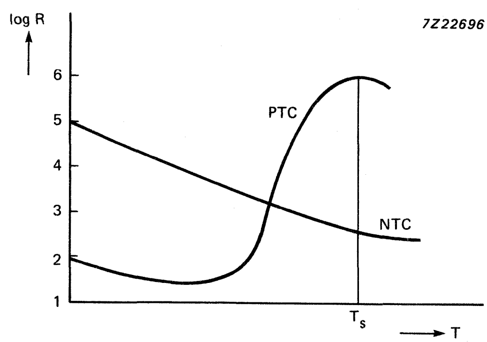


Fig.1 Typical resistance/temperature characteristic curves for PTC and NTC thermistors.

Voltage/current characteristics

Static voltage/current characteristics display the current limiting ability of PTC thermistors. Up to a certain value of voltage, the V/I characteristics follow Ohm's law, but the resistance is increased when the current passing through the PTC causes it to heat up and reach its switching temperature (see Fig.2). The V/I characteristic is dependent on ambient temperature and the heat transfer coefficient with respect to ambient temperature.

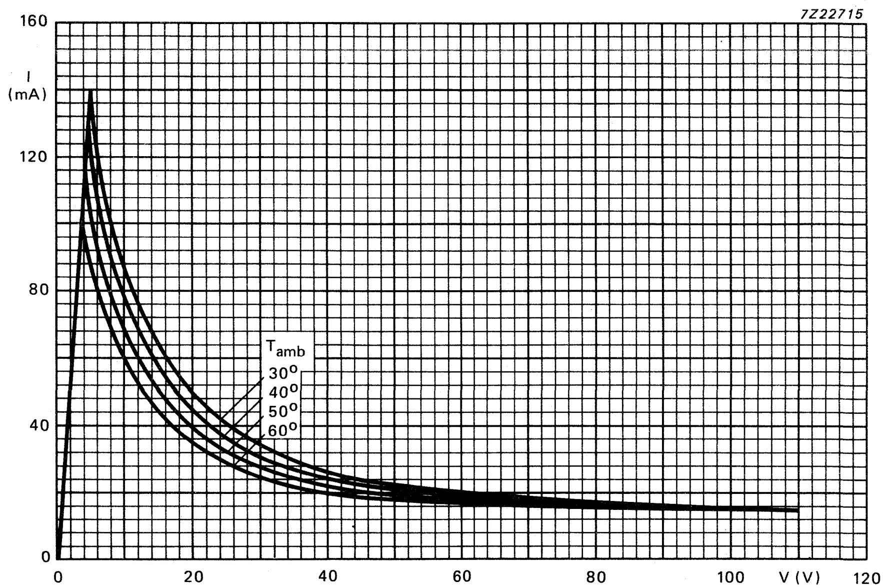


Fig.2 Voltage/current characteristics of a PTC thermistor plotted on a linear scale, using ambient temperature as the parameter.

As can be seen from Fig.2, the characteristics are plotted on a linear scale, however it is more common to plot the characteristics on a logarithmic scale (see Fig.3), since it gives a clearer view of the overall response.

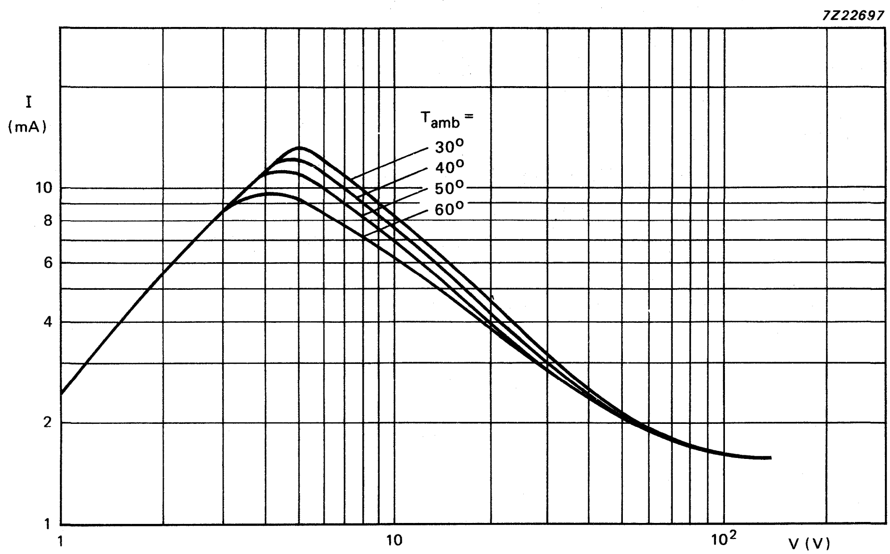


Fig.3 Voltage/current characteristics of a PTC thermistor plotted on a logarithmic scale, and using ambient temperature as the parameter.

It is possible to calculate the peak of the V/I characteristic accurately if the R/T characteristic and the dissipation factor (D) are known.

The dissipation factor (measured in mW/°C) is the ratio at a specified ambient temperature of a change in power dissipation in a thermistor, to the resultant body temperature change. By convention, the dissipation factor can only be calculated at the peak of the V/I curve, also making use of the corresponding point on the R/T characteristic.

By definition:

– the electrical power injected in the PTC thermistor is:

$$P = I^2 R$$

where R is the resistance (before switching) at T_{amb}

– the power dissipated by the ceramic is given by:

$$D\ (T_s - T_{amb})$$

where T_s is the switch temperature and T_{amb} is the ambient temperature, then,

$$I^2 R = D\ (T_s - T_{amb})$$

Note: This equation is only valid for temperatures having a value less than T_s.

The trip current (I_t) is defined as the minimum guaranteed current which will cause the thermistor to switch, and can be calculated using the formula:

$$I_t^2 R = D\ [T_s - (T_{amb} + \omega)],\ \text{hence:}$$

$$I_t = \sqrt{\frac{D[T_s - (T_{amb} + \omega)]}{R}}$$

where R is the PTC resistance at T_s.

Normally, a security margin of $+\ \omega$ °C is maintained in order to assure thermistor switching due to inaccuracies in the values of T_s and T_{amb}.

The non-trip current (I_{nt}) is defined as the guaranteed maximum current at which the thermistor will not switch, and is given by:

$$I_{nt}^2 R = D[T_s - (T_{amb} - \omega)],\ \text{hence:}$$

$$I_{nt} = \sqrt{\frac{D[T_s - (T_{amb} - \omega)]}{R}}$$

A security margin of $-\omega$ °C is maintained to ensure that the thermistor will not switch.

The slope of the R/T characteristic is designated by a series of production parameters. The relationship between R/T and V/I characteristics is demonstrated clearly in Figs 4 and 5.

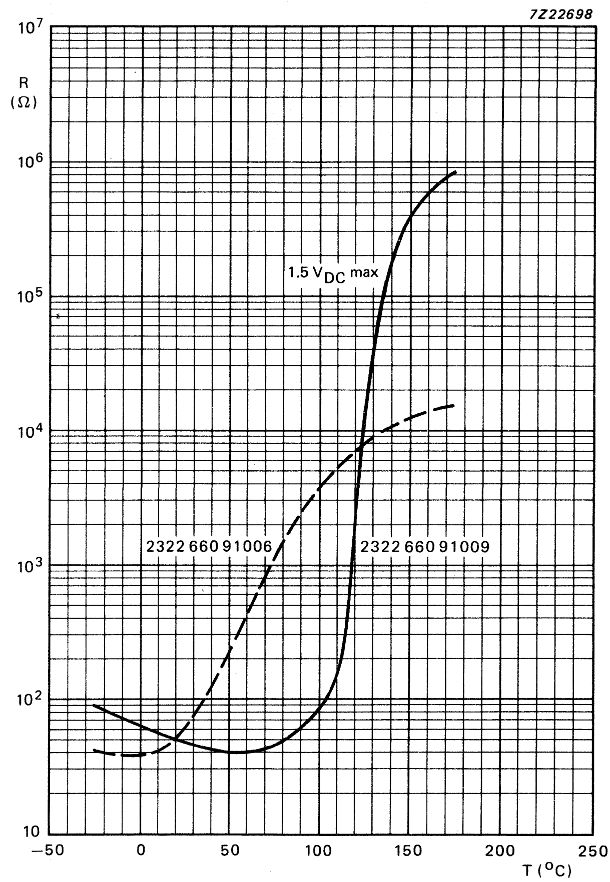


Fig.4 R/T characteristics of thermistors type 2322 660 91006 and 2322 660 91009.

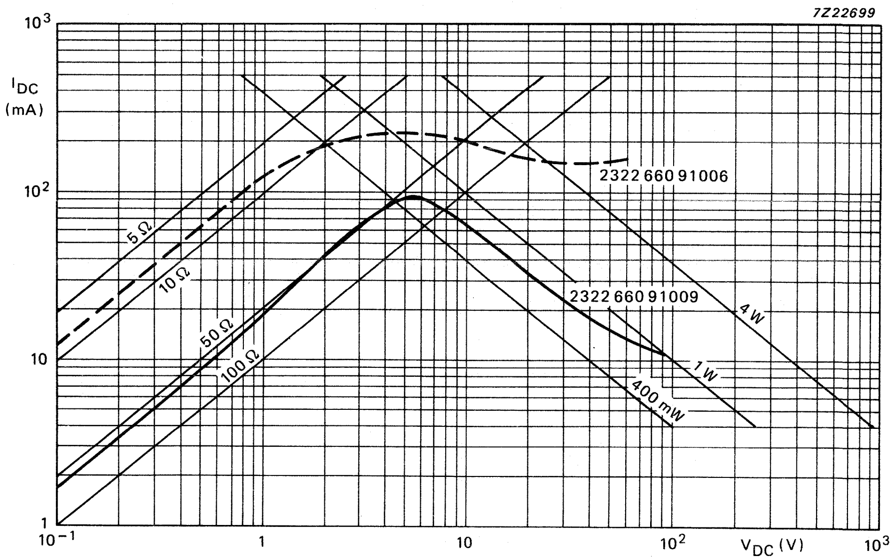


Fig.5 Typical V/I characteristics of thermistors type 2322 660 91006 and 2322 660 91009, measured in still air at 25 °C.

PTC thermistor in series with a load

It can be shown from the V/I characteristics that, because of the non-linearity of the PTC curve, three working points are possible when a load R is connected in series with a PTC (see Fig.6). The characteristic of the load is a straight line intersecting the voltage co-ordinates at the supply voltage, V_a. P_1 and P_2 are stable working points; P_3 is unstable.

When the voltage V_a is applied to the series connection, equilibrium is reached at P_1, a point with a relatively high current. P_2 can only be reached when the peak of the V/I curve lies below the load characteristic. This may happen in a number of cases:

1. V_a increases, see Fig.7.
2. the ambient temperature increases, see Fig.8
3. the load resistance decreases, see Fig.9.

It can therefore be seen that the PTC thermistor provides excellent protection properties, limiting the load to a safe value if the supply voltage, temperature or current exceeds a critical value.

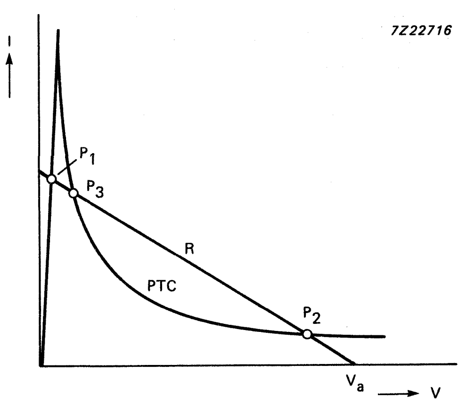


Fig.6 PTC thermistor in series with a load showing the possible working points.

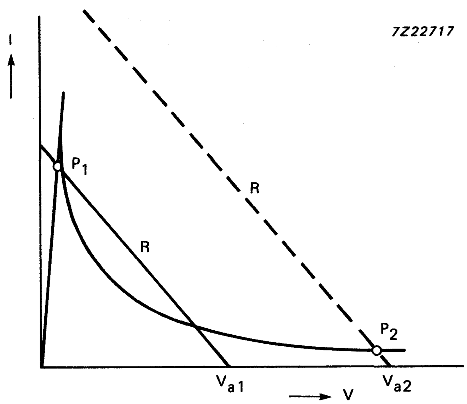


Fig.7 PTC thermistor in series with a load showing the influence of the supply voltage V_a.

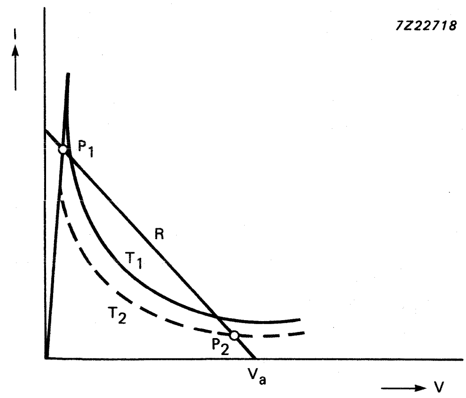


Fig.8 PTC thermistor in series with a load showing the influence of the ambient temperature.

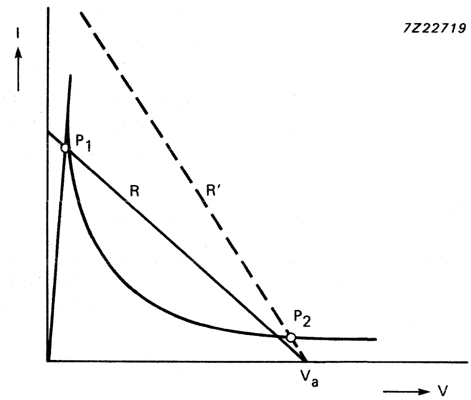


Fig.9 PTC thermistor in series with a load showing the influence of the load resistance.

Resetting resistance

When the PTC thermistor is switched i.e. its temperature rises above the switching temperature T_s, it can only return from P_2 to P_1 if the load line lies below the V/I characteristic curve. This means that:

1. either the supply voltage V_a decreases (at constant load resistance), see Fig.10, or
2. the load resistance increases (at constant voltage), see Fig.11.

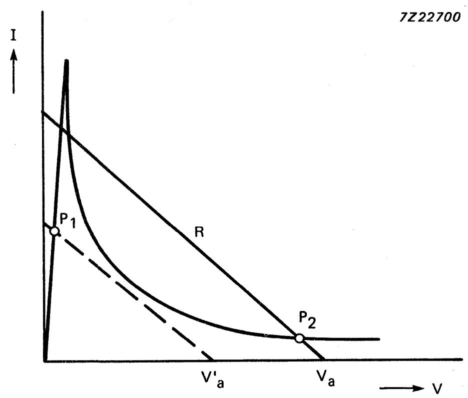


Fig.10 PTC thermistor in series with a load showing the influence of a decrease in supply voltage V_a.

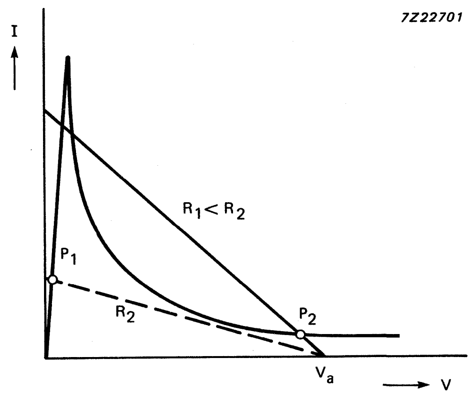


Fig.11 PTC thermistor in series with a load showing the influence of increased load resistance.

Note: When the temperature of the PTC thermistor is greater than T_s (i.e. the thermistor is in its tripped state), it will heat up causing the ambient temperature to increase (as shown in Fig.8). This must be taken into account when calculating the value of load resistance (i.e. the resistance of the PTC).

Current/time characteristics

If a PTC thermistor is connected in series with a resistance of such a value that the peak of the V/I curve lies under the load line, the PTC will heat up until the stable working point (P_2) is reached (see Fig.12). The time taken to reach this point is dependent on the value of load R (see Fig.13) and the ambient temperature.

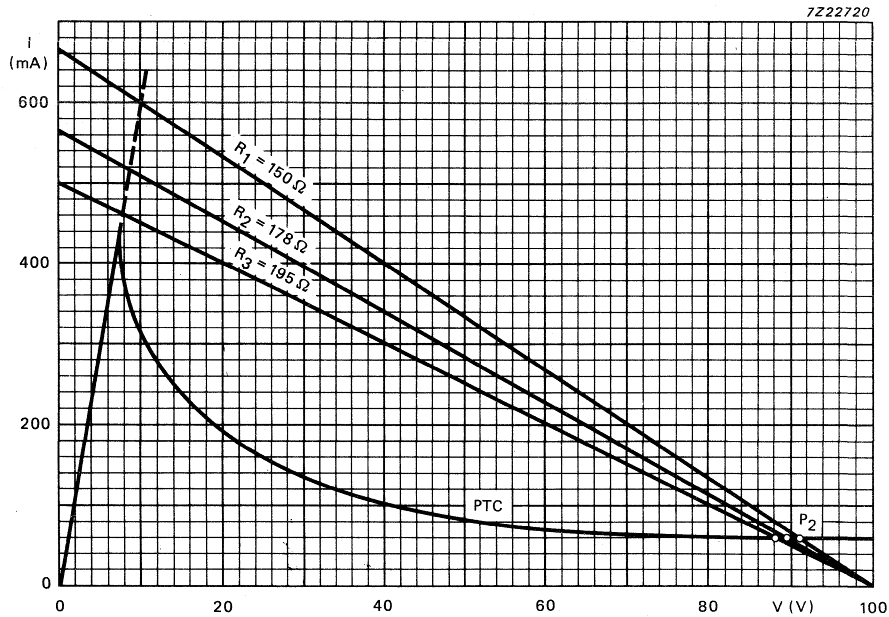


Fig.12 PTC thermistors in series with different resistors.

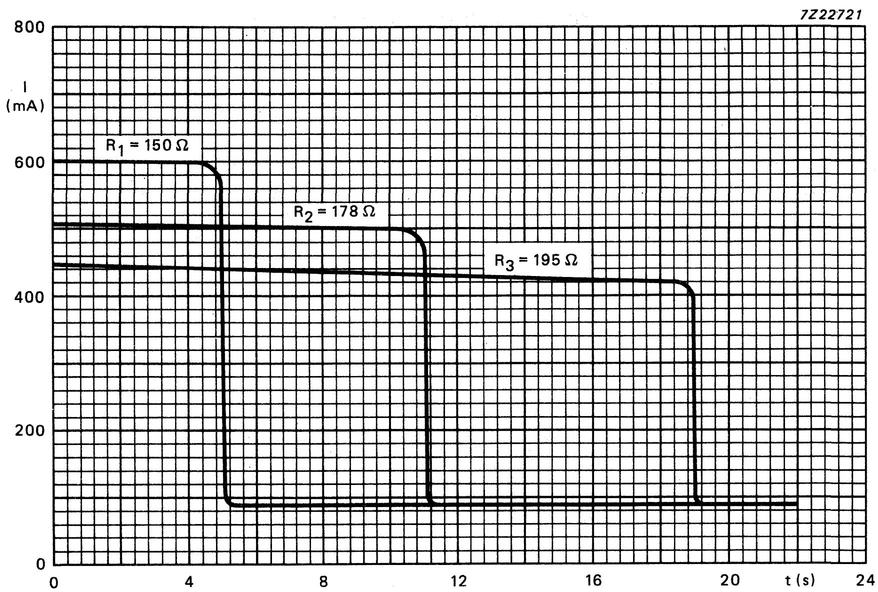


Fig.13 Current/time characteristics showing the influence of the load.

EXPLANATION OF TERMS

Switch temperature (T_s)

The switch temperature is the temperature at which the resistance R_s is equal to twice the minimum resistance R_{min} (see Fig.14), so at $T_s > T_{Rmin}$, $R_s = 2\ R_{min}$.

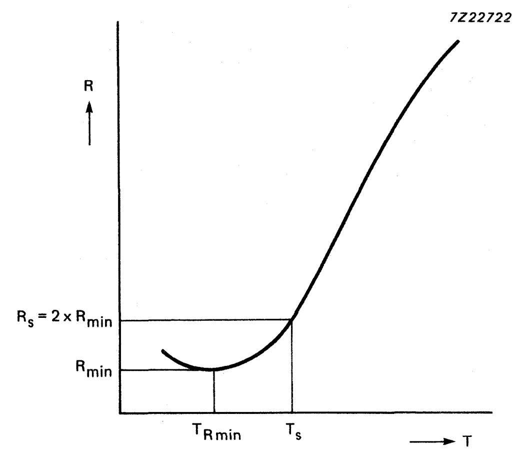


Fig.14 Switch temperature.

Temperature coefficient (α)

The temperature coefficient $\alpha = \frac{1}{R}\ \frac{dR}{dT}$

For R-T curves plotted on a log R-T scale:

$$\alpha = \frac{d\ \ln R}{dT} = \frac{1}{0.4343} \cdot \frac{d\ \log R}{dT}$$

In the data sheets, the maximum temperature coefficient (α) is given; this is measured at the point of inflection of the log R-lin T characteristic, i.e. the point where $d^2 \log R/dT^2 = 0$ (see Fig.15).

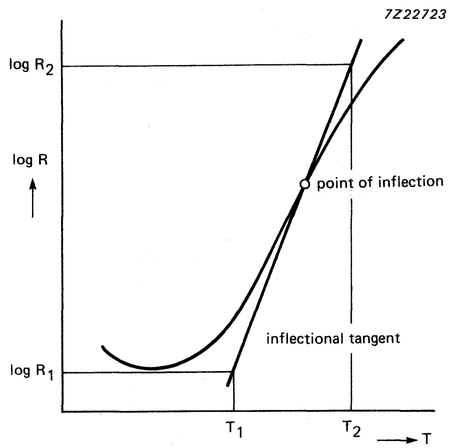


Fig.15 Temperature coefficient.

When one resistance decade is taken ($R_2 = 10\ R_1$), the formula becomes:

$$\alpha = \frac{100}{0.4343} \times \frac{1}{T_2 - T_1} \ \%/K$$

Trip time

The trip, or response time is defined as the time taken for the PTC thermistor to reach its switching temperature at a constant voltage. This time period is also equal to the time taken for the current to be reduced by a factor of 2.
The trip time (t_s) can be calculated using the formula:

$$t_s = \frac{h \,.\, v \,.\, (T_s - T_{amb})}{I_t^2 \,.\, R - D(T_s - T_{amb})}$$

where:

- v is the volume of the ceramic in mm^3
- $R = (R_{25} + R_{min})/2$
- I_t is the trip current
- the specific heat of the ceramic $h = 2.5 \times 10^{-3}$ $J/^oC/mm^3$

Thermal time constant (τ)

The thermal time constant is the time required for a thermistor to convert 63.2% of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero power conditions.

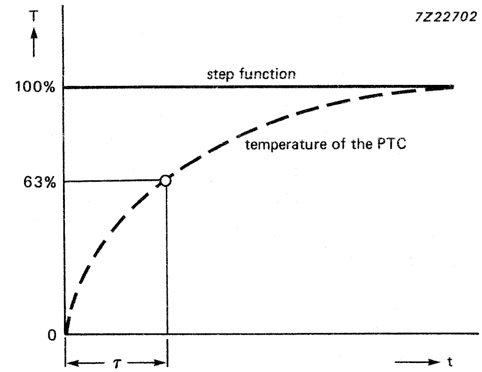


Fig.16 Thermal time constant.

Voltage dependence (VDR effect)

PTC thermistors exhibit voltage dependence. The higher the voltage applied, the more the R/T curve deviates from the R/T characteristic at 'zero voltage' (measured at a negligibly small voltage). This voltage dependancy can be demonstrated by applying a pulsed voltage to the thermistor and then measuring the R/T characteristic.

This effect can be explained with the aid of a parallel connection of an 'ideal PTC', having no voltage dependence, and an 'ideal VDR'.

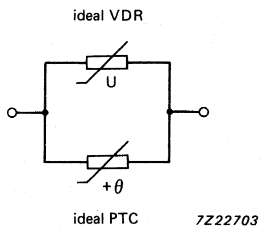


Fig.17 VDR effect.

Plotted on a log I — log V scale at an arbitrary constant temperature, the ideal PTC and the ideal VDR characteristics are straight lines (see Fig.18).

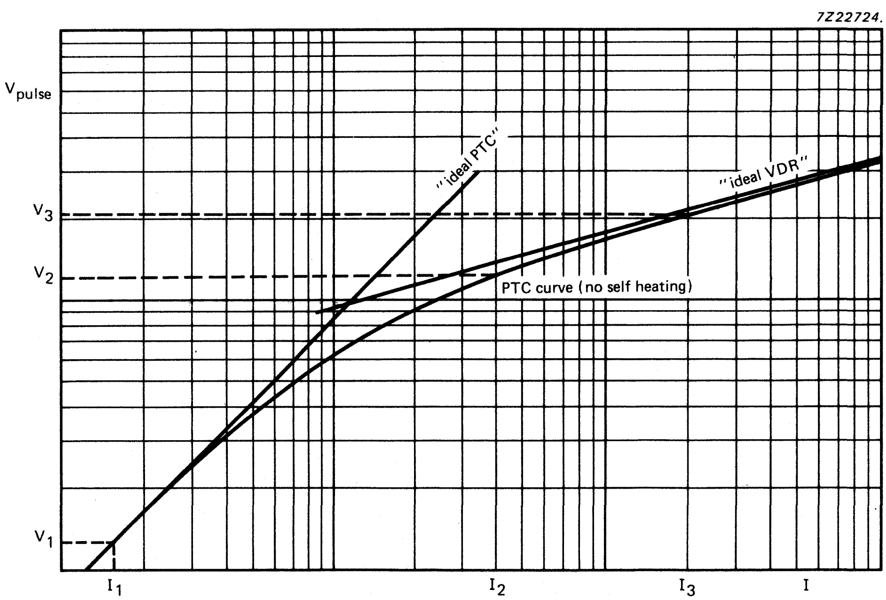


Fig.18 Relationship between an 'ideal PTC' and an 'ideal VDR'.

These lines coincide with the PTC curve (measured under pulse conditions to avoid internal heating) at low voltages where the ohmic behaviour is the deciding factor, and at high voltages where the VDR effect becomes more significant.

HOW TO MEASURE PTC THERMISTORS

Since PTC thermistors often exhibit a very high temperature coefficient, especially at high temperatures, measurement at high temperature must be carried out with particular care. Even an error of 0.1 K can give errors of a few percent in resistance value. Specially calibrated thermometers must be used. Stem correction must be applied – deviations of more than 0.1 K may result if it is not used.

The stem correction formula for fluid thermometers is:

$$T_c = T_o + F \,.\, L(T_o - T_m)$$

where:

T_c = corrected temperature
T_o = observed temperature
T_m = mean temperature of exposed stem
L = length of the exposed column in K above the surface of the substance whose temperature is being determined
F = correction factor.

F is approximately equal to 0.00016 for a mercury thermometer.

Example

If T_o = 110 °C, T_m = 70 °C, and L = 50 K, substitution in the above formula will give the result, T_c = 110.32 °C.

Without stem correction, an error of more than 0.3 K would have been made.

Note: The resistance should be measured using a voltage of less than 2 V, in order to ensure that the PTC is not heated, and also to diminish voltage dependent effects.

Tolerances

The resistances of standard PTC thermistors are generally specified at

a. 25 °C
b. a temperature having a greater value than the switch temperature.

The switch temperature is quoted in the relevant data sheets.

For each standard type, tolerances are specified for R_{25} and the high temperature resistance. The tolerance on switch temperature is not specified; normally it is only a few K.

Special types are often specified in accordance with the requirements for the particular application. For example, PTC's for motor control may be specified at a high temperature with a close tolerance, whilst the tolerance below the switch temperature, being of less importance, is much greater. PTC thermistors for current limiting applications are, in most instances, specified in terms of current and voltage.

IMPORTANT NOTES:

– the specification and tolerances of PTC thermistors depend to a great extent upon the application in which the device is to be used. They are not limited to the standard range detailed in this handbook.
– IF SPECIAL PTC CHARACTERISTICS ARE REQUIRED WHICH CANNOT BE FOUND IN THIS HANDBOOK, CONSULT THE MANUFACTURER SINCE REQUIREMENTS MAY BE FULFILLED BY A NON LISTED DEVICE.

APPLICATIONS

The applications for PTC thermistors can be divided into three main categories:

1. degaussing
2. temperature protection and sensing
3. overload (current sensitive action)

These applications are based on two principles:

a. applications where the temperature (hence the resistance) is primarily determined by the current flowing through the thermistor

b. applications where the temperature is primarily determined by the temperature of the ambient medium.

CAUTIONS

DO NOT APPLY A VOLTAGE ABOVE V_{MAX} TO THE PTC SINCE THIS MAY DESTROY THE THERMISTOR.

DO NOT CONNECT PTC THERMISTORS IN SERIES TO OBTAIN HIGHER VOLTAGES OR WATTAGES, SINCE THIS MAY CAUSE AN INDIVIDUAL PTC TO HEAT UP FASTER THAN THE OTHER(S), RESULTING IN TOO HIGH A VOLTAGE ACROSS THE PTC IN QUESTION.

GENERAL

High picture quality, and colour purity have been the goals of television manufacturers for many years. Today, with recent developments in large flatscreen televisions and high definition colour monitors, achieving those goals has become essential. One area of possible improvements is in degaussing the tube. By using our dual PTC thermistor in the degaussing circuit, a significant improvement of picture quality can be achieved.

In addition to a steadily decaying current through the degaussing coil at switch on, the two main requirements for degaussing colour televisions and monitors are:

- high inrush current, into the degaussing coil
- low residual current, after degaussing

The larger the ratio of inrush current to residual current (degaussing ratio) the better the degaussing. Our 662 96022 dual PTC, for example, has a degaussing ratio of 10000, resulting in excellent inrush current with a residual current of less than 1 mA peak to peak. This is achieved by careful manufacture, optimal matching, and intimate thermal contact between the two PTC thermistors in their dual arrangements. As inventors and world leaders in dual PTC thermistors, we have perfected their manufacture and offer a proven range and capability to cover all requirements.

What is degaussing ?

To minimize picture distortion and beam landing error (colour impurity), the shadow mask, and associated metal parts of the tube, must be demagnetized at switch on. This is done by passing decaying AC through the degaussing coil. An alternating magnetic field is generated, which gradually decays to demagnetize the tube.

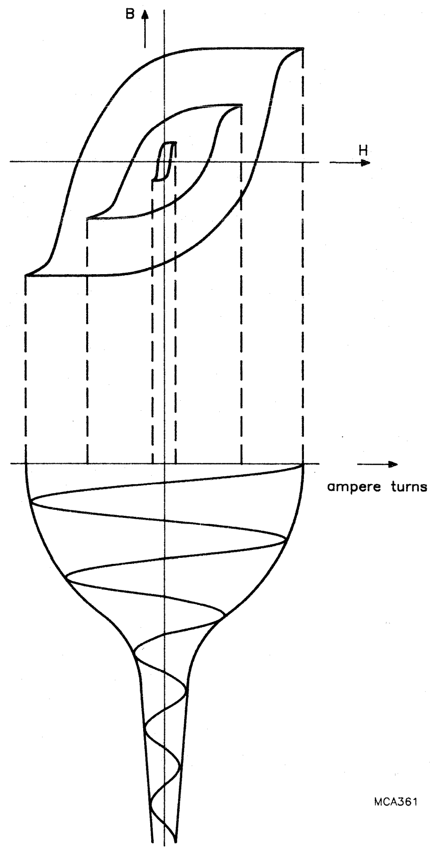


Fig.1 Typical BH curve of shadow mask and corresponding ampere-turns in the degaussing coil.

Connecting a PTC thermistor (mono PTC) in series with the AC mains and degaussing coil is the simplest method of producing the required decaying current. At switch on, the PTC thermistor is cold and has low resistance, so a large inrush current (I_{INR}) flows through the degaussing coil. As both the temperature, and therefore the resistance of the PTC thermistor increase, the current and magnetic field decay. The PTC temperature stabilizes after a few minutes, leaving a small alternating residual current (I_{RES}) flowing through the degaussing coil.

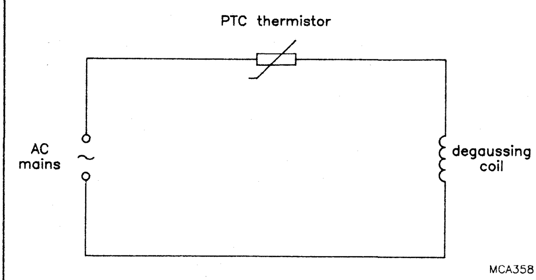


Fig.2 Mono PTC arrangement.

Dual PTC thermistors

To avoid picture distortion with large-screen televisions and high-resolution colour monitors, it is crucial that the residual current, and hence the residual magnetic field, be as low as possible. A dual PTC thermistor in the degaussing circuit achieves this.

The degaussing PTC is in series with the degaussing coil. The heater PTC, with a higher R_{25} resistance (resistance at 25 °C), is in parallel with the mains supply. At switch on, the inrush current through the degaussing coil is high, raising the temperature and resistance of the degaussing PTC. The temperature of the heater PTC also increases and its heat is dissipated towards the degaussing PTC. This further increases the degaussing PTC resistance, so further reducing the residual current. To maximize this heating effect, and thereby minimize the residual current, we carefully match the two thermistors and clamp them in close thermal contact inside a PBTP (polybutyleneteraphthalate) housing.

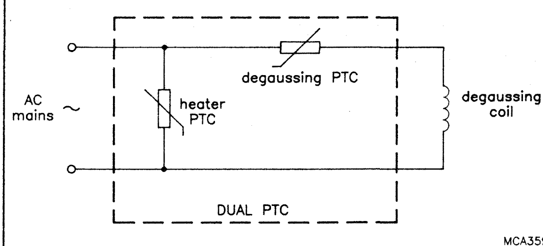
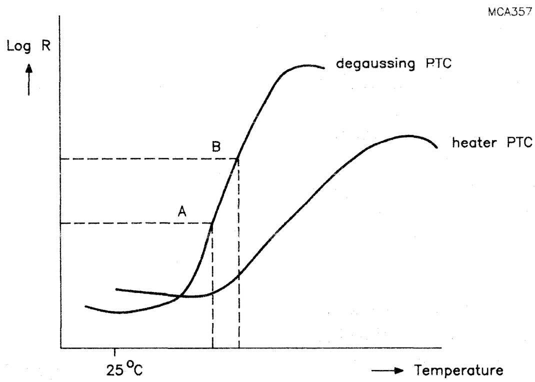


Fig.3 Dual PTC arrangement.



Resistance stabilizes at point A without the heater PTC and at point B with the heater PTC.

Fig.4 Typical RT characteristics for a PTC.

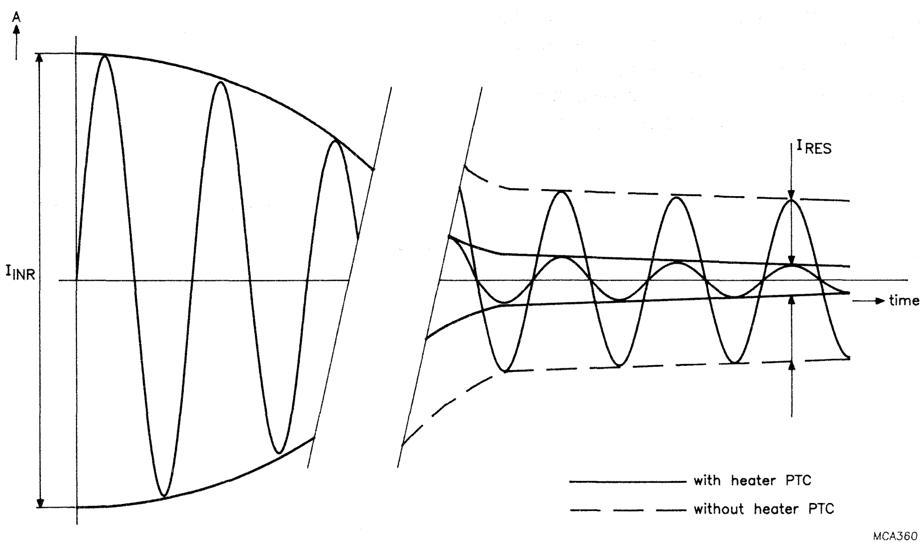


Fig.5 By using a dual PTC thermistor, I_{RES} is significantly reduced.

PTC thermistors for degaussing — 2322 662 96...

FEATURES

- Residual currents as low as 1 mA, ideal for high-resolution displays
- High inrush currents into the degaussing coil
- High-speed degaussing
- Long delay time
- Stable performance over a long time
- Non-flammable (UL 94.V.0)
- Customization by agreement.

APPLICATIONS

- Colour televisions
- Colour monitors.

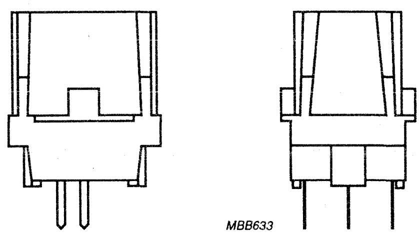


Fig.1 Component outline.

DESCRIPTION

For good picture definition, televisions and colour monitors must be degaussed by a strong alternating magnetic field which gradually and symmetrically decays to a small value of residual current. This can be achieved by connecting a PTC thermistor in the degaussing circuit.

The new generation of flat-screen, high-definition televisions and colour monitors require an excellent picture quality with high colour purity. This can only be achieved by a dual PTC device housing two PTC thermistors in intimate thermal contact, one being used to heat the other and so further reduce the residual current.

CAPABILITY

For 145 V devices, minimum peak-to-peak inrush current is 60 A, depending on type.

For 265 V devices, minimum peak-to-peak inrush current is 40 A, depending on type.

PACKING

The thermistors are supplied in cardboard boxes, each box containing 600 items.

MARKING

The thermistors are marked with the following information:

- The last five numbers of the code numbers
- Manufacturer's code of identification
- Date of manufacture (4 figures denoting year and week number).

MECHANICAL DATA

PARAMETER	CONDITIONS
Solderability	max. 240 °C, max. 4 s
Resistance to heat	max. 265 °C, max. 11 s
Operating temperatue range at zero power at maximum voltage	 −25 to 125 °C 0 to 60 °C
Impact	free fall 1 m

ELECTRICAL DATA

Table 1 Survey of types

CODE NUMBERS	MAX. RMS VOLTAGE (V)	MIN. PEAK-TO-PEAK INRUSH CURRENT AT 220 V_{rms} (A)	MAX. PEAK-TO-PEAK RESIDUAL CURRENT (mA)	R_s at 25 °C (Ω)	COIL RESISTANCE (Ω)
2322 662 96125	145	16 (note 1)	7	8	9
2322 662 96013	145	20 (note 1)	10	8	6.2
2322 662 96011	145/265	7.2 (note 1) /13	4	30	17
2322 662 96111	145/265	7.2 (note 1) /13	4	30	17
2322 662 96026	145/276	7.2 (note 1) /13	4	30	17
2322 662 96123	245	16.2	6 (note 2)	18	14
2322 662 96012	265	11.6	11.6	36	15.5
2322 662 96024	265	10	4	32	17-25
2322 662 96009	265	10	4	32	17-25
2322 662 96022	265	12	4	38	17-25
2322 662 96016	265	12	6	25	25
2322 662 96116	265	12	6	24	25
2322 662 96124	270	20	15	20	10
2322 662 96126	270	20	5	18	13

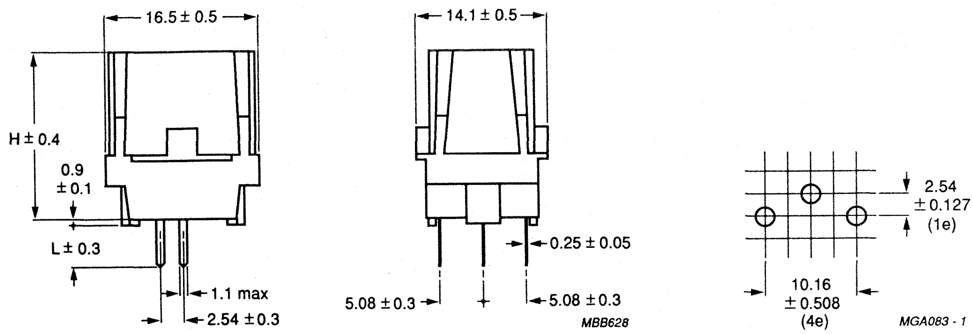
Notes

R_p = 3 000 Ω ±75%, except for 2322 662 96012; NTC 130 Ω ±25%.

1. Measured at 120 V.
2. Measured at 190 V.

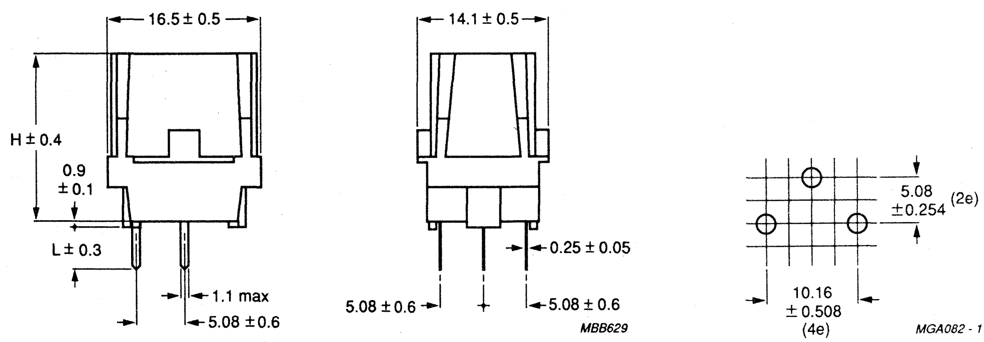
DUAL PTC PIN CONFIGURATION

Tenth digit: 0 and 1 = 4e/1e pitch and L = 3.5 mm
0 becomes 4 for 4e/2e pitch and L = 5.5 mm
1 becomes 5 for 4e/2e pitch and L = 5.5 mm
0 and 4; H = 18.4 mm
1 and 5; H = 20.4 mm.



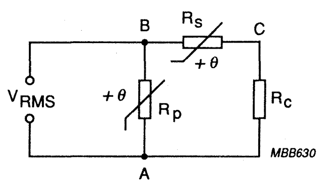
Dimensions in mm.

Fig.2 Dual PTC pin configuration 4e/1e pitch.



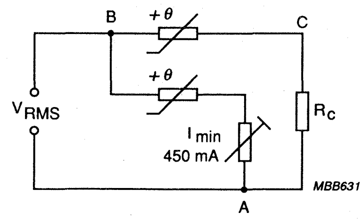
Dimensions in mm.

Fig.3 Dual PTC pin configuration 4e/2e pitch.



R_s = series PTC.
R_p = parallel PTC.
R_c replaces the degaussing coil (Z = 25 Ω).

Fig.4 Measuring circuit.



T_{amb} = 25 °C.
AB = NTC.
BC = PTC.
R_c replaces the degaussing coil (Z = 18.9 Ω).

Fig.5 Measuring circuit for 2322 662 96012 only.

PTC Thermistors

Introduction to PTC temperature protection and sensing

GENERAL

NTC thermistors are well known for temperature sensing. What is not well known, however, is that PTC (positive temperature coefficient) thermistors can be used for temperature protection. Although their operating principles are similar, the applications are very different; whereas NTC thermistors sense and measure temperature over a defined range, PTC thermistors trip at one particular temperature. Just like thermostats they protect such equipment as motors, transformers, power transistors and thyristors against overtemperature. A PTC thermistor is less expensive than a thermostat, and its trip temperature can be more accurately specified. It is also smaller and easier to design-in to electronic circuitry.

So how does it work ? The PTC thermistor is mounted in thermal contact with the equipment to be protected, and connected into the bridge arm of a comparator circuit, such as shown in Fig.1. At normal temperature, the PTC thermistors resistance (R_p) is lower than R_s (Fig.2), so the comparator's output voltage V_{out} will be low. If an equipment overtemperature occurs, the PTC thermistor will quickly heat up to its switch temperature T_s, whereupon its resistance will switch to a value much higher than R_s (Fig.2), causing V_{out} to increase to a level sufficient to activate a trip or alarm.

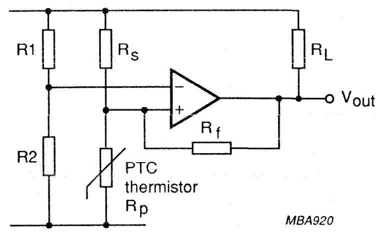


Fig.1 Typical comparator circuit.

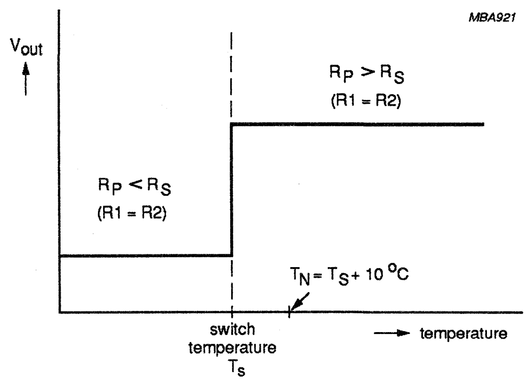


Fig.2 Typical characteristic.

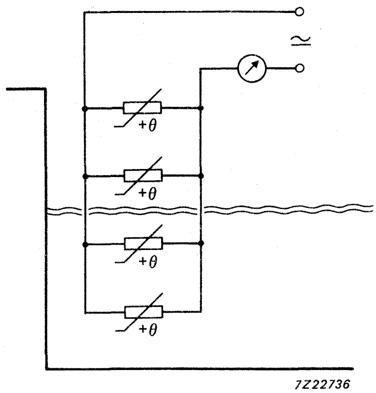
FEATURES

- Well-defined protection temperature levels
- Very fast reaction time
- Accurate resistance for ease of circuit design
- Stable over a long life
- Wide range of protection temperatures
- No need to reset supply after overtemperature trip
- Small size and rugged
- Naked and leaded devices available
- High voltage insulation and excellent thermal coupling.

APPLICATIONS

- Industrial electronics
- Power supplies
- Electronic data processing.

APPLICATION EXAMPLES



The PTC thermistors located above the fluid level will be heated to a temperature greater than T_{switch}. When immersed they are cooled such that their resistance value is reduced.

Fig.3 Liquid-level indication.

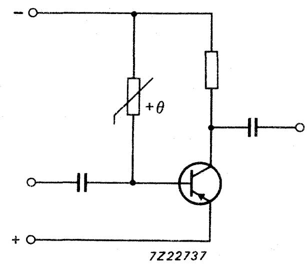
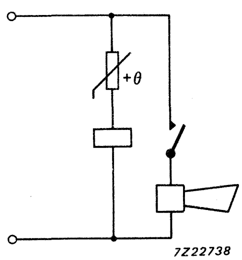
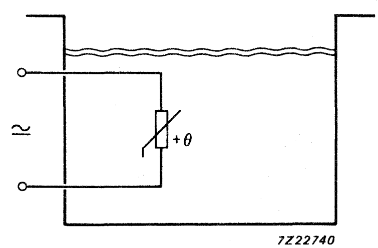


Fig.4 Temperature compensation of transistor circuits.



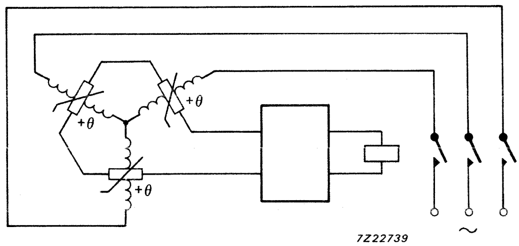
The PTC reacts to ambient temperature (too low or too high).

Fig.5 Alarm installation.



The PTC thermistor acts as a control element and heater at the same time.

Fig.6 Thermostatically controlled heating circuit.



As soon as one or more of the windings becomes too hot, the motor is switched off.

Fig.7 Temperature protection of electric motors.

PTC thermistor for temperature protection | 2322 671 91...

FEATURES

- Very fast action for maximum protection
- Well defined protection levels
- Well defined resistance for ease of circuit design
- Coated and leaded devices available
- High sensitivity to small temperature changes
- Excellent long term behaviour.

APPLICATIONS

- Industrial electronics
- Power supplies
- Electronic data processing.

DESCRIPTION

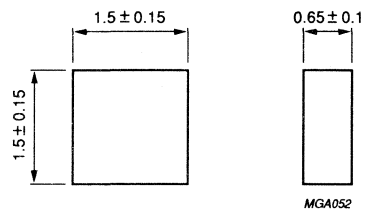
These directly heated thermistors have a positive temperature coefficient and are primarily intended for sensing.

QUICK REFERENCE DATA

Maximum resistance at 25 °C	120 Ω
Minimum resistance at (T_n +15) °C and 7.5 V_{pulse}	4000 Ω
Maximum voltage	30 V (DC)
Rated temperature range	0 to (T_n +15) °C
Weight (approx.) 91052 to 91067 91002 to 91017 91102 to 91114	 0.008 g 0.013 g 0.08 g
Climatic category	25/125/56

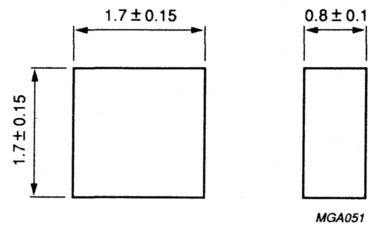
PACKAGING INFORMATION

CODE NUMBERS	PACKAGING	
	S.P.Q.	P.Q.
2322 671 91052 to 91067	5000	50000
2322 671 91002 to 91017	5000	50000
2322 671 91102 to 91114	500	5000



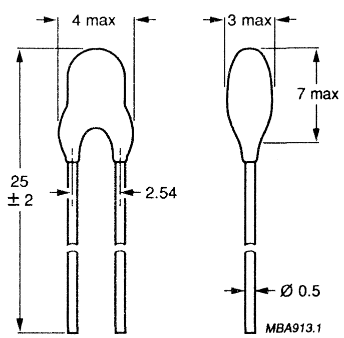
Dimensions in mm.

Fig.1 Component outline for 91052 to 91067



Dimensions in mm.

Fig.2 Component outline for 91002 to 91017



Dimensions in mm.

Fig.3 Component outline for 91102 to 91114

PTC thermistor for temperature protection | 2322 671 91...

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS
Maximum resistance at 25 °C	120 Ω
Maximum resistance at (T_n −5) °C 91052 to 91067 91002 to 91017 91102 to 91114	 see Table 1 see Table 2 see Table 3
Minimum resistance at (T_n +15) °C and 7.5 V_{pulse}	4000 Ω
Minimum resistance at (T_n +5) °C 91052 to 91067 91002 to 91017 91102 to 91114	 see Table 1 see Table 2 see Table 3
Maximum voltage	30 V (DC)

ELECTRICAL DATA

Table 1 91052 to 91067 (square chips 1.5 × 1.5 mm)

CODE NUMBERS	T_s (note 1)	T_n (T_s +10) °C	$R_{max.}$ at (T_n −5) °C (ohm)	$R_{min.}$ at (T_n +5) °C (ohm)
2322 671 91052	60	70	570	570
2322 671 91053	70	80	550	1330
2322 671 91054	80	90	550	1330
2322 671 91055	90	100	550	1330
2322 671 91056	100	110	550	1330
2322 671 91057	110	120	550	1330
2322 671 91058	115	125	550	1330
2322 671 91059	120	130	550	1330
2322 671 91061	125	135	550	1330
2322 671 91062	130	140	550	1330
2322 671 91063	135	145	550	1330
2322 671 91064	140	150	550	1330
2322 671 91065	145	155	550	1330
2322 671 91066	150	160	550	1330
2322 671 91067	160	170	550	1330

Note

1. For information only.

ELECTRICAL DATA

Table 2 91002 to 91017 (square chips 1.7 × 1.7 mm)

CODE NUMBERS	T_s (note 1)	T_n (T_s +10) °C	$R_{max.}$ at (T_n −5) °C (ohm)	$R_{min.}$ at (T_n +5) °C (ohm)
2322 671 91002	60	70	570	570
2322 671 91003	70	80	550	1330
2322 671 91004	80	90	550	1330
2322 671 91005	90	100	550	1330
2322 671 91006	100	110	550	1330
2322 671 91007	110	120	550	1330
2322 671 91009	120	130	550	1330
2322 671 91012	130	140	550	1330
2322 671 91014	140	150	550	1330
2322 671 91017	160	170	550	1330

Note

1. For information only.

ELECTRICAL DATA

Table 3 91102 to 91114 (leaded parts)

CODE NUMBERS	T_s (note 1)	T_n (T_s +10) °C	$R_{max.}$ at (T_n −5) °C (ohm)	$R_{min.}$ at (T_n +5) °C (ohm)
2322 671 91102	60	70	570	570
2322 671 91103	70	80	550	1330
2322 671 91104	80	90	550	1330
2322 671 91105	90	100	550	1330
2322 671 91106	100	110	550	1330
2322 671 91107	110	120	550	1330
2322 671 91109	120	130	550	1330
2322 671 91112	130	140	550	1330
2322 671 91114	140	150	550	1330

Note

1. For information only.

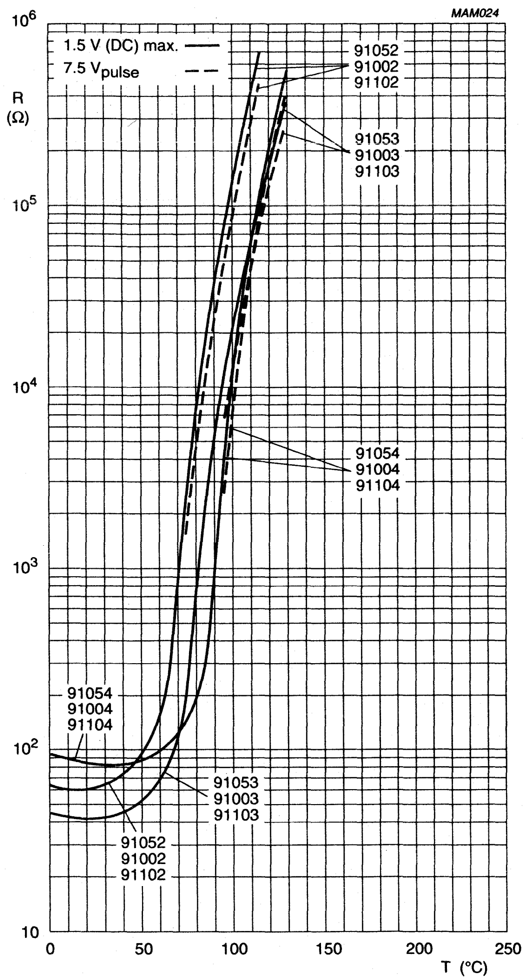


Fig.4 Typical resistance/temperature characteristic for 2322 671 91052/002/102, 91053/003/103 and 91054/004/104

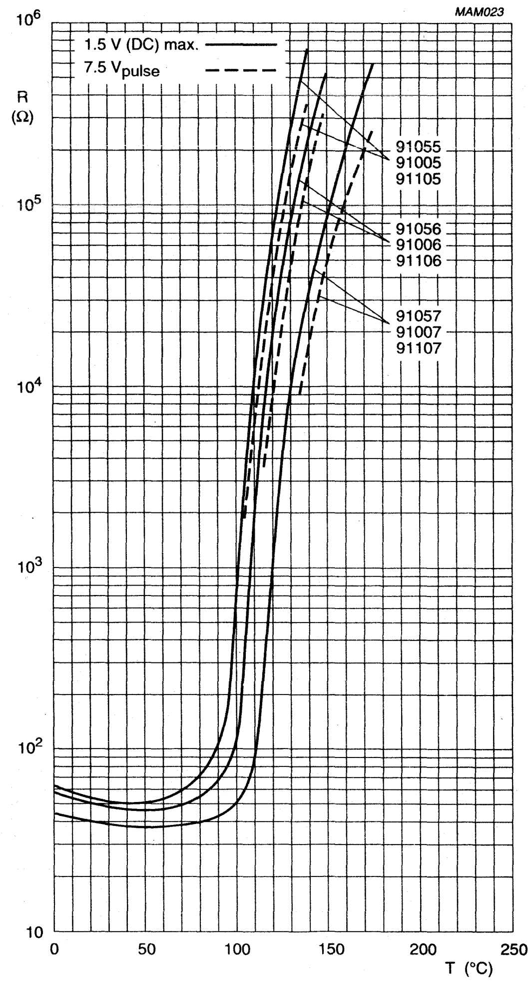


Fig.5 Typical resistance/temperature characteristic for 2322 671 91055/005/105, 91056/006/106 and 91057/007/107

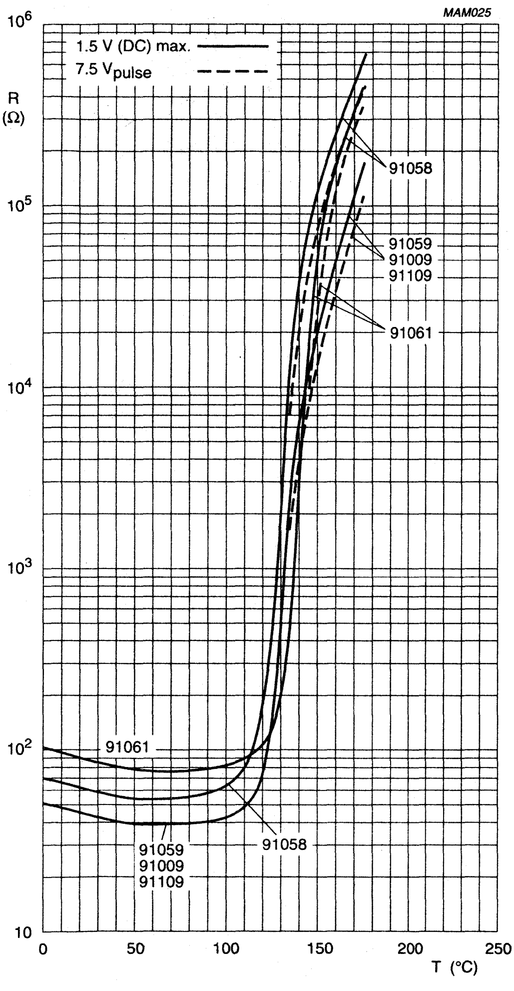


Fig.6 Typical resistance/temperature characteristic for 2322 671 91058, 91059/009/109 and 91061

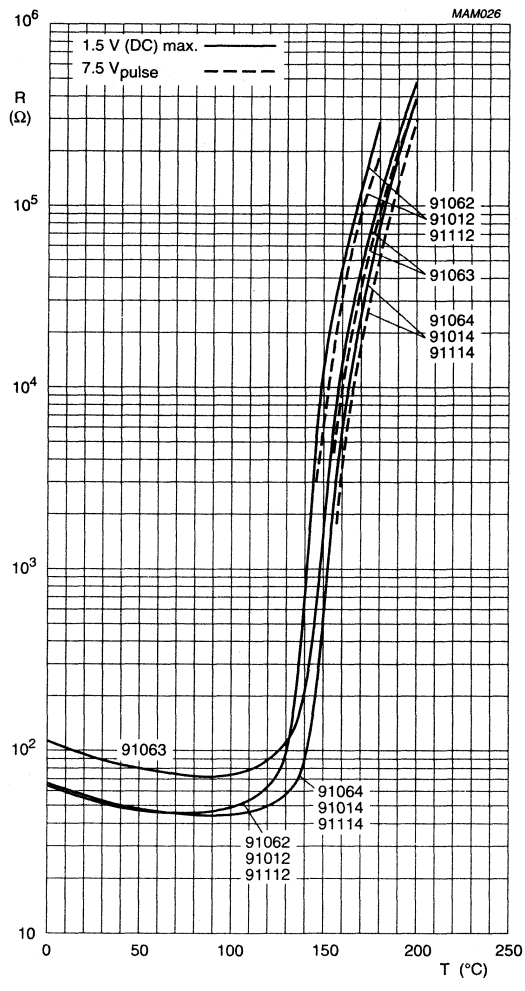


Fig.7 Typical resistance/temperature characteristic for 2322 671 91062/012/112, 91063 and 91064/014/114

PTC thermistor for temperature protection

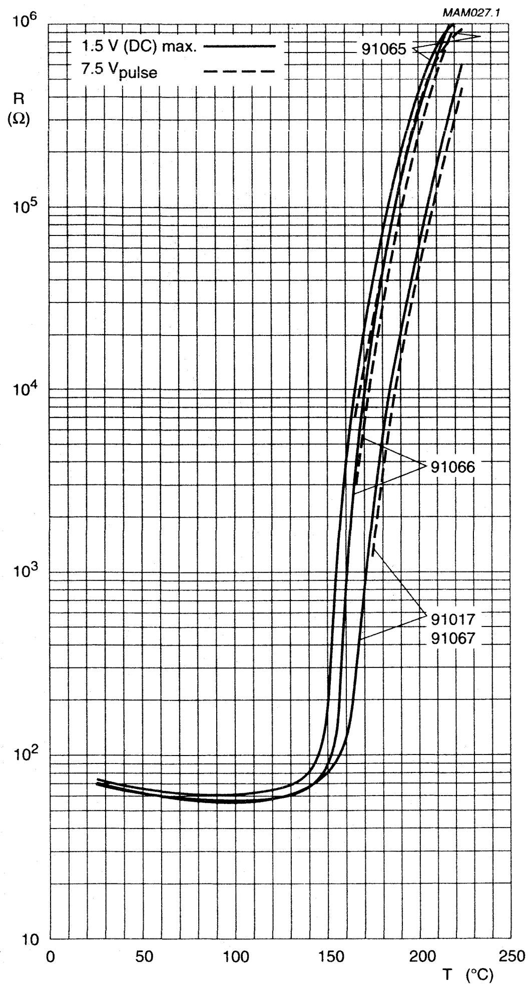


Fig.8 Typical resistance/temperature characteristic for 2322 671 91017, 91065, 91066 and 91067

TEST AND REQUIREMENTS

Note 1

Clause numbers of tests and performance requirements refer to the CECC draft secretariat 2371 (Jan. 1989).

Note 2

AQLs are selected from IEC Publication 410:

Note 3

Tables with requirements for lot by lot and periodic tests. In these tables:

D = Destructive
ND = Non-destructive

Note 4

Leads should neither come loose or break.

CLAUSE NUMBER AND TEST	D OR ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Group A inspection (lot by lot)			
Sub-group A1	ND		
4.3.1. Visual examination			no defect likely to impair function
4.3.3. Dimensions (gauging)			as specified
Sub-group A2	ND		
4.4. Zero power resistance		temperature: 25 °C (T_n −5) °C (T_n +5) °C (T_n +15) °C and 7.5 V_{pulse}	120 Ω max. as specified as specified 4000 Ω min.

CLAUSE NUMBER AND TEST	D OR ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Group B inspection (lot by lot)			
Sub-group B1	D		
4.13.1. Soldering, solderability		for 91052 to 91067 and 91002 to 91017: solder bath: 60/40, 260 ±5 °C + RMA flux duration: 30 s	75% of surface covered with solder
		for 91102 to 91114 and 91202 to 91207: solder bath method: 235 ±5 °C	the terminations shall be evenly tinned

CLAUSE NUMBER AND TEST	D OR ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Group C inspection (periodic)			
Sub-group C1	D		
4.12. Robustness of terminations		for 91102 to 91114 test Ua: 10N and Ub: 5N of IEC 68-2-21 visual examination zero power resistance at 25 °C	 as in 4.12.4. ΔR/R: ±10% max.
4.13.2. Soldering resistance to soldering heat		for 91102 to 91114 test Tb of IEC 68-2-20A visual examination zero power resistance at 25 °C	 as in 4.13.2.3 ΔR/R: ±10% max.
4.14. Rapid change of temperature		for 91052 to 91067, 91002 to 91017 and 91102 to 91114: test Na of IEC 68-2-14 T_A: lower category temperature: –25 °C T_B: upper category temperature: 125 °C number of cycles: 5 visual examination zero power resistance at 25 °C	 as in 4.14.4. ΔR/R: ±10% max. 4.14.4. ΔR/R: ±10% max.
4.18. Climatic sequence Dry heat Damp heat, cyclic, first cycle Cold Damp heat, cyclic, remaining cycles Final measurements		low air pressure test not applicable visual examination zero power resistance at 25 °C	 as in 4.18.7.1. ΔR/R: ±10% max.
Sub-group C2	D		
4.20.3. Endurance at maximum rated temperature		duration: 24 h at (T_n +15) °C and 30 V (DC) examination: at 24 h visual examination zero power resistance at 25 °C	 as in 4.20.3.10. ΔR/R: ±10% max.
Sub-group C3	D		
4.19. Damp heat, steady state		visual examination zero power resistance at 25 °C	as in 4.19.5. ΔR/R: ±10% max.

CLAUSE NUMBER AND TEST	D OR ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Group C inspection (periodic)			
Sub-group C4	D		
4.20.2. Endurance at upper category temperatures		for 91002 to 91017 and 91052 to 91067: duration: 168 h at 200 °C for 91102 to 91114 duration; 168 h at 150 °C for 91002 to 91017, 91052 to 91067 and 91102 to 91114 duration: 1000 h at 125 °C examination: at 168 h, 500 h and 1000 h visual examination zero power resistance at 25 °C	 as in 4.20.2.7. ΔR/R: ±5% max.

PTC THERMISTORS

for motor temperature protection

QUICK REFERENCE DATA

Resistance value at −20 °C and (T_n −20 °C)	30 to 250 Ω
Resistance value at (T_n + 15 °C), V_{pulse} = 7,5 V	> 4000 Ω
Maximum voltage (DC)	15 V
Switch temperature, T_s	68 to 137 °C
Dissipation factor	7 mW/K approximately
Operating temperature range	
at zero power	−20 °C to (T_n +30 °C)
at V_{max}	−20 °C to (T_n + 15 °C)

APPLICATION

These thermistors have been designed for use in transistorized circuits for the protection of electric motors against overheating. They are to be built into the windings of the stator (one PTC thermistor per phase).

DESCRIPTION

The thermistors have a positive temperature coefficient. They consist of a disc with two tinned multi-strand copper wires insulated with PTFE material complying with the requirements of the ministry of aviation specification EL1930.

MECHANICAL DATA

Outlines

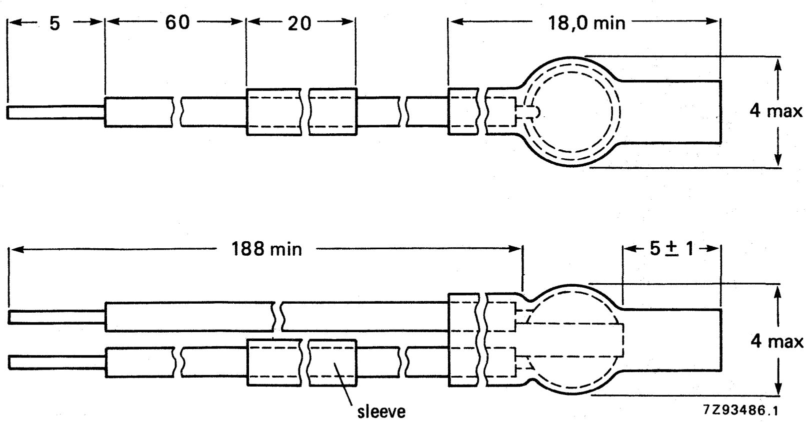


Fig. 1.

Marking The last five figures of the catalogue number are printed on the sleeve, e.g. PTC 92046.

Mass 1,6 g approximately.

Mounting In motor windings; connections to be soldered or clamped.

PACKAGING

200 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, all measurements are in accordance with IEC Publication 738-1 (1982).

T_n °C (note 1)	T_s °C	temperature coefficient %/K	catalogue number
80	68	18	2322 672 92045
90	75	21	92046
100	88	31	92047
110	99	33	92048
120	113	38	92049
130	123	27	92051
140	130	33	92052
150	137	33	92053

		notes
Resistance between −20 °C and (T_n −20 °C)	30 to 250 Ω	2
Resistance at T_n −5 °C	< 550 Ω	2
Resistance at T_n +5 °C	> 1330 Ω	
Resistance at T_n + 15 °C, V_{pulse} = 7,5 V	> 4000 Ω	3
Dissipation factor	7 mW/K approximately	4
Heat capacity	0,1 J/K approximately	4
Thermal time constant	14 s approximately	4
Response time	≤ 8 s	5
Operating temperature range		
at zero power	−20 °C to + (T_n +30 °C)	
at V_{max}	−20 °C to + (T_n + 15 °C)	
Maximum voltage (DC)	15 V	
Dielectric withstanding voltage (RMS) between terminals and lead insulation	≥ 2500 V	
Insulation resistance between terminals and lead insulation	≥ 100 MΩ	
Robustness of terminations		
tensile strength	10 N	
bending	5 N	
Soldering		
solderability	max. 240 °C, max. 4 s	
resistance to heat	max. 265 °C, max. 11 s	

Notes

1. T_n is the temperature at which the thermistor has to make the protective system operative.
2. Measuring voltage not exceeding 1,5 V (DC) to avoid internal heating.
3. Measurements made without internal heating occurring.
4. Measurements made with specimen in phosphor-bronze clips, in still air.
5. Response time is the time in which the thermistor-body temperature rises to 63,2% of the difference between initial and final body temperature, when the thermistor is subjected to a step function change in ambient temperature.
   Initial temperature: 25 °C (air).
   Final temperature: T_n + 15 °C (silicon oil MS 200/50).

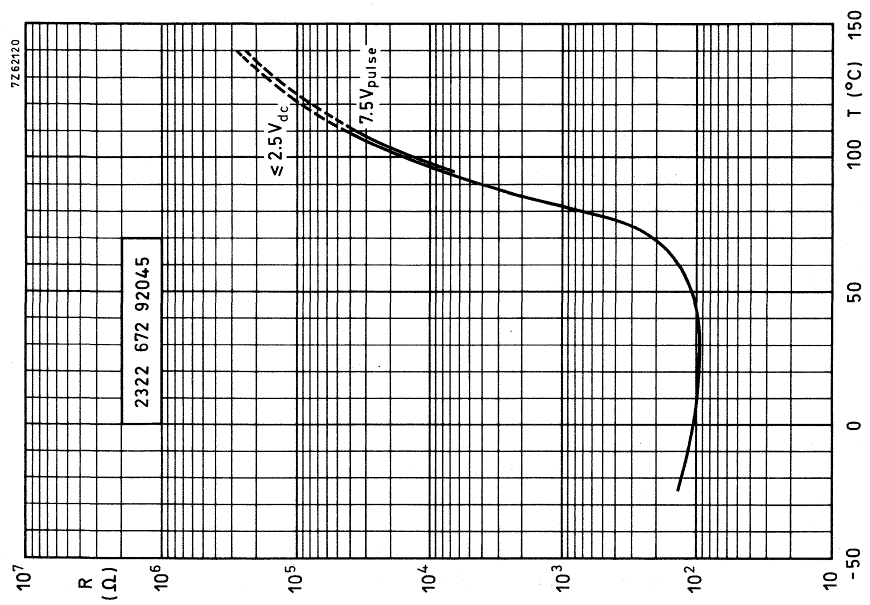


Fig. 2.

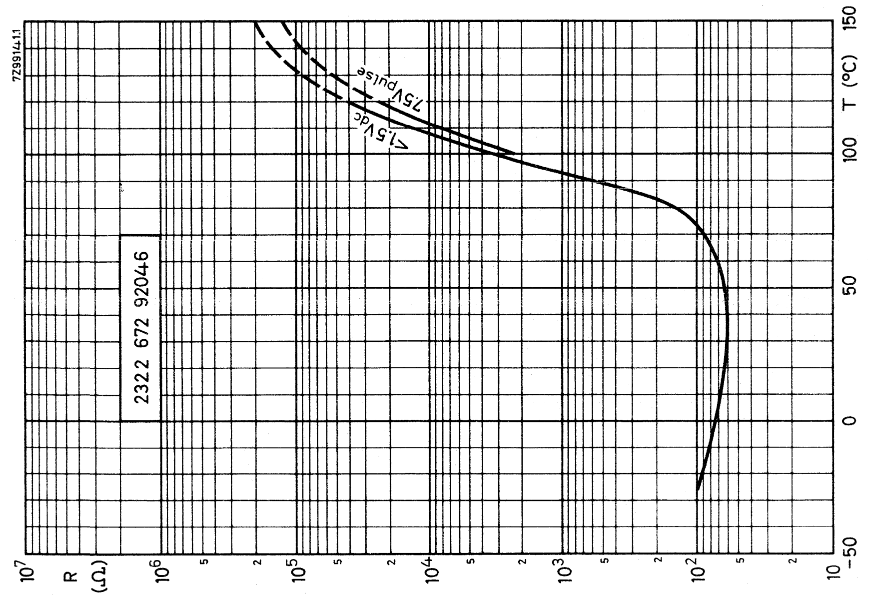


Fig. 3.

Typical resistance/temperature characteristics.

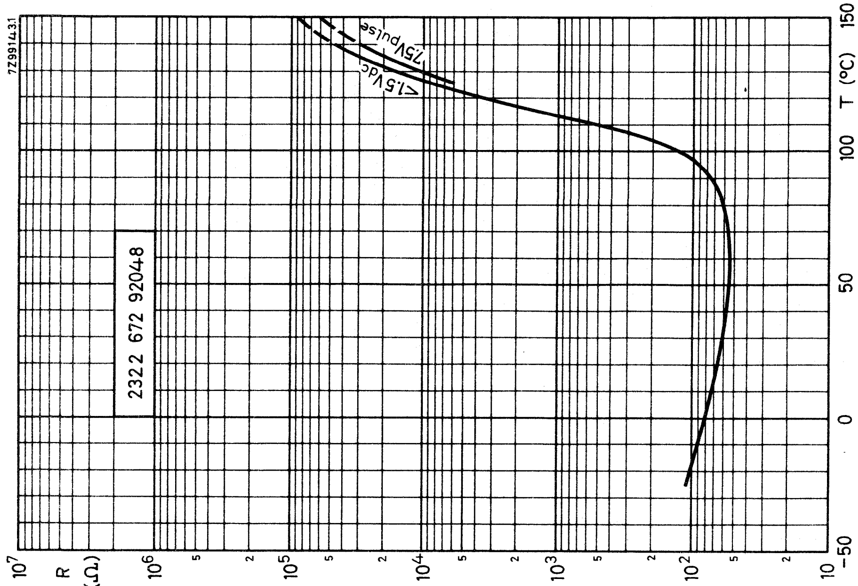


Fig. 5.

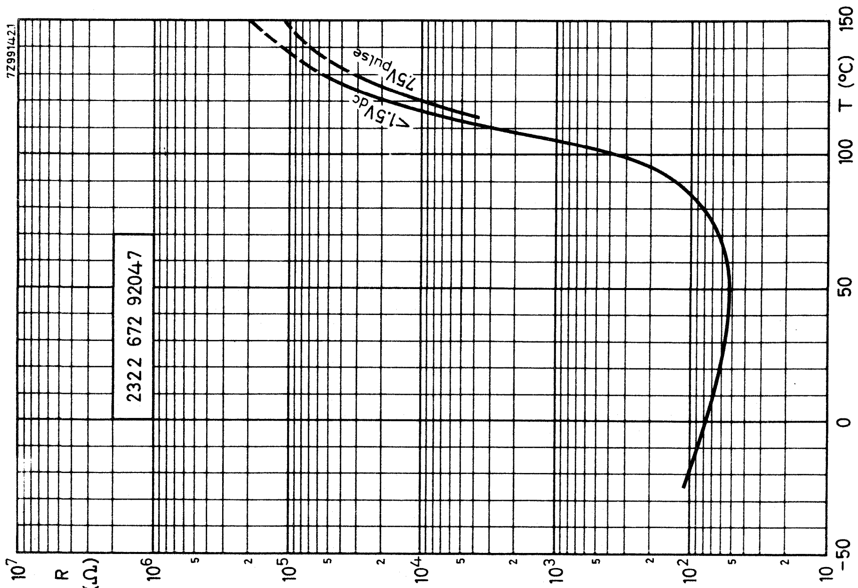


Fig. 4.

Typical resistance/temperature characteristics.

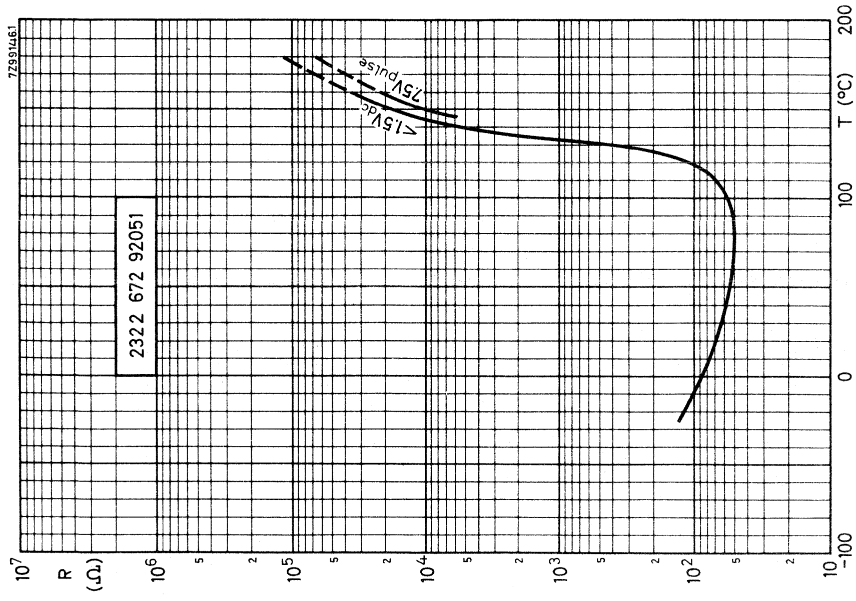


Fig. 7.

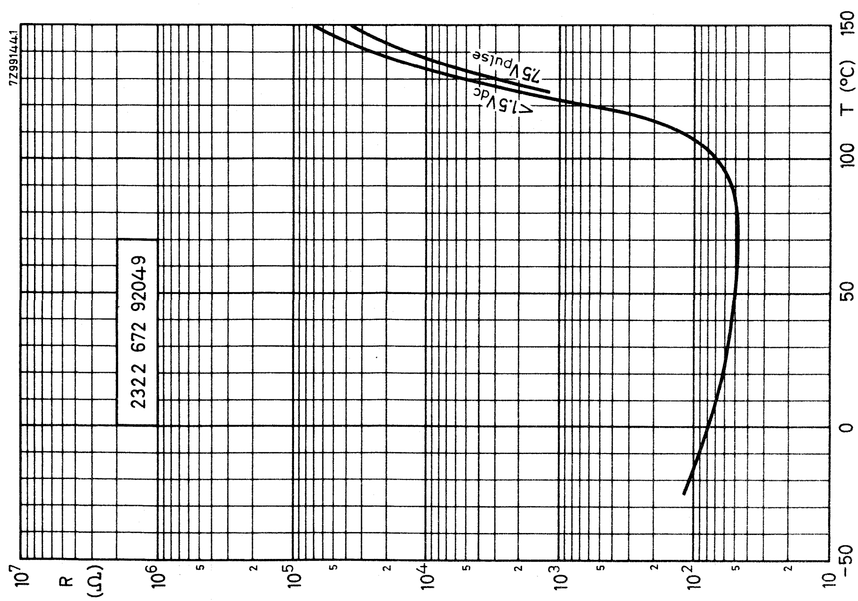


Fig. 6.

Typical resistance/temperature characteristics.

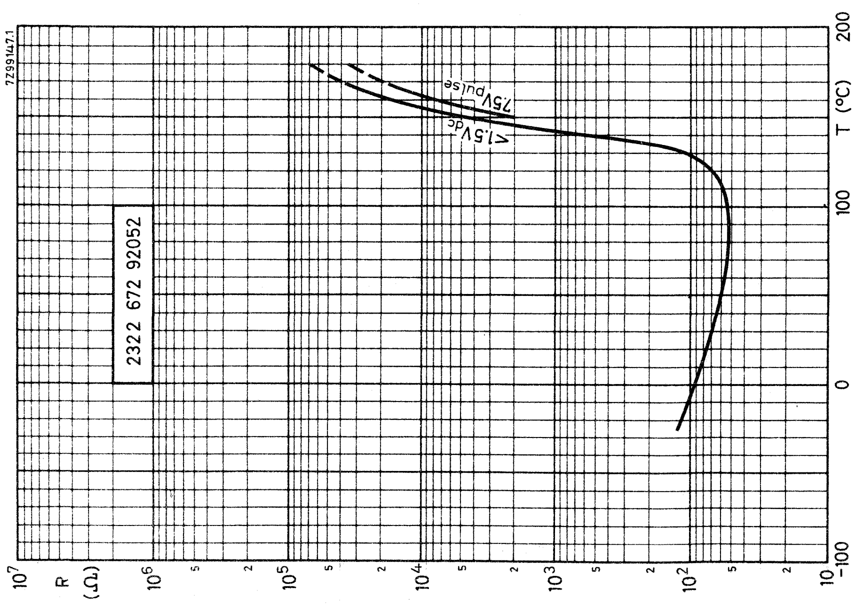


Fig. 8.

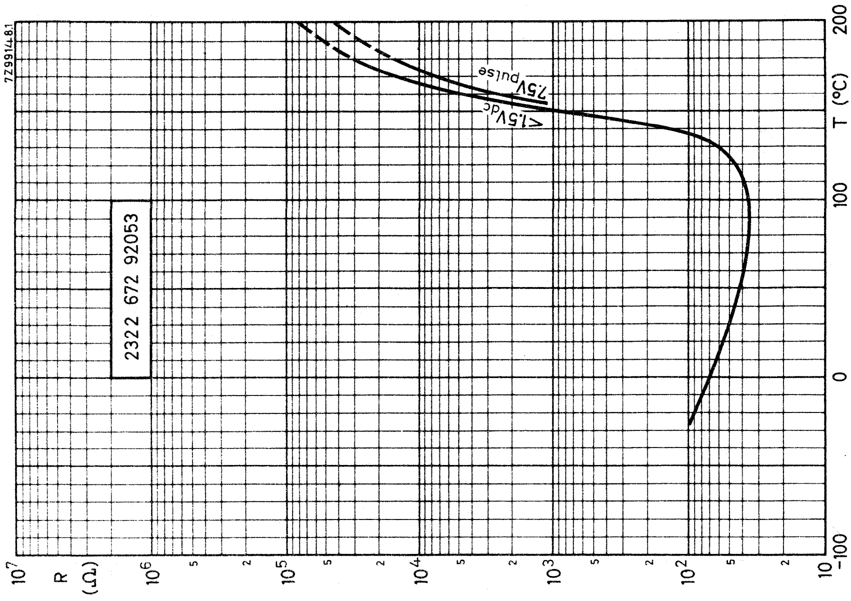


Fig. 9.

Typical resistance/temperature characteristics.

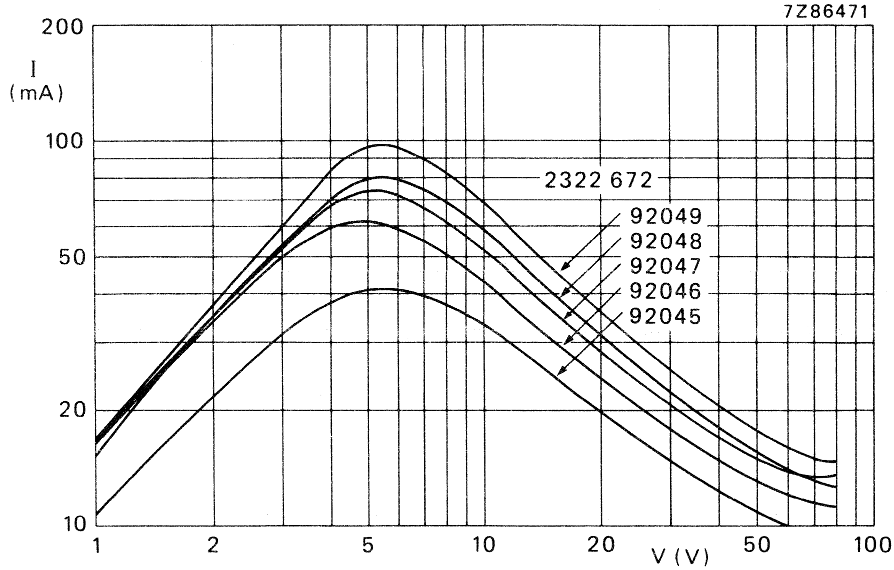


Fig. 10.

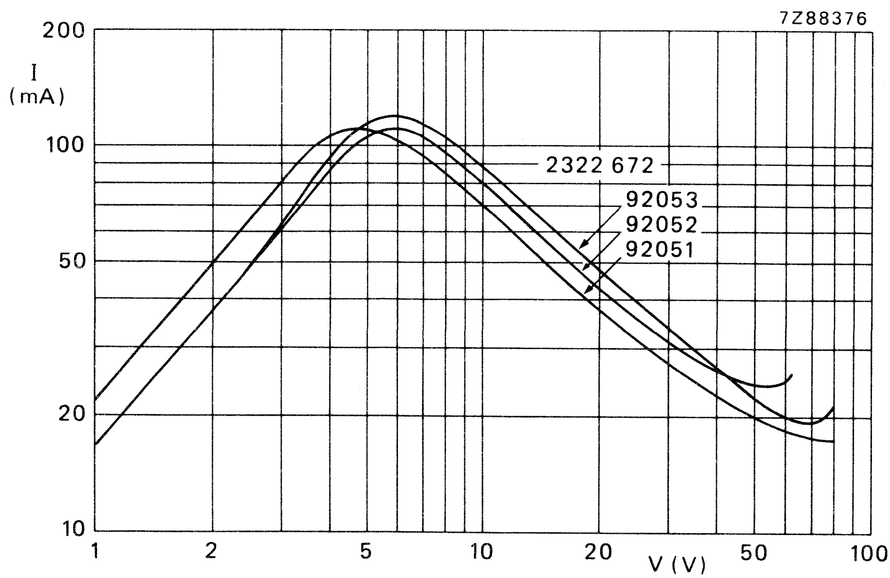


Fig. 11.

Typical voltage/current characteristics.

GENERAL

As market leaders in ceramics technology, Philips Components offer a comprehensive selection of thermistors. For overload protection of equipment such as motors, transformers, lamps, rechargeable batteries and power supplies, we offer a full range of PTC thermistors. They provide reliable protection time and time again, contrast this with a normal fuse, which is usually destroyed by the first overload.

Philips PTC thermistors have well-defined trip and non-trip currents and react quickly to overloads. Low, medium and high voltage ratings make them suitable for a wide range of applications, from low-voltage automotive systems to worldwide mains circuits. Selection is easy, simply choose the voltage rating and the required trip or non-trip current.

How PTC thermistors protect against overloads

When placed in series with the input of an electrical or electronic circuit (Fig.1), such as a small motor or power supply, a PTC thermistor acts as a non-destructive fuse, protecting the circuit against current, voltage and temperature overloads.

Normally the thermistors resistance is low (Fig.2), and the current is below its non-trip (I_{nt}) value. However, an overload will quickly heat up the PTC thermistor until, at around the switch temperature (T_s), its resistance becomes high, limiting the current to below its trip value (I_t), and so protecting the circuit.

Removing the overload or switching off the supply allows the PTC thermistor to cool down and return to its low-resistance state, ready to resume its protective function.

Fig.3 shows the PTC thermistors V/I characteristic (ABD) superimposed on the load-line (CD). The circuit will be designed such that, under normal conditions, the load-line (CD) lies below point B, the top of the thermistors V/I characteristic. Under this condition the PTC thermistors resistance is low, so most of the voltage (V) will appear across the load R_L1. Under an overload condition R_L2, the load-line (CD) will move above point B. The PTC thermistor will switch to its high-resistance state (BE) and the overload current will heat up the PTC thermistor to its overload working point (E). The PTC thermistor will therefore absorb the overload current and protect the load.

There are in fact, three overload possibilities:

1. Overcurrent (Fig. 3), where the load current increases due to a decrease in load resistance, for example when a motor winding goes short-circuit.
2. Overvoltage (Fig. 4), caused, for example, when the 220 V mains is accidentally applied to a 115 V mains appliance.
3. Overtemperature (Fig. 5), where the PTC thermistor is in intimate thermal contact with an overheating load ($T_{amb}2$). Here, due to external heating , the PTC thermistor needs less external energy to reach its switch point B, so B2 moves below the load-line CD.

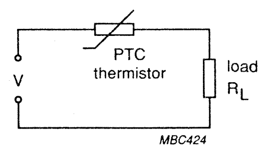


Fig.1 Typical circuit.

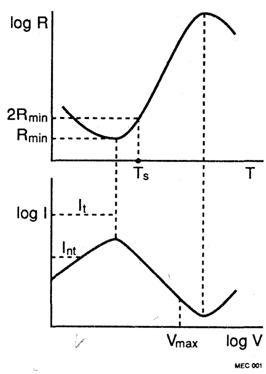


Fig.2 PTC thermistor characteristics.

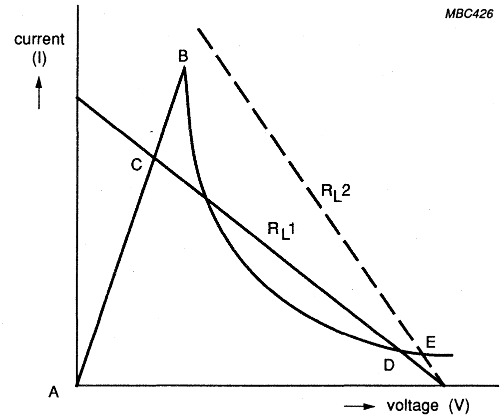


Fig.3 Overcurrent protection.

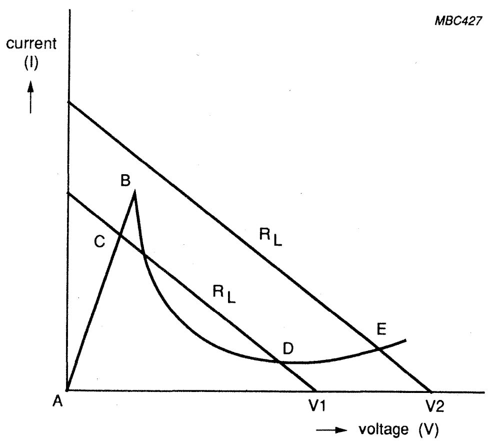


Fig.4 Overvoltage protection.

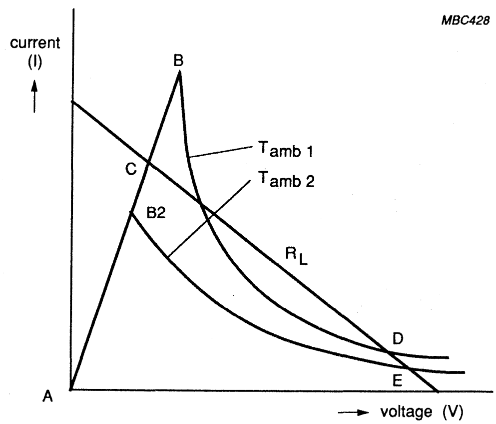


Fig.5 Overtemperature protection.

FEATURES

- Fast-acting for reliable protection time and time again
- Well-defined protection trip levels
- Low, medium and high voltage ratings
- No need to reset supply after overload
- Stable over a long life
- No current adjustment necessary
- No RF noise generated
- Small size
- Leadless and leaded versions available
- Customized design, particularly for telecommunication application.

APPLICATIONS

Applications are wide and varied, and include:

General industries

- Transformer protection
- Delay lines
- Rechargeable battery protection
- Protection of switched-mode power supplies
- Measuring equipment.

Automotive systems

- Wiper motors
- Gear boxes
- Air flow controls
- Window motor protection
- Car door lock defrosting systems.

Consumer electronics

- Loudspeaker boxes
- Video recorders, compact disk players and stereo equipment
- Electronic lighting ballast
- Colour televisions.

Domestic appliances

- Boiler protection
- Protection of shaver socket transformers
- Coffee grinders
- Hobby tools
- Ice makers
- Washing machines.

Telecommunications

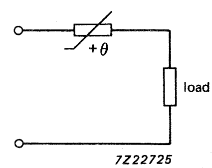
- Line protection
- Regulation of telephones, fax and modems
- Integrated service data network.

MECHANICAL OPTIONS

Philips PTC thermistors are available in the following versions:

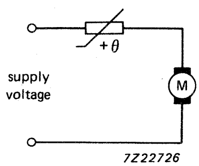
- Leadless discs, metallized for clamp-contacting
- Leaded devices, bulk-packed or taped on reel (suitable for automatic insertion).

APPLICATION EXAMPLES



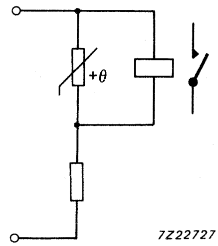
As soon as the current increases, the PTC limits it to a safe value.

Fig.6 Current limiting.



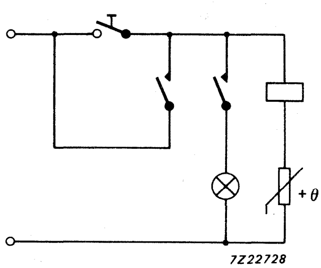
The increased current heats the PTC to its switch temperature. As a result, the total dissipated power is reduced to a safe value. The example shown could also be used as protection against overheating in transformers, lamps, printed circuit boards, rechargeable batteries, power supplies, etc.

Fig.7 Protection of a stalled electric motor against overheating.



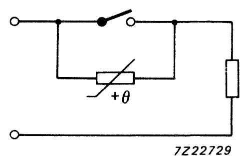
After applying the voltage for a certain time period, the relay is activated.

Fig.8 Delaying action of relays.



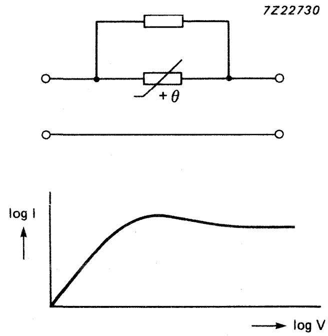
When the switch is operated, the relay is activated and the lamp is illuminated. After a certain time period, the relay is de-activated due to the increase in resistance of the PTC.

Fig.9 Time delay circuit.



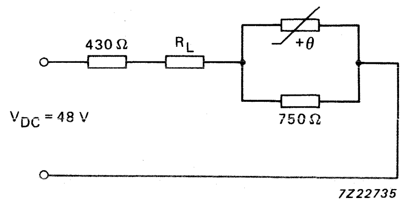
A PTC fitted in parallel with the switch acts as a spark suppressor. When the switch opens, the low resistance of the PTC prevents sparking.

Fig.10 Spark suppression circuit.



By using a resistor fitted in parallel to the PTC, a current stabilization circuit is obtained that compensates slowly varying supply voltages.

Fig.11 Current stabilization.



One very useful application is the use of this circuit to provide line resistance compensation for variations in telephone lines.

Fig.12 Line resistance (R_L) compensation.

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

FEATURES

- Different voltages to be chosen in function of the application
- Available in three mechanical versions

  2322 66. 4.... naked discs
  2322 66. 5.... leaded and coated
  2322 66. 6.... taped, on reel
  (to diameter 11.5 mm)
- Wide range of trip and non trip currents: from 17 mA up to 3 A for the trip current
- Wide range of resistance: from 0.3 Ω up to 3 kΩ
- Small ratio between trip and non trip currents (It/Int = 1.5 at 25 °C)
- High maximum inrush current
- Excellent long term behaviour, also in humidity
- Leaded parts withstand mechanical stresses and vibration
- Clear marking: The grey lacquered thermistors with a diameter of 8.5 to 12.5 mm are marked with PH, R_{25} value (example 4R6) on one side and I_{nt}, $V_{max.}$ on the other side.

QUICK REFERENCE DATA

Switch temperature (note 1)	140 °C
Maximum voltage	
2322 66. 4/5/6...1	30 to 60 V (DC)
2322 66. 4/5/6...2	145 V_{rms}
2322 66. 4/5/6...3	265 V_{rms}
Rated temperature range	
2322 66. 4/5/6...1	−40 to 85 °C
2322 66. 4/5/6...2	0 to 70 °C
2322 66. 4/5/6...3	0 to 70 °C
Climatic category	40/125/56

Note

1. For information only.

APPLICATIONS

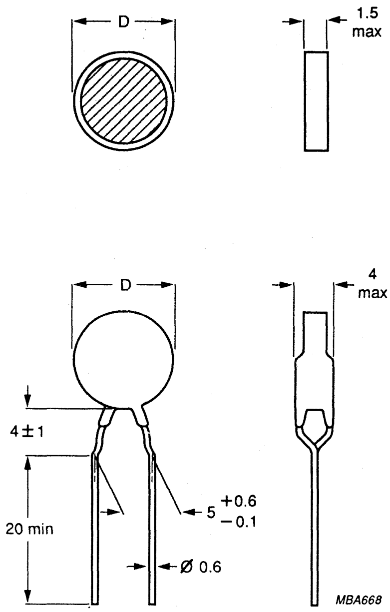
- Telecommunications
- Automotive systems
- Industrial electronics
- Consumer electronics
- Electronic data processing.

DESCRIPTION

These directly heated thermistors have a positive temperature coefficient and are primarily intended for overload protection. They consist of a naked disc or with two tinned brass leads.

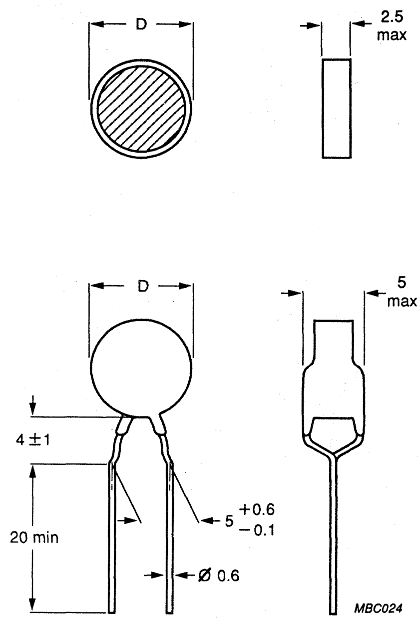
Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series



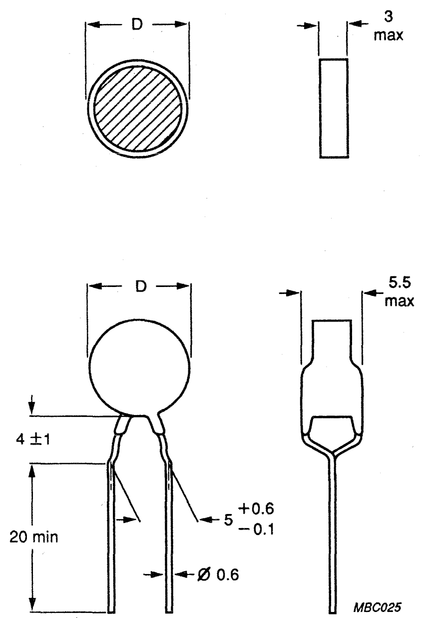
Dimensions in mm.
For D see Table 1.

Fig.1 Component outline for 2322 66. 4/5...1



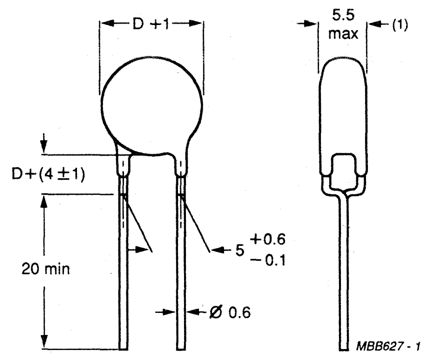
Dimensions in mm.
For D see Table 2.

Fig.2 Component outline for 2322 66. 4/5...2



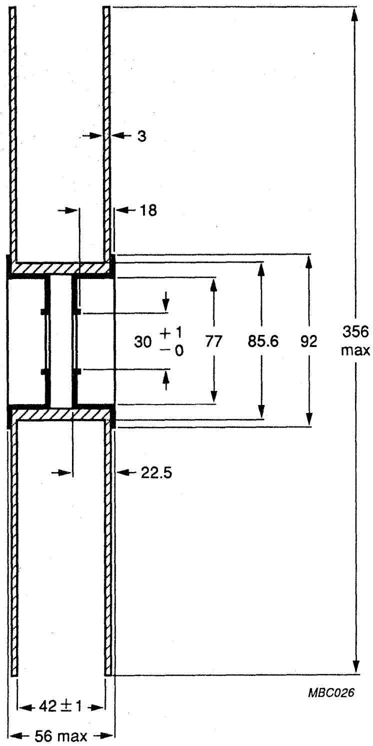
Dimensions in mm.
For D see Table 3.

Fig.3 Component outline for 2322 66. 4/5...3



Dimensions in mm.
For D see Table 2.
(1) 5.0 mm max. for 145 V series.

Fig.4 Component outline for 2322 663/4 5...2/3

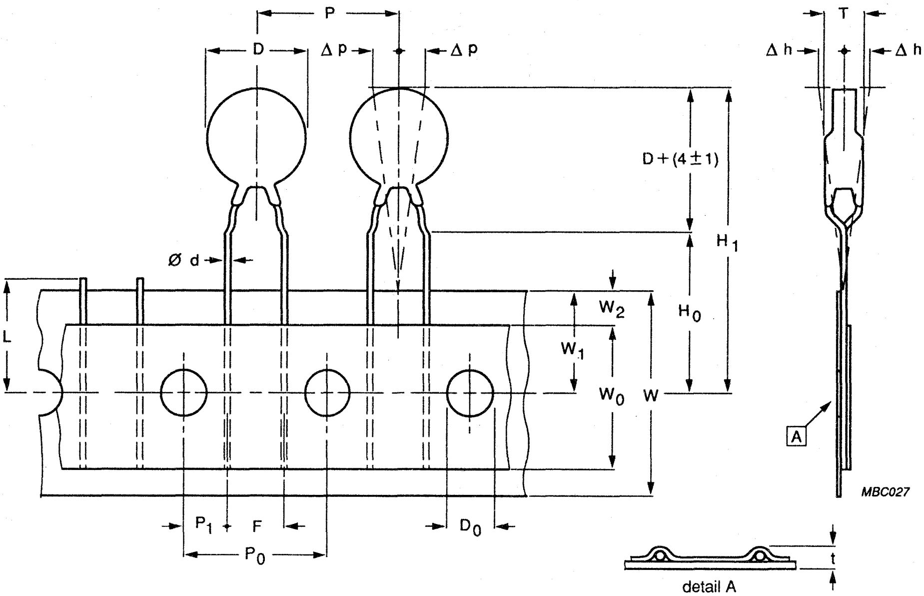


Dimensions in mm.

Fig.5 Dimensions of the reel for 2322 66. 6...1/2/3

PACKAGING INFORMATION

CODE NUMBERS		PACKAGING	
		S.P.Q.	P.Q.
2322 660	4...1	500	25000
	4...2 and 3	–	5000
	5...1, 2 and 3	500	10000
	6...1, 2 and 3	1500	3000
2322 661	43211–44111	500	25000
	44711–45411	–	5600
	4...2	–	3200
	4...3	–	2800
	5...1, 2 and 3	250	5000
	6...1, 2 and 3	1500	3000
2322 662	4...1	–	5600
	4... 3	–	2800
	56111–57011	200	4000
	66111–67011	1500	3000
	58311–59211	100	2000
	43212–43612	–	3200
	53212–53612	200	4000
	63212–63612	1500	3000
	54112–54512	100	2000
	52113–52513	200	4000
	62113–62513	1500	3000
	52813–53213	100	2000
2322 663	4...1	–	800
	4...2	–	1500
	4...3	–	1400
	5...1, 2 and 3	100	2000
2322 664	4...1	–	800
	4...2	–	1500
	4...3	–	1400
	5...1, 2 and 3	100	2000



Dimensions in mm.

Max. 0.5% of the total number of thermistors per reel may be missing, but no more than 3 consecutive positions may be vacant.

Fig.6 Thermistors on tape for 2322 66. 6...1/2/3

MECHANICAL DATA

Dimensions in mm unless otherwise specified.
AQL; Mechanical level II: 1%.

SYMBOL	PARAMETER	DIMENSIONS NOMINAL	TOLERANCE	REMARKS
D	body diameter 2322 66. 4/5/6...1 2322 66. 4/5/6...2 2322 66. 4/5/6...3	 see Table 1 see Table 2 see Table 3		
T	total thickness 2322 66. 4/5/6...1 2322 66. 4/5/6...2 2322 66. 4/5/6...3	 4 max. 5 max. 5.5 max.		
d	lead diameter	0.6	±10%	
P	pitch between thermistors	12.7	±1	
P_0	feed hole pitch	12.7	±0.3	cumulative pitch error ±1 mm/20 pitches
P_1	feed hole centre to lead centre	3.81	±0.7	guaranteed between component and tape
Δ_p	component alignment	0	±1.3	
F	lead to lead distance	5	+0.6 to −0.1	guaranteed between component and tape
Δ_h	component alignment	0	±2	
W	tape width	18	+1 to −0.5	
W_0	hold down tape width	12.5 min.		
W_1	hole position	9	±0.5	
W_2	hold down tape position	3 max.		
H_1	component height	32.2 max.		
H_O	lead-wire clinch height	16	±0.5	
D_0	feed hole diameter	4	±0.2	
t	total tape thickness	0.9 max.		with cardboard tape 0.5 ±0.1
L	length of snipped lead	11 max.		

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS
Resistance at 25 °C	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3
Maximum non-tripping current at 25 °C	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3
Minimum tripping current at 25 °C	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3
Maximum current at 25 °C	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3
Maximum residual current at $V_{max.}$ and 25 °C	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3
Dissipation factor	
2322 66. 4/5/6...1	see Table 1
2322 66. 4/5/6...2	see Table 2
2322 66. 4/5/6...3	see Table 3

CHARACTERISTICS CONCERNING TAPED THERMISTORS

Minimum pull out force of the component	5 N
Minimum pull off force of adhesive tape	6 N
Minimum tearing force tape	15 N
Maximum pull off force tape-reel	5 N
Storage conditions	
Storage temperature range	–25 to 40 °C
Maximum relative humidity	80%

ELECTRICAL DATA

Table 1 2322 66. 4/5/6...1 (max. voltage = 30 to 60 V (DC))

CODE NUMBERS (note 1)	I_{nt} at 25 °C (mA)	I_t at 25 °C (mA)	R_{25} ±20% (ohm)	V max. (V DC)	I max. (A)	I_{res} max. (mA)	DISSIP. FACTOR (mW/K)	D max. (mm)
2322 660 .9491	94	145	50	60	0.8	22	6.9	5
2322 660 .1311	130	195	25	60	1.2	25	6.9	5
2322 660 .1811	180	270	13	30	1.7	45	6.9	5
2322 660 .2711	270	405	6	30	2.5	60	6.9	5
2322 661 .3211	320	480	5	30	3.5	62	7.8	7
2322 661 .4111	410	615	3	30	4.5	65	7.8	7
2322 661 .4711	470	705	2.5	30	5	70	8.8	8.5
2322 661 .5411	540	810	1.9	30	6	75	8.8	8.5
2322 662 .6111	610	915	1.7	30	7	80	9.9	10.5
2322 662 .7011	700	1050	1.3	30	8	90	9.9	10.5
2322 662 .8311	830	1245	1.1	30	10	100	11.5	12.5
2322 662 .9211	920	1380	0.9	30	11	105	11.5	12.5
2322 663 .1121	1170	1755	0.7	30	13.5	140	14.5	16.5
2322 663 .1321	1390	2085	0.5	30	16	170	14.5	16.5
2322 664 .1721	1770	2655	0.4	30	20	200	18.7	20.5
2322 664 .2021	2050	3075	0.3	30	23	220	18.7	20.5

Note

1. For leadless types replace the dot in the code numbers by 4, for types with leads replace it by 5, and for reel packing (to ∅ 10.5 mm) replace it by 6.

   For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted according to IEC TC 40. Thermistor dissipation depends on mounting and can slightly affect the typical values.

   The items are clamped at the seating plane.

ELECTRICAL DATA

Table 2 2322 66. 4/5/6...2 (max. voltage = 145 V_{rms})

CODE NUMBERS (note 1)	I_{nt} at 25 °C (mA)	I_t at 25 °C (mA)	R_{25} ±20% (ohm)	V max. (V_{rms})	I max. (mA)	I_{res} max. (mA)	DISSIP. FACTOR (mW/K)	D max. (mm)
2322 660 .4792	47	70	240	145	200	9	7.2	5
2322 660 .6592	65	100	115	145	300	11	7.2	5
2322 660 .9392	93	140	55	145	450	13	7.2	5
2322 660 .1112	110	165	40	145	500	13	7.2	5
2322 660 .1312	130	195	28	145	600	13	7.2	5
2322 661 .1712	170	255	19	145	1000	15	8.2	7
2322 661 .2112	210	315	12	145	1400	15	8.2	7
2322 661 .2512	250	375	9.4	145	2000	16.5	9	8.5
2322 661 .2712	270	405	8	145	2200	16.5	9	8.5
2322 662 .3212	320	480	6.7	145	3000	19	10.5	10.5
2322 662 .3612	360	540	5.3	145	3500	19	10.5	10.5
2322 662 .4112	410	615	4.6	145	4500	22.5	11.7	12.5
2322 662 .4512	450	675	3.8	145	5000	22.5	11.7	12.5
2322 663 .6012	600	900	2.9	145	7200	28.5	15.5	16.5
2322 663 .7112	710	1065	2.1	145	8500	28.5	15.5	16.5
2322 664 .8812	880	1320	1.7	145	11000	37.5	19.8	20.5
2322 664 .1022	1000	1500	1.3	145	13000	37.5	19.8	20.5

Note

1. For leadless types replace the dot in the code numbers by 4, for types with leads replace it by 5, and for reel packing (to ∅ 10.5 mm) replace it by 6.

   For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted according to IEC TC 40. Thermistor dissipation depends on mounting and can slightly affect the typical values.

   The items are clamped at the seating plane.

ELECTRICAL DATA

Table 3 2322 66. 4/5/6...3 (max. voltage = 265 V_{rms})

CODE NUMBERS (note 1)	I_{nt} at 25 °C (mA)	I_t at 25 °C (mA)	R_{25} ±25% (ohm)	V max. (V_{rms})	I max. (mA)	I_{res} max. (mA)	DISSIP. FACTOR (mW/K)	D max. (mm)
2322 660 .1193	11	17	3000	265	80	6.5	7.3	5
2322 660 .1593	15	23	1900	265	110	6.5	7.3	5
2322 660 .1993	19	29	1200	265	140	6.5	7.3	5
2322 660 .2893	28	42	500	265	200	6.8	7.3	5
2322 660 .3993	39	59	260	265	300	6.8	7.3	5
2322 660 .6393	63	95	120	265	450	7	7.3	5
2322 660 .7693	76	115	85	265	550	7	7.3	5
2322 660 .9593	95	143	56	265	600	7	7.3	5
2322 661 .1113	110	165	48	265	650	7.5	8.3	7
2322 661 .1413	140	210	29	265	800	8	8.3	7
2322 661 .1713	170	255	22	265	900	9	9	8.5
2322 661 .1913	190	285	18	265	1000	9.5	9	8.5
2322 662 .2113	210	315	17	265	1300	10	10.5	10.5
2322 662 .2513	250	375	12	265	1500	11	10.5	10.5
2322 662 .2813	280	420	11	265	1800	12	11.7	12.5
2322 662 .3213	320	480	8.4	265	2200	13	11.7	12.5
2322 663 .4013	400	600	6.6	265	3000	15	15.5	16.5
2322 663 .4913	490	735	4.4	265	3500	16	15.5	16.5
2322 664 .5913	590	855	4	265	4500	19.5	19.8	20.5
2322 664 .7013	700	1050	2.8	265	5500	21	19.8	20.5

Note

1. For leadless types replace the dot in the code numbers by 4, for types with leads replace it by 5, and for reel packing (to Ø 11.5 mm) replace it by 6.

   For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted according to IEC TC 40. Thermistor dissipation depends on mounting and can slightly affect the typical values.

   The items are clamped at the seating plane.

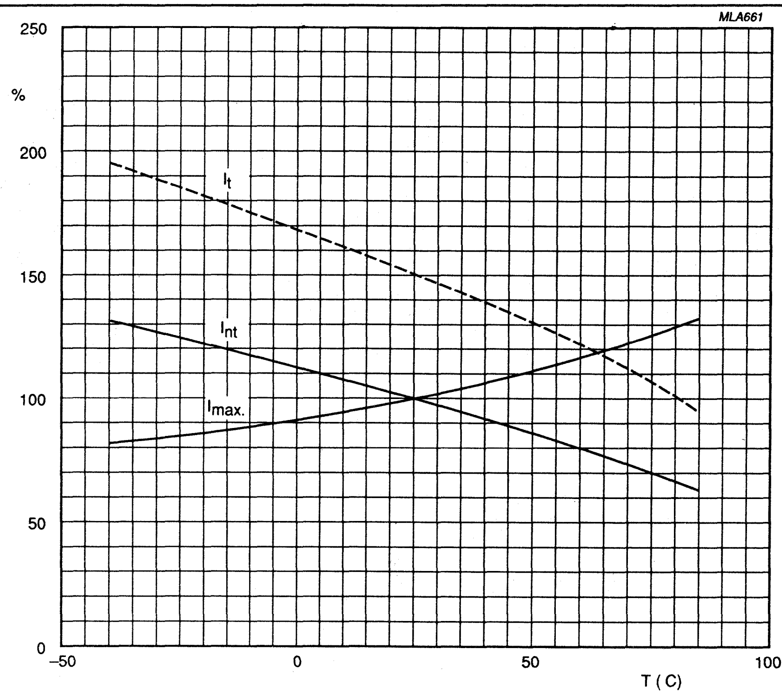


Fig.7 Current deviation in function of the ambient temperature.

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

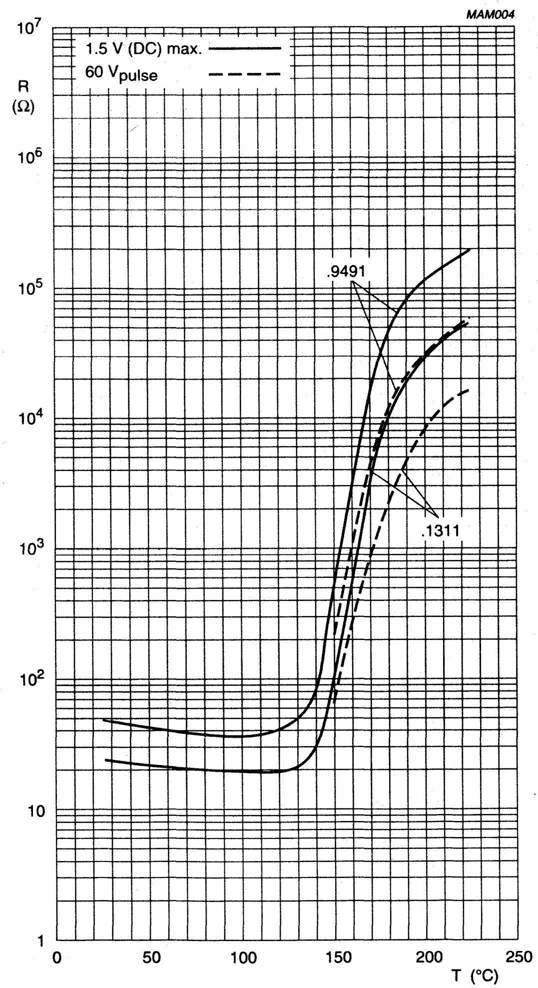


Fig.8 Typical resistance/temperature characteristic for 2322 660 .9491/.1311

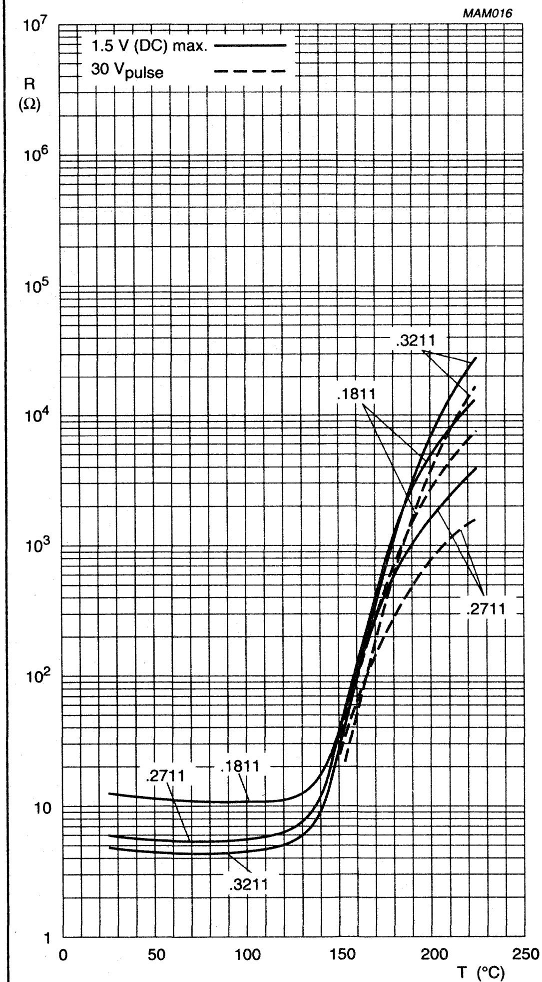


Fig.9 Typical resistance/temperature characteristic for 2322 660 .1811/.2711 and 661 .3211

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

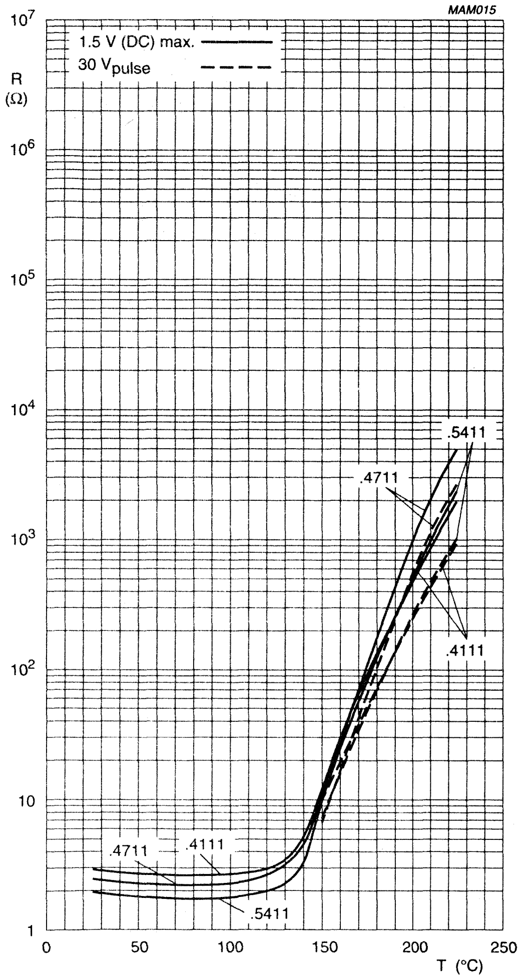


Fig.10 Typical resistance/temperature characteristic for 2322 661 .4111/.4711/.5411

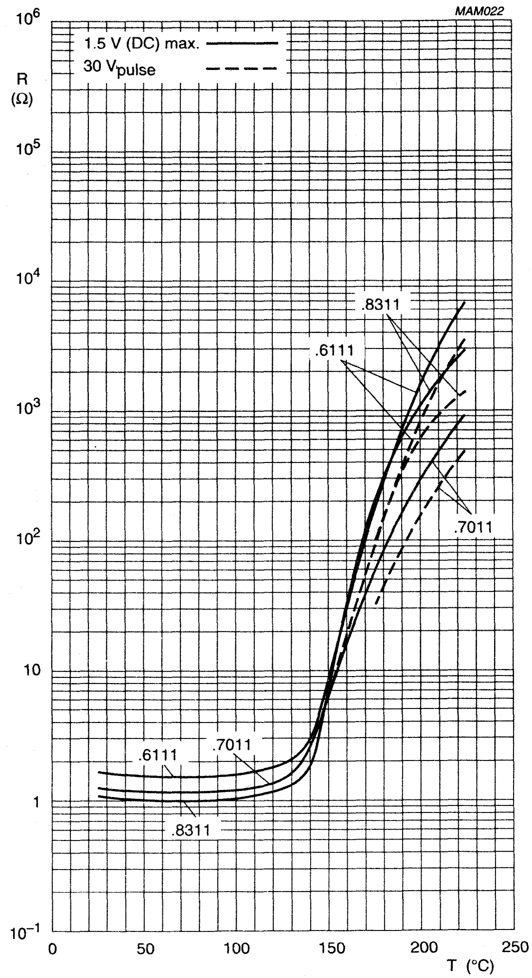


Fig.11 Typical resistance/temperature characteristic for 2322 662 .6111/.7011/.8311

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

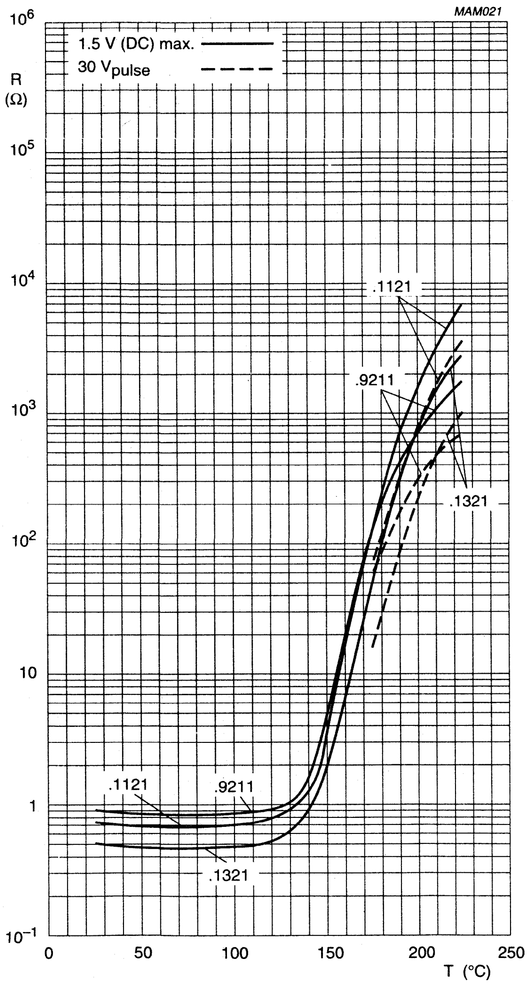


Fig.12 Typical resistance/temperature characteristic for 2322 662 .9211 and 663 .1121/.1321

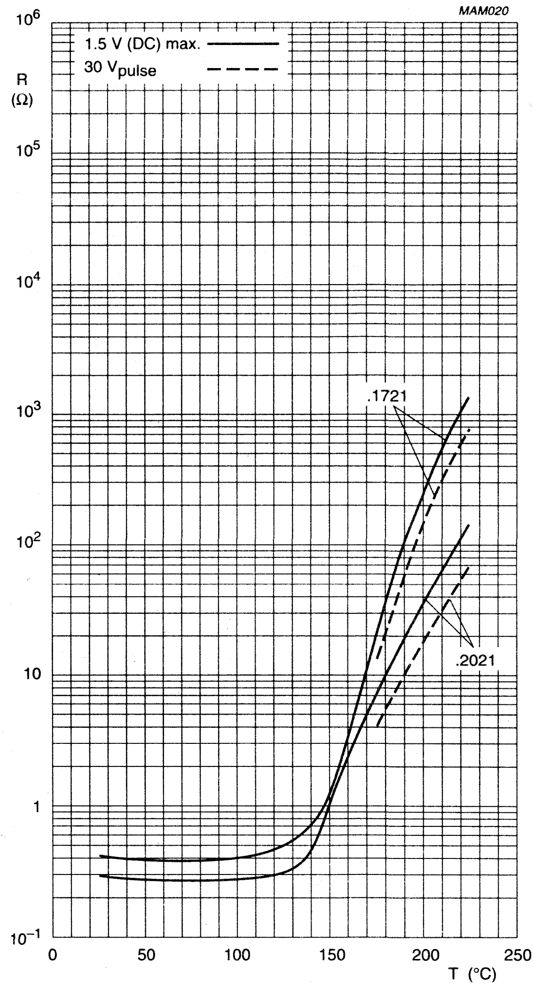


Fig.13 Typical resistance/temperature characteristic for 2322 664 .1721/.2021

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

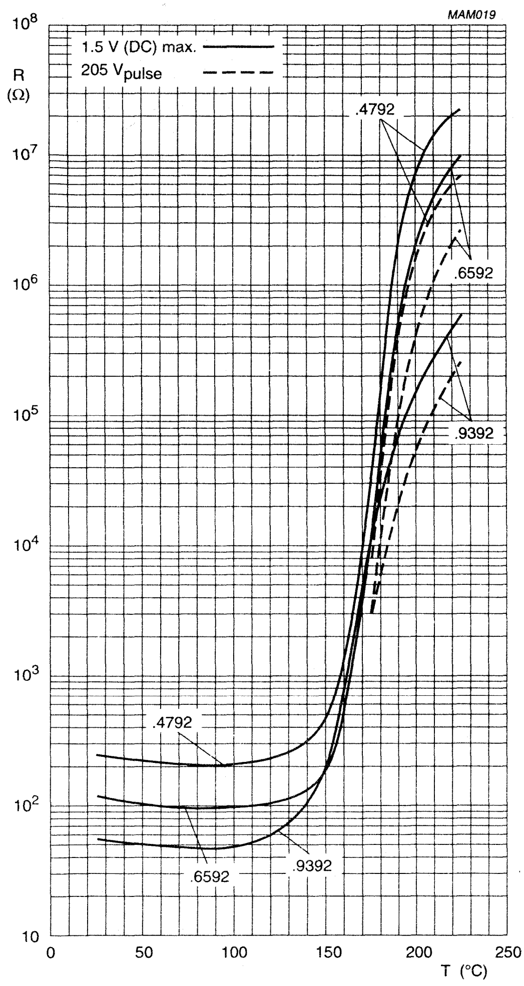


Fig.14 Typical resistance/temperature characteristic for 2322 660 .4792/.6592/.9392

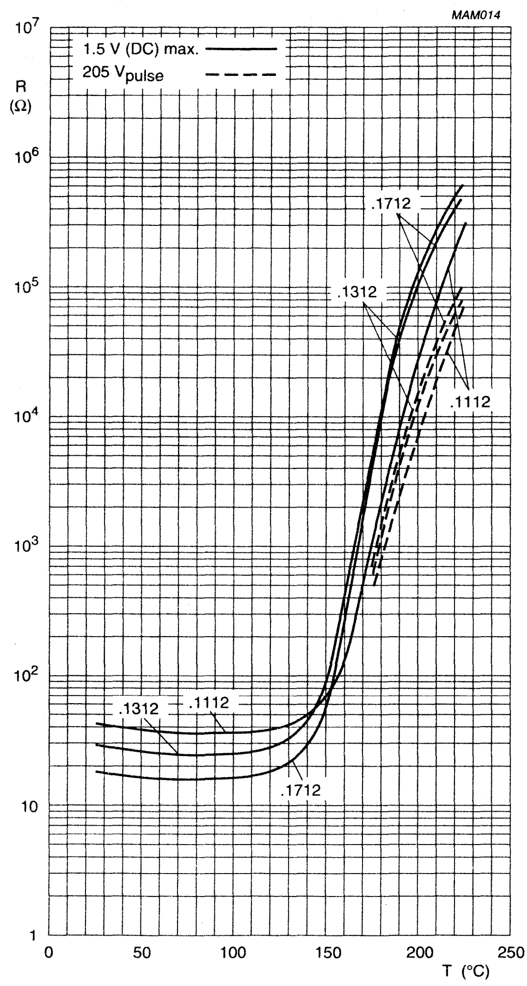


Fig.15 Typical resistance/temperature characteristic for 2322 660 .1112/.1312 and 661 .1712

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

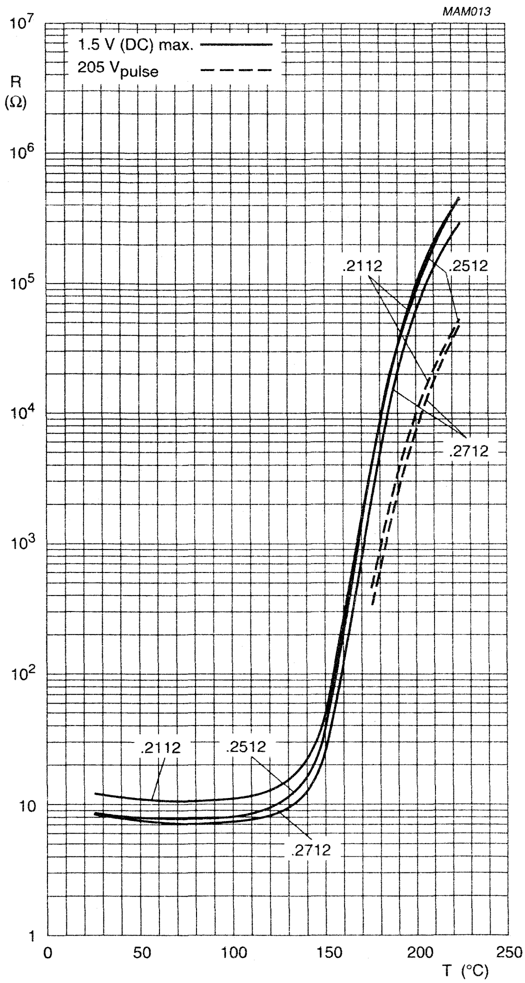


Fig.16 Typical resistance/temperature characteristic for 2322 661 .2112/.2512/.2712

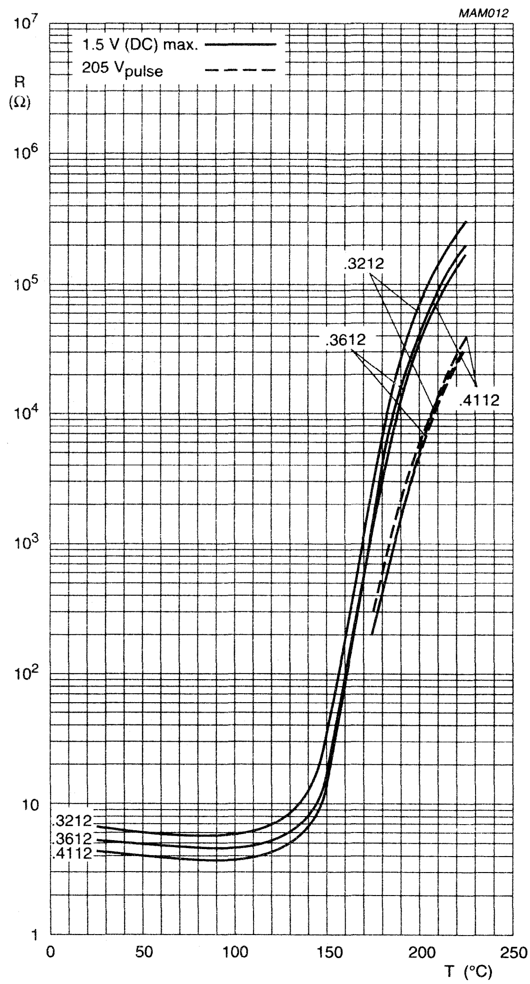


Fig.17 Typical resistance/temperature characteristic for 2322 662 .3212/.3612/.4112

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

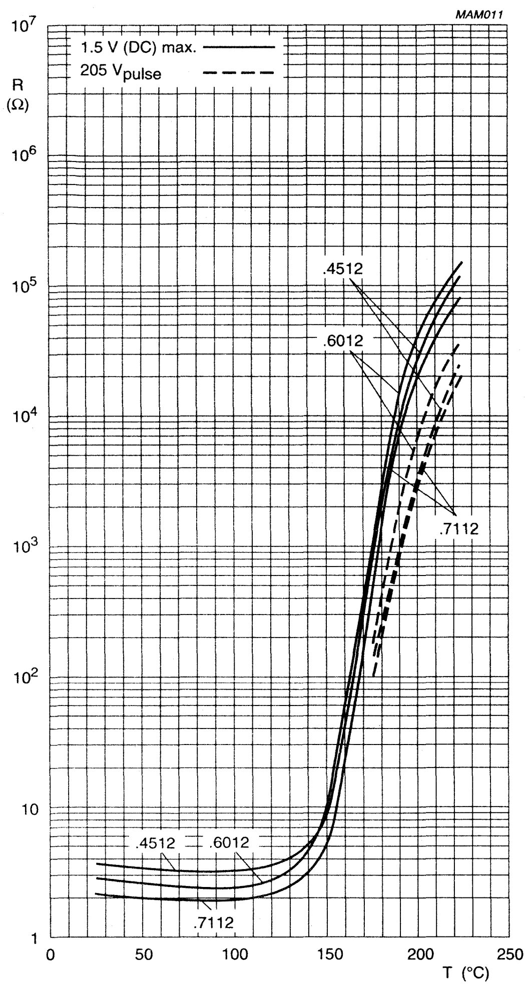


Fig.18 Typical resistance/temperature characteristic for 2322 662 .4512 and 663 .6012/.7112

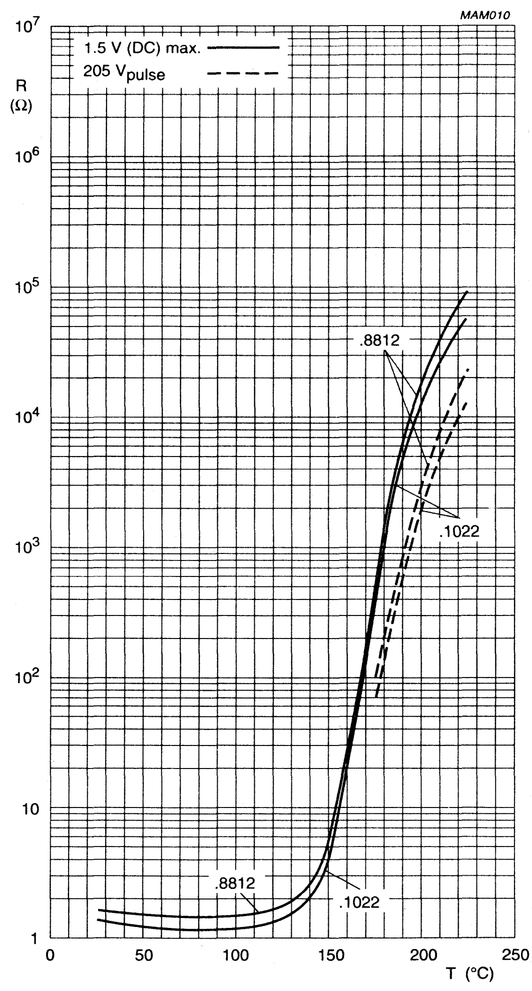


Fig.19 Typical resistance/temperature characteristic for 2322 664 .8812/.1022

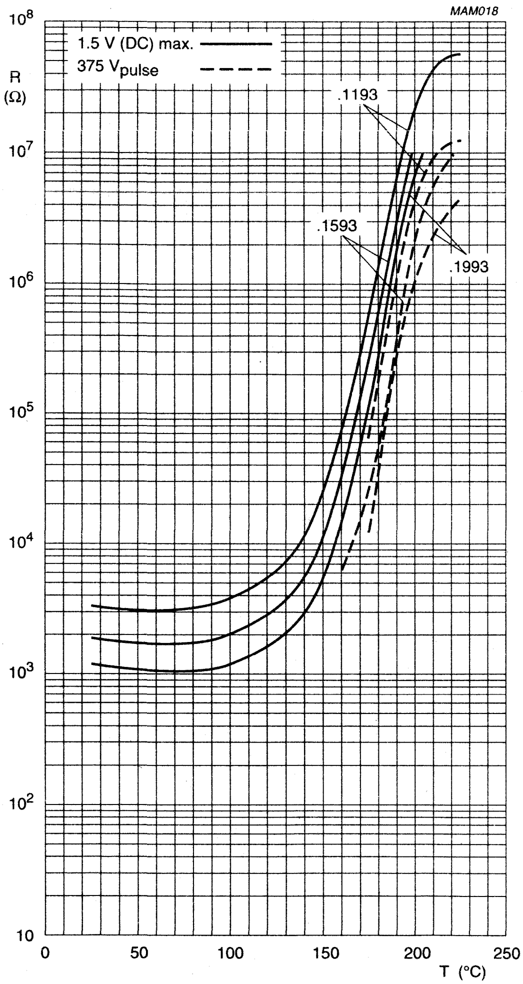


Fig.20 Typical resistance/temperature characteristic for 2322 660 .1193/.1593/.1993

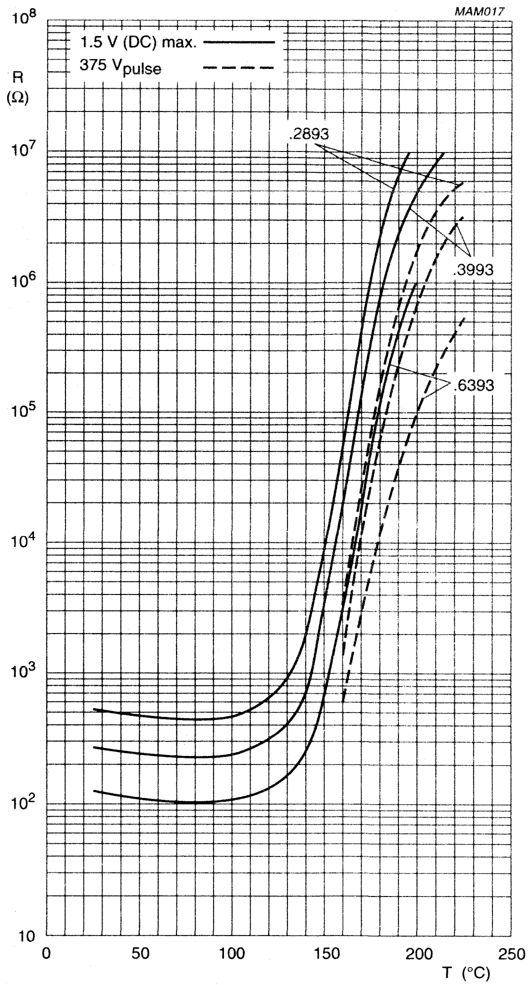


Fig.21 Typical resistance/temperature characteristic for 2322 660 .2893/.3993/.6393

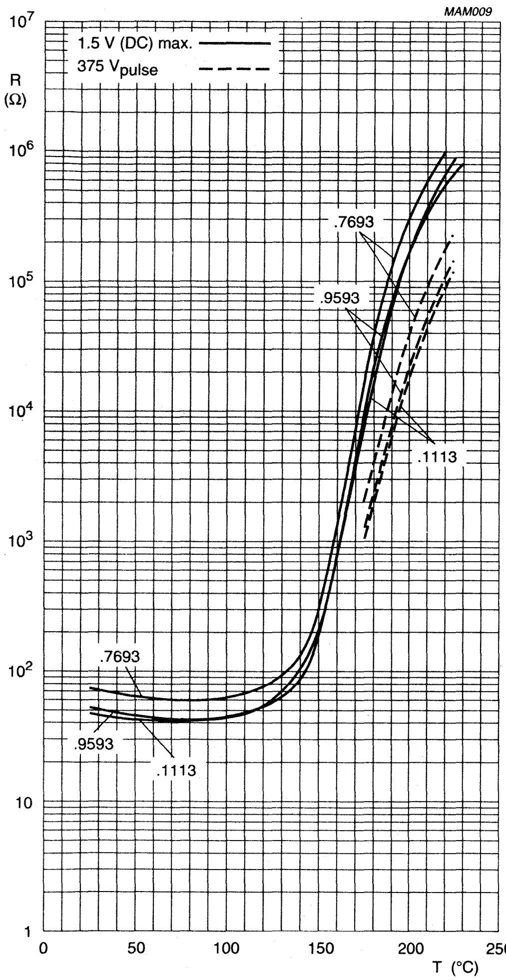


Fig.22 Typical resistance/temperature characteristic for 2322 660 .7693/.9593 and 661 .1113

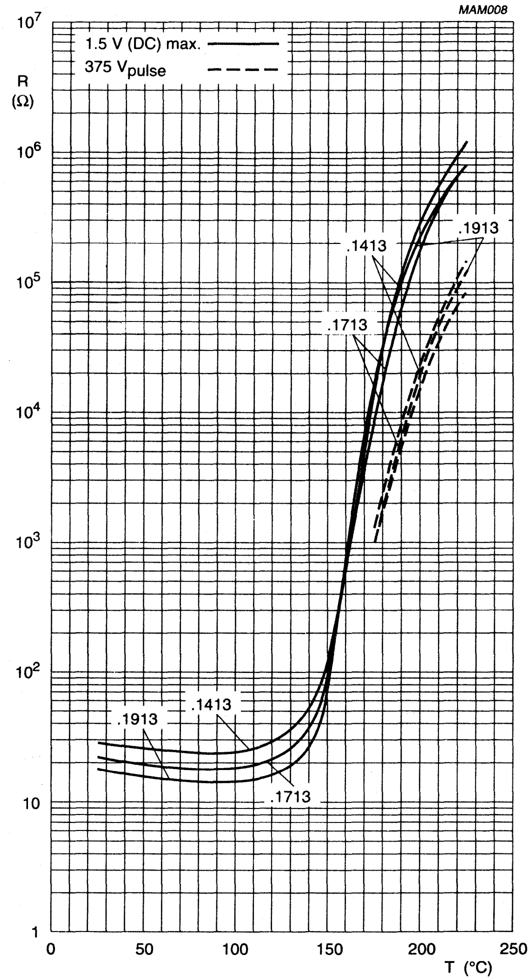


Fig.23 Typical resistance/temperature characteristic for 2322 661 .1413/.1713/.1913

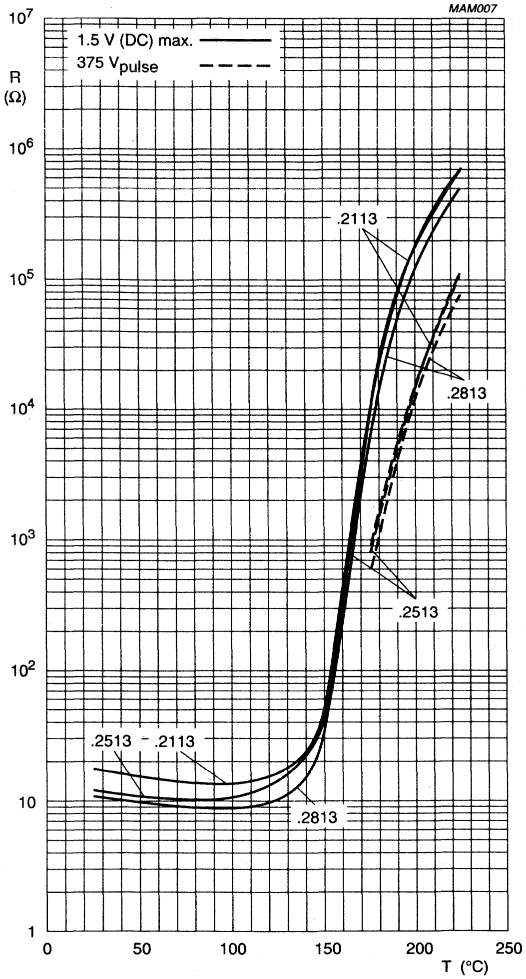


Fig.24 Typical resistance/temperature characteristic for 2322 662 .2113/.2513/.2813

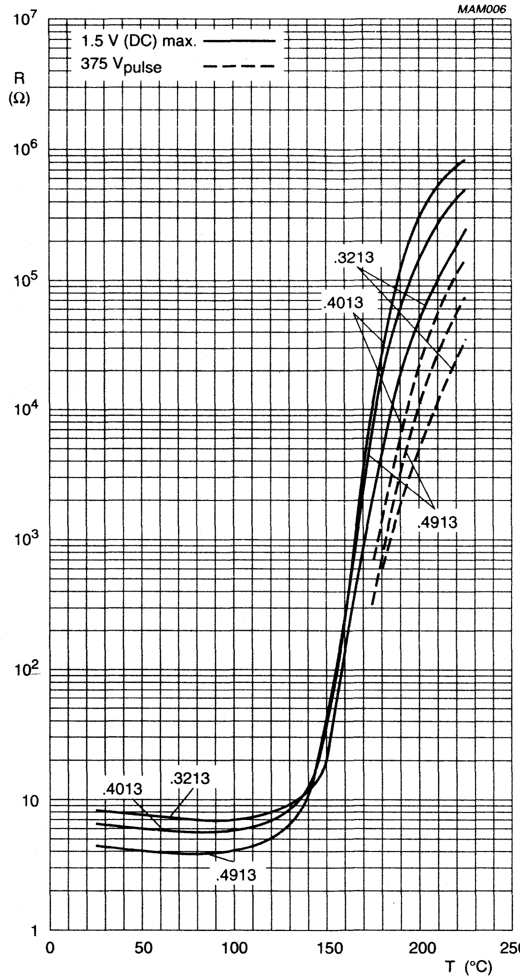


Fig.25 Typical resistance/temperature characteristic for 2322 662 .3213 and 663 .4013/.4913

Thermistor for overload protection PTC 30 V (DC), 145 and 265 V_{rms}

2322 66. series

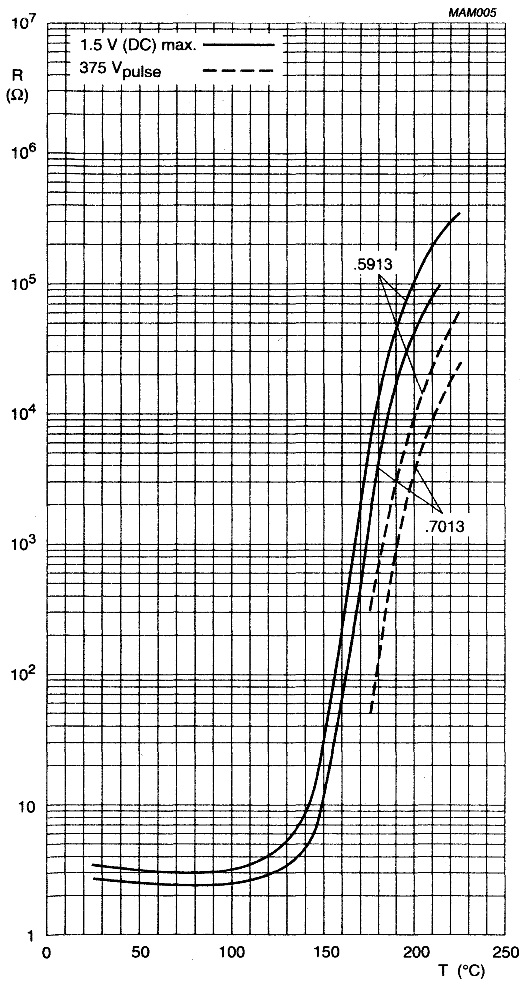


Fig.26 Typical resistance/temperature characteristic for 2322 664 .5913/.7013

TEST AND REQUIREMENTS

Note 1

Clause numbers of tests and performance requirements refer to the CECC draft secretariat 2371 (Jan. 1989).

Note 2

AQLs are selected from IEC Publication 410.

Note 3

Tables with requirements for lot by lot and periodic tests. In these tables:

D = Destructive

ND = Non-destructive.

Note 4

Leads should neither come loose or break.

Note 5

Proposal under examination.

CLAUSE NUMBER AND TEST	D OR ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Group A inspection (lot by lot)			
Sub-group A1	ND		
4.3.1. Visual examination			no defect likely to impair function
4.3.2. Marking			
4.3.3. Dimensions (gauging)			as specified
Sub-group A2	ND		
4.4. Zero power resistance		temperature: 25 °C	as specified
4.21. Tripping current		measured at 25 °C	as specified
4.22. Non-tripping current		measured at 25 °C	as specified
4.23. Residual current at $V_{max.}$		measured at 25 °C	as specified

CLAUSE NUMBER AND TEST	D OR ND	CONDITION	PERFORMANCE REQUIREMENTS
Group B inspection (lot by lot)			
Sub-group B1	D		
4.13.1. Soldering, solderability		solder bath method: 235 ±5 °C	the terminations shall be evenly tinned

CLAUSE NUMBER AND TEST	D OR ND	CONDITION	PERFORMANCE REQUIREMENTS
Group C inspection (periodic) (see note 5)			
Sub-group C1	D		
4.20.1. Endurance (cycling)		<u>10 samples</u> duration: 10 cycles temperature: 25 °C voltage: for 66. 4/5/6....1, 30 to 60 V (DC) for 66. 4/5/6....2, 145 V_{rms} for 66. 4/5/6....3, 265 V_{rms} $I_{max.}$: see electrical data cycle: 1 minute on/9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8. ΔR/R: ±10% max.
		<u>10 samples</u> duration: 10 cycles temperature: for 66. 4/5/6....1, –40 °C for 66. 4/5/6....2 and 3, 0 °C voltage: for 66. 4/5/6....1, 30 to 60 V (DC) for 66. 4/5/6....2, 145 V_{rms} for 66. 4/5/6....3, 265 V_{rms} $I_{max.}$: see electrical data cycle: 1 minute on/9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8. ΔR/R: ±10% max.

CLAUSE NUMBER AND TEST	D OR ND	CONDITION	PERFORMANCE REQUIREMENTS
Sub-group C2	D		
4.12. Robustness of terminations		half of the sample test Ua and Ub of IEC 68-2-21 visual examination zero power resistance at 25 °C	 as in 4.12.4. (see note 4) ΔR/R: ±10% max.
4.13.2. Soldering resistance to soldering heat		test Tb of IEC 68-2-20A visual examination zero power resistance at 25 °C	 as in 4.13.2.3. ΔR/R: ±10% max.
4.14. Rapid change of temperature		other half of the sample test Na of IEC 68-2-14 T_A: lower category temperature: −40 °C T_B: upper category temperature: 125 °C number of cycles: 5 visual examination zero power resistance at 25 °C	 as in 4.14.4. ΔR/R: ±10% max.
4.18. Climatic sequence Dry heat Damp heat, cyclic, first cycle Cold Damp heat, cyclic, remaining cycles Final measurement		all the sample low air pressure test not applicable visual examination zero power resistance at 25 °C	 as in 4.18.7.1. ΔR/R: ±10% max.
Sub-group C3	D		
4.20.3. Endurance at maximum rated temperature		duration: for 66. 4/5/6....1, 24 hours at 85 °C and 30 to 60 V (DC) for 66. 4/5/6....2, 24 hours at 70 °C and 145 V_{rms} for 66. 4/5/6....3, 24 hours at 70 °C and 265 V_{rms} examination at 24 hours visual examination zero power resistance at 25 °C	 as in 4.20.3.10. ΔR/R: ±10% max.
Sub-group C4	D		
4.19. Damp heat, steady state		visual examination zero power resistance at 25 °C	as in 4.19.5. ΔR/R: ±10% max.

PTC THERMISTORS

for overload protection

QUICK REFERENCE DATA

Resistance at 25 °C	1,6 to 90 Ω
Switch temperature	120 °C approximately
Maximum DC voltage	56 V
Trip current at 10 °C	112 to 1360 mA
Operating temperature range at V_{max}	0 to + 55 °C

APPLICATION

Overload protection, for use in electric and electronic equipment such as electric motors, transformers and semiconductor circuits.

DESCRIPTION

These thermistors have a positive temperature coefficient. They consist of a disc with two tinned brass wires, see Fig. 1a. Leadless types having metallized sides for soldering by the user are also available, see Fig. 1b.

MECHANICAL DATA

Outlines

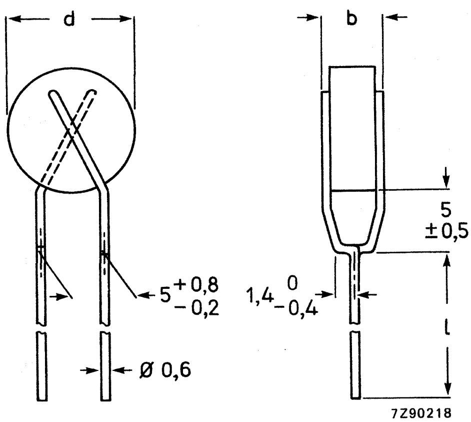


Fig. 1a.

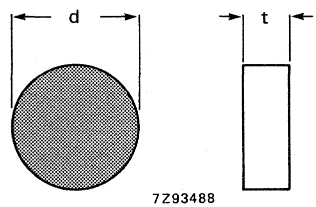


Fig. 1b.

For dimensions b, d, l and t see Table 1.

Marking	None
Mass (types with leads only)	See Table 1
Mounting	In any position by soldering

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

When soldering leadless types it is recommended to use a flux containing colofonium and aethyl alcohol only and to pre-heat the discs to approx. 100 °C in order to avoid thermal shocks which might damage the thermistors.

Impact	200 mm free fall
Inflammability	non-flammable

Packaging (for types with leads)

Cardboard boxes containing following items for:

2322 6601 . . . 1:	500	2322 6621 . . . 1:	100
2322 6611 . . . 1:	250	2322 6631 . . . 1:	100
2322 6621 1811.	200	2322 6631 . . . 1:	100

ELECTRICAL DATA

Unless otherwise specified measured according to IEC publication 738-1 (1982).

Maximum current for not tripping at 55 °C (measuring time 5 minutes)	I_{nt}	See Table 1
Minimum current for tripping after 5 minutes at 10 °C	$I_t = 2 \times I_{nt}$	See Table 1
Resistance at + 25 °C	R_{25}	See Table 1
Switch temperature	T_s	≈ 120 °C
Maximum admissible current at 0 °C	I_{max}	See Table 1
Maximum residual current at 56 V (DC) at 10 °C	$I_{res\ max}$	See Table 1
Maximum DC voltage with a series resistor		56 V
Series resistor	R_s	See Table 1
Maximum d.c. voltage without series resistor		18 V
Dissipation factor at T_s	D	See Table 1
Heat capacity	H	See Table 1
Operating temperature range		
at zero power		–25 to + 125 °C
at maximum voltage		0 to + 55 °C

Table 1

catalogue number (see Notes 1 and 2)	I_{nt} at 55 °C mA	I_t at 10 °C mA	R_{25} approx. Ω	I_{max} at 0 °C mA	$I_{res\ max}$ at 10 °C mA	R_s ± 5% Ω	D approx. mW/K	H approx. J/K	d mm	b max. mm	l ± 3 mm	t max. mm	mass approx. (types with leads only) g
2322 660 .5691	56	112	90	460	30	56	6	0,08	4,5	4	20	1,8	0,35
660 .6891	68	136	60	600	30	51	6	0,08	4,5	4	20	1,8	0,35
660 .8291	82	164	42	750	30	43	6	0,08	4,5	4	20	1,8	0,35
661 .1011	100	200	32	950	35	36	7	0,15	6,5	4	20	1,8	0,47
661 .1211	120	240	22	1300	35	27	7	0,15	6,5	4	20	1,8	0,47
661 .1511	150	300	18	1600	40	22	7,5	0,16	8,0	4	20	1,8	0,65
662 .1811	180	360	12,5	2200	45	16	8	0,42	10,0	4,5	20	2,2	1,05
662 .2211	220	440	9	2900	50	13	9	0,55	12,0	4,5	20	2,2	1,43
662 .2711	270	540	6,5	4000	50	10	9	0,55	12,0	4,5	20	2,2	1,43
663 .3311	330	660	4,3	6300	60	5,6	10	0,83	13,0	5	20	2,9	2,15
663 .3911	390	780	3,8	7300	70	5,1	12	1,24	16,0	5	20	2,9	2,90
663 .4711	470	940	2,6	12000	70	2,7	12	1,24	16,0	5	20	2,9	2,90
664 .5611	560	1120	2,2	14000	100	2,4	16	2,34	20,0	6	16	3,6	5,30
664 .6811	680	1360	1,6	18000	100	2,0	16	2,34	20,0	6	16	3,6	5,30

Notes to Table 1

1. For leadless types, replace the dot in the catalogue number by 0; for types with leads, replace it by 1.
2. For taped devices up to 12 mm in diameter, replace the dot by 3.

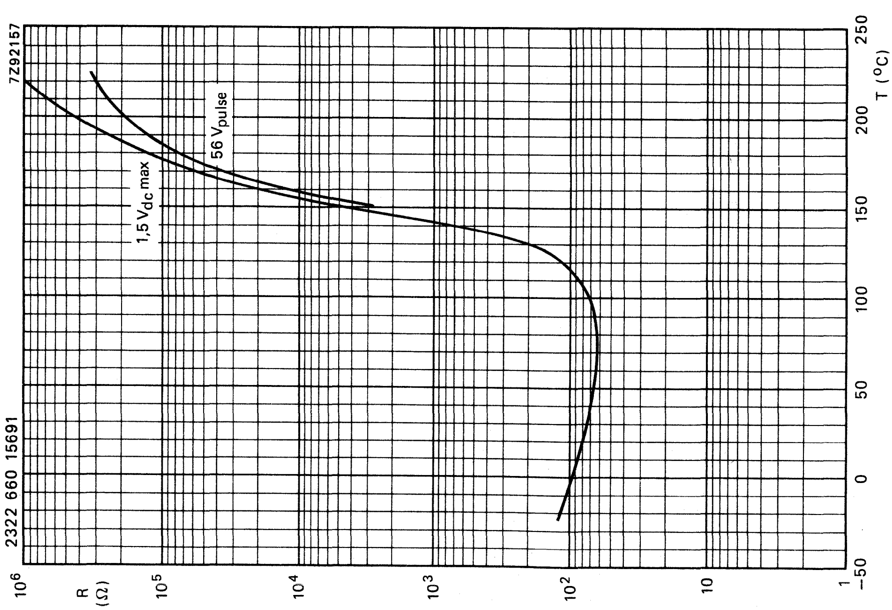


Fig. 2.

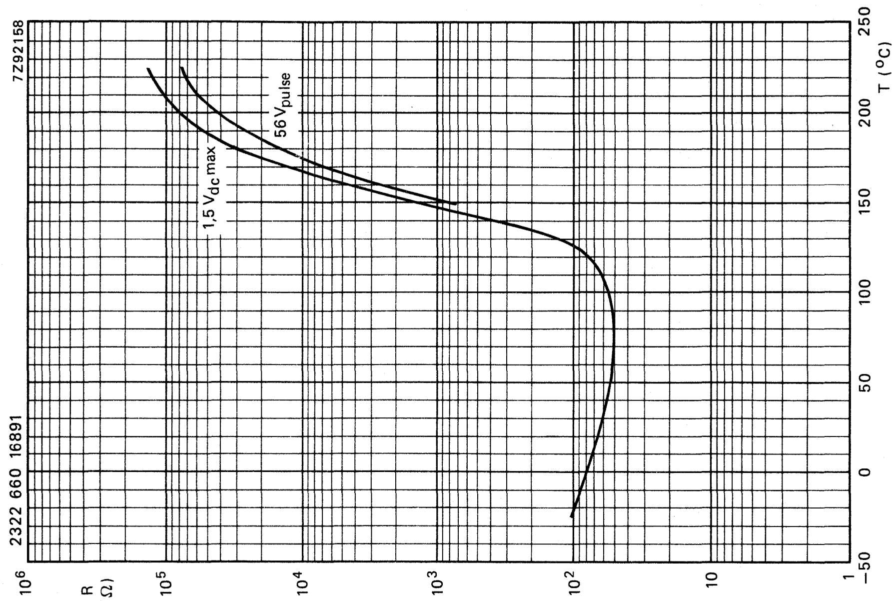


Fig. 3.

Typical resistance/temperature characteristics.

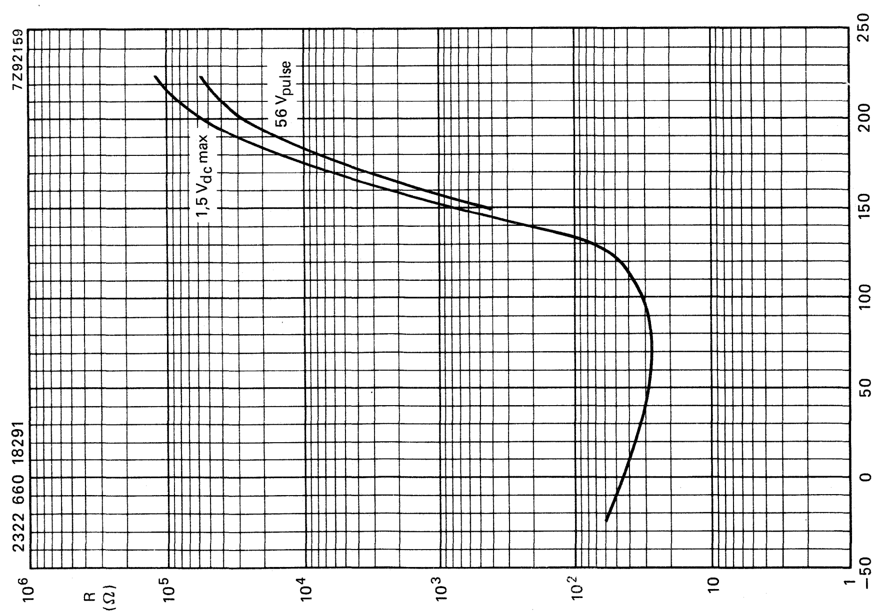


Fig. 4.

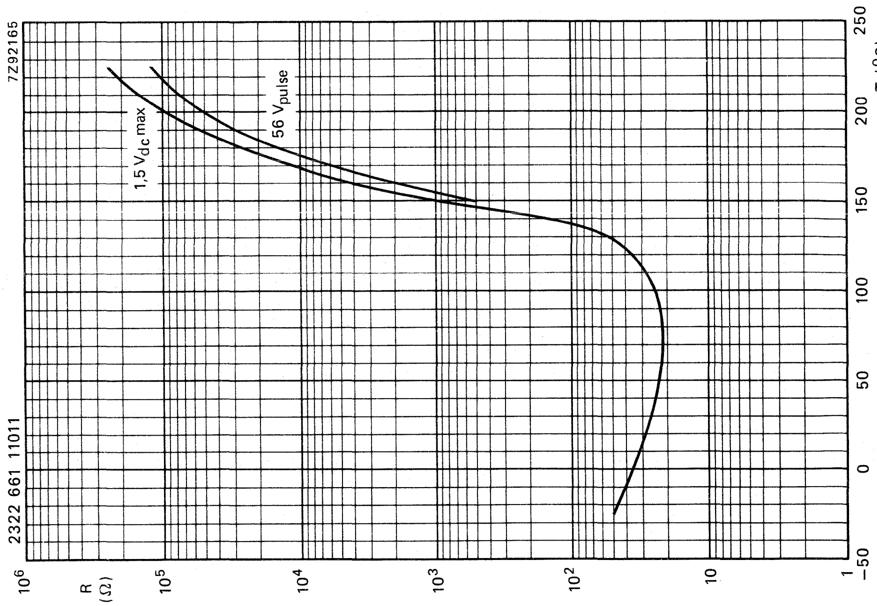


Fig. 5.

Typical resistance/temperature characteristics.

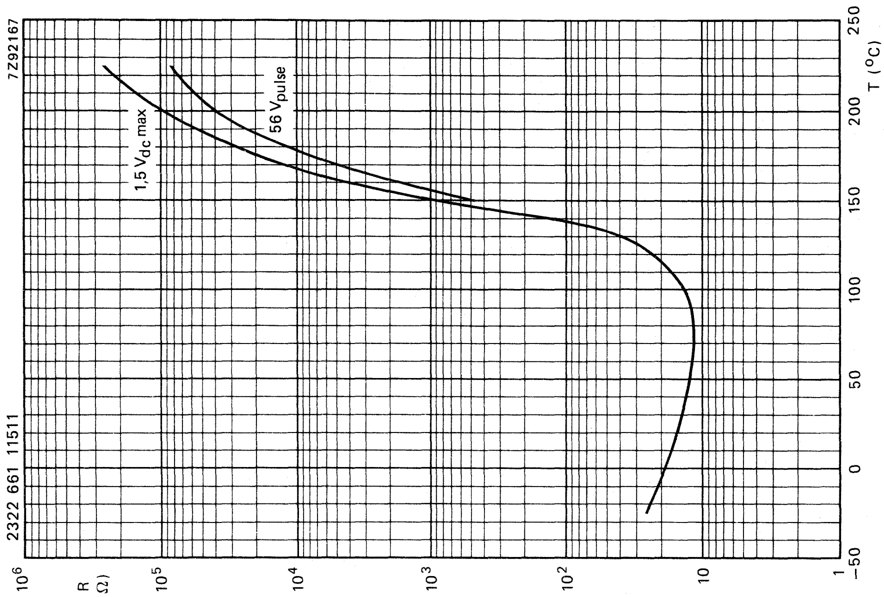


Fig. 7.

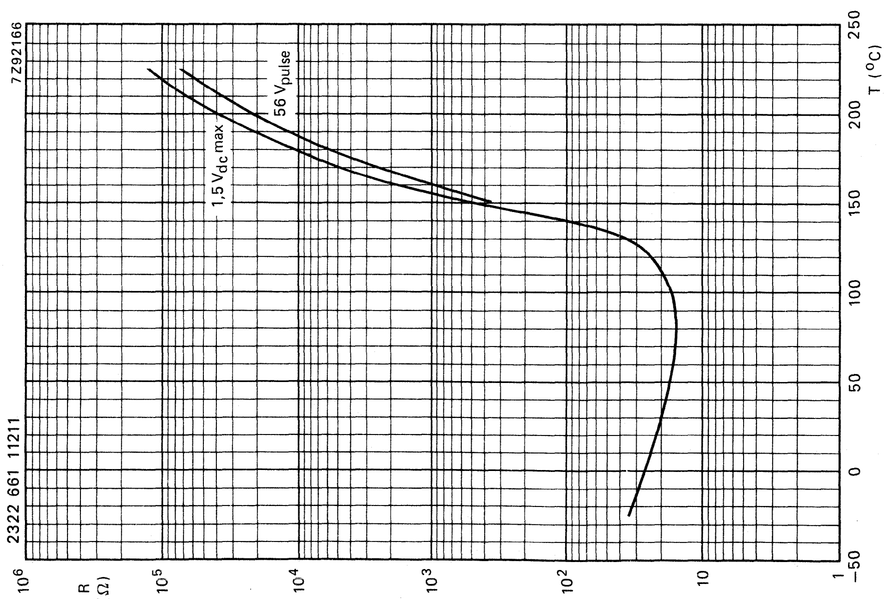


Fig. 6.

Typical resistance/temperature characteristics.

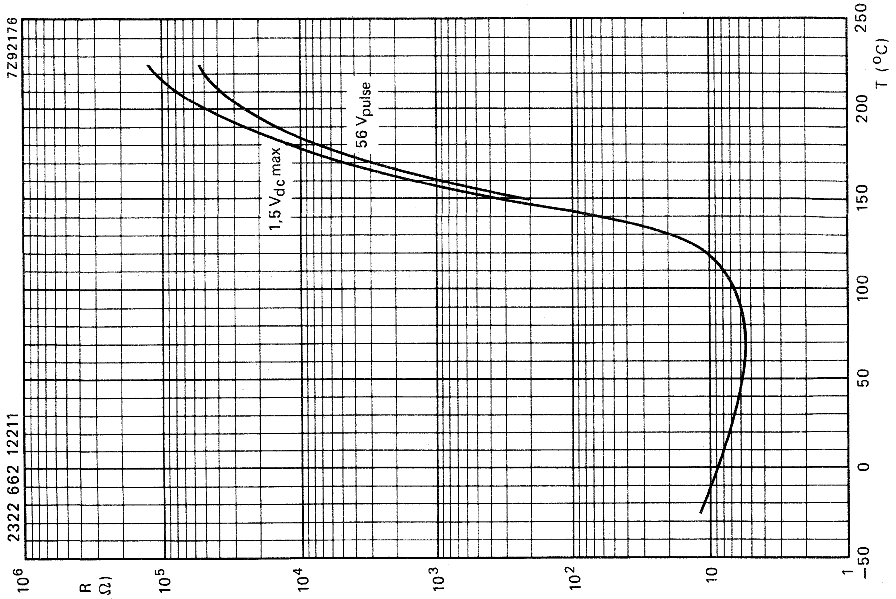


Fig. 9.

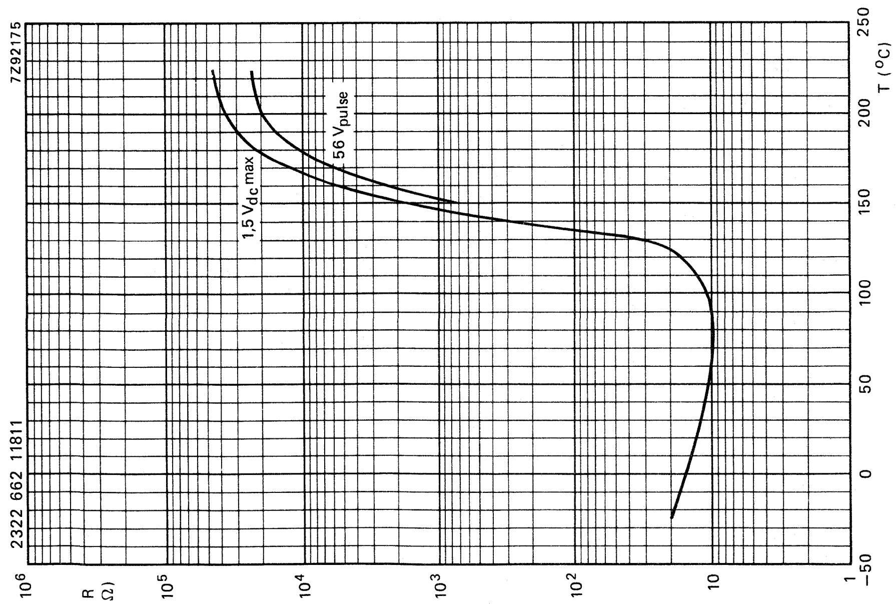


Fig. 8.

Typical resistance/temperature characteristics.

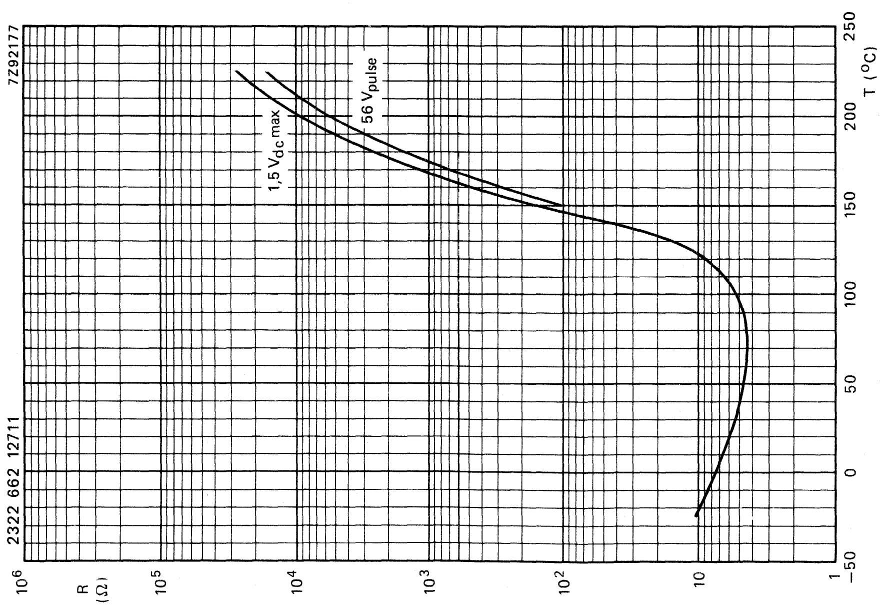


Fig. 10.

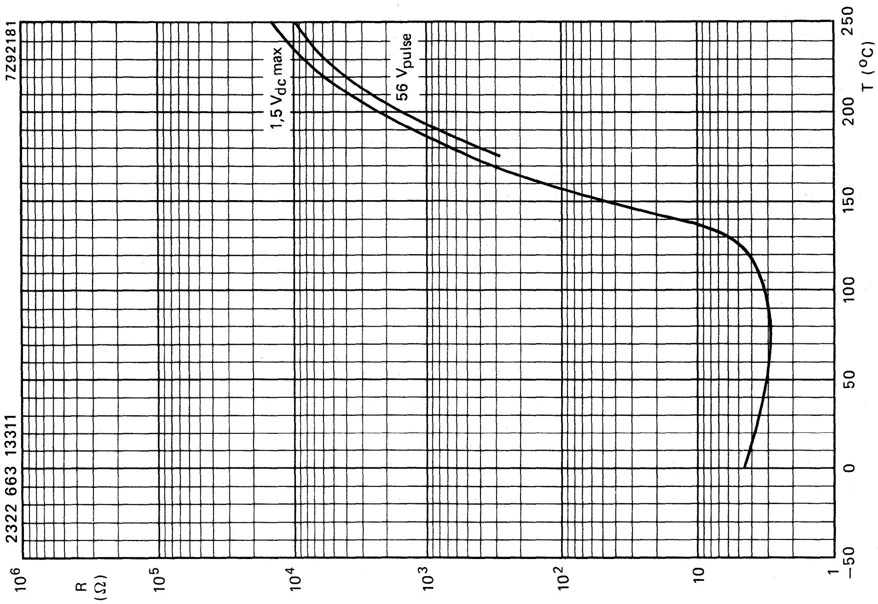


Fig. 11.

Typical resistance/temperature characteristics.

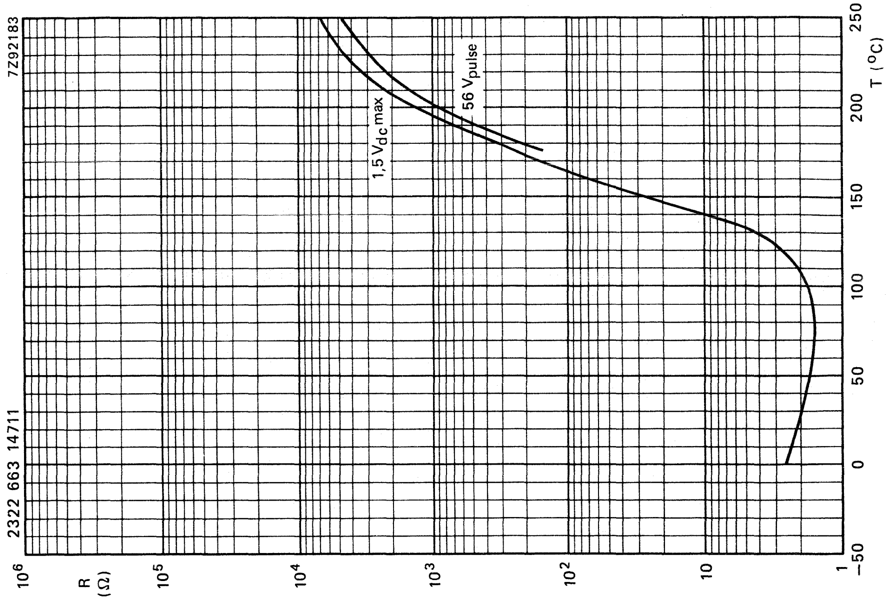


Fig. 13.

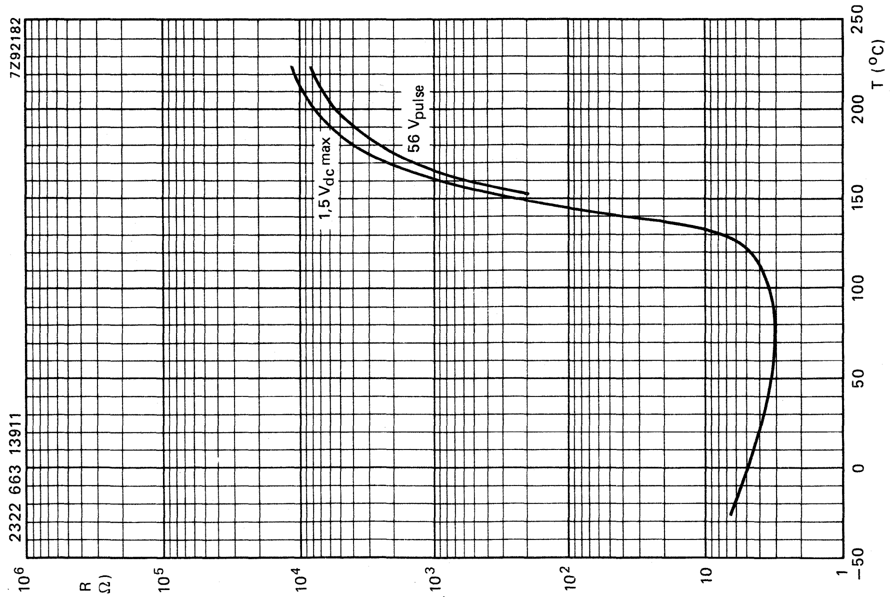


Fig. 12.

Typical resistance/temperature characteristics.

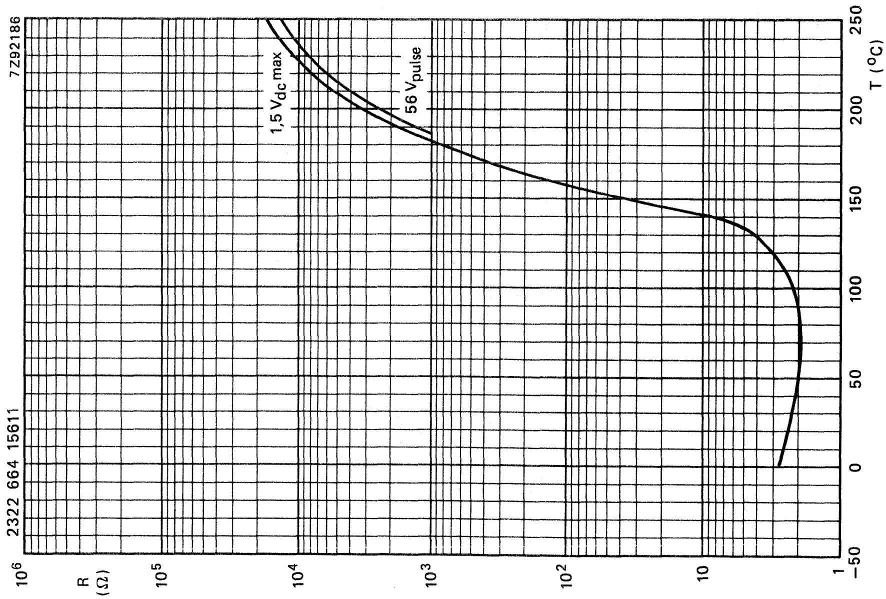


Fig. 14.

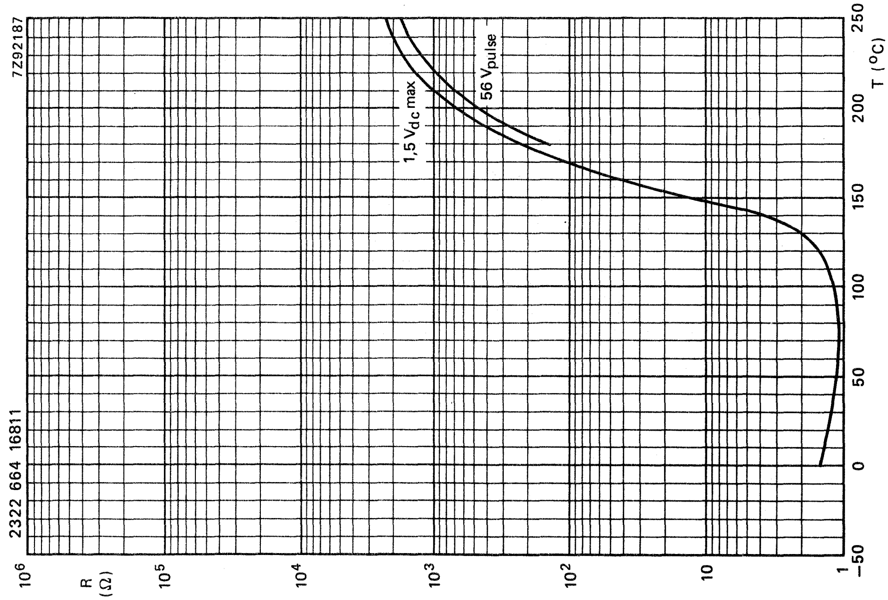


Fig. 15.

Typical resistance/temperature characteristics.

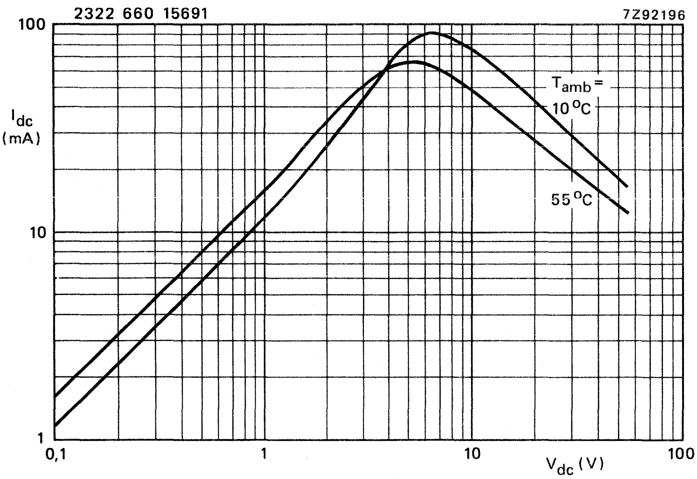


Fig. 16.

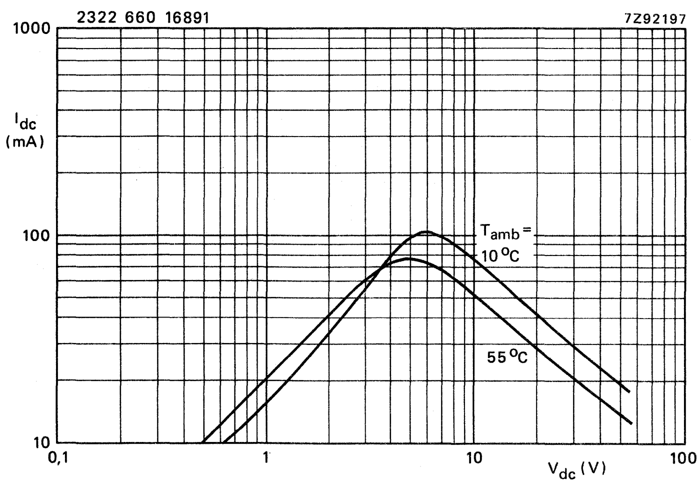


Fig. 17.

Typical voltage/current characteristics.

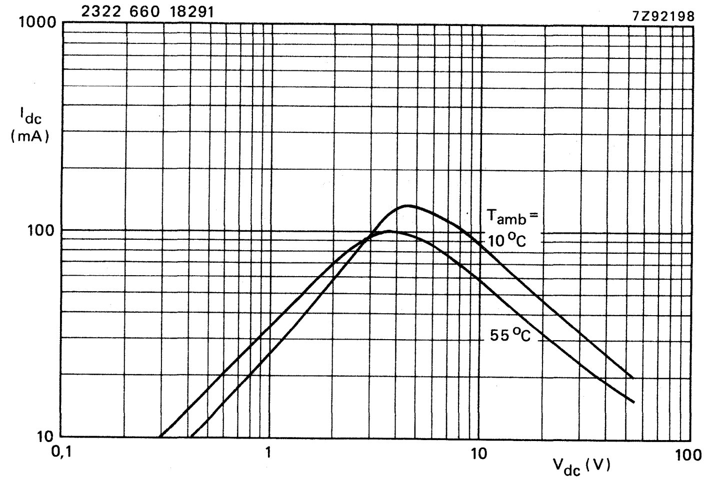


Fig. 18.

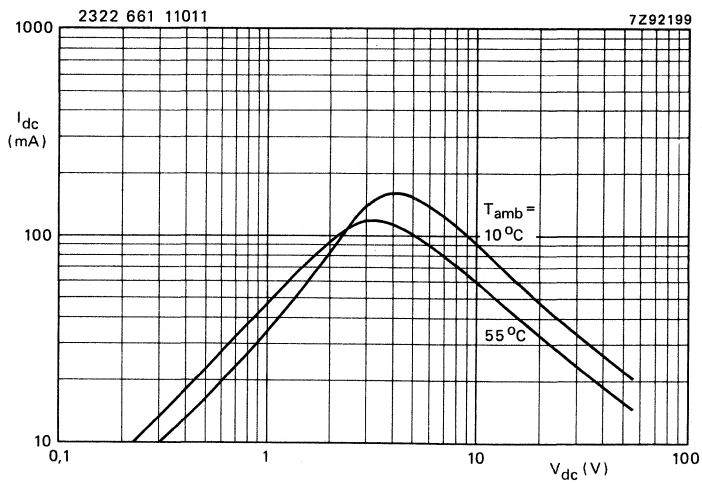


Fig. 19.

Typical voltage/current characteristics.

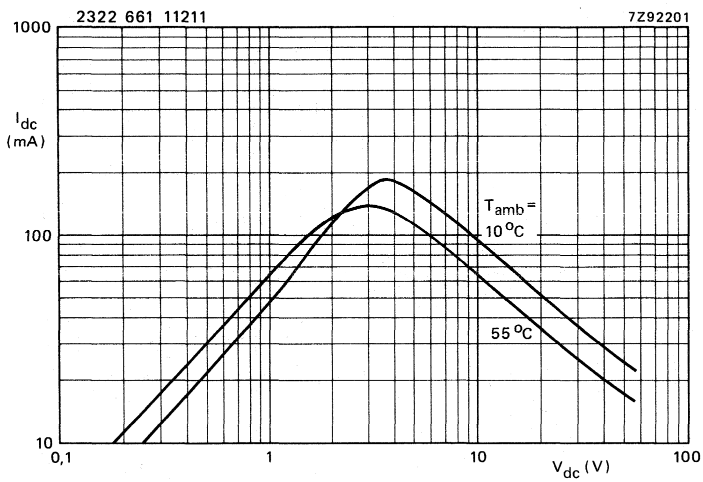


Fig. 20.

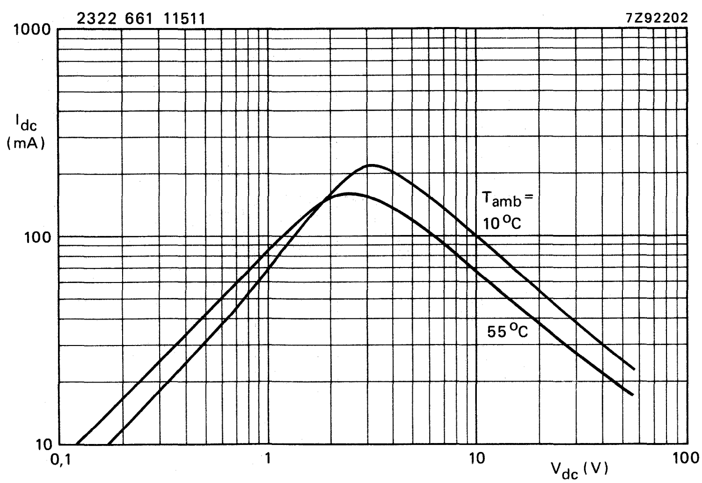


Fig. 21.

Typical voltage/current characteristics.

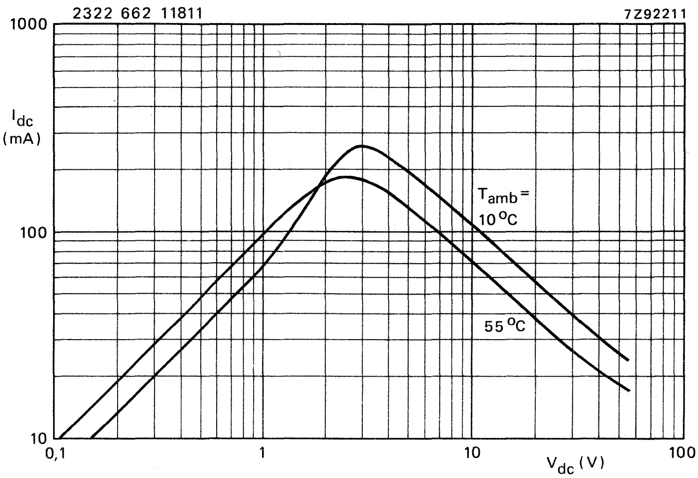


Fig. 22.

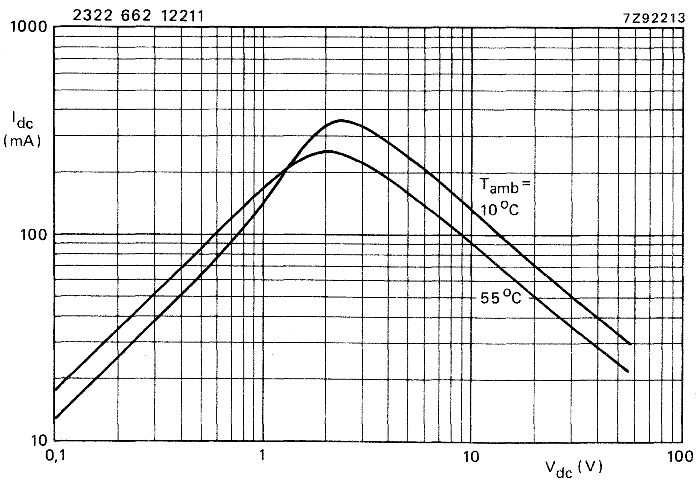


Fig. 23.

Typical voltage/current characteristics.

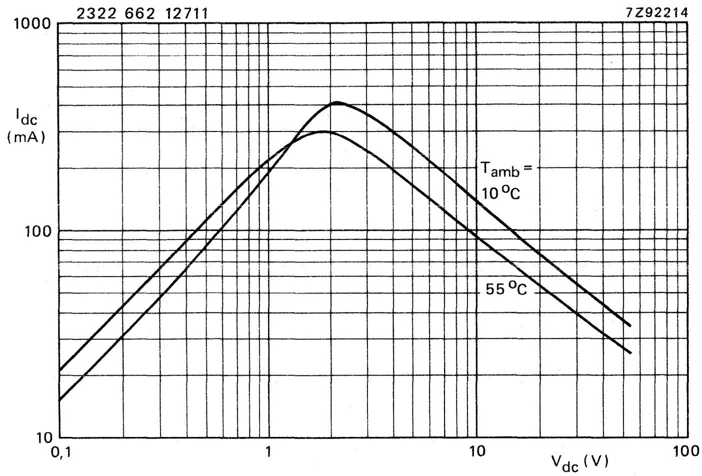


Fig. 24.

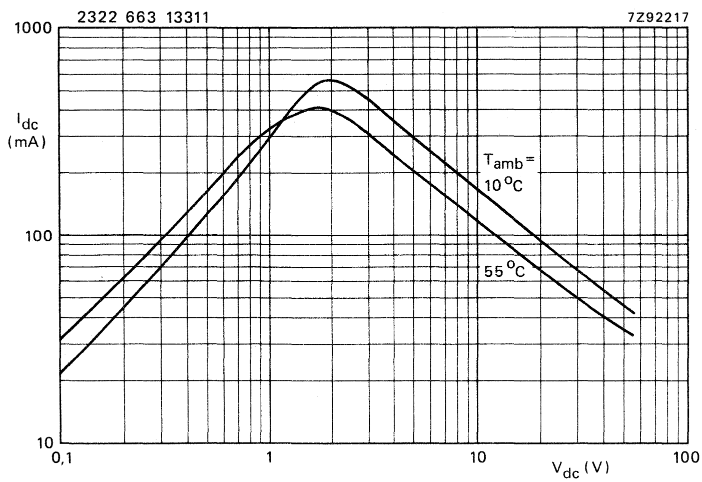


Fig. 25.

Typical voltage/current characteristics.

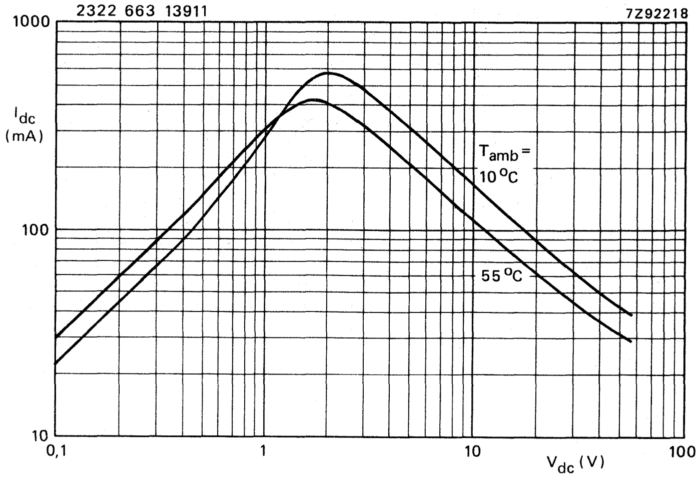


Fig. 26.

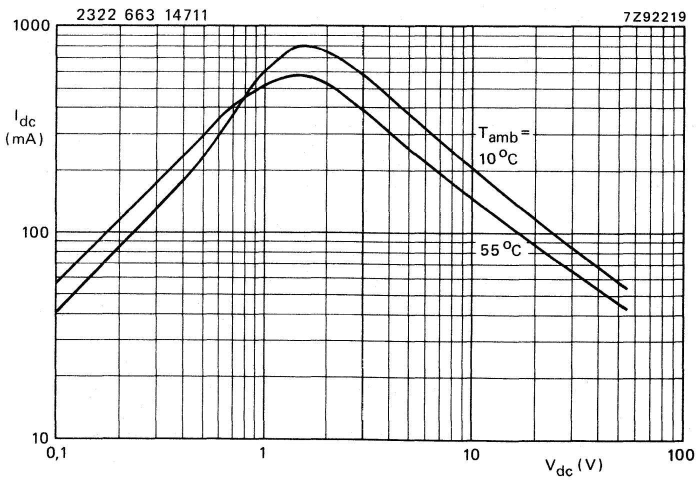


Fig. 27.

Typical voltage/current characteristics.

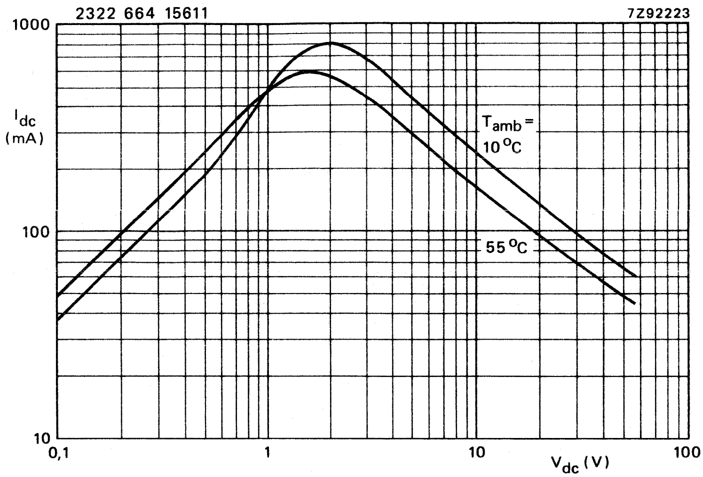


Fig. 28.

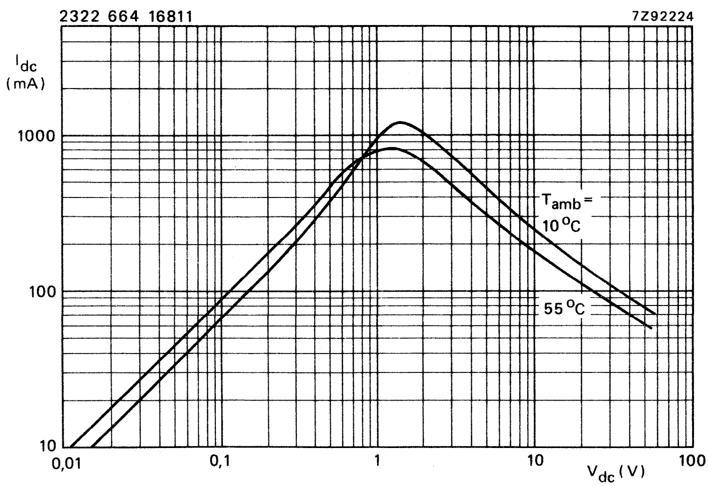


Fig. 29.

Typical voltage/current characteristics.

PTC THERMISTORS

for overload protection

QUICK REFERENCE DATA

Resistance at 25 °C	3,5 to 1900 Ω
Switch temperature	120 °C approximately
Maximum RMS voltage	265 V
Trip current at 10 °C	24 to 940 mA
Operating temperature range at V_{max}	0 to +55 °C

APPLICATION

Overload protection; for use in electrical and electronic equipment such as electric motors, transformers and semiconductor circuits.

DESCRIPTION

These thermistors have a positive temperature coefficient. They consist of a disc with two tinned brass wires, see Fig. 1a. Leadless types having metallized sides for soldering by the user are also available, see Fig. 1b.

MECHANICAL DATA

Outlines

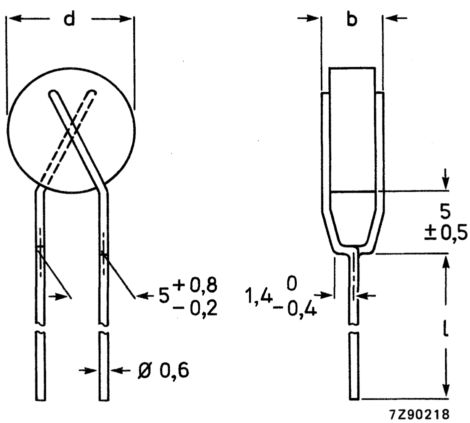


Fig. 1a.

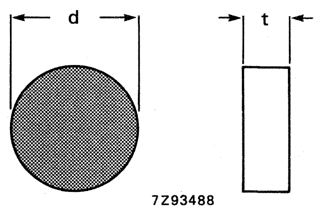


Fig. 1b.

For dimensions b, d, l and t see Table 1.

Marking	None
Mass (types with leads only)	See Table 1
Mounting	in any position by soldering

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

When soldering leadless types it is recommended to use a flux containing colofonium and aethyl alcohol only and to pre-heat the discs to approx. 100 °C in order to avoid thermal shocks which might damage the thermistors.

Impact	200 mm free fall
Inflammability	non-flammable

Packaging (for types with leads)

Cardboard boxes containing following items for:

2322 6601 . . . 3:	500	2322 6621 . . . 3:	100
2322 6611 . . . 3:	250	2322 6631 . . . 3:	100
2322 6621 1213:	200	2322 6641 . . . 3:	100

ELECTRICAL DATA

Unless otherwise specified measured according to IEC publication 738-1 (1982)

Maximum current for not tripping at 55 °C (measuring time 5 minutes)	I_{nt}	See Table 1
Minimum current for tripping after 5 minutes at 10 °C	$I_t = 2 \times I_{nt}$	See Table 1
Resistance at + 25 °C	R_{25}	See Table 1
Switch temperature	T_s	≈ 120 °C
Maximum admissible current at 0 °C	I_{max}	See Table 1
Maximum residual current at 265 V (RMS) at 10 °C	$I_{res\ max}$	See Table 1
Maximum RMS voltage with a series resistor		265 V
Series resistor	R_s	See Table 1
Dissipation factor at T_s	D	See Table 1
Heat capacity	H	See Table 1
Operating temperature range		
at zero power		−25 to + 125 °C
at minimum voltage		0 to + 55 °C

Table 1

catalogue number (see Notes 1 and 2) 2322 followed by	I_{nt} at 55 °C mA	I_t at 10 °C mA	R_{25} approx. Ω	I_{max} at 0 °C mA	$I_{res\,max}$ at 10 °C mA	R_s ± 5% Ω	D approx. mW/K	H approx. J/K	d mm	b max. mm	l ± 3 mm	t max. mm	mass approx. (types with leads only) g
2322 660 .1293	12	24	1900	110	5	1100	6	0,12	4,5	5	20	2,9	0,45
660 .1593	15	30	1200	135	5	1100	6	0,12	4,5	5	20	2,9	0,45
660 .1893	18	36	850	165	5	1000	6	0,12	4,5	5	20	2,9	0,45
660 .2293	22	44	560	200	6	910	6	0,12	4,5	5	20	2,9	0,45
660 .2793	27	54	380	250	6	820	6	0,12	4,5	5	20	2,9	0,45
661 .3393	33	66	280	290	7	750	7	0,22	6,5	5	20	2,9	0,70
661 .3993	39	78	200	350	7	620	7	0,22	6,5	5	20	2,9	0,70
661 .4793	47	94	140	420	7	560	7	0,22	6,5	5	20	2,9	0,70
661 .5693	56	112	100	500	8	470	7	0,22	6,5	5	20	2,9	0,70
661 .6893	68	136	72	600	8	390	8	0,33	8,0	5	20	2,9	0,90
661 .8293	82	164	50	730	9	330	8	0,33	8,0	5	20	2,9	0,90
661 .1013	100	200	33	900	9	270	8	0,33	8,0	5	20	2,9	0,90
662 .1213	120	240	26	1100	12	220	8,5	0,48	10,0	5	20	2,9	1,30
662 .1513	150	300	20	1300	12	200	9,5	0,68	12,0	5	20	2,9	1,80
662 .1813	180	360	14	1700	14	150	9,5	0,68	12,0	5	20	2,9	1,80
663 .2213	220	440	10	2100	16	120	10	0,85	13,0	5	20	2,9	2,15
663 .2713	270	540	8	2500	19	100	12	1,30	16,0	5	20	2,9	2,90
664 .3313	330	660	7	3000	25	82	16	2,40	20,0	6	16	3,6	5,30
664 .3913	390	780	5	3600	25	68	16	2,40	20,0	6	16	3,6	5,30
664 .4713	470	940	3,5	4300	25	56	16	2,40	20,0	6	16	3,6	5,30

Notes to Table 1

1. For leadless types, replace the dot in the catalogue number by 0; for types with leads, replace it by 1.
2. For taped devices up to 12 mm in diameter, replace the dot by 3.

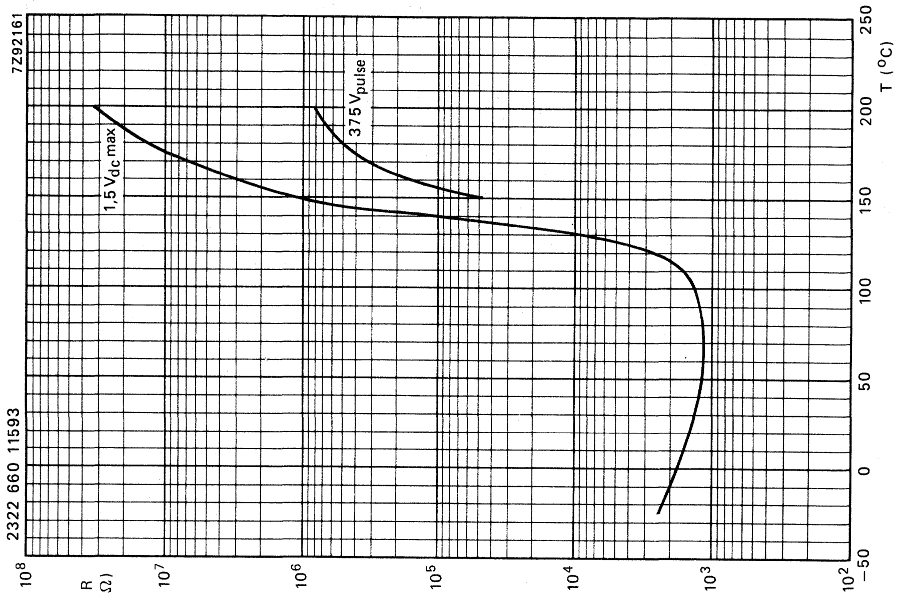


Fig. 3.

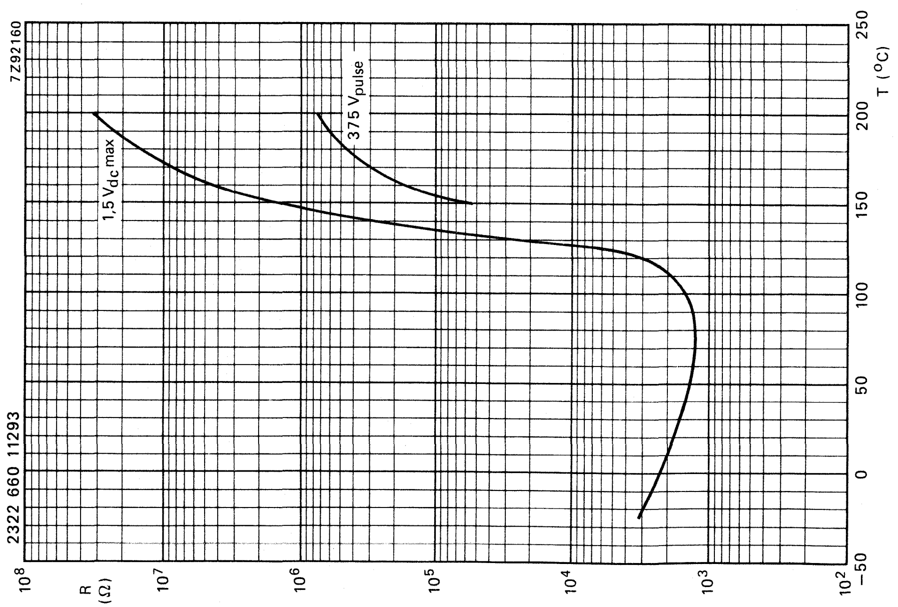


Fig. 2.

Typical resistance/temperature characteristics.

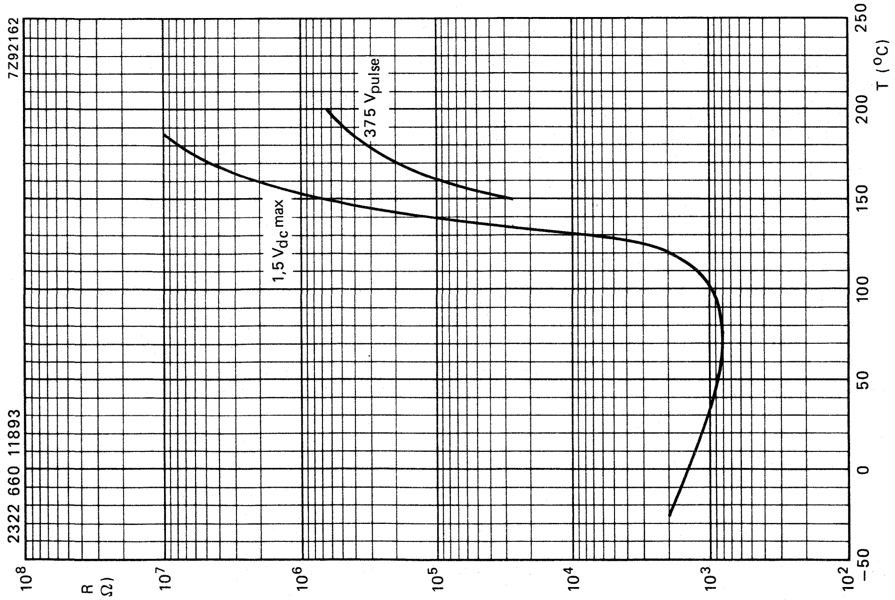


Fig. 4.

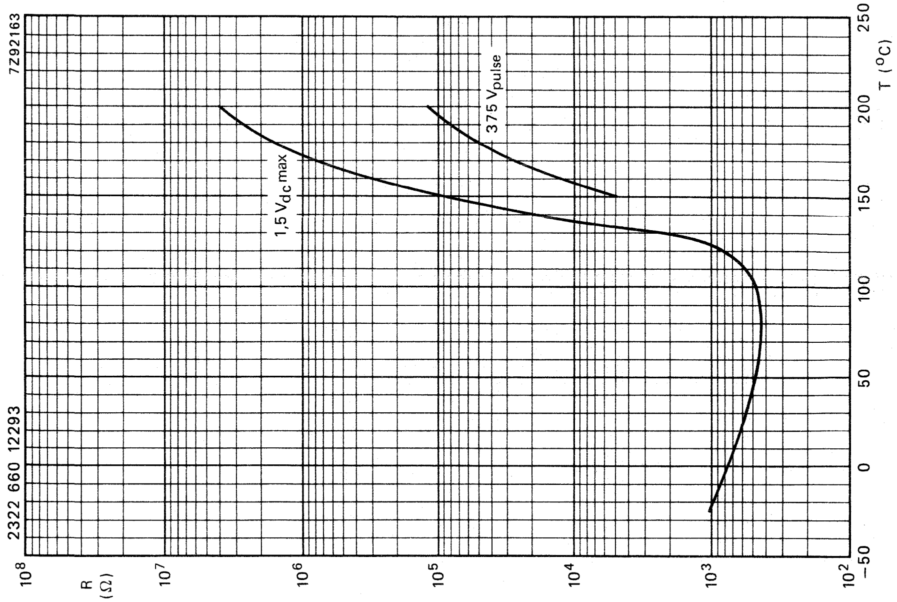


Fig. 5.

Typical resistance/temperature characteristics.

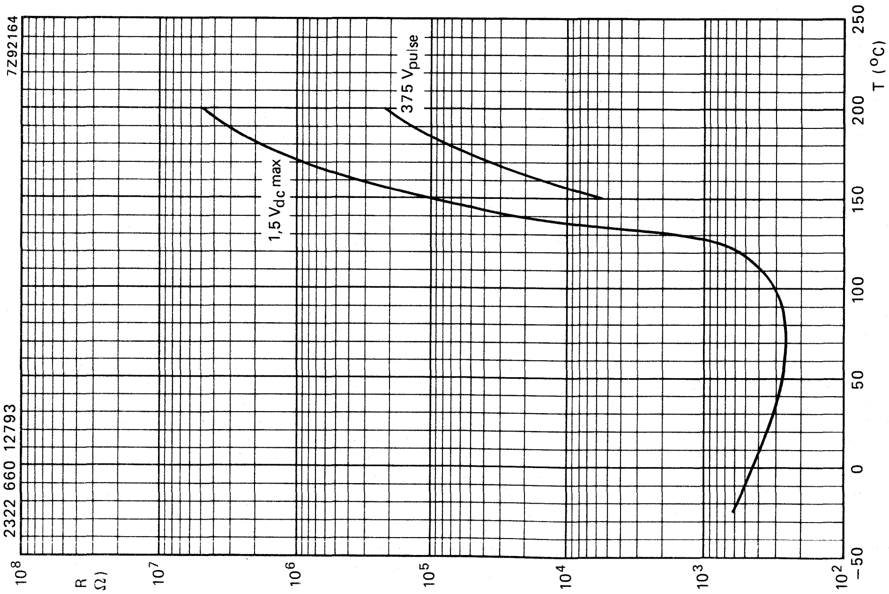


Fig. 6.

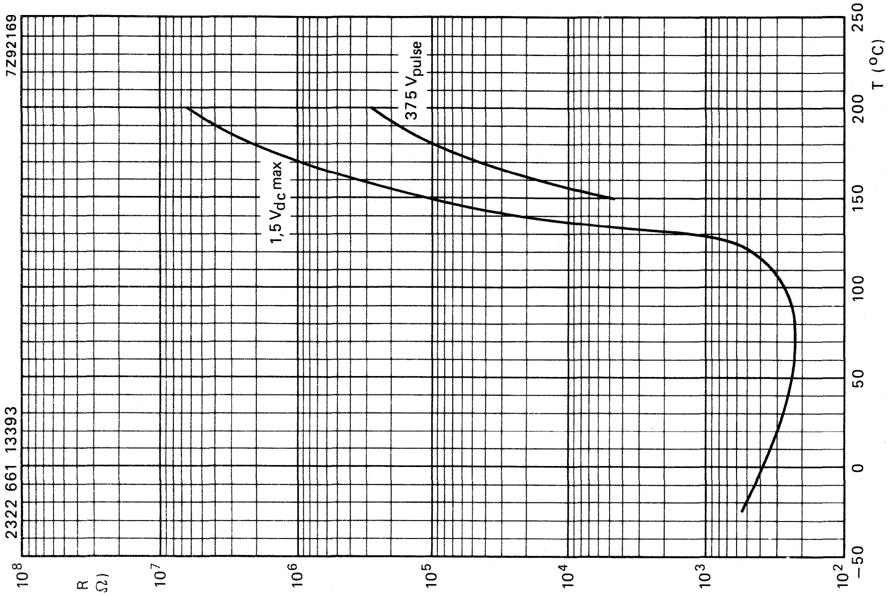


Fig. 7.

Typical resistance/temperature characteristics.

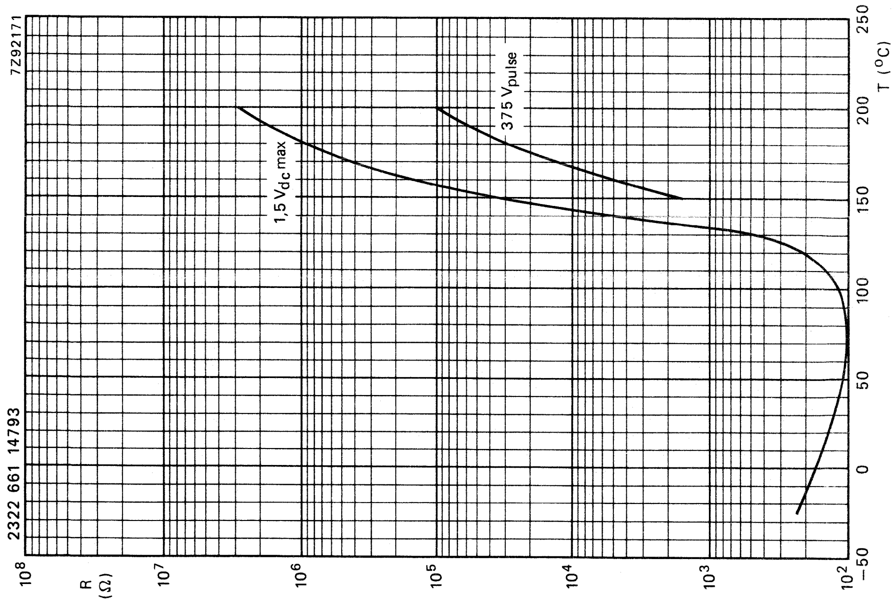


Fig. 9.

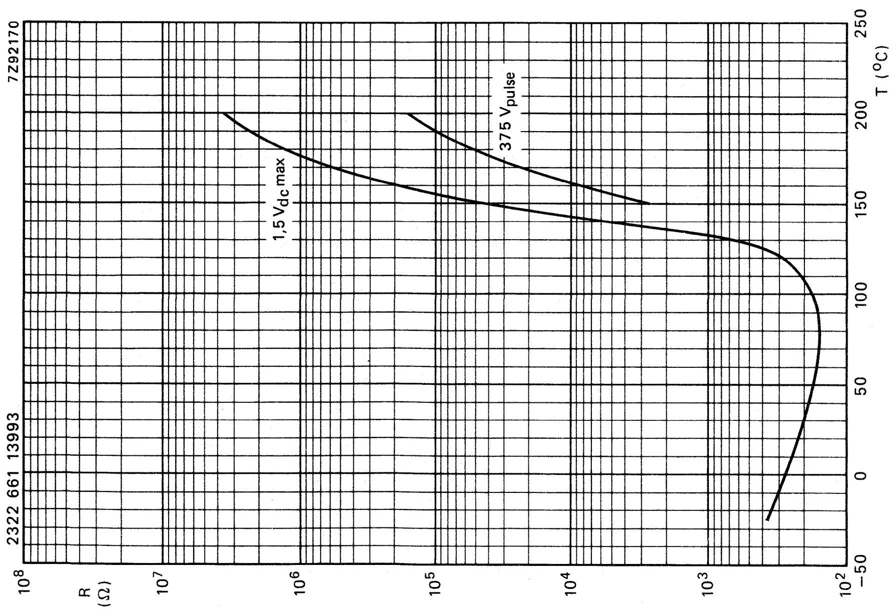


Fig. 8.

Typical resistance/temperature characteristics.

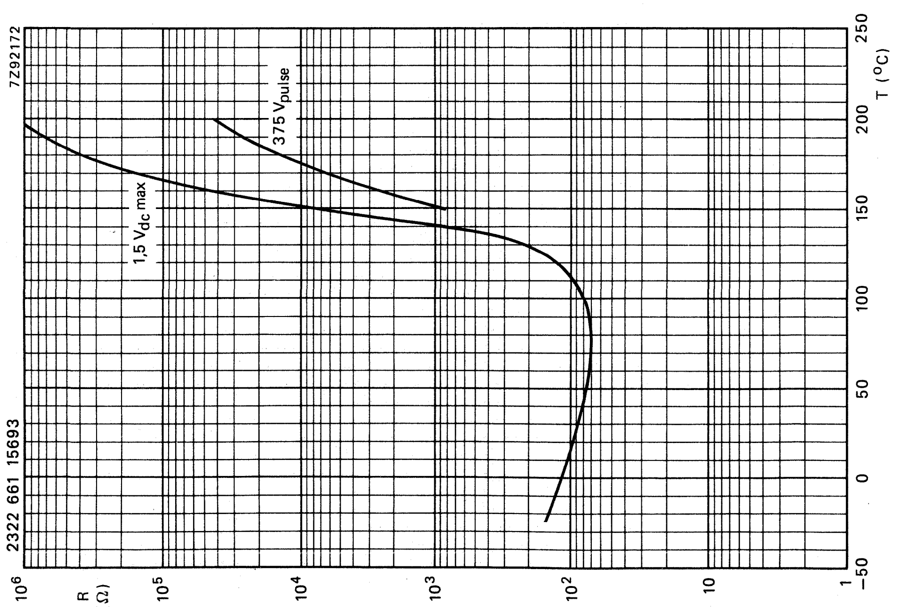


Fig. 10.

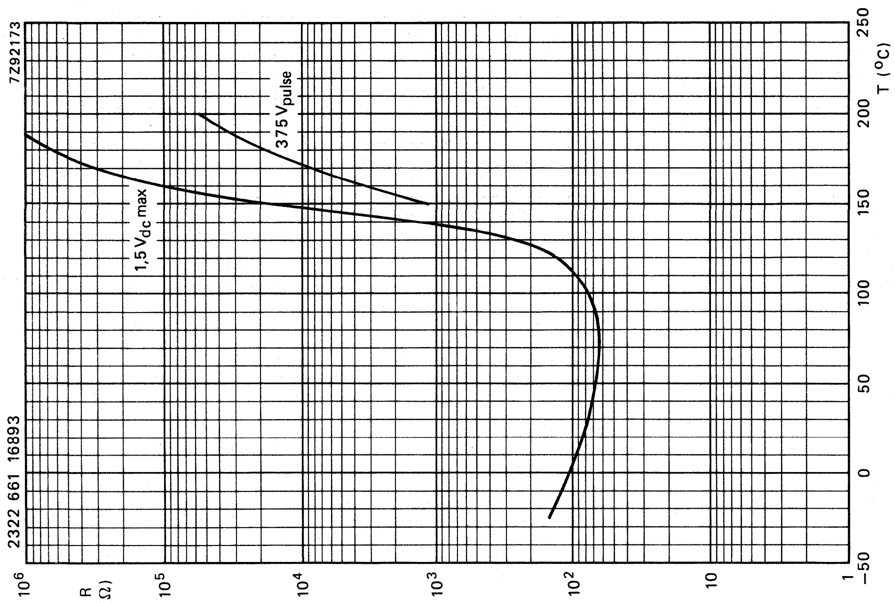


Fig. 11.

Typical resistance/temperature characteristics.

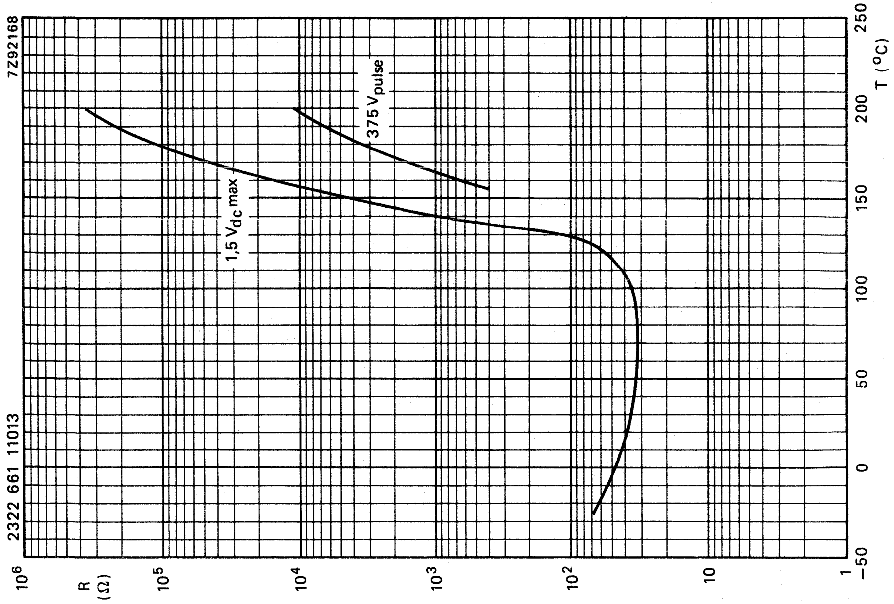


Fig. 13.

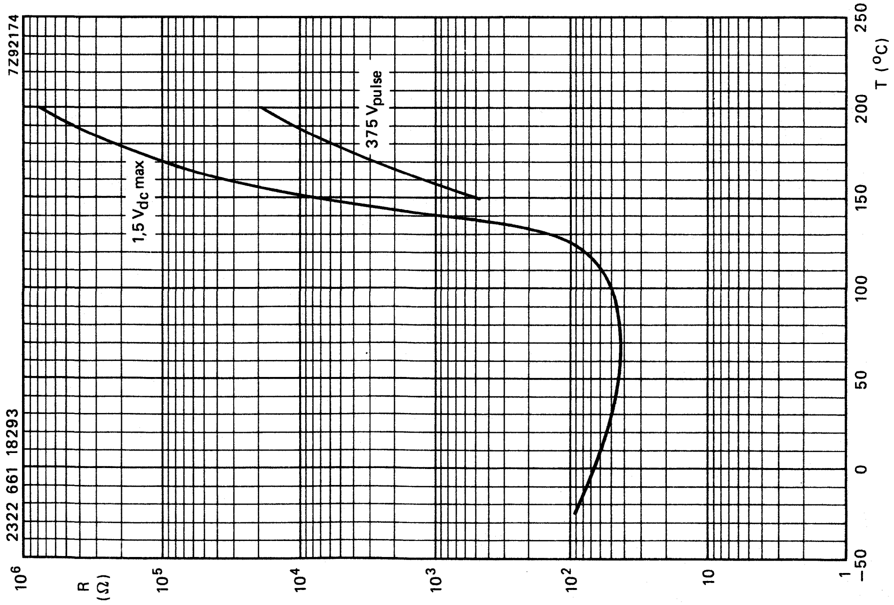


Fig. 12.

Typical resistance/temperature characteristics.

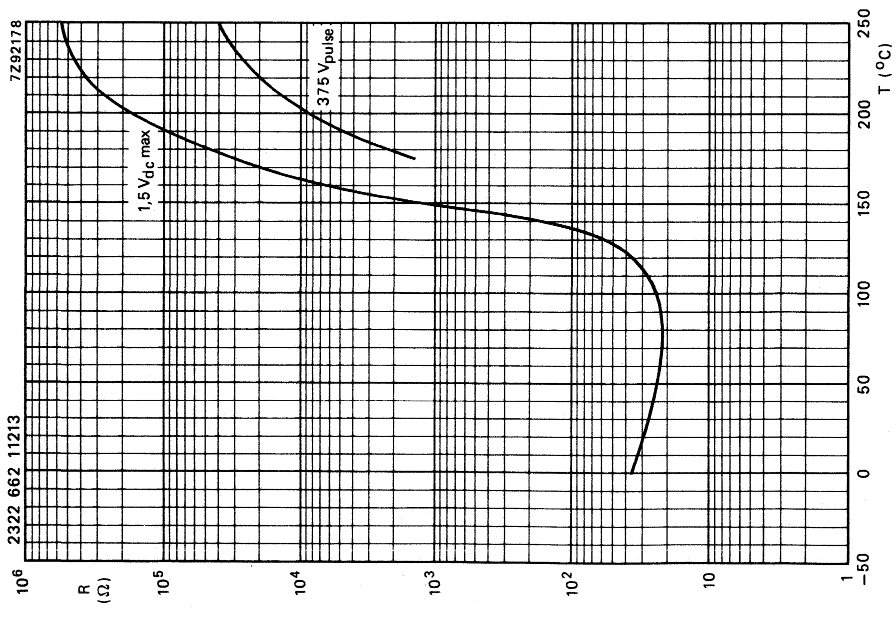


Fig. 14.

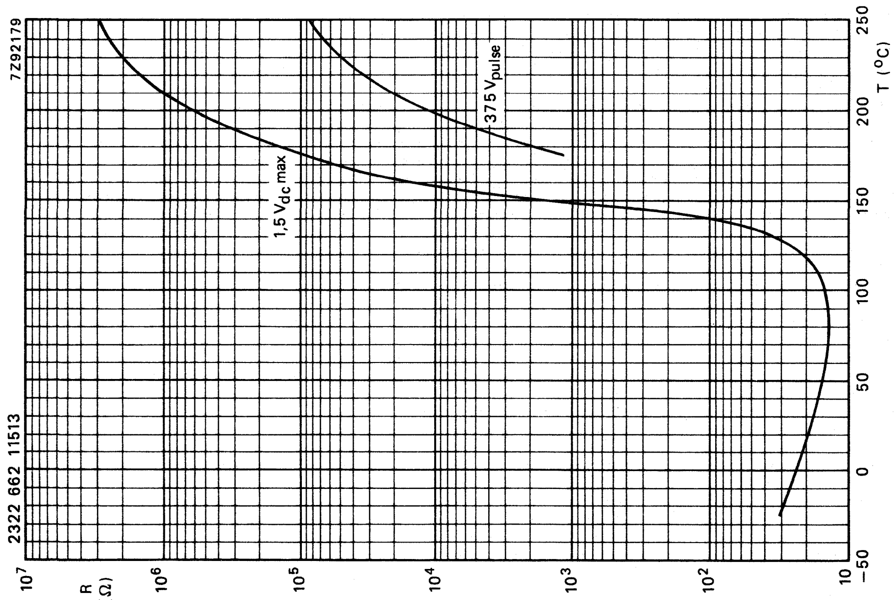


Fig. 15.

Typical resistance/temperature characteristics.

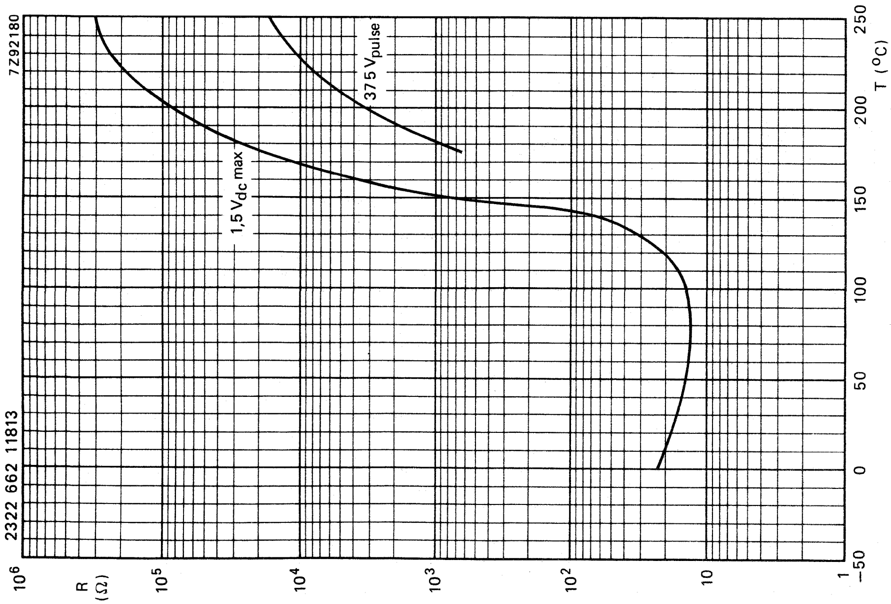


Fig. 16.

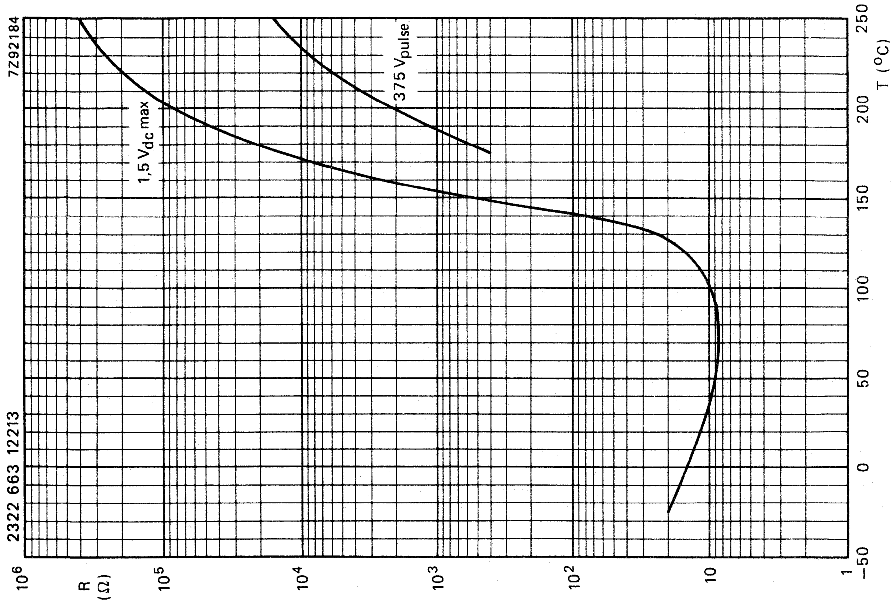


Fig. 17.

Typical resistance/temperature characteristics.

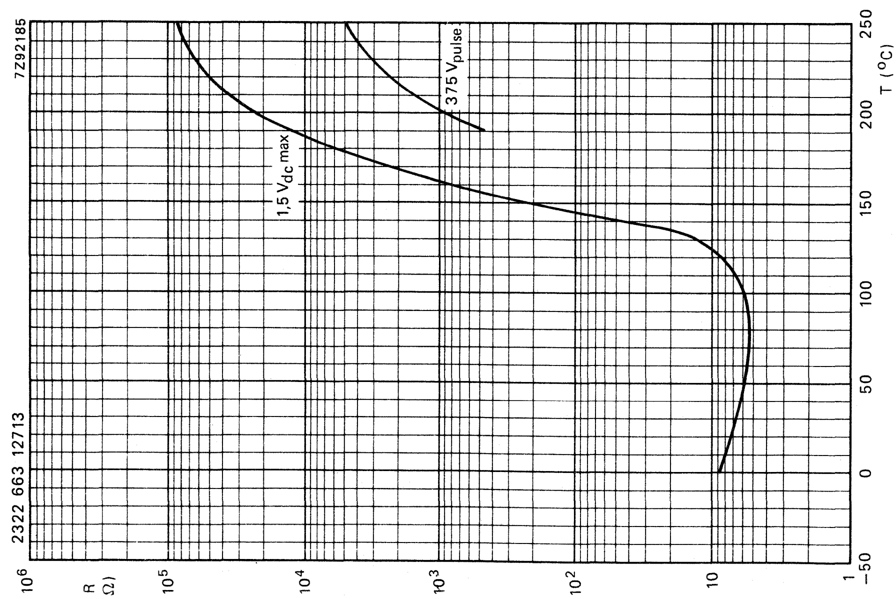


Fig. 18.

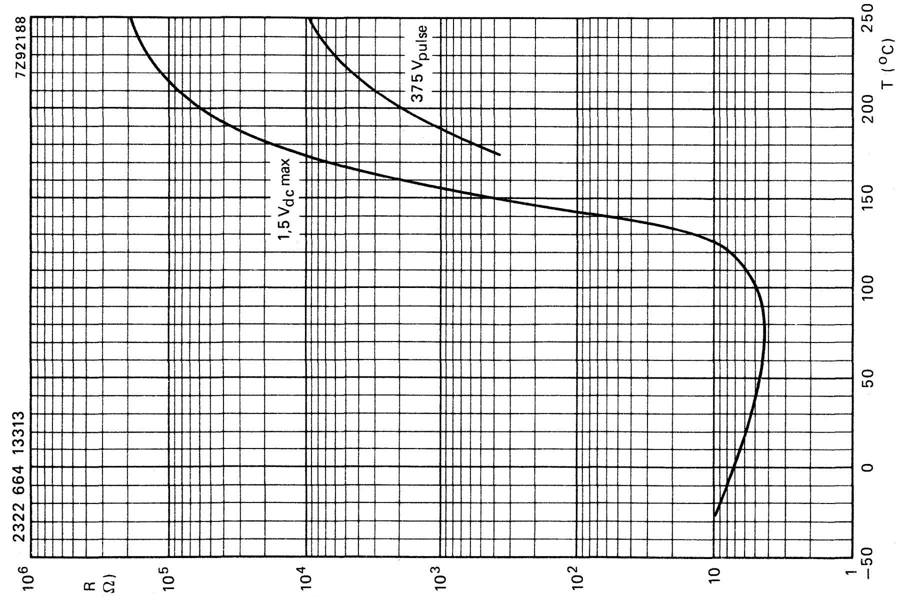


Fig. 19.

Typical resistance/temperature characteristics.

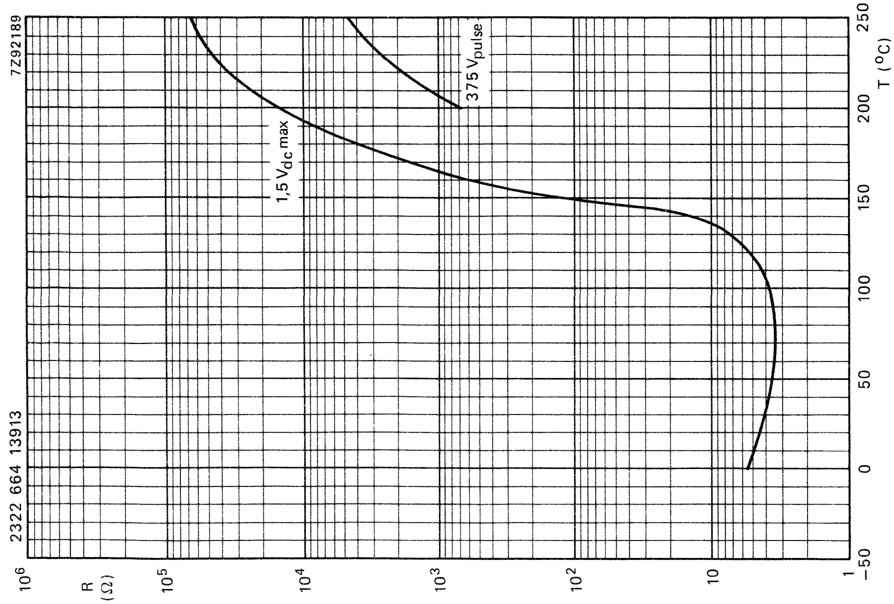


Fig. 20.

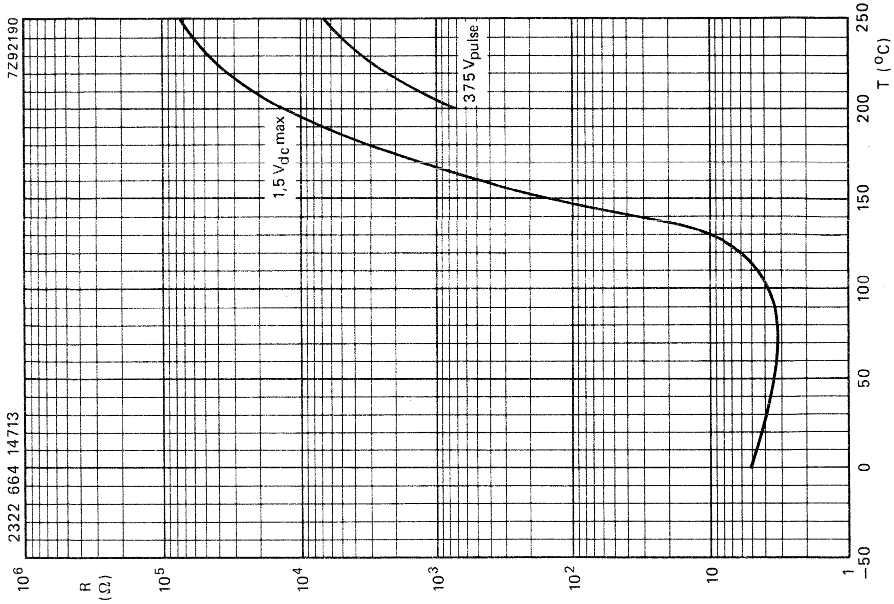


Fig. 21.

Typical resistance/temperature characteristics.

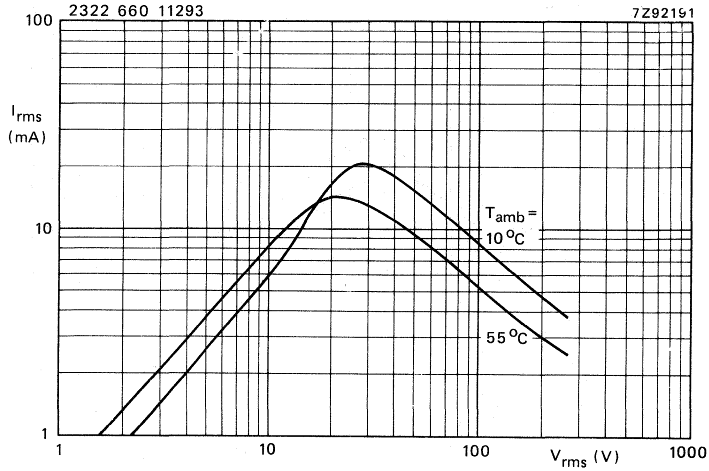


Fig. 22.

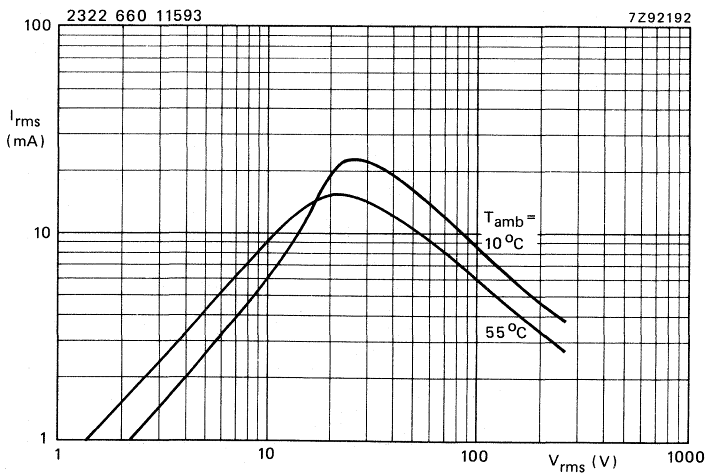


Fig. 23.

Typical voltage/current characteristics.

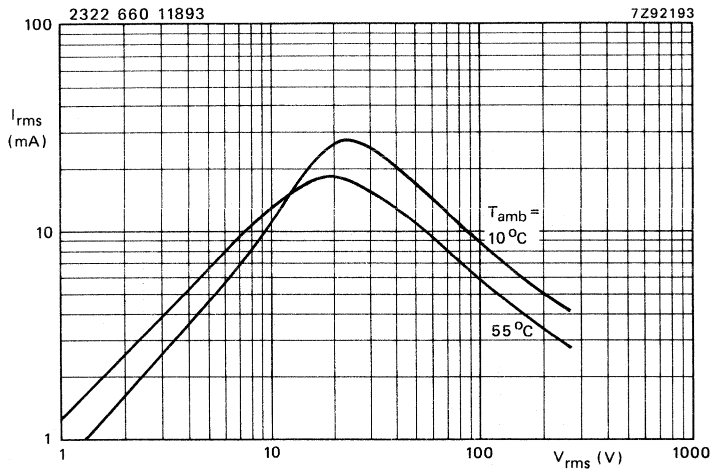


Fig. 24.

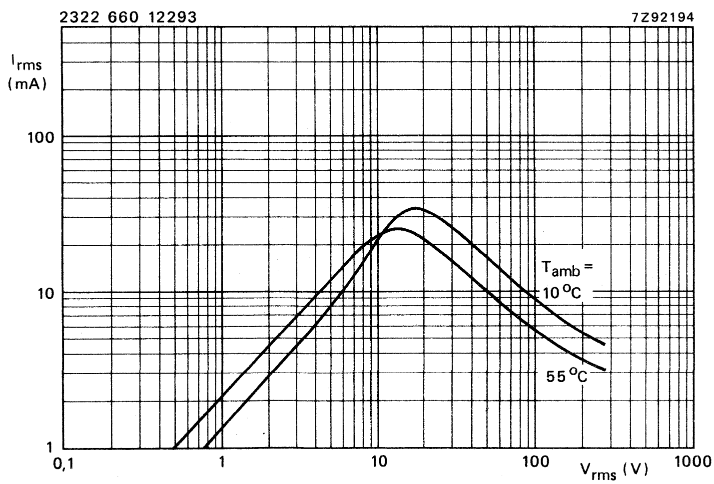


Fig. 25.

Typical voltage/current characteristics.

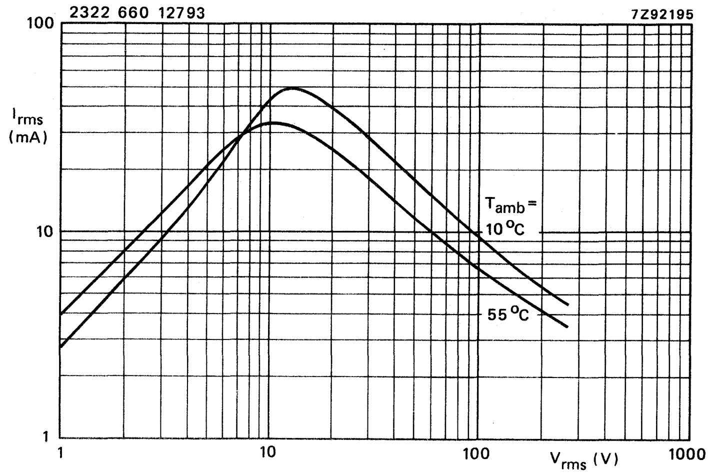


Fig. 26.

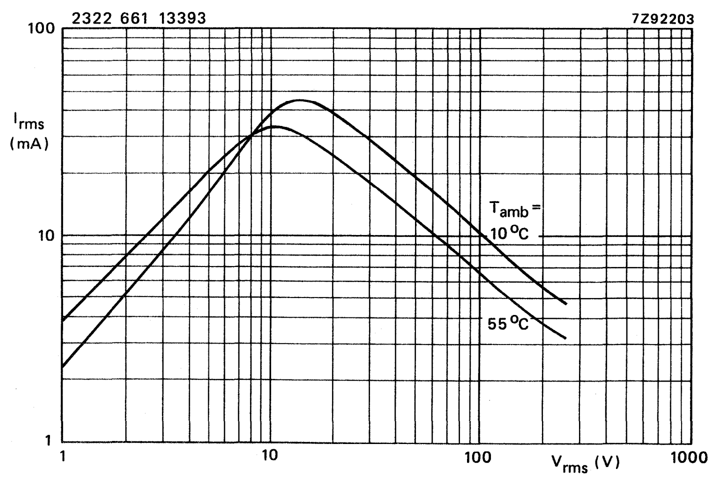


Fig. 27.

Typical voltage/current characteristics.

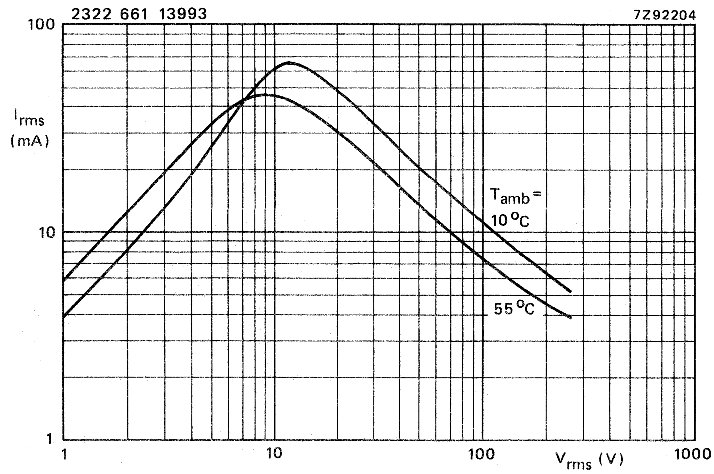


Fig. 28.

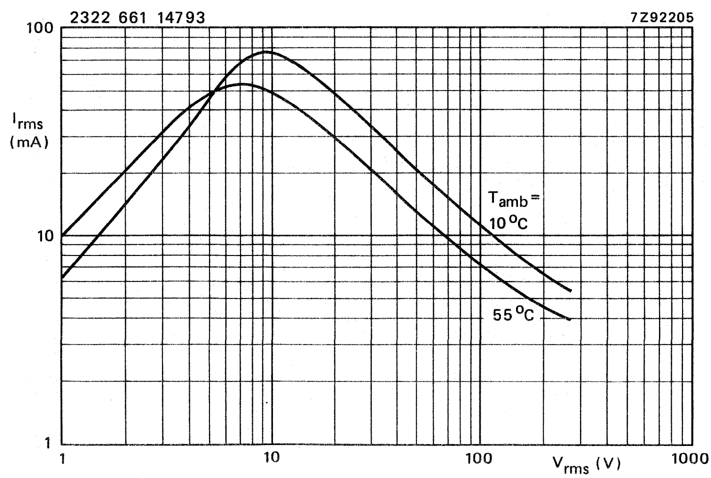


Fig. 29.

Typical voltage/current characteristics.

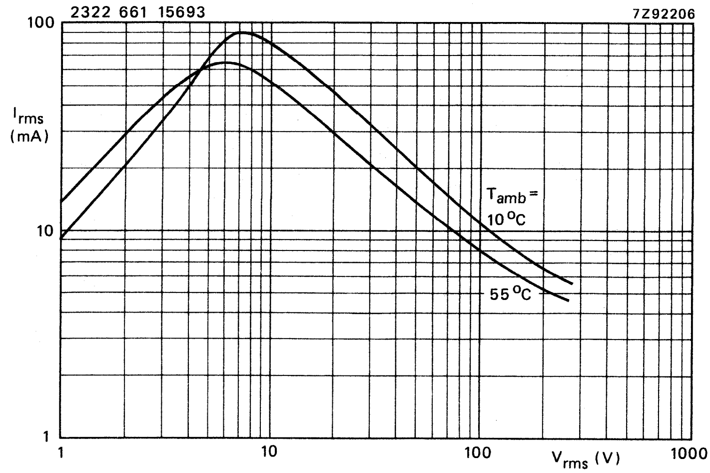


Fig. 30.

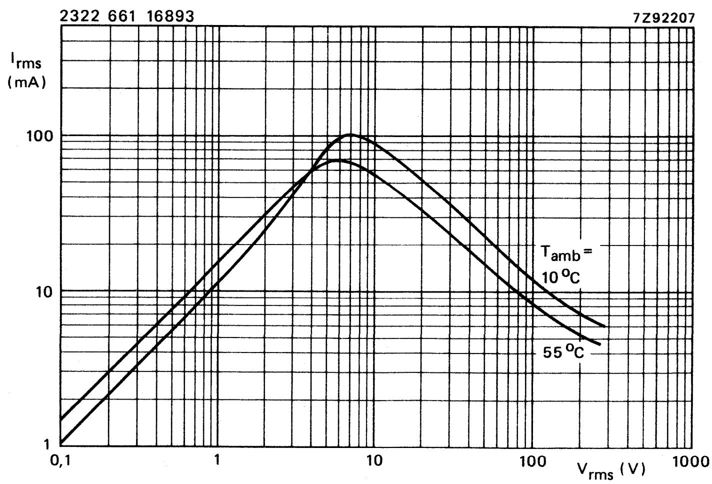


Fig. 31.

Typical voltage/current characteristics.

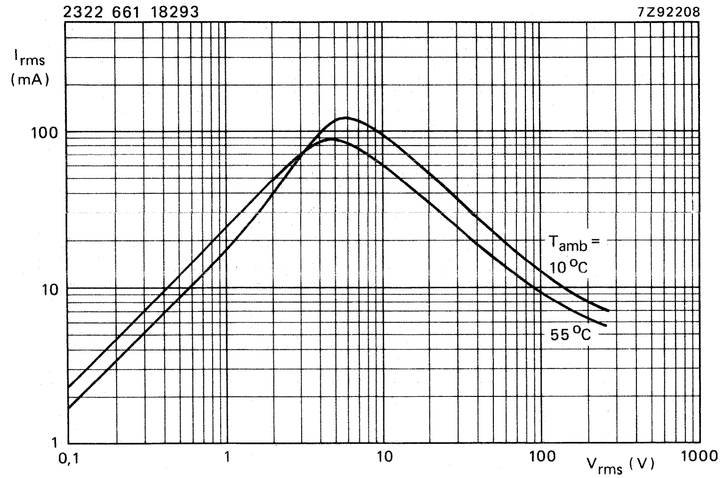


Fig. 32.

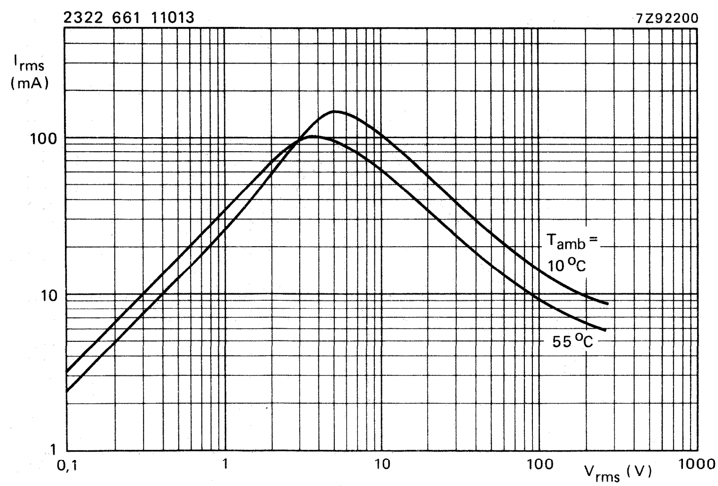


Fig. 33.

Typical voltage/current characteristics.

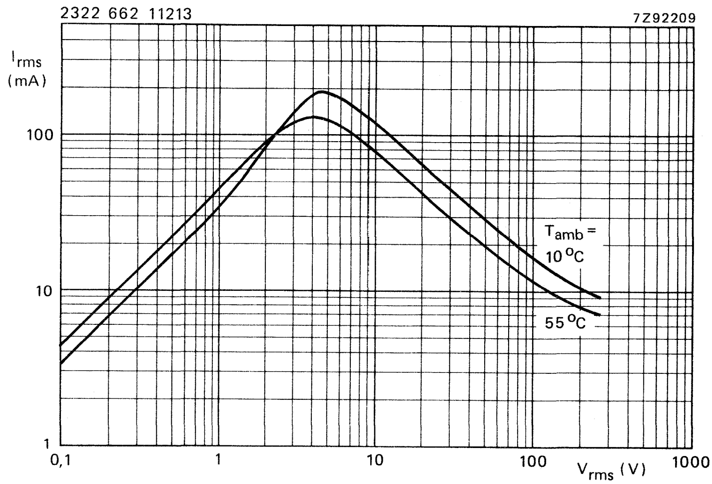


Fig. 34.

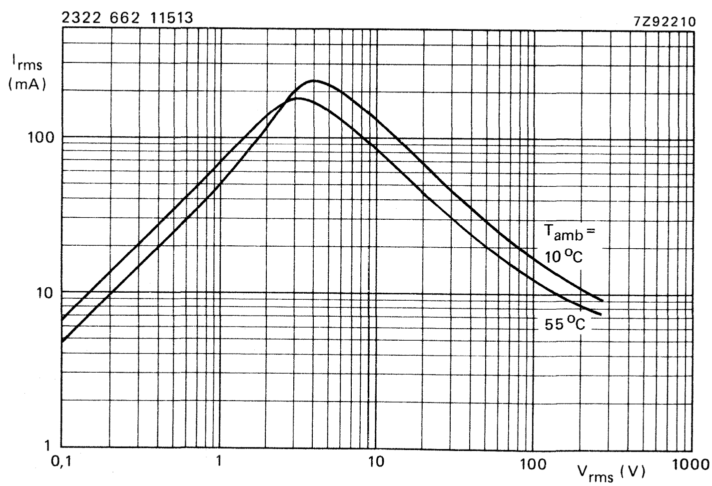


Fig. 35.

Typical voltage/current characteristics.

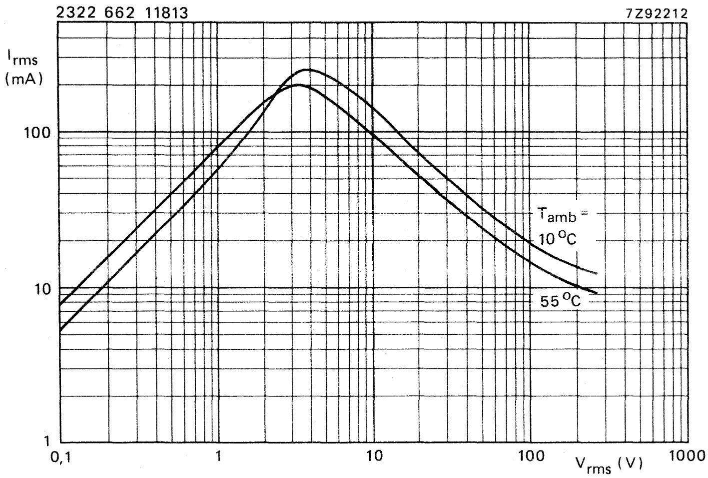


Fig. 36.

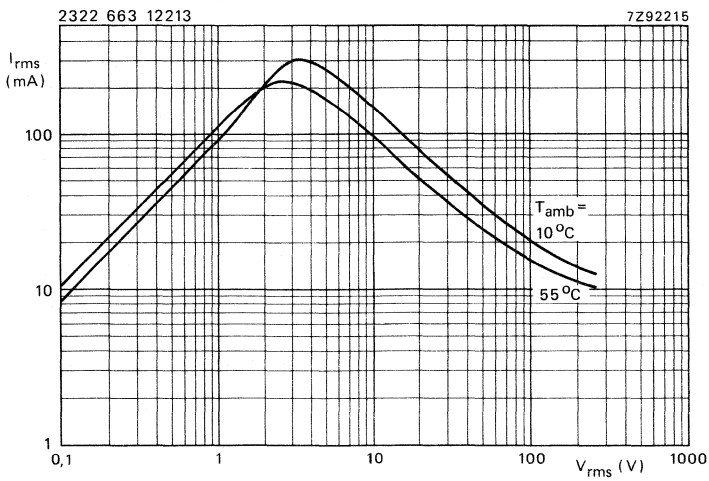


Fig. 37.

Typical voltage/current characteristics.

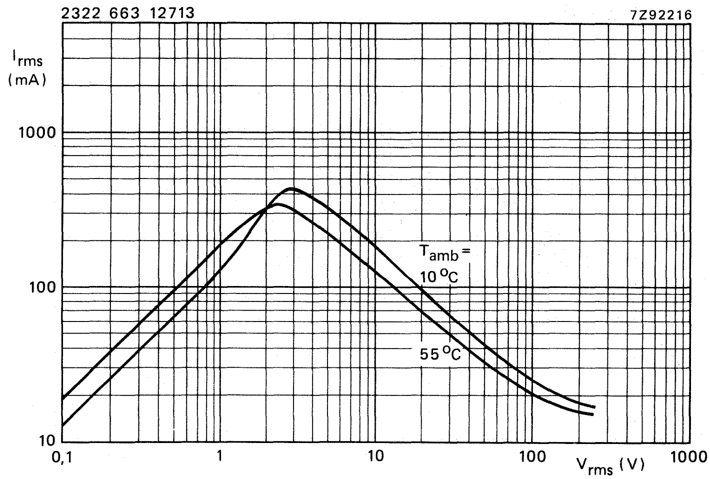


Fig. 38.

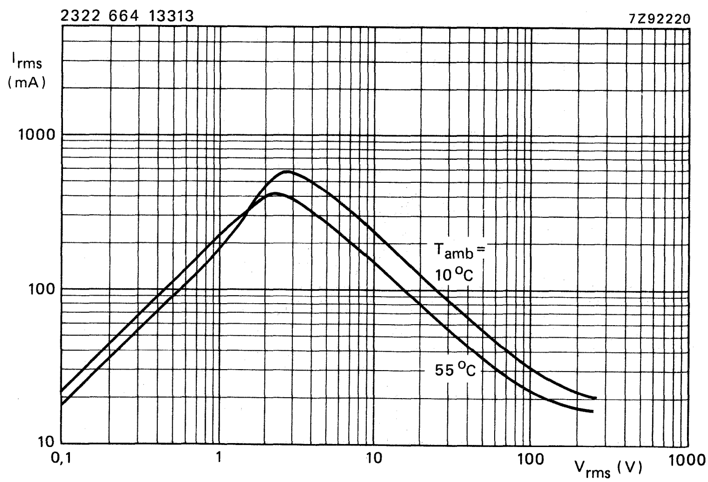


Fig. 39.

Typical voltage/current characteristics.

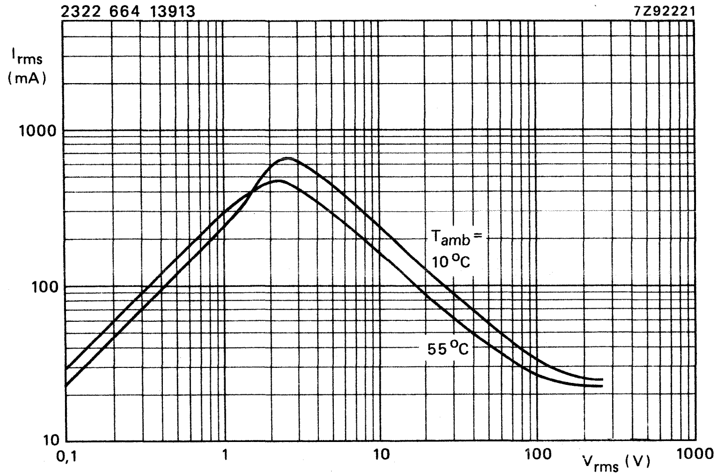


Fig. 40.

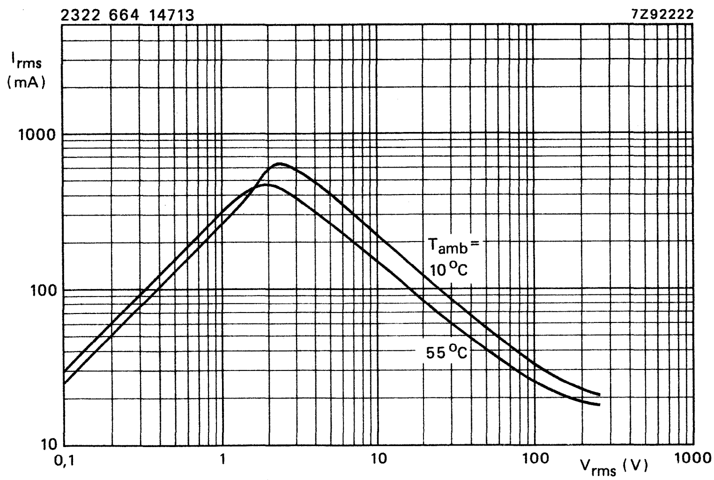


Fig. 41.

Typical voltage/current characteristics.

NEGATIVE TEMPERATURE COEFFICIENT (NTC) THERMISTORS

INTRODUCTION

Definition and composition

Negative temperature coefficient thermistors (NTCs) are resistive components, of which the resistance decreases as temperature increases. They are made from polycrystalline semiconductors, the compositions of which are a mixture of chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co) and nickel (Ni).

Manufacture

The manufacturing process is comparable to that of ceramics. After intensive mixing and the addition of a plastic binder, the mass is shaped into the required form, e.g. extrusion (rods) or pressing (discs), and fired at a temperature high enough to sinter the constituent oxide. New technologies have led to the sawing of isostatic pressed wafers, the compositions of which are very stable with, as a result, high accuracy and high reproducibility.

Electrical contacts are then added by burning them in with silver paste or by other methods, such as evaporation. Finally, leads (isolated or not), are fitted. Different encapsulations are possible, depending on the size of the ceramic and the application of the component.

Miniature NTC thermistors are made by placing a bead of oxide paste between two parallel platinum alloy wires and then drying and sintering. The platinum alloy wires are 60 μm in diameter and spaced 0.25 mm apart. During sintering, the bead shrinks onto the wires to make a solid and reliable contact. Miniature NTC thermistors are usually mounted in glass to protect them against aggressive gases and fluids.

Relationship of resistance with temperature

The conductivity (σ) of a material is its capacity to drive a current when a voltage is applied to it. As the current is driven by carriers that are free to move (i.e. which are not bound to atoms), then it follows that the conductivity will be proportional to the number of carriers (n) that are free and also to the mobility (μ) that those carriers can acquire under the influence of electrical fields. Thus:

$$\sigma = ne\mu$$

where e is the unit of electrical charge stored by each carrier.

Both n and μ are functions of temperature. For μ, the dependance on temperature is related to the interactions of a carrier with other carriers and with the total net amount of vibrating atoms, the vibration varying with temperature. It can be shown that:

$$\mu \propto e^{-q2/kT}$$

For n, the dependance on temperature can be explained in the following way: electrons are bound to atoms by certain energies. As one gives the electron an energy equal to, or greater than, the binding energy (e.g. by raising its temperature), there is a probability that the electron will become free to move. As for many semiconductors, this probability has the form of the well known Maxwell-Boltzmann distribution. Thus:

$$n \propto e^{-q1/kT}$$

Relationship of resistance with temperature (continued)

The total temperature dependence of the conductivity is:

$$\sigma = T^{-c} e^{-(q_1 + q_2)/kT}$$

In practice, the exponential factor is the most important. Remembering that resistivity is the inverse of conductivity, the following can be derived:

$$R = A\, e^{B/T} \text{ or } \log R = A + (B/T)$$

where A and B are parameters depending on each component (resistivity and shape).

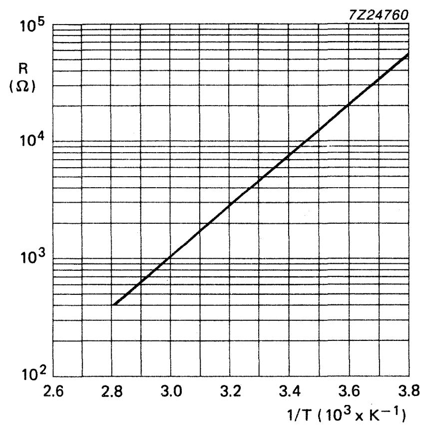


Fig.1 Resistance (in ohms) as a function of inverse of temperature (in 10^3 x K^{-1}) for a typical NTC.

Shape of a NTC curve and determination of B value

In Fig.1, resistance is plotted as a function of the inverse of temperature. Even in semi-log scale, it can be seen that this curve is not a straight line. This is due to the fact that A and B are not perfectly constant with temperature. However, over a wide range of temperatures, it may be assumed that these parameters are constant.

If this range is defined between T_1 and T_2, and it is assumed that the curve on this range could be approximated with a straight line, the slope of which will be B, this last value between T_1 and T_2 may be found as follows:

The resistance value is measured at T_1 and T_2.

$R_1 = A\, e^{B/T_1}$ and $R_2 = A\, e^{B/T_2}$

Dividing yields:

$R_1/R_2 = e^{(B/T_1 - B/T_2)}$

or:

$\log R_1 - \log R_2 = B\,(1/T_1 - 1/T_2) \log e$

solving for B gives:

$$B = \frac{\ln R_1/R_2}{1/T_1 - 1/T_2}$$

In practice, B varies slightly with increasing temperature.

The temperature coefficient of a NTC may be derived from:

$\alpha = 1/R \,.\, dR/dT = - B/T2$

For the different materials, the constant B may vary between 2000 and 5500 K; e.g. a value of 3600 K yields α = –4% per K at a temperature of 300 K.

A and B are assumed to be constant between T_1 and T_2 ($B_{T1/T2}$)

In practice, most NTC's are specified with a reference value at 25 °C and a constant B value between 25 °C and 85 °C. For commodity reasons, the curves printed in this handbook show the resistance as a function of temperature, instead of its inverse.

V/I characteristics

Figure 2 shows the relationship between current and voltage drop through the NTC thermistor heated by this current to a temperature much higher than the ambient temperature.

With very small values of current, it can be seen that the curve remains straight, following an isoresistive line. Remembering that an isoresistive line is in fact an isothermal line (R = fct[T]), it indicates that the power consumption is too small to register a distinct rise in temperature.

For higher current intensities, the temperature rises by Joule effect (P = VI). The equilibrium temperature is reached when the power dissipated by the NTC is in equilibrium with the power applied to it. It can be seen that as the dissipated power is dependent on the environment, the equilibrium will also depend on it and thus the V-I characteristic also. The characteristic shown in Fig.2 was measured at a constant ambient temperature after equilibrium had been reached.

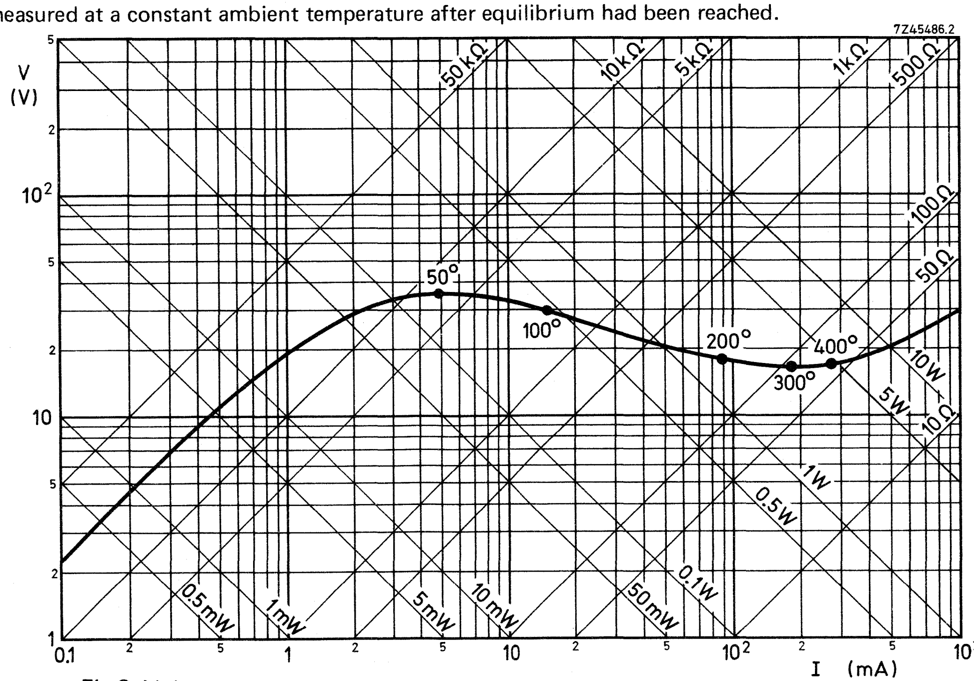


Fig.2 Voltage as a function of the current characteristics of an NTC thermistor.

Assuming:

(A) a constant temperature throughout the body of the thermistor;

(B) the heat transfer to be proportional to the difference in temperature between the thermistor and the surrounding medium (which is true for low temperatures).

V/I characteristics (continued)

In case of equilibrium:

$$W = VI = \delta(T - T_0)$$

in which T_0 is the ambient temperature and δ the dissipation factor (defined in the following paragraph).

From this relationship, it is obvious that the temperature of the component will be that of its surroundings if the power applied to the component (W) is equal to zero (power off value). If the applied power is not very small (< 0.01 W), then T is no longer equal to T_0 and will be strongly dependent on δ (power on conditions).

Because it is not possible to define δ without any doubt, (δ is not dependent on the component itself, but also on special housing, if any, convection, turbulence, etc.), all components are specified with their power off values.

To choose a component that will be used in a 'power on' application, it is necessary to determine δ in that application.

SPEED OF RESPONSE

Thermal Time Constant

The thermal time constant is an indication of the time that a component needs to reach thermal equilibrium. This constant depends on two important parameters.

One is the thermal capacity (H) of the component, i.e. the energy that must be applied to the component in order to raise its temperature by 1 Kelvin (or the energy that the component must lose in order to lower its temperature by 1 Kelvin). The units are thus quoted in Joules/Kelvin. The second parameter is called the dissipation factor (δ). If the temperature of a component rises, it will tend to dissipate energy. This dissipation will depend on the surroundings and also on the component itself. The dissipation factor is defined as the ratio of the change in power dissipation with respect to the resultant body temperature change (units in W/K).

If a step change in temperature is applied to a component e.g. from high (T_1) to low (T_0) temperature, the energy lost by the component ($-HdT$) is equal to the energy dissipated by it ($\delta[T - T_0]dt$).

$$-HdT = \delta(T - T_0)dt$$

This equation yields:

$$T - T_1 = (T_0 - T_1)e^{-t/\tau}$$

where the thermal time constant (τ) is defined as the ratio of the heat capacity (H) of the thermistor with respect to its dissipation factor (δ).

The temperature value when the time elapsed is ($t = \tau$) is given in the formula:

$$T - T_0/T_1 - T_0 = (1 - e^{-1}) = 0.632$$

This equation gives the following definition:

The thermal time constant is the time required for the temperature of a thermistor to change by 63.2% of the difference between its initial and final body temperatures (in accordance wit IEC 539; 85 °C and 25 °C respectively), when subjected to a step function temperature change.

It is entirely dependent on the component design. The thermal time constant depends on δ, which varies for different media.

The thermal time constants referred to in the data sheets are measured as follows, the method used depending on the application:

- by cooling in air under zero power conditions (T_c)
- by warming or cooling, transferring the thermistor from ambient temperature of + 25 °C to a bath with a fluid with a higher or lower temperature under zero power conditions (T_r, termed 'response time' in the data sheets).

Tolerances on the Nominal NTC Specification

As already mentioned, an NTC thermistor is normally specified by giving a reference value (generally R_{25}) and the B value ($B_{25/85}$). Unfortunately, the manufacturing process dictates that identical components cannot be guaranteed, so there are some tolerances.

These tolerances can mean an upward or downward shift in the resistance value, equal at all temperatures due to, for example, soldering tolerances. The entire curve moves equally up or down:

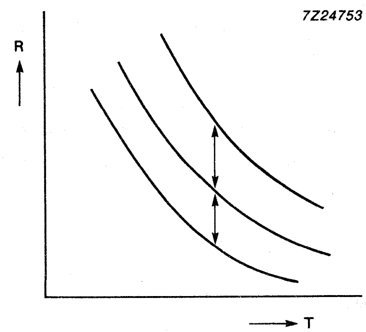


Fig.3 Effect of soldering as a function of resistance against time.

This tolerance is usually indicated by giving the shift at the reference temperature, so for example, R_{25} = 10 kΩ ± 5%.

A tolerance also exists on the slope of the curve. Because the B value is an indication of that slope, it is normally indicated as a tolerance on $B_{25/85}$. This is covered mainly by variations in the material composition and the effect of sintering on the material.

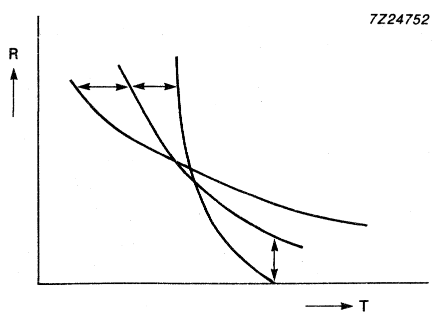


Fig.4 Effect of sintering on resistance against time.

The effect of the slope or the B-value deviation on the resistance at several temperatures can be calculated.

Tolerances on the Nominal NTC Specification (continued)

The fundamental equation of a NTC is:

$$R_n\,(T) = R_{ref}\ ^{B(1/T\,-\,1/T_{ref})}$$

where R_n and B are nominal values (specified values without any tolerance).

If B is not a nominal value, it is expressed as:

$$R\,(T) = R_n\,(T) + \Delta R(T) = R_{ref}\,e^{\,(B + \Delta B)\,(1/T\,-\,1/T_{ref})}$$

where $\Delta R(T)$ is the absolute deviation at temperature T.

$$\Delta R(T) = R_{ref}\,[\,e^{\,(B + \Delta B)\,(1/T\,-\,1/T_{ref})} - e^{\,B(1/T\,-\,1/T_{ref})}\,]$$

If relative deviation is applied:

$$\Delta R(T)/R_n\,(T) = e^{\Delta B(1/T\,-\,1/T_{ref})} - 1$$

Developing this equation (Taylor's formulae), the following simplified expression can be derived:

$$\Delta R(T)/R_n(T)\ (\text{in }\%) = \Delta B\,(1/T - 1/T_{ref})$$

This calculation has been performed for all the major sensor ranges to be found in this handbook, where 'R deviation due to B tolerance' values can be found in the data tables.

If the R deviation due to B tolerance, is called 'Y' and the tolerance at the reference temperature 'X', then the total tolerance can be calculated as:

$$Z = [(1 + X/100) \times (1 + Y/100) - 1] \times 100$$

or, $Z = X + Y$ (approximation)

If TC = temperature coefficient and ΔT = temperature deviation,

$$\Delta T = Z/TC$$

Example: at 0 °C, let X = 5%, Y = 0.089% and TC = 5.08%/K, then:

$$Z = \{[1 + (5/100)] \times [1 + (0.89/100)] - 1\} \times 100$$
$$= \{1.05 \times 1.0089 - 1\} \times 100 = 5.9345 \text{ or } 5.93\%$$

$$\Delta T = Z/TC = 5.93/5.08 = 1.167 \text{ or } 1.17\ ^{o}C$$

Hence, a NTC having a R_{25} value of 10 kΩ has a value of 32.51 kΩ between + 1.17 °C and −1.17 °C.

Resistance specified at more than one temperature (2 or 3-point sensors)

Thermistors which are specified at 2 or 3 points of their R/T characteristic are more accurate. They have a closer tolerance and the spread in B-value has less influence because it is included in the tolerance at the specified points.

The tolerances in the reference points can be expressed either as a temperature deviation for the reference resistance or as a resistance tolerance at the reference temperature. This has no influence on the resulting measuring error which is minimal in the temperature region between the reference points, as illustrated in Fig.5.

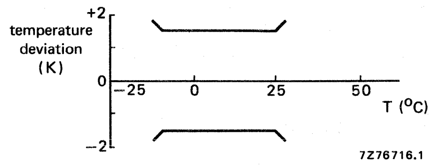


Fig.5 Temperature measurement at more than one point.

The 2 or 3-point sensors are particularly suited for applications with the following characteristics:

– temperature measurement over a certain temperature range
– high accuracy
– no further calibration for sensor tolerances in the electrical circuitry required.

HOW TO MEASURE NTC THERMISTORS

The published R_T values are measured at the temperature T.

The published B-value at 25 °C is the result of a measurement at 25 °C and one at 85 °C, hence these values should be used when checking.

The following general precautions have to be taken when measuring NTC thermistors:

- Never measure thermistors in air; this is quite inaccurate and gives deviations of 1 or 2 K. For measurement at room temperature or below, use petrol or some other non-conductive and non-aggressive fluid. For higher temperatures use oil, preferably silicon oil.
- Use a thermostat with an accuracy of better than 0.1 °C. Even if the liquid is well stirred, there is still a temperature gradient in the fluid. Measure the temperature as close as possible to the NTC.
- After placing the NTC in the thermostat, wait until temperature equilibrium between the NTC and the fluid is obtained. For some types this may take more than 1 minute.
- Keep the measuring voltage as low as possible otherwise the NTC will be heated by the measuring current. Miniature NTC thermistors are especially sensitive in this respect. Measuring voltages of less than 0.5 V are recommended.
- For high temperature measurements it is recommended that stem correction be applied to the thermometer reading.

CHOICE OF TYPE

When selecting an NTC thermistor the following main characteristics should be considered:

- Resistance value(s) and temperature coefficient
- Accuracy of resistance value(s)
- Power to be dissipated
  (a) without perceptible change in resistance value due to self heating
  (b) with maximum change in resistance value
- Permissible temperature range
- Thermal time constant, if applicable
- Types best suited to the purpose: basic forms are rod, disc and bead
- Protection against undesired external influences, if necessary.

When it is impossible to find an NTC thermistor to fulfil all requirements, it is often more economical to adapt the values of other circuit components to the value of a series-manufactured NTC. Sometimes, a standard NTC can be used with simple parallel and series resistors where otherwise a special type would have been necessary.

If no suitable combination can be found, the development of a special type can be considered. In this case a specification of the requirements is necessary. A description of the circuit in which the NTC has to be used is most useful.

Deviating characteristics

The following example explains the resistance values resulting from combinations of NTC with normal resistors.

Suppose an NTC must have a resistance of 50 Ω at 30 °C and 10 Ω at 100 °C. A standard type having this characteristic is not included in our programme. The problem may, however, be solved by using a standard NTC and two fixed resistors if a NTC disc with a cold resistance of 130 Ω is mounted in a series and parallel arrangement with two fixed resistors of 6 Ω and 95 Ω. It should be remembered that the temperature coefficient of the combination will always be lower than that of the NTC thermistor alone.

Remarks on the use of NTC Thermistors

Do not use unprotected thermistors in conducting fluids or aggressive and reducing gases which may cause a change in thermistor characteristics.

For temperature measurements do not use too high a voltage on the NTC thermistor as self-heating may cause incorrect readings. The dissipation constant indicates the maximum permissible measuring power, if an error of 1 °C is allowed.

GLOSSARY OF TERMS

Resistance

Also called nominal resistance. Formerly specified at only one temperature, or sometimes at two or maximum three. Now new technologies allow the specification of resistance values on all application ranges for several types.

Tolerance on resistance

The limits of the values that the resistance can take at the reference temperature.

B value

The B value may be calculated using the following formula:

$$\frac{\ln R_1/R_2}{1/T_1 - 1/T_2}$$

where R_1 and R_2 are the nominal values of resistance at T_1 and T_2.

Tolerance on B value

The limits of the value that B can take due to the process variations.

R tolerance due to B deviation

Due to the tolerance on the B value, the limits of the value that R can take at a certain temperature increase with the difference of that temperature to the reference temperature.

Tolerance on R at a temperature different to T_{ref}

The sum of the tolerances on resistance and tolerance due to B deviation.

α value

Variation of resistance (in %) for small variations of temperature around a defined temperature.

Maximum dissipation

Maximum power which could be applied without any risk of failure.

APPLICATIONS

Applications of NTC's may be classified into three main groups depending on their physical properties:

(1) Applications in which advantage is taken of the dependence of the resistance on the temperature, shown in the formula:

$$R = f(T)$$

This group is split into two sub sections:

(a) The temperature of the NTC thermistor is determined only by the temperature of the ambient medium (or by the current in a separate heater winding).

(b) The temperature of the NTC thermistor is also determined by the dissipation in the NTC thermistor itself.

(2) Applications in which the time dependence is decisive. In that case the temperature is considered as a parameter, and is written:

$$R = f(t)$$

This group comprises all applications which make use of the thermal inertia of NTC thermistors.

(3) The third group of applications uses mainly the property of the temperature coefficient being highly negative:

$$\alpha < 0$$

Also in this group, applications are listed which take advantage of the fact that the absolute value of the temperature is so high, that a part of the $V = f(I)$ curve shows a negative slope.

The classifications given above are supported by practical examples in Figs 6 to 23.

APPLICATION EXAMPLES

Application (1) (a) — Temperature sensing

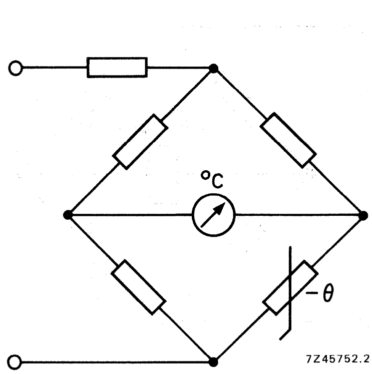
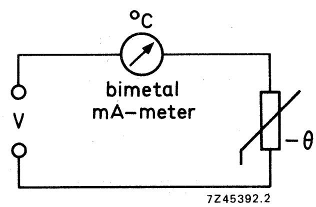


Fig.6 Temperature measurement in industrial and medical thermometers.



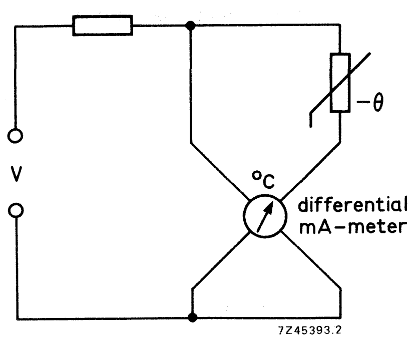


Fig.7 Temperature measurement in cars. Cooling water measurements with bimetal or differential milliammeters.

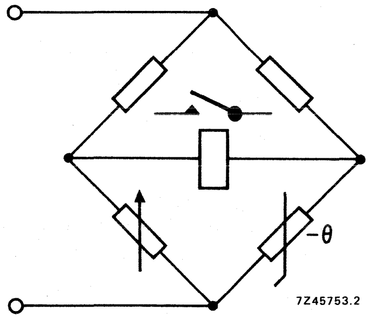


Fig.8 Temperature measurement with a bridge incorporating an NTC thermistor and a relay or a static switching device.

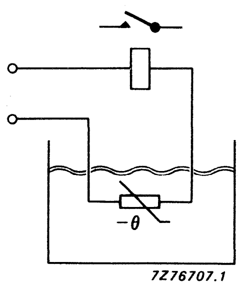


Fig.9 Liquid level control.

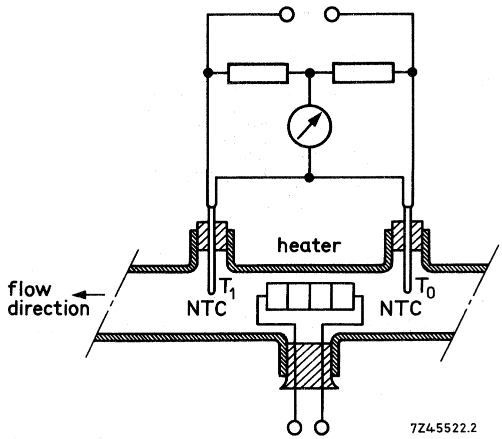


Fig.10 Flow measurement of liquids and gases. The temperature difference between T_1 and T_0 is measured for the velocity of the fluid.

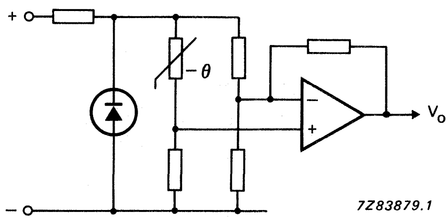


Fig.11 Temperature sensing bridge with amplifier. The op-amp acts as differential amplifier. The sensitivity can be very high.

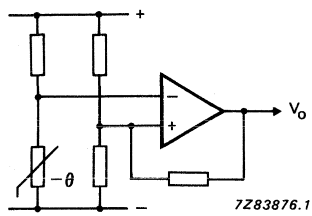


Fig.12 Basic temperature sensing configuration. The operational amplifier, e.g. type NE532, acts as a Schmitt trigger. The transfer characteristic is shown in Fig.13.

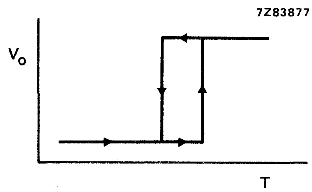


Fig.13 Transfer characteristic of circuit shown in Fig.12.

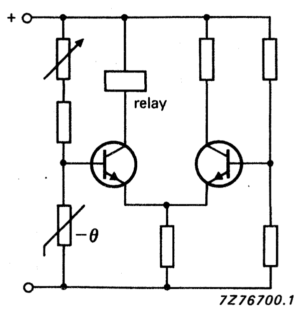


Fig.14 Simple thermostat.

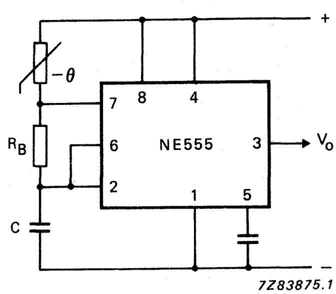


Fig.15 Temperature controlled oscillator. This is a simple interface circuit for digital and microcomputer-controlled systems. The frequency of the output pulses is proportional to the temperature of the NTC thermistor. See Fig.16.

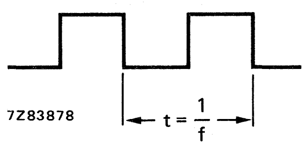


Fig.16 Characteristic of circuit shown in Fig.15.

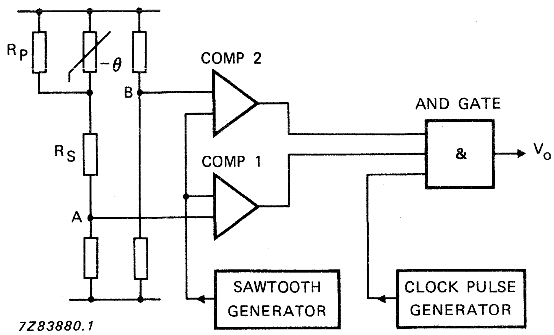


Fig.17 Temperature sensing bridge with 0 °C offset and analogue to digital conversion. Due to R_p and R_s the voltage at point A varies linearly with the temperature of the NTC thermistor. The voltage at point B is equal to the voltage at point A when the temperature of the NTC thermistor is 0 °C. Both voltages are fed to the comparator circuit. See also Fig.18.

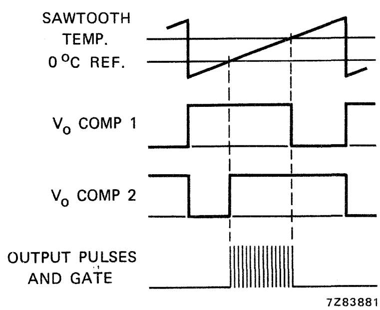
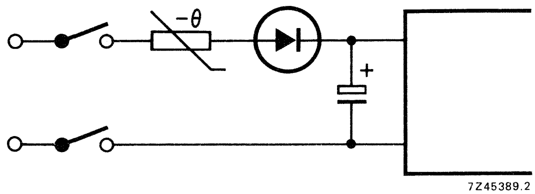
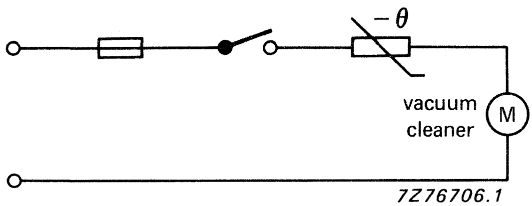


Fig.18 Characteristic of circuit shown in Fig.17.

Application (1) (b) — Limiting





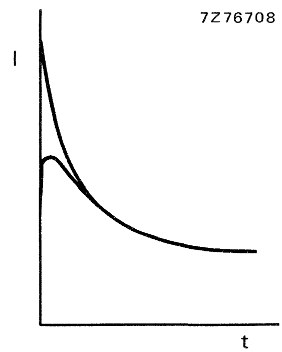


Fig.19 Inrush current limiter, e.g. for protection of Si-diodes (allowing similar types to be used), fuses and switches.

Application (2) – Timing

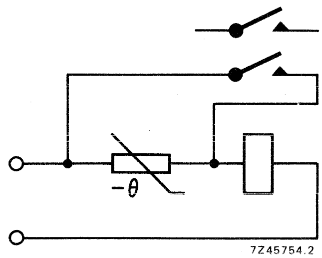


Fig.20 Delaying action of relays. Due to the thermal inertia of the NTC, it takes some time before the relay is activated. If necessary the NTC can be short-circuited after the relay is activated thus leaving the NTC time for cooling.

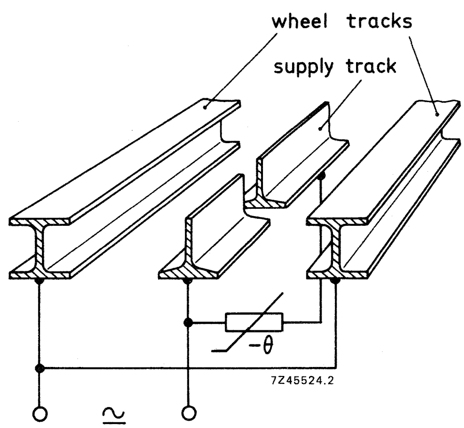


Fig.21 Model trains. As soon as the train comes on the isolated supply trip, it stops. The NTC heats up and gradually the train starts again.

Application (3) — Compensation

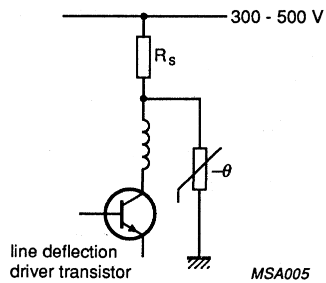


Fig.22 Constant current (sure start-up) for line deflection stage.

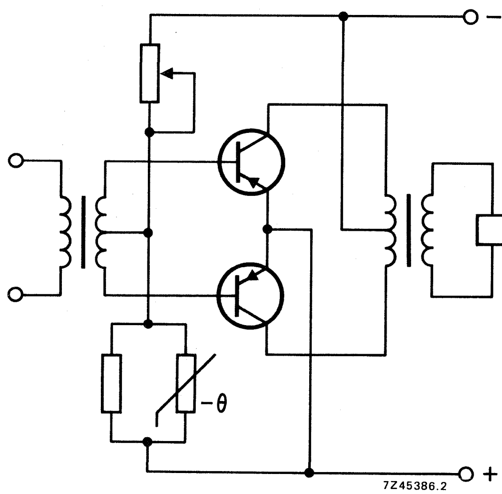


Fig.23 Temperature compensation in transistor circuits. Push-pull compensation.

NTC Thermistors

Introduction to NTC temperature sensing and control

GENERAL

Temperature is one of the variables that must be measured most frequently. There are as many as nineteen ways of measuring it electronically, most commonly by thermocouples, platinum-bulb thermometers and negative temperature coefficient (NTC) thermistor sensors. For general-purpose temperature measurement, NTC temperature sensors are accurate over a wide temperature range (−55 to +300 °C). They are stable throughout a long life time, have a high impedance and are small and inexpensive. In fact they are the first choice for most temperature measurements. Typically, they have a negative temperature coefficient of around −4.5% per K at room temperature (25 °C). This is more than ten times the sensitivity of a platinum-bulb thermometer of the same nominal resistance at the same temperature.

Philips have been making NTC temperature sensors for many years and we have gained an enviable reputation for our value for money ranges. Our component manufacturing and marketing activities are represented in more than 60 countries. This world-wide commitment ensures that you have security of supply, guaranteed quality and technical support in every major industrial market.

Recent developments in ceramic technology have allowed us to introduce sensors with resistance tolerances up to 1%, which are extremely stable over a wide temperature range.

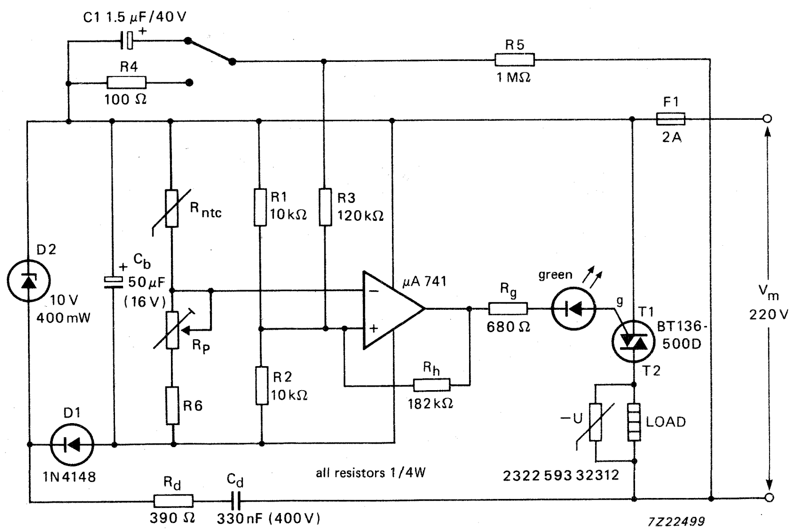


Fig.1 Refrigerator thermostat using a NTC temperature sensor.

APPLICATIONS

The NTC temperature sensor as a thermal switch

A common use for an NTC temperature sensor is in one of the bridge arms of a thermal switch circuit using an operational amplifier such as the µA741. Fig.1 shows a typical thermal switch circuit for a refrigerator thermostat. The circuit consists of a 10 V DC zener stabilized power supply, a Wheatstone Bridge (containing the NTC temperature sensor) and an integrated comparator circuit controlling a triac. The circuit is designed to switch a maximum load current of 2 A off at −5 °C and on at +5 °C.

Automotive systems

NTC temperature sensors are used extensively in cars. For example in:

- Electronic fuel injection, in which air-inlet, air/fuel mixtures and cooling water temperature are used to determine fuel concentration for optimum injection
- Climatization systems, such as air-conditioning and seat temperature controls
- Warning indicators, such as oil and fluid temperatures, oil level and turbo-charger switch off
- Fan motor control, based on cooling water temperature
- Frost sensors, for outside temperature measurement
- Acoustic systems.

Industrial systems

NTC temperature sensors are used in thermal switches, measurement systems and detectors in all segments of industry, notably the following:

- Aerospace/military
- Biomedical/health care
- Education/research
- Electronics
- Energy/environmental
- Food processing
- Heating and ventilating
- Metallurgy
- Petrochemical/chemical
- Weather forecasting
- Fire and smoke detectors.

Domestic appliances

NTC temperature sensor are used extensively to control domestic central-heating systems, they are also used in most domestic appliances for example:

- Refrigerators/freezers
- Cookers/ microwave ovens/food warmers/deep fryers
- Kettles/coffee makers
- Washing machines/dishwashers
- Electric irons/hair dryers
- Electric blankets
- Sunbeds.

NTC THERMISTORS
accuracy line
(low heat loss accuracy line)

Features

- Accurate over a wide temperature range (tolerance on B-value between 3% and 0.75%)
- Good stability
- Excellent price/performance ratio
- Flexible leads
- Low heat conductivity through leads (0.4 mm diameter Ni leads)

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at 25 °C	2.7 kΩ to 470 kΩ
Tolerance on R_{25} value	± 5%, ± 3%, ± 2%, ± 1%
Tolerance on $B_{25/85}$ value	± 3% to ± 0.75%
Response time (for information only)	1.7 s
Operating temperature range	
at zero power (continuously)	−40 to 125 °C
(for short periods)	up to 150 °C
at maximum power (100 mW)	0 to 55 °C

APPLICATION

Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two tinned Nickel wires. It is black lacquered and not colour coded, or insulated.

MECHANICAL DATA

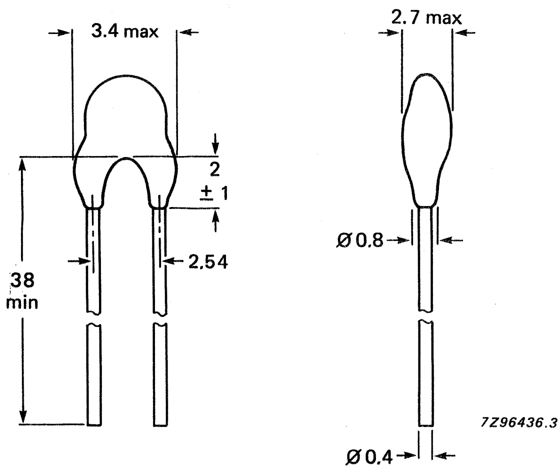


Fig.1 Component outline.

MECHANICAL DATA (continued)

Marking: The thermistors have a black coloured body

Mass: 0.11 grams approx.

Mounting: By soldering (in any position)

Robustness of terminations:

Tensile strength	10 N
Bending (leads not allowed to break or become loose)	5 N

Soldering:

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

Resistance to solvents:

In accordance with IEC 68-2-45, resistant to R113 at ambient temperature

Impact:

Free fall	1 m

Shock: 490 m/s for 11 ms, half sine-wave

Inflammability:

The thermistors meet the requirements of IEC Publication 695-2-2 (1980, needle flame test)

PACKING

The thermistors are packed in cardboard boxes; the smallest packing quantity is 500 thermistors.

ELECTRICAL DATA

Unless otherwise stated, the thermistors have been measured in accordance with IEC Publication 539.

Standard selection tolerance on R_{25}	± 5%, ± 3%, ± 2% and ± 1%
Stability	in accordance with CECC 43 000 and IEC; see Table 2
Climatic category	40/125/56
Rated dissipation	100 mW
Dissipation factor (for information only)	2.2 mW/K
Response time (for information only)	1.7 s (see note 1)
Thermal time constant (for information only)	13 s
Operating temperature range	
at zero power (continuously)	–40 to 125 °C
(for short periods)	up to 150 °C (note 2)
at maximum power (100 mW)	0 to 55 °C

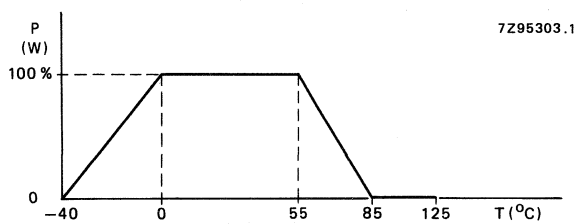


Fig.2 Derating curve.

Table 1 Electrical data

R_{25} value kΩ	$B_{25/85}$ value	catalogue number 2322 640 5. . . . . R_{25} ± 5%	catalogue number 2322 640 5. . . . . R_{25} ± 3%	catalogue number 2322 640 5. . . . . R_{25} ± 2%	catalogue number 2322 640 5. . . . . R_{25} ± 1%
2.7	3977 K± 0.75%	. 3272	. 6272	. 4272	. 5272
4.7	3977 K± 0.75%	. 3472	. 6472	. 4472	. 5472
10	3977 K± 0.75%	. 3103	. 6103	. 4103	. 5103
47	4090 K± 1.5%	. 3473	. 6473	. 4473	
100	4190 K± 2%	. 3104	. 6104		
470	4570 K± 3%	. 3474			

Notes

1. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.
2. Valid for all types with the exception of 2322 640 5.474.

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical) (note 1)
D3 4.20.1		endurance	25 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.1%
	68-2-1	endurance	–40 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen	endurance	100 mW, 55 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.5%
	68-2-2	dry heat, steady state	125 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	ΔR/R < 3%	ΔR/R = –0.2%
C2 4.14	68-2-14	rapid change of temperature	–40 °C to 125 °C 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%

Note to Table 2

1. Typical drift is based on sample products with a $B_{25/85}$ value of 3977 K and a $B_{25/75}$ value of 3965 K.

R_T values and tolerance on R_T values

These thermistors have a narrow tolerance on the B value, the result of which provides a very small tolerance on the nominal resistance value over a wide temperature range. The same table describing R as a function of T with steps of 5 °C as published for the series 2322 640 6. . . . range is relevant here. Also the 'Steinhart and Hart' equation of the above range can be used here to calculate intermediate resistance values. The relevant part of the table is that containing the R_{25} values and $B_{25/85}$ values of the 2322 640 5. . . . range.

NTC THERMISTORS

accuracy line
(extended accuracy line)

Features

- Accurate over wide temperature range
- High stability
- Excellent price/performance ratio

TEMPERATURE SENSING AND CONTROL
TEMPERATURE COMPENSATION

QUICK REFERENCE DATA

Resistance value at 25 °C	2.2 kΩ to 470 kΩ
Tolerance on R_{25} value	± 2%, ± 3%, ± 5%, ± 10%
Tolerance on $B_{25/85}$ value	± 3% to ± 0.75%
Response time	1.2 s
Operating temperature range	
at zero power (continuously)	−40 to 125 °C
(for short periods) (note 1)	up to 150 °C
at maximum power (500 mW)	0 to 55 °C

APPLICATION

Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two tinned copper plated wires. It is grey lacquered and colour coded, but not insulated.

MECHANICAL DATA

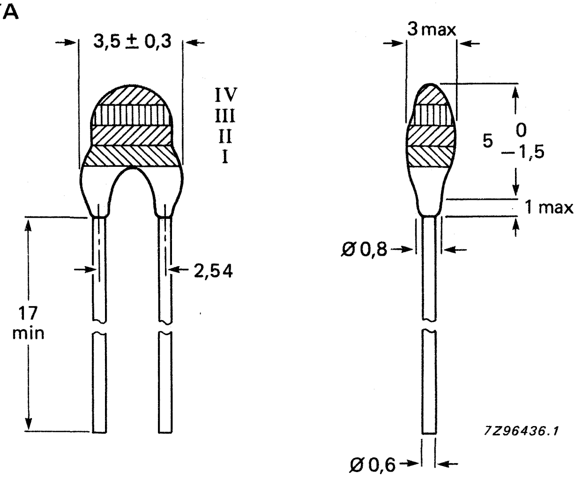


Fig.1 Component outline.

Note

1. For part of product range only; see Table 1 for details.

MECHANICAL DATA (continued)

Marking: The thermistors are marked with colour bands in accordance with Fig.1 and Table 3.

Mass: 0.22 g approx.

Mounting: in any position by soldering.

Robustness of terminations

Tensile strength	10 N
Bending (leads not allowed to break or become loose)	5 N

Soldering

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

Resistance to solvents

Resistant to R113 at ambient temperatures in accordance with IEC Publication 68-2-45.

Impact

Free fall	1 m

Shock: 490 m/s, 11 ms, half sine-wave

Inflammability

The thermistors meet the requirements of IEC Publication 695-2-2 (1980, needle flame test)

PACKING

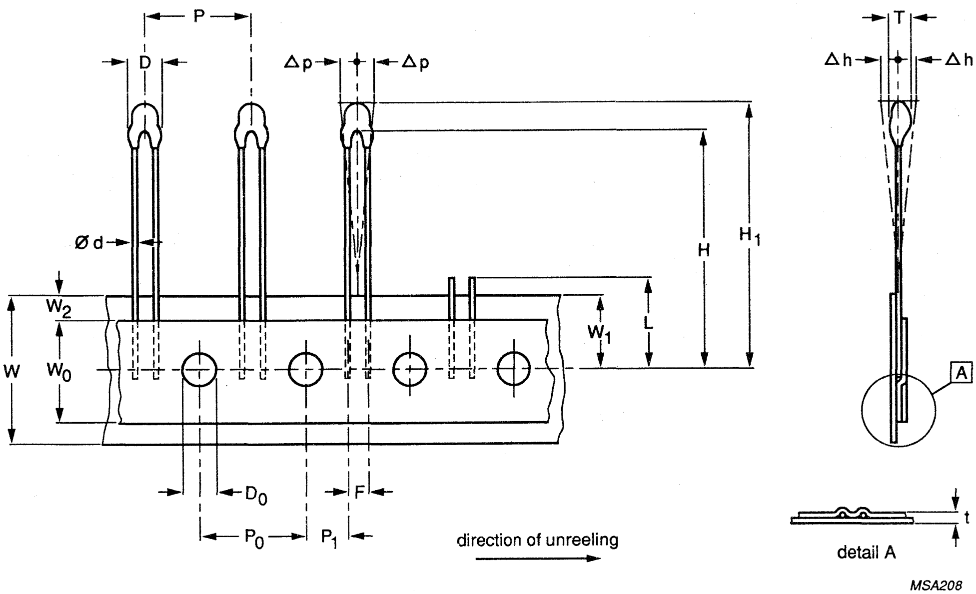
The thermistors are packed on cardboard boxes.
Products can be supplied on tape on special request:

Packing	bulk	tape and reel 1E pitch	tape and reel 2E pitch
Code number	640.6xxxx	640.4xxxx	640.3xxxx
Drawing	Fig.1	Fig.2	Fig.3
Quantity	500	1500 per reel 2 reels per box	1500 per reel 2 reels per box

Reel dimension, see Fig.4

Note

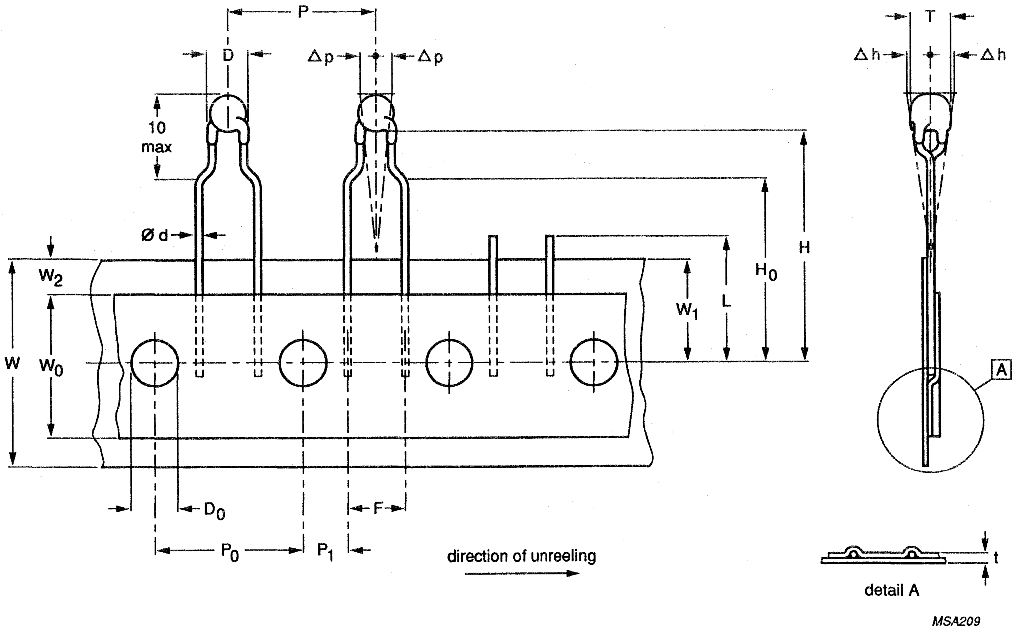
1. Max. 0.5% of the total number of the thermistors per reel may be missing, but no more than 3 consecutive positions may be vacant.



1E Pitch
640.4xxxx
Fig.2.

Table 1 Dimensional Data (refer to Fig.2)

details	symbol	dimensions nominal	tolerance	remarks
Body diameter	D	3.5	± 0.3	
Total thickness	T	3 max.		
Lead diameter	d	0.6	± 10%	
Pitch between thermistors	P	12.7	± 1	
Feed hole pitch	P_0	12.7	± 0.3	cumulative pitch error ± mm/20 p
Feed hole centre to lead centre	P_1	5.08	± 0.7	guaranteed between component/tape
Component alignment	Δp	0	± 1.3	
Lead to lead distance	F	2.54	± 0.3	guaranteed between component/tape
Component alignment	Δh	0	± 2	
Tape width	W	18	+ 1/−0.5	
Hold down tape width	W_0	12.5 min.		
Hole position	W_1	9	± 0.5	
Hold down tape position	W_2	3 max.		
Component height	H_1	32.2 max.		
Feed hole diameter	D_0	4	± 0.2	
Total tape thickness	t	0.9 max.		with cardboard tape 0.5 ± 0.1
Distance component to tape centre	H	22	−1	
Length of snipped lead	L	11 max.		
AQL: mechanical Level 11			1%	



2E Pitch
640.3xxxx

Fig.3.

Table 2 Dimensional Data (refer to Fig.3)

details	symbol	dimensions nominal	tolerance	remarks
Body diameter	D	3.5	± 0.3	
Total thickness	T	3.2 max.		
Lead diameter	d	0.6	± 10%	
Pitch between thermistors	P	12.7	± 1	
Feed hole pitch	P_0	12.7	± 0.3	cumulative pitch error ± mm/20 p
Feed hole centre to lead centre	P_1	3.85	± 0.7	guaranteed between component/tape
Component alignment	Δp	0	± 1.3	
Lead to lead distance	F	5	+ 0.6 −0.1	guaranteed between component/tape
Component alignment	Δh	0	± 2	
Tape width	W	18	+ 1/−0.5	
Hold down tape width	W_0	12.5 min.		
Hole position	W_1	9	+0.75 −0.5	
Hold down tape position	W_2	3 max.		
Component to tape centre	H	20	+ 1	
Lead - wire clinch height	H_0	16	± 0.5	
Feed hole diameter	D_0	4	± 0.3	
Total tape thickness	t	0.7	± 0.2	with cardboarded tape 0.5 ± 0.1
Length of snipped lead	L	11 max.		
AQL: mechanical Level 11			1%	

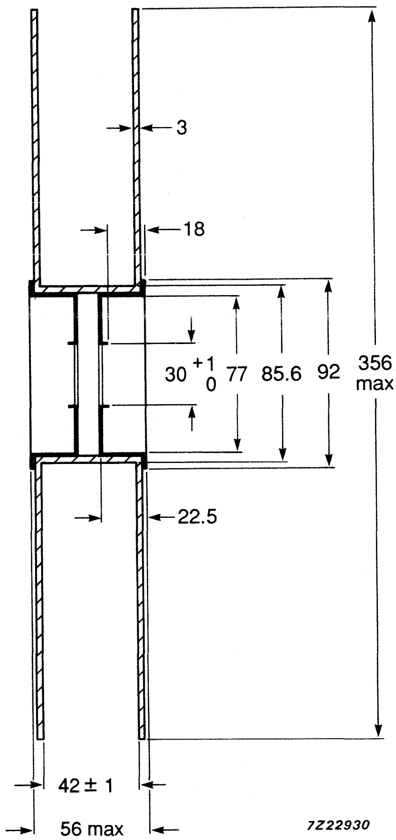


Fig.4 Dimensions of the reel.

Characteristics concerning taped thermistors

Minimum pull out force of the component	5 N
Minimum pull off force of adhesive tape	6 N
Minimum tearing force tape	15 N
Maximum pull off force tape-reel	5 N

Storage conditions

Storage temperature range	−25 to 40 °C
Maximum relative humidity	80 °C

ELECTRICAL DATA

Unless otherwise stated, the thermistors have been measured in accordance with IEC Publication 539 (see also Table 3).

Standard selection tolerance on R_{25}	± 2%, ± 3%, ± 5%, ± 10%
Stability	in accordance with CECC 43 000 and IEC; see Table 2
Climatic category	40/125/56
Rated dissipation	500 mW
Dissipation factor (for information only)	7 mW/K
Response time (for information only)	1.2 s (note 1)
Thermal time constant (for information only)	11 s
Operating temperature range	
at zero power (continuously)	−40 to 125 °C
(for short periods)	up to 150 °C (note 2)
at maximum power (500 mW)	0 to 55 °C

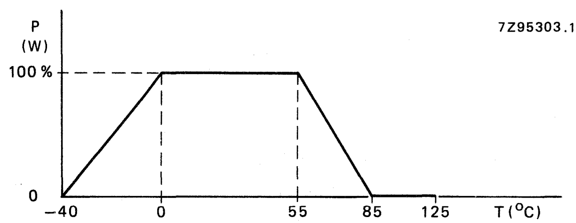


Fig.5 Derating curve.

Notes

1. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.
2. Valid for part of product range only, see Table 3.

Table 3 Electrical data

R_{25} value kΩ	$B_{25/85}$ value	catalogue number 2322 640 6 .... R_{25} ± 2%	catalogue number 2322 640 6 .... R_{25} ± 3%	catalogue number 2322 640 6 .... R_{25} ± 5%	catalogue number 2322 640 6 .... R_{25} ± 10%	colour code band I (note 2)	colour code band II (note 2)	colour code band III (note 2)
2.2	3977 K ± 0.75%	.4222	.6222	.3222	.2222	red	red	red
2.7 (note 1)	3977 K ± 0.75%	.4272	.6272	.3272	.2272	red	violet	red
3.3 (note 1)	3977 K ± 0.75%	.4332	.6332	.3332	.2332	orange	orange	red
4.7 (note 1)	3977 K ± 0.75%	.4472	.6472	.3472	.2472	yellow	violet	red
6.8 (note 1)	3977 K ± 0.75%	.4682	.6682	.3682	.2682	blue	grey	red
10 (note 1)	3977 K ± 0.75%	.4103	.6103	.3101	.2103	brown	black	orange
12	3740 K ± 3%	.4123	.6123	.3123	.2123	brown	red	orange
15	3740 K ± 3%	.4153	.6153	.3153	.2153	brown	green	orange
22	3740 K ± 3%	.4223	.6223	.3223	.2223	red	red	orange
33 (note 1)	4090 K ± 1.5%	.4333	.6333	.3333	.2333	orange	orange	orange
47 (note 1)	4090 K ± 1.5%	.4473	.6473	.3473	.2473	yellow	violet	orange
68 (note 1)	4190 K ± 2%		.6683	.3683	.2683	blue	grey	orange
100 (note 1)	4190 K ± 2%		.6104	.3104	.2104	brown	black	yellow
150	4370 K ± 3%			.3154	.2154	brown	green	yellow
220	4370 K ± 3%			.3224	.2224	red	red	yellow
330	4570 K ± 3%			.3334	.2334	orange	orange	yellow
470	4570 K ± 3%			.3474	.2474	yellow	violet	yellow

Table 4 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical (note 1)
D3 4.20.1		endurance	25 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.1\%$
	68-2-1	endurance	−40 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.15\%$
	539-gen	endurance	500 mW, 55 °C, 1000 hours	$\Delta R/R < 3\%$ (note 2)	$\Delta R/R = 0.5\%$
	68-2-2	dry heat, steady state	125 °C, 1000 hours	$\Delta R/R < 3\%$	$\Delta R/R = 0.1\%$
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	$\Delta R/R < 3\%$	$\Delta R/R = -0.2\%$
C2 4.14	68-2-14	rapid change of temperature	−40 °C to 125 °C, 50 cycles	$\Delta R/R < 2\%$	$\Delta R/R = 0.1\%$

Notes to Table 3

1. Operating temperature range at zero power is 150 °C max.
2. Dependent upon R_{25} tolerance, the band IV is colour coded as follows:
   For R_{25} ± 2%, band IV is coloured red
   For R_{25} ± 3%, band IV is coloured orange
   For R_{25} ± 5%, band IV is coloured gold
   For R_{25} ± 10%, band IV is coloured silver

Note to Table 4

1. Typical drift is based on sample products with a $B_{25/85}$ value of 3977 K and a $B_{25/75}$ value of 3965 K.
2. For $R_{25} \geqslant 100$ kΩ the drift requirement is $\Delta R/R < 5\%$.

R_T values and tolerance on R_T values

These thermistors have a narrow tolerance on the B value, the result of which provides a very small tolerance on the nominal resistance value over a wide temperature range. For this reason, the usual graphs of R = f(T) are replaced by Table 5 together with a formula with which the characteristics can be calculated with high accuracy.

Formula to determine nominal resistance values

The resistance values at intermediate temperatures can be calculated using the 'Steinhart and Hart' equation:

$$R_T = (R_{25}/R_{ref}) \times e^{\left[\sqrt[3]{\left(\sqrt{E^2 + D} - E\right)} - \sqrt[3]{\left(\sqrt{E^2 + D} + E\right)}\right]}$$

Table 4 shows a list of different 'E', 'D', and 'R_{ref}' values for different B values. In the Table, the value of 'T' is the temperature in K.

Table 5 Values to be used with 'Steinhart and Hart' formula

B value (K)	E	D	R_{ref} (kΩ)
3977	5766.8 – [5.0541 x 10^6/T]	4.7692 x 10^8	10
3740	3498.5 – [4.1026 x 10^6/T]	2.7574 x 10^8	22
4090	4194.7 – [4.5876 x 10^6/T]	2.8108 x 10^8	47
4190	4169.4 – [5.0802 x 10^6/T]	3.4453 x 10^8	100
4370	4185.0 – [5.2748 x 10^6/T]	3.1658 x 10^8	220
4570	4404.9 – [5.6266 x 10^6/T]	3.1666 x 10^8	470

Determination of the resistance/temperature deviation from the nominal

The complete resistance deviation is obtained by combining the 'R_{25} tolerance' value with the 'resistance deviation due to B tolerance' value.

Let X = R_{25} tolerance
Y = resistance deviation due to B tolerance
Z = complete resistance deviation

Then,

$$Z = \{[1 + (X/100)] \times [1 + (Y/100)] - 1\} \times 100$$

or

$$Z = X + Y \text{ (approximation)}$$

TC = temperature coefficient
ΔT = temperature deviation

so

$$\Delta T = Z/TC$$

Example: (at 0 °C)

Let
$X = 5\%$
$Y = 0.89\%$ (see Table 6)
$TC = 5.08\%/K$ (see Table 6)

Then

$$
\begin{aligned}
Z &= \{ [1 + (5/100)] \times [1 + (0.89/100)] - 1 \} \times 100 \\
&= \{ [1 + 0.05] \times [1 + 0.0089] - 1 \} \times 100 \\
&= \{ [1.05 \times 1.0089] - 1 \} \times 100 \\
&= \{ 1.0593 - 1 \} \times 100 \\
&= 0.0593 \times 100 \\
&= 5.93\%
\end{aligned}
$$

or, (by approximation)

$$
\begin{aligned}
Z &= X + Y \\
&= 5 + 0.89 \\
&= 5.89\%
\end{aligned}
$$

$$
\begin{aligned}
\Delta T &= Z/TC \\
&= 5.93/5.08 \\
&= 1.167\ (1.17)
\end{aligned}
$$

So, a NTC having a R_{25} value = 10 kΩ has a value of 32.51 kΩ between ± 1.17 °C.

Table 6 Resistance values at intermediate temperatures

temp.	ratio R_T/R_{25}	$\Delta R/B_{tol}$	temp. coeff.	resistance value (kΩ) for 2322 640 ..... (note 1)					
°C		%	%/K	6.222	6.272	6.332	6.472	6.682	6.103
−40	32.84	2.64	6.57	72.2400	88.67	108.4	154.3	223.3	328.4
−35	23.77	2.40	6.36	52.2800	64.18	78.44	111.7	161.6	237.7
−30	17.39	2.16	6.15	38.2500	46.95	57.39	81.72	118.3	173.9
−25	12.85	1.93	5.95	28.2700	34.70	42.41	60.40	87.38	128.5
−20	9.589	1.71	5.76	21.0900	25.89	31.64	45.07	65.21	95.89
−15	7.223	1.49	5.58	15.8900	19.50	23.84	33.95	49.12	72.23
−10	5.489	1.29	5.40	12.0700	14.82	18.11	25.80	37.33	54.89
−5	4.207	1.08	5.24	9.2540	11.36	13.88	19.77	28.61	42.07
0	3.251	0.89	5.08	7.1510	8.778	10.73	15.28	22.11	32.51
5	2.531	0.70	4.92	5.5690	6.834	8.352	11.90	17.21	25.31
10	1.986	0.52	4.78	4.3690	5.362	6.554	9.334	13.50	19.86
15	1.569	0.34	4.64	3.4520	4.236	5.178	7.374	10.67	15.69
20	1.249	0.17	4.50	2.7470	3.372	4.122	5.870	8.493	12.49
25	1.000	0.00	4.37	2.2000	2.700	3.300	4.700	6.800	10.00
30	0.8060	0.16	4.25	1.7730	2.176	2.660	3.788	5.481	8.060
35	0.6536	0.32	4.13	1.4380	1.765	2.157	3.072	4.444	6.536
40	0.5331	0.47	4.02	1.1730	1.439	1.759	2.506	3.625	5.331
45	0.4373	0.62	3.91	0.9619	1.181	1.443	2.055	2.973	4.373
50	0.3606	0.77	3.80	0.7933	0.9736	1.190	1.695	2.452	3.606
55	0.2989	0.91	3.70	0.6576	0.8070	0.9864	1.405	2.033	2.989
60	0.2490	1.05	3.60	0.5478	0.6723	0.8217	1.170	1.693	2.490
65	0.2085	1.18	3.51	0.4586	0.5630	0.6881	0.9800	1.418	2.085
70	0.1753	1.31	3.42	0.3857	0.4733	0.5785	0.8239	1.192	1.753
75	0.1481	1.44	3.33	0.3258	0.3999	0.4887	0.6961	1.007	1.481
80	0.1256	1.57	3.25	0.2764	0.3391	0.4145	0.5903	0.8541	1.256
85	0.1070	1.69	3.16	0.2355	0.2889	0.3531	0.5029	0.7276	1.070
90	0.09155	1.81	3.09	0.2014	0.2472	0.3021	0.4303	0.6225	0.9155
95	0.07861	1.93	3.01	0.1729	0.2122	0.2594	0.3695	0.5345	0.7861
100	0.06775	2.04	2.94	0.1490	0.1829	0.2236	0.3184	0.4607	0.6775
105	0.05860	2.15	2.87	0.1289	0.1582	0.1934	0.2754	0.3985	0.5860
110	0.05086	2.26	2.80	0.1119	0.1373	0.1678	0.2390	0.3458	0.5086
115	0.04429	2.37	2.73	0.0974	0.1196	0.1462	0.2082	0.3012	0.4429
120	0.03870	2.47	2.67	0.0851	0.1045	0.1277	0.1819	0.2632	0.3870
125	0.03392	2.57	2.61	0.0746	0.0916	0.1119	0.1594	0.2307	0.3392
130	0.02982	2.67	2.55	0.0655	0.0805	0.0984	0.1402	0.2028	0.2982
135	0.02629	2.77	2.49	0.0578	0.0710	0.0868	0.1236	0.1788	0.2629
140	0.02324	2.86	2.43	0.0511	0.0627	0.0767	0.1092	0.1580	0.2324
145	0.02061	2.95	2.38	0.0453	0.0556	0.0680	0.0969	0.1402	0.2061
150	0.01832	3.05	2.33	0.0403	0.0495	0.0605	0.0861	0.1246	0.1832

Note

1. Replace dot in catalogue number by one of the following, depending on tolerance on required R_{25} for:
   4 for tolerance of ± 2% (from 2.2 kΩ to 47 kΩ)
   6 for tolerance of ± 3% (from 2.2 kΩ to 100 kΩ)
   3 for tolerance of ± 5%
   2 for tolerance of ± 10%

Table 6 (continued)

temperature	ratio R_T/R_{25}	deviation in R value due to B tolerance	temperature coefficient	resistance value (kΩ) for 2322 640 . . . . . (note 1)		
°C		%	%/K	6.123	6.153	6.223
−40	25.80	10.24	6.09	309.5	386.9	567.5
−35	19.12	9.26	5.89	229.4	286.8	420.6
−30	14.31	8.31	5.70	171.7	214.6	314.8
−25	10.81	7.40	5.52	129.7	162.1	237.8
−20	8.235	6.53	5.35	98.82	123.5	181.2
−15	6.328	5.69	5.19	75.94	94.92	139.2
−10	4.902	4.88	5.03	58.82	73.52	107.8
−5	3.826	4.11	4.88	45.91	57.39	84.17
0	3.009	3.36	4.73	36.10	45.13	66.19
5	2.383	2.64	4.60	28.59	35.74	52.42
10	1.900	1.94	4.46	22.79	28.49	41.79
15	1.524	1.27	4.34	18.29	22.87	33.54
20	1.231	0.63	4.21	14.77	18.46	27.08
25	1.000	0.00	4.10	12.00	15.00	22.00
30	0.8171	0.61	3.98	9.805	12.26	17.98
35	0.6713	1.20	3.88	8.055	10.07	14.77
40	0.5545	1.79	3.77	6.653	8.317	12.20
45	0.4603	2.35	3.67	5.524	6.905	10.13
50	0.3840	2.91	3.57	4.609	5.761	8.449
55	0.3219	3.46	3.48	3.863	4.829	7.083
60	0.2711	3.99	3.39	3.253	4.067	5.964
65	0.2293	4.52	3.30	2.752	3.440	5.045
70	0.1948	5.03	3.22	2.337	2.922	4.285
75	0.1661	5.53	3.14	1.994	2.492	3.655
80	0.1423	6.02	3.06	1.707	2.134	3.130
85	0.1223	6.51	2.99	1.467	1.834	2.690
90	0.1055	6.98	2.92	1.266	1.582	2.321
95	0.09133	7.44	2.85	1.096	1.370	2.009
100	0.07935	7.90	2.78	0.9522	1.190	1.746
105	0.06917	8.34	2.71	0.8300	1.037	1.522
110	0.06048	8.78	2.65	0.7258	0.9072	1.331
115	0.05305	9.21	2.59	0.6366	0.7958	1.167
120	0.04668	9.63	2.53	0.5602	0.7002	1.027
125	0.04119	10.04	2.47	0.4943	0.6179	0.9061

Note

1. Replace dot in catalogue number by one of the following, depending on tolerance on required R_{25} value:
   4 for a tolerance of ± 2% (from 2.2 kΩ to 47 kΩ)
   6 for a tolerance of ± 3% (from 2.2 kΩ to 100 kΩ)
   3 for a tolerance of ± 5%
   2 for a tolerance of ± 10%

temperature	ratio R_T/R_{25}	deviation in R value due to B tolerance	temperature coefficient	resistance value (kΩ) for 2322 640 . . . . . (note 1)	
°C		%	%/K	6.333	6.473
−40	33.74	5.42	6.55	1114	1586
−35	24.44	4.91	6.34	806.7	1149
−30	17.89	4.42	6.15	590.3	840.7
−25	13.21	3.95	5.96	436.1	621
−20	9.852	3.49	5.78	325.1	463
−15	7.41	3.05	5.61	244.5	348.3
−10	5.620	2.62	5.45	185.5	264.1
−5	4.297	2.21	5.29	141.8	202
0	3.311	1.81	5.14	109.3	155.6
5	2.571	1.43	4.99	84.83	120.8
10	2.01	1.05	4.85	66.33	94.47
15	1.582	.69	4.72	52.21	74.37
20	1.254	.34	4.59	41.38	58.93
25	1	0	4.46	33.00	47
30	.8024	.33	4.34	26.48	37.71
35	.6476	.65	4.23	21.37	30.44
40	.5256	.97	4.12	17.35	24.70
45	.4289	1.28	4.01	14.16	20.16
50	.3519	1.58	3.91	11.61	16.54
55	.2902	1.87	3.81	9.575	13.64
60	.2404	2.16	3.71	7.934	11.3
65	.2001	2.44	3.62	6.605	9.407
70	.1674	2.72	3.53	5.524	7.867
75	.1406	2.99	3.44	4.640	6.608
80	.1186	3.25	3.36	3.913	5.574
85	.10045	3.51	3.28	3.315	4.721
90	.08541	3.76	3.2	2.819	4.014
95	.07291	4.01	3.13	2.406	3.427
100	.06246	4.25	3.06	2.061	2.936
105	.05371	4.48	2.98	1.772	2.524
110	.04634	4.72	2.92	1.529	2.178
115	.04012	4.94	2.85	1.324	1.885
120	.03484	5.16	2.79	1.150	1.637
125	.03035	5.38	2.73	1.001	1.427
130	.02653	5.6	2.67	.8754	1.247
135	.02325	5.8	2.61	.7673	1.093
140	.02044	6.01	2.55	.6744	.9605
145	.01801	6.21	2.5	.5944	.8466
150	.01592	6.41	2.44	.5254	.7482

Note

1. Replace dot in catalogue number by one of the following, depending on tolerance on required R_{25} value:
   4 for a tolerance of ± 2% (from 2.2 kΩ to 47 kΩ)
   6 for a tolerance of ± 3% (from 2.2 kΩ to 100 kΩ)
   3 for a tolerance of ± 5%
   2 for a tolerance of ± 10%

Table 6 (continued)

temperature	ratio R_T/R_{25}	deviation in R value due to B tolerance	temperature coefficient	resistance value (kΩ) for 2322 640 . . . . . (note 1)	
°C		%	%/K	6.683	6.104
−40	36.65	7.47	6.70	2492	3665
−35	26.35	6.76	6.49	1792	2635
−30	19.14	6.08	6.29	1302	1914
−25	14.04	5.43	6.10	954.7	1404
−20	10.40	4.79	5.92	707.2	1040
−15	7.769	4.19	5.74	528.3	776.9
−10	5.855	3.60	5.57	398.1	585.5
−5	4.449	3.03	5.41	302.5	444.9
0	3.407	2.48	5.26	231.7	340.7
5	2.629	1.95	5.11	178.8	262.9
10	2.044	1.44	4.97	139.0	204.4
15	1.600	0.94	4.83	108.8	160.0
20	1.261	0.46	4.70	85.75	126.1
25	1.000	0.00	4.57	68.00	100.0
30	0.7982	0.45	4.45	54.28	79.82
35	0.6410	0.89	4.35	43.59	64.10
40	0.5176	1.33	4.22	35.20	51.76
45	0.4204	1.75	4.11	28.59	42.04
50	0.3432	2.16	4.00	23.34	34.32
55	0.2817	2.57	3.90	19.16	28.17
60	0.2323	2.96	3.80	15.80	23.23
65	0.1925	3.35	3.71	13.09	19.25
70	0.1603	3.73	3.62	10.90	16.03
75	0.1340	4.10	3.53	9.113	13.40
80	0.1126	4.46	3.45	7.654	11.26
85	0.09498	4.82	3.36	6.458	9.498
90	0.08043	5.17	3.28	5.469	8.043
95	0.06838	5.51	3.21	4.650	6.838
100	0.05836	5.85	3.13	3.969	5.836
105	0.04999	6.18	3.06	3.399	4.999
110	0.04297	6.50	2.99	2.922	4.297
115	0.03706	6.81	2.92	2.520	3.706
120	0.03207	7.12	2.86	2.181	3.207
125	0.02784	7.43	2.80	1.893	2.784

Note

1. Replace dot in catalogue number by one of the following, depending on tolerance on required R_{25} value:
   4 for a tolerance of ± 2% (from 2.2 kΩ to 47 kΩ)
   6 for a tolerance of ± 3% (from 2.2 kΩ to 100 kΩ)
   3 for a tolerance of ± 5%
   2 for a tolerance of ± 10%

temperature	ratio R_T/R_{25}	deviation in R value due to B tolerance	temperature coefficient	resistance value (kΩ) for 2322 640 . . . . . (note 1)	
°C		%	%/K	6.154	6.224
−40	41.38	11.82	6.89	6206	9103
−35	29.47	10.68	6.68	4420	6483
−30	21.20	9.60	6.48	3180	4664
−25	15.41	8.55	6.29	2311	3389
−20	11.30	7.55	6.11	1695	2486
−15	8.363	6.58	5.93	1254	1840
−10	6.243	5.65	5.76	936.5	1374
−5	4.700	4.75	5.60	704.9	1034
0	3.566	3.89	5.44	534.9	784.5
5	2.726	3.05	5.29	409.0	599.8
10	2.100	2.25	5.15	315.0	462.0
15	1.629	1.47	5.01	244.3	358.4
20	1.272	0.72	4.88	190.8	279.9
25	1.000	0.00	4.75	150.0	220.0
30	0.7911	0.71	4.62	118.7	174.0
35	0.6296	1.40	4.51	94.44	138.5
40	0.5040	2.08	4.39	75.60	110.9
45	0.4058	2.74	4.28	60.87	89.27
50	0.3285	3.40	4.17	49.27	72.26
55	0.2673	4.04	4.07	40.09	58.80
60	0.2186	4.67	3.97	32.79	48.09
65	0.1797	5.28	3.87	26.95	39.53
70	0.1484	5.89	3.78	22.25	32.64
75	0.1231	6.49	3.69	18.46	27.08
80	0.1026	7.07	3.60	15.38	22.56
85	0.08582	7.64	3.52	12.87	18.88
90	0.07211	8.21	3.44	10.82	15.86
95	0.06083	8.76	3.36	9.125	13.38
100	0.05152	9.31	3.28	7.728	11.33
105	0.04380	9.84	3.21	6.570	9.635
110	0.03737	10.36	3.14	5.605	8.221
115	0.03199	10.88	3.07	4.799	7.038
120	0.02749	11.39	3.00	4.124	6.048
125	0.02369	11.88	2.94	3.554	5.212

Note

1. Replace dot in catalogue number by one of the following, depending on tolerance on required R_{25} value:
   4 for a tolerance of ± 2% (from 2.2 kΩ to 47 kΩ)
   6 for a tolerance of ± 3% (from 2.2 kΩ to 100 kΩ)
   3 for a tolerance of ± 5%
   2 for a tolerance of ± 10%

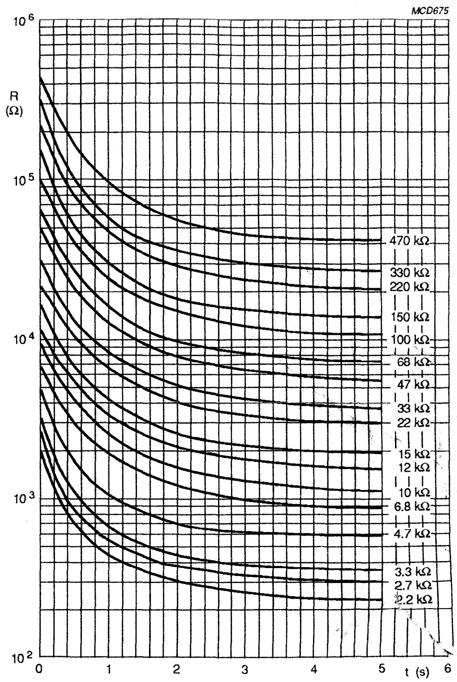


Fig.8 Typical resistance/heating time characteristics, from air of 25 °C to oil of 85 °C.

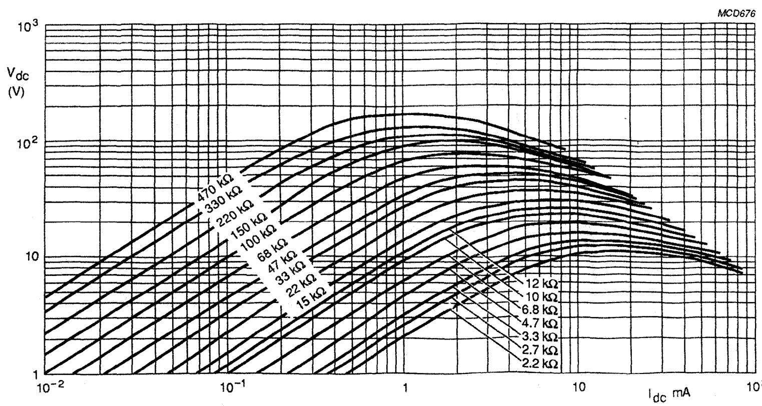


Fig.9 Typical voltage/current characteristics, T_{amb} = + 25 °C, still air.

NTC THERMISTOR

low, medium, and high temperature

Features

- excellent accuracy between 25 °C and 85 °C
- high stability

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at 25 °C	4.7 kΩ to 100 kΩ
Tolerance on R_{25} value	± 0.5 °C
Resistance at 85 °C	502.9 Ω to 9.498 kΩ
Tolerance on R_{85} value	0.5 °C
Response time (for information only)	1.2 s
Operating temperature range	
at zero power	−40 to + 125 °C
at maximum power	0 to + 55 °C

MECHANICAL DATA

Dimensions in mm

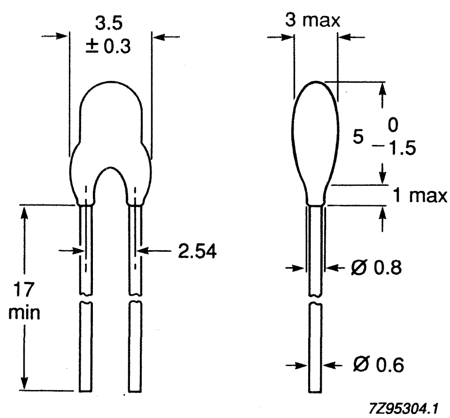


Fig.1 Component outline.

Marking: grey lacquered body
Mass : 0.22 grams approx.

PACKING

The thermistors are packed in cardboard boxes, each box containing 500 items.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	40/125/56
Resistance at 25 °C (see note 1)	4.7 kΩ to 100 kΩ
Tolerance on R_{25} value	± 0.5 °C
Resistance at 85 °C	502.9 Ω to 9.498 kΩ
Tolerance on R_{85} value	0.5 °C
Response time (see note 2) (for information only)	1.2 s
Rated dissipation	250 mW
Dissipation factor (for information only)	7 mW/K
Thermal time constant (for information only)	11 s
Operating temperature range	
at zero power	−40 to + 125 °C
at maximum power	0 to + 55 °C

Table 1 Electrical data

catalogue number	R_{25} value ± 0.5 °C kΩ	R_{85} value ± 0.5 °C Ω	$B_{25/85}$ value (typical) K	temperature coefficient at 25 °C %/K
2322 640 10472	4.7	502.9	3977	−4.37
2322 640 10103	10	1070	3977	−4.37
2322 640 10473	47	4721	4090	−4.46
2322 640 10104	100	9498	4190	−4.57

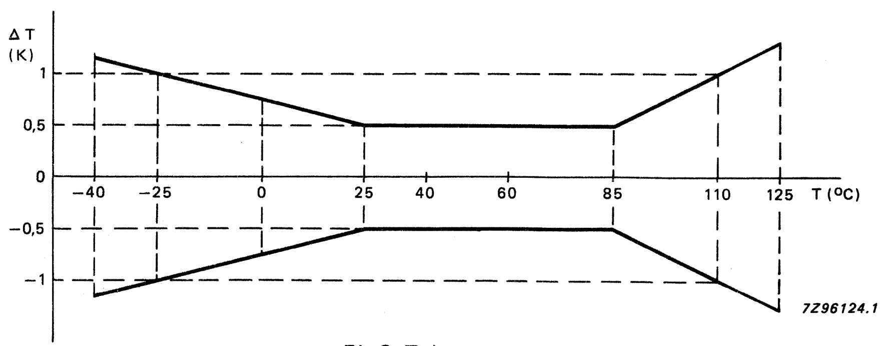


Fig.2 Tolerance curve.

Notes

1. For values of nominal resistance value and tolerance at intermediate temperatures, please refer to Table 2.
2. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.

Table 2 Resistance values at intermediate temperatures

temperature °C	2322 640 10472 kΩ	2322 640 10103 kΩ	2322 640 10473 kΩ	2322 640 10104 kΩ
−40	154.3	328.4	1586	3665
−35	111.7	237.7	1149	2635
−30	81.72	173.9	840.7	1914
−25	60.40	128.5	621	1404
−20	45.07	95.89	463	1040
−15	33.95	72.23	348.3	776.9
−10	25.80	54.89	264.1	585.5
−5	19.77	42.07	202	444.9
0	15.28	32.51	155.6	340.7
5	11.90	25.31	120.8	262.9
10	9.334	19.86	94.47	204.4
15	7.374	15.69	74.37	160.0
20	5.87	12.49	58.93	126.1
25	4.7	10.00	47.00	100.0
30	3.788	8.06	37.71	79.82
35	3.072	6.536	30.44	64.10
40	2.506	5.331	24.70	51.76
45	2.055	4.373	20.16	42.04
50	1.695	3.606	16.54	34.32
55	1.405	2.989	13.64	28.17
60	1.17	2.49	11.30	23.23
65	0.98	2.085	9.407	19.25
70	0.8239	1.753	7.867	16.03
75	0.6961	1.481	6.608	13.40
80	0.5903	1.256	5.574	11.26
85	0.5029	1.07	4.721	9.498
90	0.4303	0.9155	4.014	8.043
95	0.3695	0.7861	3.427	6.838
100	0.3184	0.6775	2.936	5.836
105	0.2754	0.586	2.524	4.999
110	0.2390	0.5086	2.178	4.297
115	0.2082	0.4429	1.885	3.706
120	0.1819	0.387	1.637	3.207
125	0.1594	0.3392	1.427	2.784

NTC THERMISTORS
moulded range

Features

- Excellent for surface temperature measurement
- Metal strip for heat conduction and easy mounting
- High accuracy at 100 °C
- Minimum 350 V dielectric withstanding voltage

TEMPERATURE SENSING AND CONTROL
TEMPERATURE COMPENSATION

QUICK REFERENCE DATA

	2322 640 90004	2322 640 98004	
Resistance value at			
+ 25 °C	12 ± 7%	12 ± 7%	kΩ
+ 100 °C	950 ± 5%	950 ± 5%	Ω
$B_{25/85}$-value	3750	3750	K
Dissipation factor	7	9.5	mW/K
when mounted on a heat-sink	19	27	mW/K
Thermal time constant	19	33	s
when mounted on a heat-sink	10	5	s
Operating temperature range			
at zero power	−10 to + 125	−10 to + 125	°C
at maximum power	0 to + 55	0 to + 55	°C

APPLICATION

For temperature control.

DESCRIPTION

Moulded disc thermistor with negative temperature coefficient and with two solid tinned copper wires.
The body colour is dark grey.
The thermistor 2322 640 98004 is provided with a metal strip for mounting.

MECHANICAL DATA

Outlines

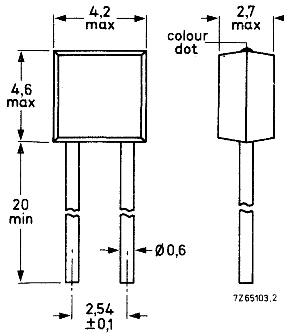


Fig.1 Type 2322 640 90004.

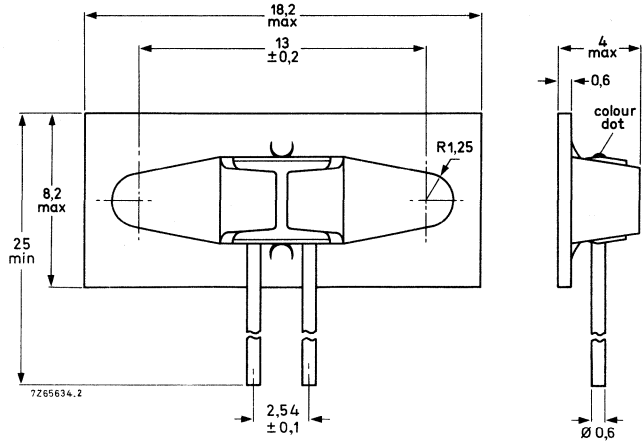


Fig.2 Type 2322 640 98004
with metal strip for mounting.

Marking

The thermistors have a grey dot.

Mass

Type 2322 640 90004	0.3 g approx.
Type 2322 640 98004	0.5 g approx.

Mounting

Type 2322 640 90004	in any position by soldering
Type 2322 640 98004	by means of the mounting strip

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

Impact

Free fall	1 m

Inflammability

Uninflammable – CCTU-01-01A specification, test 22.

PACKAGING

Type 2322 640 90004: 500 thermistors in a cardboard box.
Type 2322 640 98004: 400 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, measured in accordance with IEC publication 539.

Unless otherwise stated, all values are approximate.

	2322 640 90004	2322 640 98004	
Resistance at			
+ 25 °C	12 ± 7%	12 ± 7%	kΩ
+ 100 °C	950 ± 5%	950 ± 5%	Ω
$B_{25/85}$-value	3750	3750	K
Temperature coefficient	−4.2	−4.2	%/K
Maximum dissipation	0.25	0.25	W
Dissipation factor	7	9.5	mW/K
when mounted on a heatsink (see note 1)	19	27	mW/K
Thermal time constant	19	33	s
when mounted on a heatsink (see note 1)	10	5	s
Heat capacity of ceramic (in air)	0.028	0.028	J/K
of complete component (on heatsink)	0.13	0.3	J/K
Response time (see note 2)	3	3	s
Operating temperature range			
at zero power	−10 to + 125	−10 to + 125	°C
at maximum power	0 to + 55	0 to + 55	°C
Dielectric withstanding voltage (RMS) between terminals and coating/strip	min. 350	min. 350	V
Insulation resistance between terminals and coating/strip at 100 V (DC)	min. 100	min. 100	MΩ

Notes

1. Measurements made in still air with the thermistor mounted on a heatsink of 100 cm^2, thickness 1.5 mm, connected between phosphor-bronze wires (ϕ 1.3 mm).
2. The thermistor being transferred from ambient air of + 25 °C to a silicone oil (MS200/50) bath of + 85 °C.

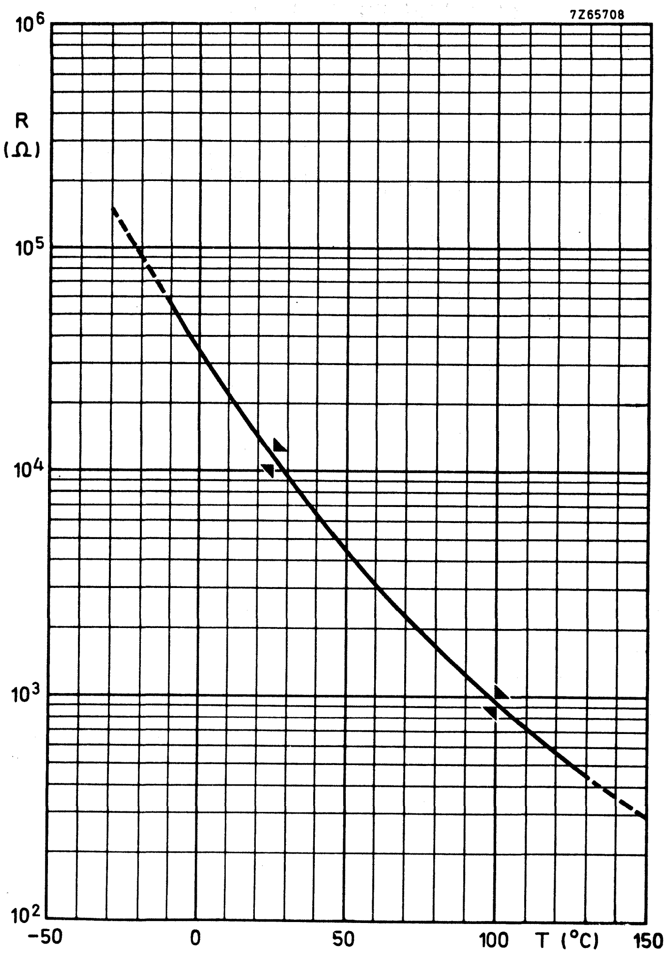


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTORS

moulded range

Features

- Excellent for surface temperature measurement
- Metal strip for easy mounting
- Will withstand temperatures up to 200 °C
- High accuracy at 200 °C
- Minimum 300 V dielectric withstanding voltage

TEMPERATURE SENSING AND CONTROL
TEMPERATURE COMPENSATION

QUICK REFERENCE DATA

	2322 640 90005	2322 640 98005	
Resistance value at			
+ 100 °C	16.7 ± 7%	16.7 ± 7%	kΩ
+ 200 °C	1120 ± 7%	1120 ± 7%	Ω
$B_{25/85}$-value	4300	4300	K
Maximum dissipation	0.25	0.25	W
Dissipation factor	7	9.5	mW/K
when mounted on a heat-sink	17.5	20.5	mW/K
Thermal time constant	19	33	s
when mounted on a heat-sink	12	8.5	s
Operating temperature range			
at zero power	−25 to + 200	−25 to + 200	°C
at maximum power	0 to + 55	0 to + 55	°C

APPLICATION

For high temperature control.

DESCRIPTION

Moulded disc thermistor with negative temperature control and with two solid tinned copper wires.
The body colour is dark grey.
The thermistor 2322 640 98005 is provided with a metal strip for mounting.

MECHANICAL DATA

Outlines

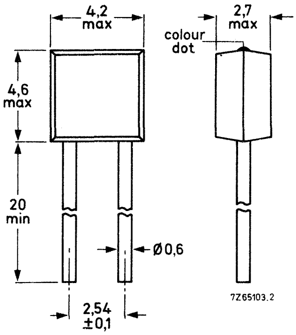


Fig.1 Type 2322 640 98005.

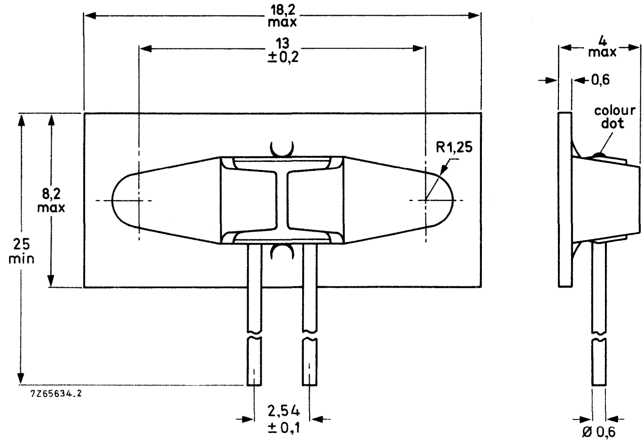


Fig.2 Type 2322 640 98005 with metal strip for mounting.

Marking

The thermistors have a blue dot.

Mass

Type 2322 640 90005	0.3 g approx.
Type 2322 640 98005	0.5 g approx.

Mounting

Type 2322 640 90005	in any position by soldering
Type 2322 640 98005	by means of the mounting strip

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

Impact

Free fall	1 m

Inflammability

Uninflammable -- CCTU-01-01A specification, test 22.

PACKAGING

Type 2322 640 90005: 500 thermistors in a cardboard box.
Type 2322 640 98005: 400 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, measured in accordance with IEC publication 539.

Unless otherwise stated, all values are approximate.

	2322 640 90005	2322 640 98005	
Resistance at			
+ 100 °C	16.7 ± 7%	16.7 ± 7%	kΩ
+ 200 °C	1120 ± 7%	1120 ± 7%	Ω
+ 25 °C (for information only)	310	310	kΩ
$B_{25/85}$-value	4300	4300	K
Temperature coefficient	−4.85	−4.85	%/K
Maximum dissipation	0.25	0.25	W
Dissipation factor	7	9.5	mW/K
when mounted on a heatsink (see note 1)	17.5	20.5	mW/K
Thermal time constant	19	33	s
when mounted on a heatsink (see note 1)	12	8.5	s
Heat capacity of ceramic (in air) of complete component	0.028	0.028	J/K
Response time (see note 2)	3	3	s
Operating temperature range			
at zero power	−25 to + 200	−25 to + 200	°C
at maximum power	0 to + 55	0 to + 55	°C
Dielectric withstanding voltage (RMS) between terminals and coating	min. 350	min. 350	V
Insulation resistance between terminals and coating at 100 V (DC)	min. 100	min. 100	MΩ

Notes

1. Measurements made in still air with the thermistor mounted on a heatsink of 100 cm^2, thickness 1.5 mm, connected between phosphor-bronze wires (ϕ 1.3 mm).
2. The thermistor being transferred from ambient air of + 25 °C to a silicone oil (MS200/50) bath of + 85 °C.

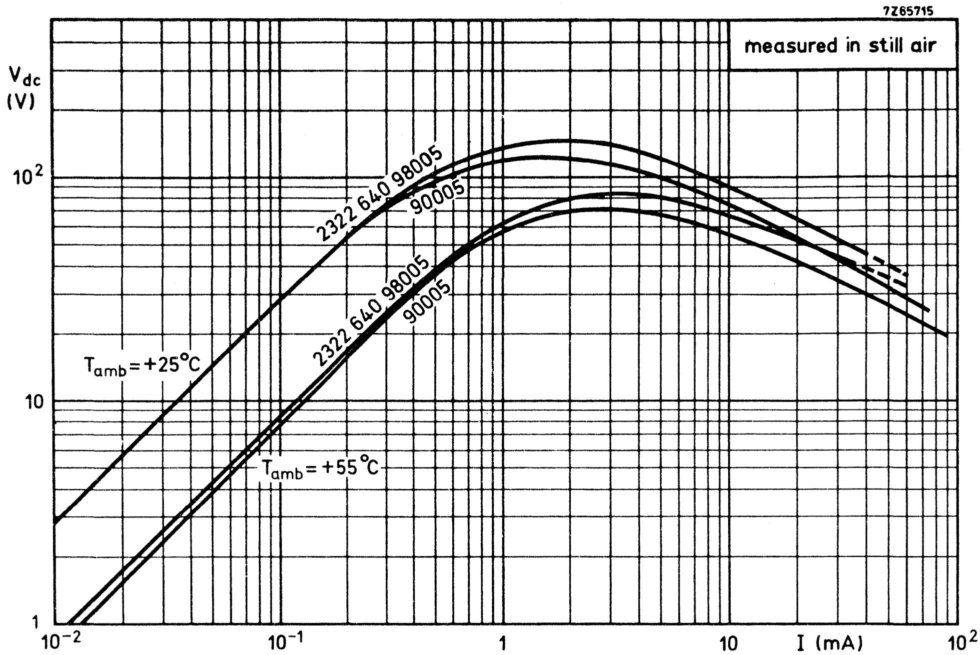


Fig.3 Typical voltage/current characteristics.

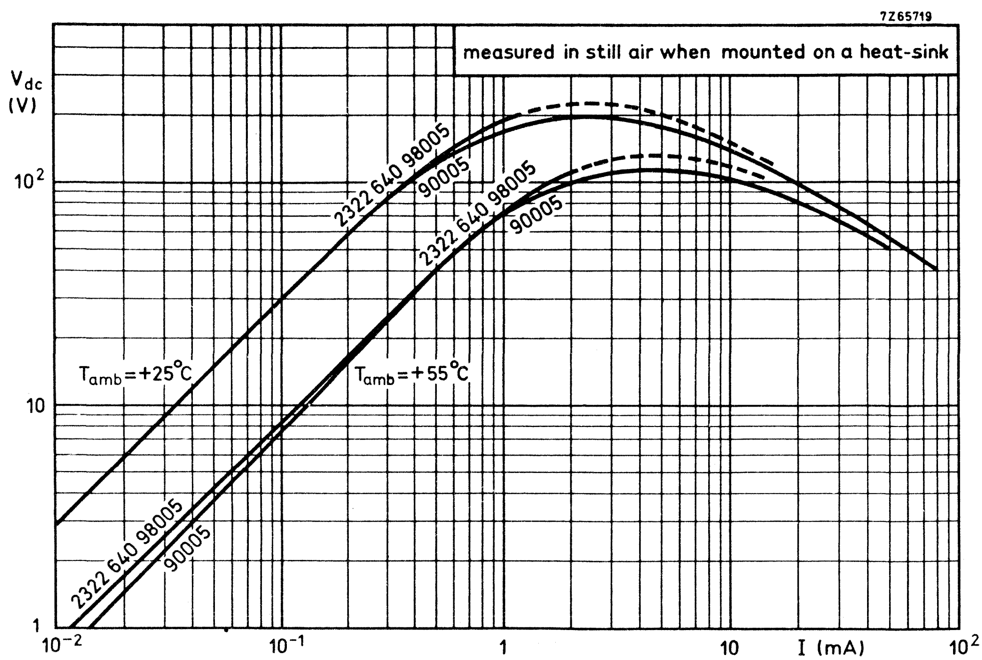


Fig.4 Typical voltage/current characteristics.

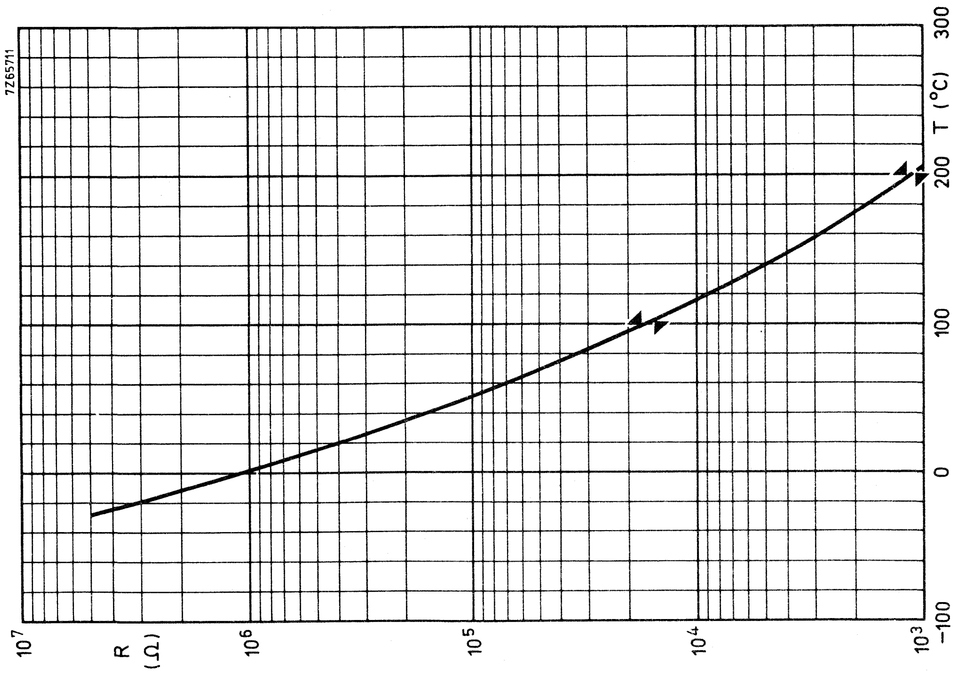


Fig.5 Typical resistance/temperature characteristics.

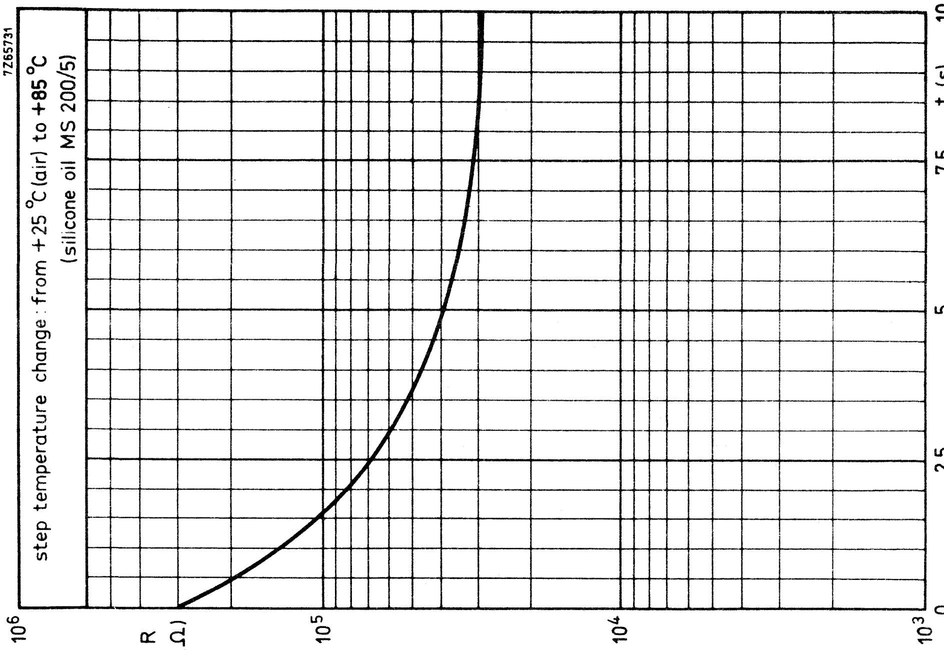


Fig.6 Typical resistance/response time characteristics.

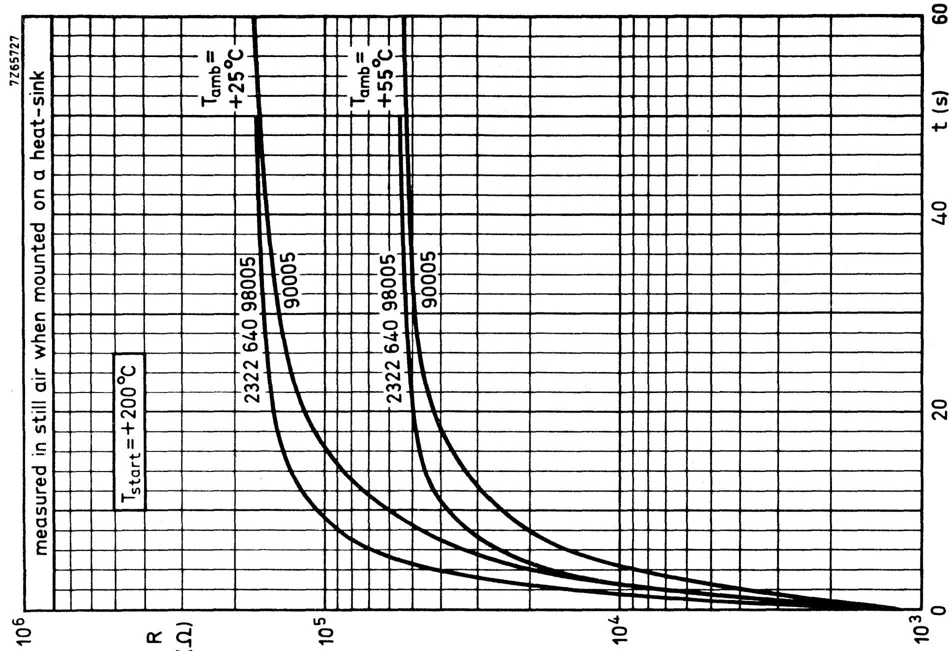


Fig.8 Typical resistance/time (cooling) characteristics.

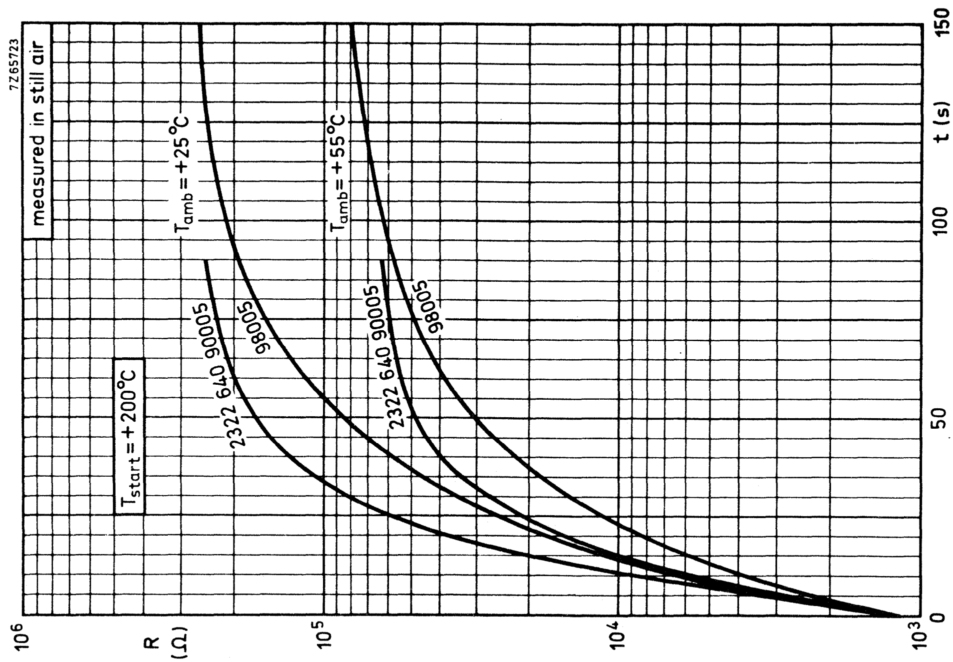


Fig.7 Typical resistance/time (cooling) characteristics.

NTC THERMISTOR
low temperature

Features

- Accurate type with several mechanical alternatives
- High stability

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at	
−30 °C	48.5 kΩ
−20 °C	26.74 kΩ
−10 °C	15.31 kΩ
Tolerance on	
R_{30} value	± 5.91% (± 1 °C)
R_{20} value	± 5.44% (± 1 °C)
R_{10} value	± 5% (± 1 °C)
Response time (for information only)	0.85 s
Operating temperature range	
at zero power	−55 to + 125 °C
for short periods	max. 150 °C
at maximum power	−55 to + 55 °C

MECHANICAL DATA

Dimensions in mm

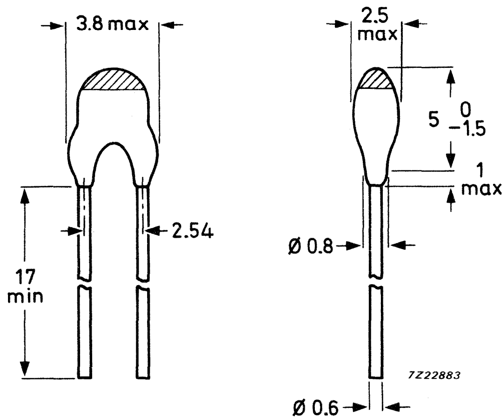


Fig.1 Component outline.

Marking: brown band on grey lacquered body

Mass: 0.21 grams approx.

PACKING

The thermistors are packed in cardboard boxes, each box containing 500 items.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	55/125/56
Resistance at (see note 1)	
− 30 °C	48.5 kΩ
− 20 °C	26.74 kΩ
− 10 °C	15.31 kΩ
Tolerance on (see note 1)	
R_{30} value	± 5.91% (± 1 °C)
R_{20} value	± 5.44% (± 1 °C)
R_{10} value	± 5% (± 1 °C)
$B_{25/85}$ value	3977 K
Response time (see note 2) (for information only)	0.85 s
Thermal time constant, τ (for information only)	8 s
Rated dissipation	250 mW
Dissipation factor, δ	7 mW/K
Operating temperature range	
at zero power	−55 to + 125 °C
for short periods	max. 150 °C
at maximum power	−55 to + 55 °C

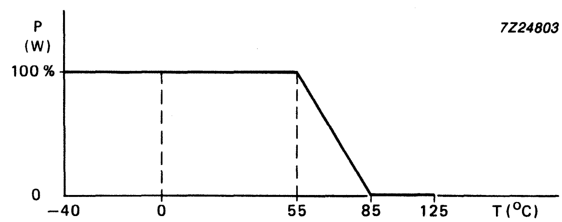


Fig.2 Tolerance curve.

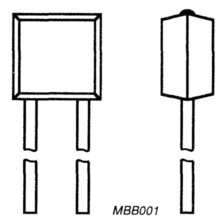
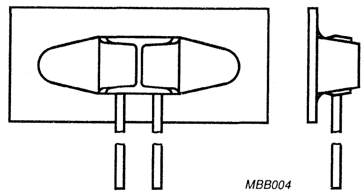
Notes

1. For values of nominal resistance value and tolerance at intermediate temperatures, please refer to Table 1.
2. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.

Table 1 Resistance values at intermediate temperatures

Temperature °C	Nominal resistance value Ω	Tolerance ± %	Temperature coefficient – %/K
–40	91590	6.42	6.57
–35	66290	6.16	6.35
–30	48500	5.91	6.15
–25	35840	5.67	5.95
–20	26740	5.44	5.76
–15	20150	5.22	5.58
–10	15310	5.00	5.40
–5	11730	5.21	5.24
0	9067	5.41	5.08
5	7059	5.61	4.92
10	5539	5.80	4.78
15	4376	5.99	4.64
20	3483	6.17	4.50
25	2789	6.35	4.37
30	2248	6.52	4.25
35	1823	6.69	4.13
40	1487	6.85	4.02
45	1220	7.01	3.91
50	1006	7.17	3.80
55	833.6	7.32	3.70
60	694.5	7.46	3.60
65	851.5	7.61	3.51
70	488.9	7.75	3.42
75	413.1	7.88	3.33
80	350.3	8.02	3.25
85	298.4	8.15	3.16
90	255.3	8.27	3.09
95	219.2	8.40	3.01
100	189.0	8.52	2.94
105	163.4	8.64	2.87
110	141.8	8.75	2.80
115	123.5	8.86	2.73
120	107.9	8.98	2.67
125	94.6	9.08	2.61

ASSEMBLY VARIATIONS

catalogue number	description	outline
2322 640 90013	moulded 2322 640 90012	
2322 640 98013	moulded 2322 640 90012 with metal plate	

NTC THERMISTORS

screw range

TEMPERATURE SENSING AND CONTROL

Features

- Easy mounting
- Rugged construction

QUICK REFERENCE DATA

	640 7....	642 7....
Resistance value at +25 °C	2.2 kΩ to 470 kΩ	3.3 Ω to 1.5 kΩ
Dissipation factor approx. (see note 1)	23 mW/K	25 mW/K
Thermal time constant approx. (see note 1)	7.5 s	20 s
Operating temperature range		
at zero power	−25 to +100 °C	−25 to +100 °C
at maximum power	0 to +55 °C	0 to +55 °C

APPLICATION

Suitable for all kinds of applications, especially when a good insulation and/or a good thermal contact with the chassis is required.

DESCRIPTION

Disc thermistor with negative temperature coefficient mounted in the head of aluminium screws M4 and with two solid tinned copper wires.

MECHANICAL DATA

Outline drawing

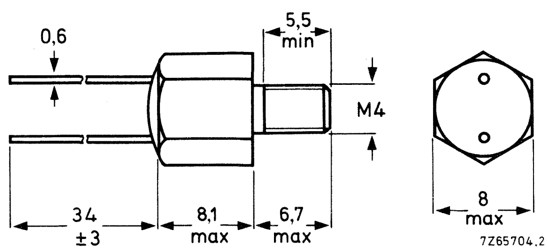


Fig.1 Component outline.

Note

1. Measured with screw mounted on an aluminium heatsink of 100 cm^2, thickness 1.5 mm, in still air, T_{amb} = +25 °C.

Marking

The last 4 digits of the catalogue number are printed on the stud in accordance with the information in Tables 1 and 2.

Mass

1.5 g approx.

Mounting

By means of a washer and M4 nut supplied with the device.
Applied torque shall not exceed 1.2 Nm. Leads to be soldered.

Robustness of terminations

Tensile strength	10 N
Bending	5 N
Torque applied on screw	1.2 Nm max.

Soldering

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

PACKAGING

100 thermistors in a cardboard box.

ELECTRICAL DATA

Maximum dissipation	0.5 W
Heat capacity	0.5 J/K approx.
Operating temperature range	
at zero power	−25 to + 100 °C
at maximum power	0 to + 55 °C
Dielectric withstanding voltage between terminals and screw	min. 100 V RMS
Insulation resistance between terminals and screw at 100 V DC	min. 100 MΩ

Also see Tables 1 and 2.

For typical resistance/temperature and voltage/current characteristics, refer to data for type 2322 640 6.... or 2322 642 6....

Table 1 Catalogue number 2322 640 7....

suffix of catalogue number		R_{25}	$B_{25/85}$-value		temperature coefficient at 25 °C
R_{25} ±5%	R_{25} ±10%	Ω	K	±%	%/K
3222	2222	2200	3977	0.75	–4.37
3332	2332	3300	3977	0.75	–4.37
3472	2472	4700	3977	0.75	–4.37
3682	2682	6800	3977	0.75	–4.37
3103	2103	10000	3977	0.75	–4.37
3123	2123	12000	3740	3	–4.10
3153	2153	15000	3740	3	–4.10
3223	2223	22000	3740	3	–4.10
3333	2333	33000	4090	1.5	–4.46
3473	2473	47000	4090	1.5	–4.46
3683	2683	68000	4190	2	–4.57
3104	2104	100000	4190	2	–4.57
3154	2154	150000	4370	3	–4.75
3224	2224	220000	4370	3	–4.75
3334	2334	330000	4570	3	–4.95
3474	2474	470000	4570	3	–4.95

Table 2 Catalogue number 2322 642 7....

suffix of catalogue number		R_{25}	$B_{25/85}$-value ± 5%	temperature coefficient at 25 °C
tol. 5%	tol. 10%	Ω	K	%/K
3338	2338	3.3	2675	–3.0
3478	2478	4.7	2750	–3.1
3688	2688	6.8	2800	–3.2
3109	2109	10	2875	–3.2
3159	2159	15	2950	–3.3
3229	2229	22	3025	–3.4
3339	2339	33	3100	–3.5
3479	2479	47	3150	–3.5
3689	2689	68	3225	–3.6
3101	2101	100	3300	–3.7
3151	2151	150	3375	–3.8
3221	2221	220	3475	–3.9
3331	2331	330	3575	–4.0
3471	2471	470	3650	–4.1
3681	2681	680	3725	–4.2
3102	2102	1 000	3825	–4.3
3152	2152	1 500	3975	–4.5

NTC THERMISTORS
accuracy line
(american standard line)

Features

- Excellent accuracy over a wide temperature range (± 0.75% tolerance on B value)
- Good stability
- Good price/performance ratio

TEMPERATURE SENSING AND CONTROL
TEMPERATURE COMPENSATION

QUICK REFERENCE DATA

Resistance at 25 °C	5 to 10 kΩ
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.75%
Maximum dissipation	0.1 W
Response time (for information only)	1.2 s
Operating temperature range	
at zero power	−40 to 125 °C
for short periods	max. 150 °C
at maximum power	0 to 55 °C

DESCRIPTION

These thermistors have a negative temperature coefficient. They consist of a chip or disc with two tinned solid copper wires. The range comprises 4 types which have been made from one base material, selected because of its extremely stable characteristics. The various R_{25} values are determined by the varying dimensions of the chip or disc, and the choice of R_{25} values are based on the American standard. The thermistors have a non-flammable coating of protective lacquer which, in accordance with IEC 68-2-45, is resistant to most commonly used cleaning solvents.

APPLICATION

For accurate temperature sensing, measurement and control up to 150 °C.

MECHANICAL DATA

Dimensions in mm

Outlines

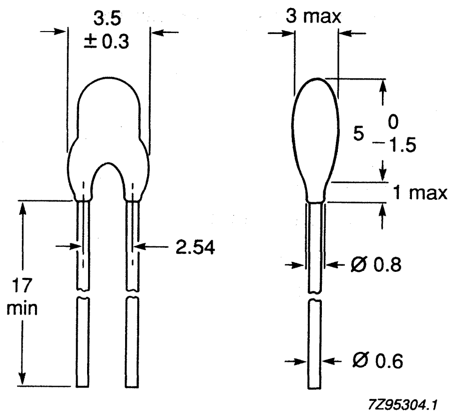


Fig.1 Component outline.

Marking : none

Mass : 0.22 grams

Mounting : by soldering, in any position

Robustness of terminations

tensile strength	10 N
bending (leads are not allowed to break or become loose)	5 N

Soldering

solderability	240 °C max., duration 4 s max.
resistance to heat	265 °C max., duration 11 s max.

Impact

free fall	1 m

Inflammability

non-flammable, in accordance with IEC publication 695-2-2 (1980, needle flame)

PACKING

The thermistors are packed in cardboard boxes. The smallest packing quantity is 500 items. The thermistors are also available on tape on special request.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with the IEC publication 539; also see Table 1.

$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.75%
Maximum dissipation	0.1 W
Dissipation factor, δ (for information only)	7 mW/K
Thermal time constant, τ (for information only)	11 s
Response time (see note 1) (for information only)	1.2 s
Operating temperature range (see Fig.2)	
at zero power	−40 to 125 °C
for short periods	max. 150 °C
at maximum power	0 to 55 °C

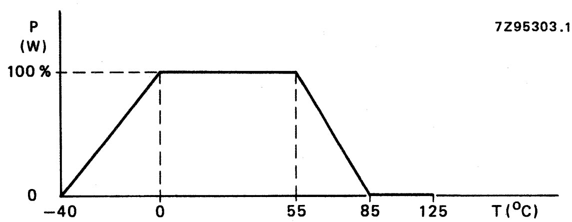


Fig.2 Derating curve.

Table 1 R_{25} values

catalogue number 2322 645 . . . . . tolerance ± 5%	catalogue number 2322 645 . . . . . tolerance ± 10%	R_{25} value kΩ
03502	02502	5
03602	02602	6
03802	02802	8
03103	02103	10

Note:

1. Response time in silicon oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air, to 85 °C in oil.

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.1\%$
	68-2-1	endurance	–40 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.15\%$
	539-gen	endurance	100 mW, 55 °C 1000 hours	$\Delta R/R < 3\%$	$\Delta R/R = 0.5\%$
	68-2-2	dry heat, steady state	125 °C, 1000 hours	$\Delta R/R < 3\%$	$\Delta R/R = 0.1\%$
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	$\Delta R/R < 3\%$	$\Delta R/R = -0.2\%$
C2 4.14	68-2-14	rapid change of temperature	–40 °C to 125 °C, 50 cycles	$\Delta R/R < 2\%$	$\Delta R/R = 0.1\%$

* Typical drift based on sample products with $B_{25/75}$ value of 3965 K.

R_T values and tolerance on R_T values

These thermistors have a narrow tolerance on the B value, the result of which is to provide a very small tolerance on the nominal resistance value over a wide temperature range. For this reason the usual graphs of R = f(T) are replaced by Table 3, together with a formula with which the characteristics can be calculated with a high precision.

Formula to determine nominal resistance values.

The resistance values at intermediate temperatures can be calculated using the "Steinhert and Hart" equation:

$$R_T = \left(\frac{R_{25}}{10\,000}\right).e^{\left\{\sqrt[3]{\sqrt{E^2+D}-E} \;-\; \sqrt[3]{\sqrt{E^2+D}+E}\right\}}$$

in which $D = 4.76919 \times 10^8$ and

$$E = \frac{1.14102 - 10^3/T}{1.9786 \times 10^{-4}}$$

T= temperature in K.

Determination of the resistance/temperature deviation from nominal

The complete resistance deviation is obtained by combining the "R_{25} tolerance" and the "resistance deviation due to B tolerance".

Let X = R_{25} tolerance;

Y = resistance deviation due to B tolerance;

Z = complete resistance deviation; then:

$Z = [(1 + X/100) \times (1 + Y/100) - 1] \times 100$ or $Z = X + Y$ (approximation)

TC = temperature coefficient;

ΔT = temperature deviation, so:

$\Delta T = Z/TC$

Example: at 0 °C, let X = 5%, Y = 0.89%. and TC = 5.08 %/K (see Table 3), then

$Z = \{ [1 + (5/100)] \times [1 + (0.89/100)] - 1 \} \times 100$
$= \{ 1.05 \times 1.0089 - 1 \} \times 100 = 5.9345$ or 5.93%

$\Delta T = Z/TC = 5.93/5.08 = 1.167$ or 1.17 °C

So, a NTC having a R_{25} value of 10 kΩ has a value of 32.51 kΩ between −1.17 and + 1.17 °C.

Table 3 Resistance values at intermediate temperatures

temperature	ratio R_T/R_{25}	deviation in R value due to B tolerance	temperature coefficient	resistance value (kΩ) for 2322 645 . . . . . (see note 1)			
°C		%	%/K	0.502	0.602	0.802	0.103
−40	32.84	2.64	6.57	164.2	197.0	262.7	328.4
−35	23.77						
−30	17.39	2.16	6.15	86.95	104.3	139.1	173.9
−25	12.85						
−20	9.589	1.71	5.76	47.95	57.53	76.71	95.89
−15	7.223						
−10	5.489	1.29	5.40	27.45	32.93	43.91	54.89
−5	4.207						
0	3.251	0.89	5.08	16.26	19.51	26.01	32.51
5	2.531						
10	1.986	0.52	4.78	9.930	11.92	15.88	19.86
15	1.569						
20	1.249	0.17	4.50	6.245	7.494	9.992	12.49
25	1.000	0.0	4.37	5.000	6.000	8.000	10.00
30	0.8060	0.16	4.25	4.030	4.836	6.448	8.060
35	0.6536						
40	0.5331	0.47	4.02	2.666	3.199	4.265	5.331
45	0.4372						
50	0.3606	0.77	3.80	1.803	2.164	2.885	3.606
55	0.2989						
60	0.2490	1.05	3.60	1.245	1.494	1.992	2.490
65	0.2085						
70	0.1753	1.31	3.42	0.8765	1.052	1.402	1.753
75	0.1481						
80	0.1256	1.57	3.25	0.6280	0.7536	1.005	1.256
85	0.1070						
90	0.09155	1.81	3.09	0.4578	0.5493	0.7324	0.9155
95	0.07861						
100	0.06775	2.04	2.94	0.3388	0.4065	0.5420	0.6775
105	0.05860						
110	0.05086	2.26	2.80	0.2543	0.3052	0.4069	0.5086
115	0.04429						
120	0.03870	2.47	2.67	0.1935	0.2322	0.3096	0.3870
125	0.03392						
130	0.02982	2.67	2.55	0.1491	0.1789	0.2386	0.2982
135	0.02629						
140	0.02324	2.86	2.43	0.1162	0.1394	0.1859	0.2324
145	0.02061						
150	0.01832	3.05	2.33	0.0916	0.1099	0.1466	0.1832

Note:

1. Replace dot in catalogue number by 2 for a ± 10% tolerance, and 3 for a ± 5% tolerance.

NTC THERMISTOR
medium temperature

Features
- accurate type with several mechanical alternatives
- high stability

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at 25 °C	10 kΩ
Tolerance on R_{25} value	± 3% (0.7 °C)
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
Response time (for information only)	1.2 s
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−55 to + 55 °C

MECHANICAL DATA

Dimensions in mm

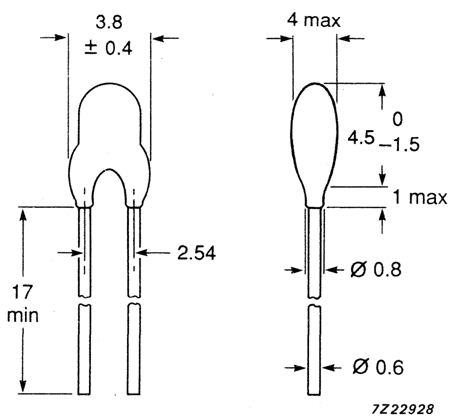


Fig.1 Component outline.

Marking: grey lacquered body

Mass: 0.18 grams approx.

PACKING

The thermistors are packed in cardboard boxes, each box containing 500 items.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	40/125/56
Resistance at 25 °C (see note 1)	10 kΩ
Tolerance on R_{25} value	± 3% (0.7 °C)
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
$B_{25/85}$ value	3977 K
Response time (see note 2) (for information only)	1.2 s
Rated dissipation	100 mW
Dissipation factor, δ	7 mW/K approx.
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−55 to + 55 °C

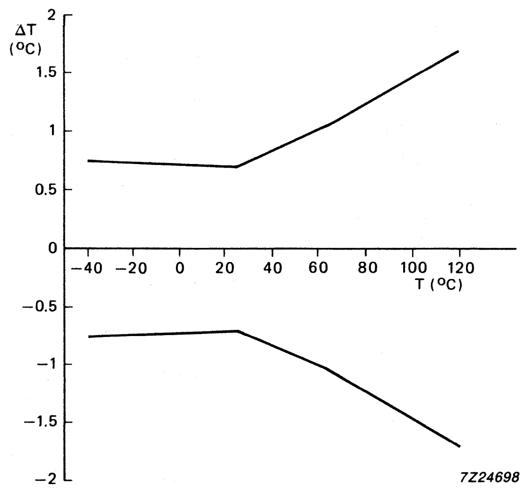


Fig.2 Tolerance curve.

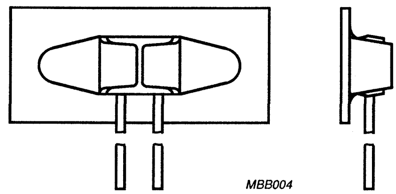
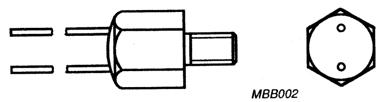
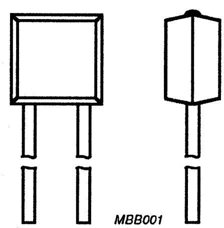
Notes

1. For values of nominal resistance value and tolerance at intermediate temperatures, please refer to Table 1.
2. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.

Table 1 Resistance values at intermediate temperatures

Temperature °C	Nominal resistance value kΩ	Tolerance ± %	Temperature coefficient – %/K
–40	328.4	4.80	6.57
–35	237.7		
–30	173.9	4.50	6.15
–25	128.5		
–20	95.89	4.16	5.76
–15	72.23		
–10	54.89	3.88	5.40
–5	42.07		
0	32.51	3.60	5.08
5	25.31		
10	19.86	3.36	4.78
15	15.69		
20	12.49	3.12	4.50
25	10.00	3.00	4.37
30	8.06	3.12	4.25
35	6.536		
40	5.331	3.32	4.02
45	4.372		
50	3.606	3.52	3.80
55	2.989		
60	2.49	3.72	3.60
65	2.085		
70	1.753	3.88	3.42
75	1.481	3.96	3.33
80	1.256	4.04	3.25
85	1.070		
90	0.9155	4.20	3.09
95	0.7861		
100	0.6775	4.36	2.94
105	0.5860		
110	0.5086	4.52	2.80
115	0.4429		
120	0.3870	4.68	2.67
125	0.3392		
130	0.2982	4.84	2.61
135	0.2629		
140	0.2324	4.97	2.43
145	0.2061		
150	0.1832	5.1	2.33

ASSEMBLY VARIATIONS

catalogue number	description	outline
2322 645 98001	moulded 2322 645 90001 with metal plate	
2322 645 97001	2322 645 90001 in screw	
2322 645 96001	moulded 2322 645 90001	

NTC THERMISTOR
low temperature

Features

- high accuracy over a wide temperature range
- high stability

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value at 25 °C	5 kΩ
Tolerance on R_{25} value	± 3% (± 0.7 °C)
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
Response time (for information only)	1.2 s
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−40 to + 55 °C

MECHANCIAL DATA

Dimensions in mm

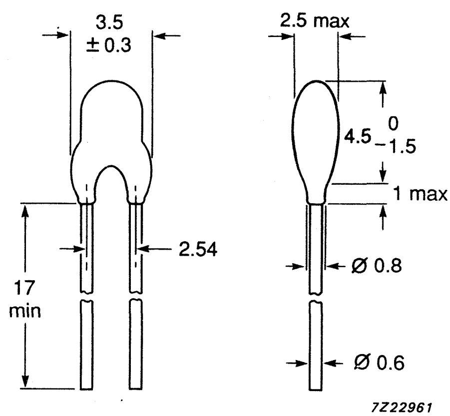


Fig.1 Component outline.

Marking: grey lacquered body, no other marking

Mass: 0.21 grams approx.

PACKING

The thermistors are packed in cardboard boxes, each box containing 500 items.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	40/125/56
Resistance value at 25 °C (note 1)	5 kΩ
Tolerance on R_{25} value	± 3% (± 0.7 °C)
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
$B_{25/85}$ value	3977 K
Response time (see note 2) (for information only)	1.2 s
Rated dissipation	250 mW
Dissipation factor, δ (for information only)	7 mW/K
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−40 to + 55 °C

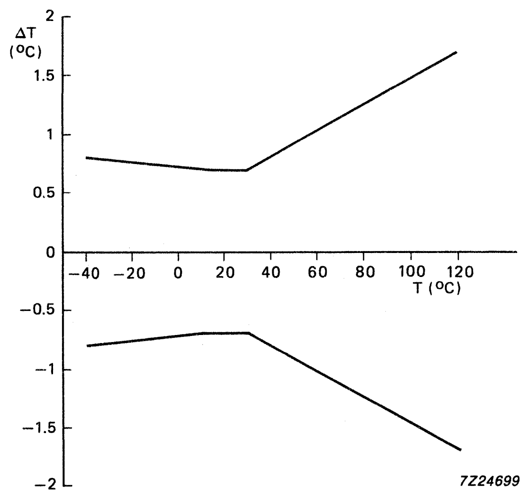


Fig.2 Tolerance curve.

Notes:

1. For values of nominal resistance value and tolerance at intermediate temperatures, please refer to Table 1.
2. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.

Formula to determine nominal resistance values

The resistance values at intermediate temperatures can be calculated using the modified 'Steinhart and Hart' equation:

$$R_T = (R_{25}/10000)\ [\sqrt[3]{(\sqrt{E^2 + D} - E)} - \sqrt[3]{(\sqrt{E^2 + D} + E)}]$$

in which $D = 4.76919 \times 10^8$

and $E = \dfrac{1.4102 - 10^3/T}{1.9786 \times 10^{-4}}$

T is measured in Kelvin.

Table 1 Resistance values at intermediate temperatures

Temperature °C	Ratio R_T/R_{25}	Resistance kΩ	Tolerance %	Temperature coefficient %/K
–40	32.84	164.2	4.80	–6.57
–35	23.77			
–30	17.39	86.95	4.50	–6.15
–25	12.85			
–20	9.589	47.95	4.16	–5.76
–15	7.223			
–10	5.489	27.45	3.88	–5.40
–5	4.207			
0	3.251	16.26	3.60	–5.08
5	2.531			
10	1.986	9.930	3.36	–4.78
15	1.569			
20	1.249	6.245	3.12	–4.50
25	1.000	5.000	3.00	–4.37
30	0.8060	4.030	3.12	–4.25
35	0.6536			
40	0.5331	2.666	3.32	–4.02
45	0.4372			
50	0.3606	1.803	3.52	–3.80
55	0.2989			
60	0.2490	1.245	3.72	–3.60
65	0.2085			
70	0.1753	0.8765	3.88	–3.42
75	0.1481			
80	0.1256	0.6280	4.04	–3.25
85	0.1070			
90	0.09155	0.4578	4.20	–3.09
95	0.07861			
100	0.06775	0.3388	4.36	–2.94
105	0.05860			
110	0.05086	0.2543	4.52	–2.80
115	0.04429			
120	0.03870	0.1935	4.68	–2.67
125	0.03392			

NTC THERMISTOR
medium temperature

Features

- excellent accuracy over a wide temperature range
- high stability

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at 25 °C	5 kΩ
Tolerance on R_{25} value	± 2%
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
Response time (for information only)	1.2 s
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−40 to + 55 °C

MECHANICAL DATA

Dimensions in mm

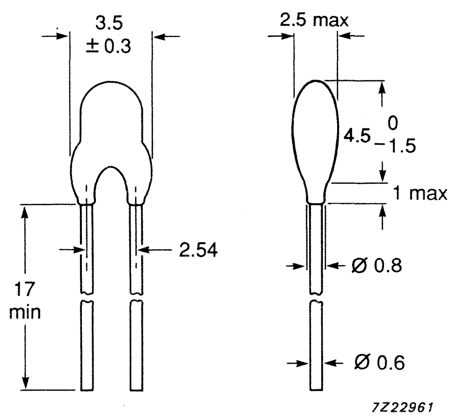


Fig.1 Component outline.

Marking: grey lacquered body

Mass: 0.21 grams approx.

PACKING

The thermistors are packed in cardboard boxes, each box containing 500 items.

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	40/125/56
Resistance at 25 °C (see note 1)	5 kΩ
Tolerance on R_{25} value	± 2%
$B_{25/75}$ value	3965 K
Tolerance on $B_{25/75}$ value	± 0.5%
$B_{25/85}$ value	3977 K
Response time (see note 2) (for information only)	1.2 s
Rated dissipation	100 mW
Dissipation factor, δ	7 mW/K approx.
Operating temperature range	
at zero power	−40 to + 125 °C
for short periods	max. 150 °C
at maximum power	−40 to + 55 °C

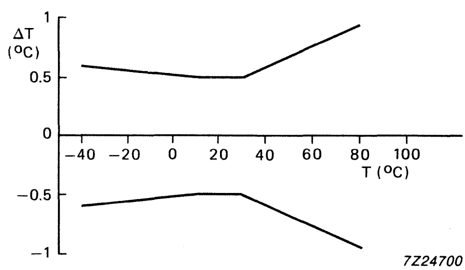


Fig.2 Tolerance curve.

Notes:

1. For values of nominal resistance value and tolerance at intermediate temperatures, please refer to Table 1.
2. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air to 85 °C in oil.

Table 1 Resistance values at intermediate temperatures

Temperature °C	Nominal resistance value kΩ	Tolerance ± %	Temperature coefficient – %/K
–40	164.2	3.80	6.57
–35			
–30	86.95	3.50	6.15
–25			
–20	47.95	3.16	5.76
–15			
–10	27.45	2.88	5.40
–5			
0	16.26	2.60	5.08
5			
10	9.93	2.36	4.78
15			
20	6.245	2.25	4.50
25	5.000	2.18	4.37
30	4.03	2.12	4.25
35			
40	2.666	2.32	4.02
45			
50	1.803	2.52	3.80
55			
60	1.245	2.72	3.60
65			
70	0.8765	2.88	3.42
75			
80	0.6280	3.04	3.25
85			
90	0.4578	3.20	3.09
95			
100	0.3388	3.36	2.94
105			
110	0.2543	3.52	2.80
115			
120	0.1935	3.68	2.67
125			
130	0.1491	3.81	2.55
135			
140	0.1162	3.94	2.43
145			
150	0.0916	4.07	2.33

NTC THERMISTOR
long leads

Features

- Long and flexible leads for special mounting or assembly requirements
- Electrical features of 'accuracy line'
- Small diameter

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance at 25 °C	10 kΩ
Tolerance on R_{25} value	± 5%
$B_{25/100}$ value	3993 K ± 1.2%
Operating temperature range	
at zero power	−40 to + 125 °C
at maximum power	0 to + 55 °C

DESCRIPTION

This thermistor has a negative temperature coefficient. It consists of a chip with two Ni leads.

APPLICATION

Temperature sensing and control.

MECHANICAL DATA

Dimensions in mm

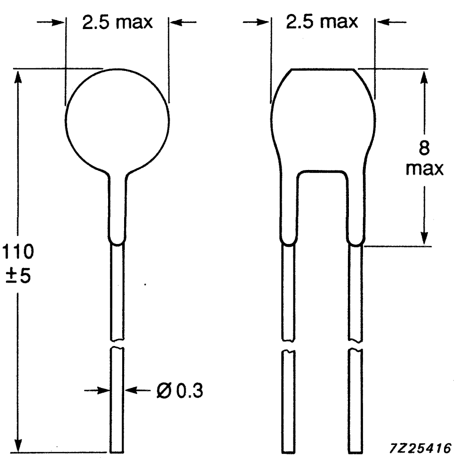


Fig.1 Component outline.

MECHANICAL DATA (continued)

Marking

Body coated with black coloured EPQ lacquer

Mass

0.21 grams approximately

PACKING

The thermistors are packed in cardboard boxes, each box containing 1000 items (10 plastic bags, each containing 100 items).

ELECTRICAL DATA

Unless otherwise stated, measurements are in accordance with IEC Publication 539.

Climatic category	40/125/56
Resistance at 25 °C	10 kΩ
Tolerance on R_{25} value	± 5%
$B_{25/100}$ value	3993 K ± 1.2%
Rated dissipation	100 mW
Dissipation factor, δ	1.35 mW/K
Operating temperature range	
at zero power	−40 to + 125 °C
at maximum power	0 to + 55 °C

NTC THERMISTORS

miniature bead

Features

- Very small
- Very quick response to changes in temperature
- Very high long term stability
- High temperature uses

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value at 25 °C	1 kΩ to 1 MΩ
Tolerance on R_{25} value	± 5%, ± 10%
$B_{25/85}$ value	2075 to 4100 K
Tolerance on $B_{25/85}$ value	± 5%
Response time	0.5 s approx.
Operating temperature range at zero power	−55 to 200 °C

APPLICATION

Temperature measurement, level and flow sensing.

DESCRIPTION

Bead thermistor with negative temperature coefficient, with two solid platinum-iridium leads in axial or radial configuration.

MECHANICAL DATA

Outlines

Fig.1
version 2322 633 0....
(axial leads).

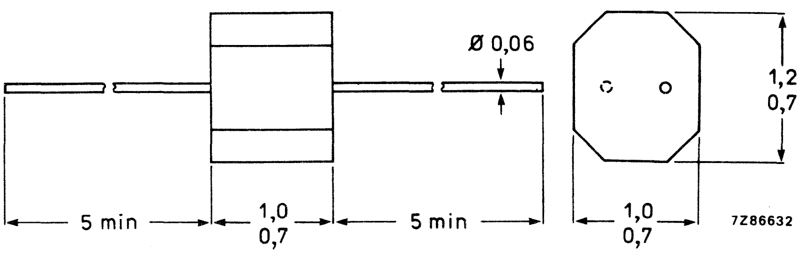
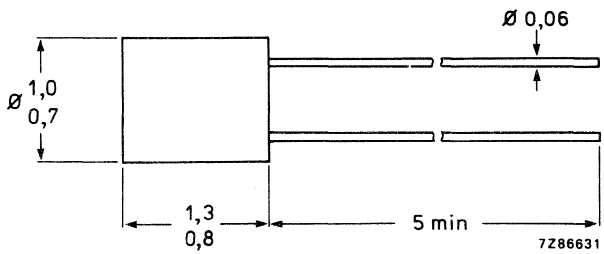


Fig.2
version 2322 633 1....
(radial leads).



Marking

none.

Mounting

In any position by spot welding of the leads to conducting wires or other supports.

Mass

5 mg. approximately.

Inflammability

Uninflammable.

PACKAGING

100 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, measured according to IEC publication 539.

Table 1 Electrical data

catalogue number 2322 633 0.... axial leads		catalogue number 2322 633 1.... radial leads		R_{25}	temperature coefficient at 25 °C	$B_{25/85}$-value ± 5%
tol. ± 5%	tol. ± 10%	tol. ± 5%	tol. ± 10%	kΩ	%/K	K
3102	2102	3102	2102	1	–2.3	2075
3222	2222	3222	2222	2.2	–2.6	2285
3472	2472	3472	2472	4.7	–2.8	2485
3103	2103	3103	2103	10	–4.2	3750
3223	2223	3223	2223	22	–4.0	3560
3473	2473	3473	2473	47	–4.2	3750
3104	2104	3104	2104	100	–4.4	3900
3224	2224	3224	2224	220	–4.3	3860
3474	2474	3474	2474	470	–4.5	3950
3105	2105	3105	2105	1000	–4.6	4100

Response time (see Note 1) — 0.5 s approx.

Operating temperature range, at zero power — –55 to + 200 °C

Note:

1. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air, to 85 °C in oil.

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.1%
	68-2-1	endurance	−40 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen	endurance	30 mW, 55 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.5%
	68-2-2	dry heat, steady state	125 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	ΔR/R < 3%	ΔR/R = −0.2%
C2 4.14	68-2-14	rapid change of temperature	−40 °C to 125 °C 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%

* Typical drift based on sample products with $B_{25/85}$ value of 3797 K.

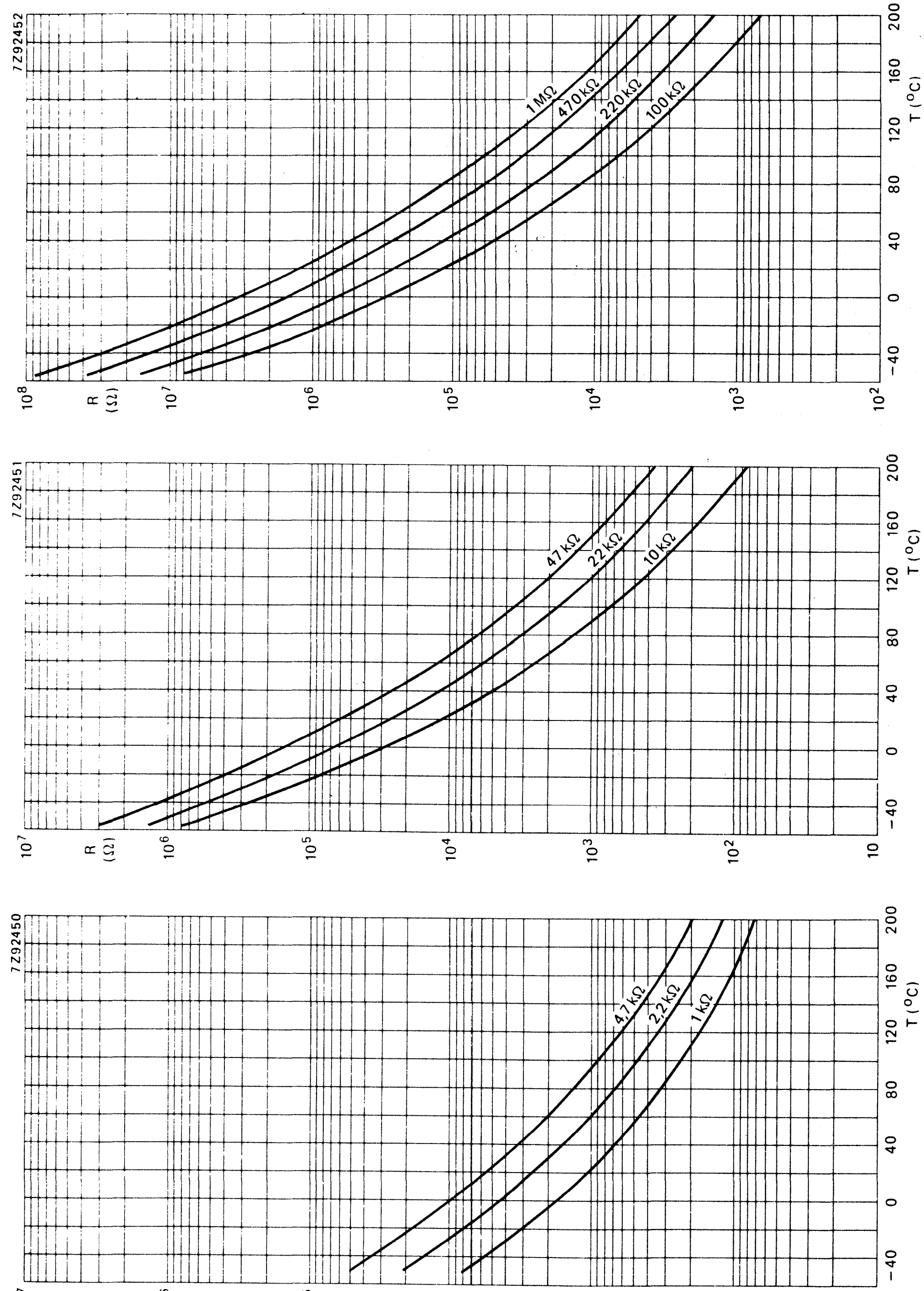


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTORS

glass encapsulated miniature bead

Features

- Small diameter
- Quick response to changes in temperature
- High stability over long time periods
- High temperature operation
- Resistant to aggressive environments

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value at 25 °C	1 kΩ to 1 MΩ
Tolerance on R_{25} value	± 5%, ± 10%
$B_{25/85}$ value	2075 to 4100 K
Tolerance on $B_{25/85}$ value	± 5%
Response time	6 s approx.
Thermal time constant	5.5 s approx.
Operating temperature range	
at zero power	−55 to 200 °C
at maximum power	0 to 55 °C

APPLICATION

Temperature measurements

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned dumet (CuNiFe) wires.

MECHANICAL DATA

Outlines

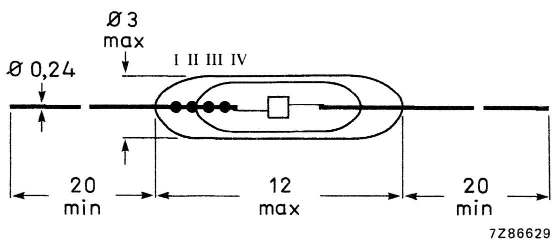


Fig.1 Component outline.

Marking

Colour dots on the glass envelope, see Fig.1 and Table 1.

Mass

0.1 g approximately.

Mounting

In any position by soldering.

Soldering

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

Inflammability

Uninflammable.

Impact

free fall	100 mm

Robustness of terminations

Tensile strength	1.0 N
Bending	0.5 N
Torsion	3 times
Resistance to solvents:	in accordance with IEC 68-2-45, resistant to R113 at T_{amb}

Packaging

100 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, measured in accordance with IEC publication 539.

Maximum dissipation at +55 °C	60 mW
Dissipation factor	0.5 mW/K approx.
Thermal time constant	5.5 s approx.
Response time (see note 1)	6 s approx.
Operating temperature range (Fig.2)	
at zero power	−55 to +200 °C
at maximum power	0 to +55 °C
Dielectric withstanding voltage (RMS) between terminals and glass envelope	min. 1500 V
Insulation resistance between terminals and glass envelope at 100 V (DC)	min. 100 MΩ

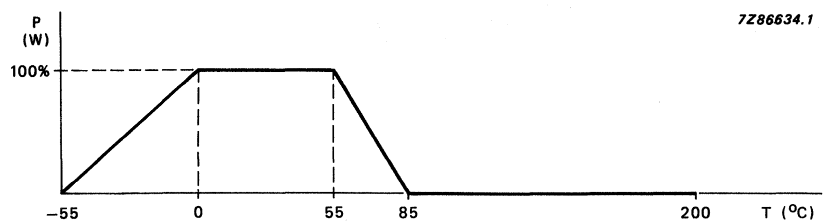


Fig.2 Derating curve.

Note

1. Response time in silicone oil MS 200/50. The response time in silicone oil is the time necessary to change of 63.2% of the total difference between the initial and the final body temperature, when subjected to a step function change in ambient temperature. Step change: initial temperature: air at 25 °C; final temperature: oil (MS 200/50) at 85 °C.

Table 1 Catalogue number 2322 633 2 ....

suffix of the catalogue number		R_{25}	$B_{25/85}$-value ± 5%	temperature coefficient at 25 °C	colour code*		
tol. ± 5%	tol. ± 10%	kΩ	K	%/K	I	II	III
3102	2102	1	2075	−2.3	brown	black	red
3222	2222	2.2	2285	−2.6	red	red	red
3472	2472	4.7	2485	−2.8	yellow	violet	red
3103	2103	10	3750	−4.2	brown	black	orange
3223	2223	22	3560	−4.0	red	red	orange
3473	2473	47	3750	−4.2	yellow	violet	orange
3104	2104	100	3900	−4.4	brown	black	yellow
3224	2224	220	3860	−4.3	red	red	yellow
3474	2474	470	3950	−4.5	yellow	violet	yellow
3105	2105	1000	4100	−4.6	brown	black	green

* Thermistors with 5% tolerance have a gold dot IV; 10% tolerance is identified by a silver dot IV, (Fig.1).

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.1\%$
	68-2-1	endurance	−40 °C, 1000 hours	$\Delta R/R < 1\%$	$\Delta R/R = 0.15\%$
	539-gen	endurance	60 mW, 55 °C, 1000 hours	$\Delta R/R < 3\%$	$\Delta R/R = 0.5\%$
	68-2-2	dry heat, steady state	125 °C, 1000 hours	$\Delta R/R < 3\%$	$\Delta R/R = 0.1\%$
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	$\Delta R/R < 3\%$	$\Delta R/R = -0.2\%$
C2 4.14	68-2-14	rapid change of temperature	−40 °C to 125 °C, 50 cycles	$\Delta R/R < 2\%$	$\Delta R/R = 0.1\%$

* Typical drift based on sample products with $B_{25/85}$ value of 3797 K.

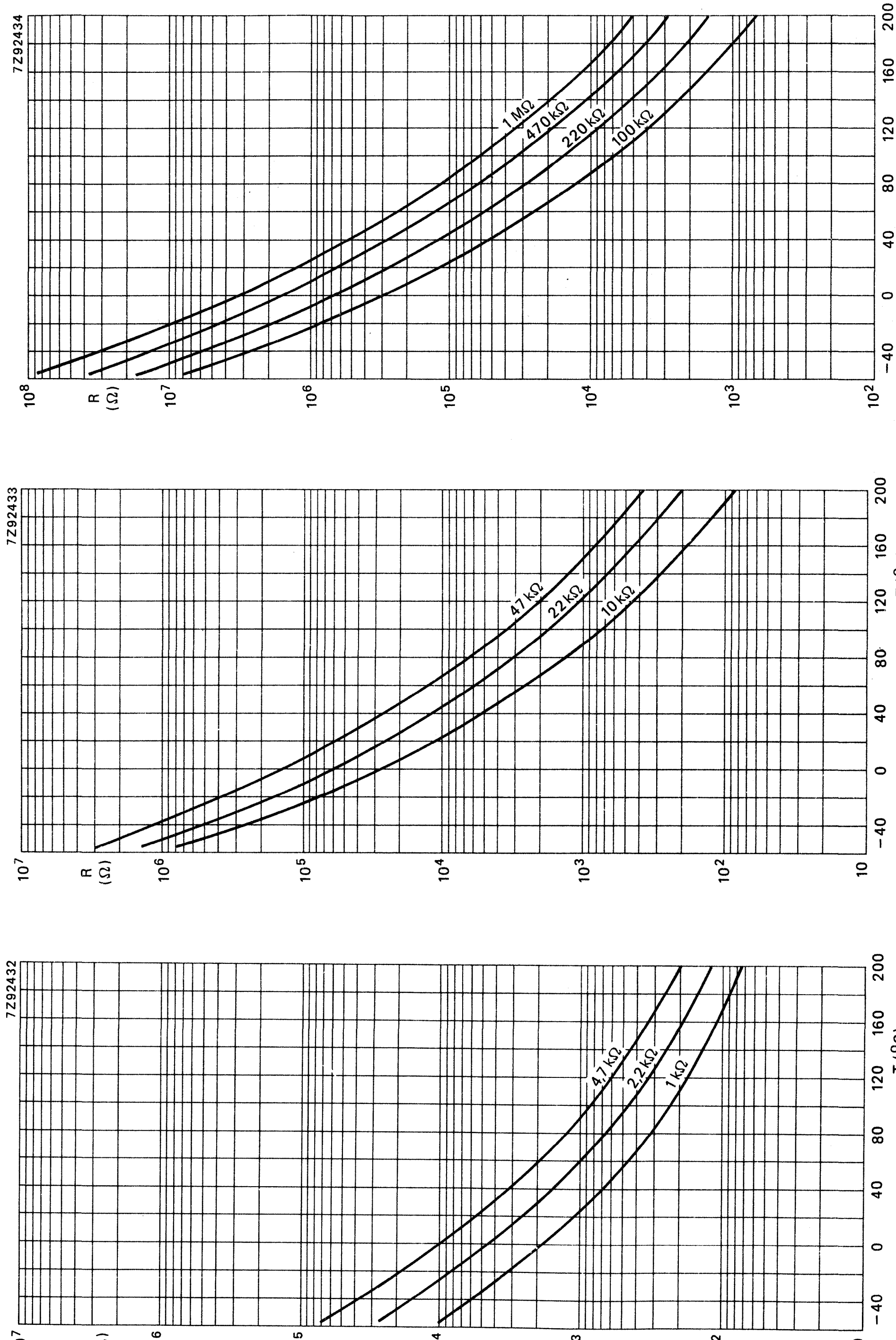


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTORS
SOD27 range

Features

- Small diameter
- Quick response to changes in temperature
- High long term stability
- High temperature
- Resistant to aggressive environments

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Type	2322 633	72224	73224
Resistance at 25 °C	220 kΩ	± 10%	± 5%
Response time		0.75 s approx.	
Operating temperature range			
at zero power		25 to 300 °C	
at maximum power		25 to 55 °C	

APPLICATION

For high temperature measurement and control in domestic appliances and industrial process control equipment.

DESCRIPTION

These thermistors have a negative temperature coefficient and are mounted in a glass envelope (SOD27). They have two nickel plated copper clad iron connecting leads.

MECHANICAL DATA

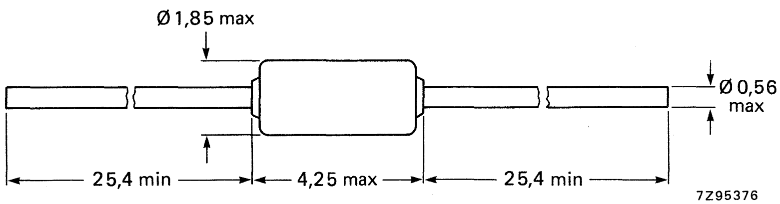


Fig.1 Component outline; SOD27.

Marking	: none
Mass	: 0.14 g approximately
Mounting	: in any position by soldering
Resistance to solvents	: according to IEC 68-2-45

Robustness of terminations

tensile strength	10 N
bending	5 N
torsion	3 times

Soldering

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

For operating temperatures up to 300 °C spot welding is preferred.

Impact

Free fall — 100 mm

Inflammability — not inflammable, according to IEC 695-2-2

Packaging

500 thermistors in a cardboard box.

ELECTRICAL DATA

Unless otherwise specified, measured according to IEC publication 539.

Resistance at 25 °C	
type 2322 633 72224	220 kΩ ± 10%
type 2322 633 73224	220 kΩ ± 5%
$B_{25/85}$ value	3797 K ± 3%
Maximum dissipation	100 mW
Response time (see note 1)	0.75 s approx.
Operating temperature range	
at zero power	25 to 300 °C
at maximum power	25 to 55 °C
Derating	See Fig.2.

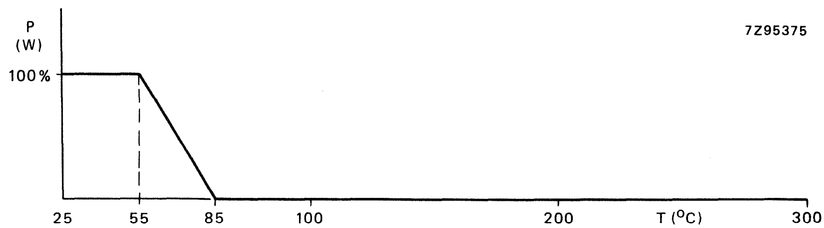


Fig. 2 Derating curve.

Dry heat at 300 °C, steady state	max. 1000 hours
Rapid change of temperature, 30 s at 25 °C/15 s at 300 °C	50 000 cycles

For resistance values at intermediate temperatures, see Table 1

Note:

1. Response time in silicone oil MS 200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change, in this case from 25 °C in air, to 85 °C in oil.

Table 1 Resistance values at intermediate temperatures

temperature	resistance	2322 633 72224 tolerance on R		2322 633 73224 tolerance on R		temp. coefficient
°C	Ω	+ %	– %	+ %	– %	%/K
25	220 000	10,00	10,00	5,00	5,00	–4,12
30	179 500	10,61	10,61	5,61	5,61	–4,02
40	121 300	11,80	11,76	6,80	6,76	–3,81
50	83 630	12,94	12,58	7,94	7,58	–3,63
60	58 710	14,04	13,88	9,04	8,88	–3,45
70	41 920	15,10	14,84	10,10	9,84	–3,29
80	30 410	16,12	15,75	11,12	10,75	–3,13
90	22 390	17,10	16,65	12,10	11,65	–2,99
100	16 720	18,01	17,41	13,01	12,41	–2,87
110	12 630	18,95	18,23	13,95	13,23	–2,74
120	9 663	19,83	18,95	14,83	13,95	–2,62
130	7 478	20,68	19,64	15,68	14,64	–2,51
140	5 851	21,50	20,32	16,50	15,32	–2,40
150	4 625	22,28	20,94	17,28	15,94	–2,30
160	3 691	23,06	21,54	18,06	16,54	–2,21
170	2 973	23,79	22,14	18,79	17,14	–2,12
180	2 415	24,49	22,67	19,49	17,67	–2,04
190	1 978	25,17	23,20	20,17	18,20	–1,96
200	1 632	25,87	23,66	20,87	18,66	–1,90
210	1 355	26,46	24,17	21,46	19,17	–1,83
220	1 132	27,14	24,60	22,14	19,60	–1,76
230	952	27,70	25,07	22,70	20,07	–1,70
240	806	28,32	25,48	23,32	20,48	–1,64
250	686	28,90	25,90	23,90	20,90	–1,58
260	587	29,45	26,42	24,45	21,42	–1,53
270	506	29,99	26,67	24,99	21,67	–1,47
280	437	30,50	27,03	25,50	22,03	–1,43
290	380	31,02	27,36	26,02	22,36	–1,38
300	332	31,50	27,72	26,50	22,72	–1,33

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.1%
	68-2-1	endurance	–40 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen	endurance	100 mW, 55 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.5%
	68-2-2	dry heat, steady state	125 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	ΔR/R < 3%	ΔR/R = –0.2%
C2 4.14	68-2-14	rapid change of temperature	–40 °C to 125 °C, 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%

* Typical drift based on sample products with $B_{25/85}$ value of 3797 K.

NTC thermistor, SOD27 and SOD80 ranges

2322 633 5..../8....

FEATURES

- The non-dimensioned details do not affect the performance of the device
- The SOD27 leads (tinned copper clad iron) are suitable for soldering
- The SOD80 envelope ends are tinned copper clad iron, and are suitable for surface mounting.

APPLICATIONS

- Temperature sensing and control
- Domestic appliances
- Industrial uses
- Automotive.

DESCRIPTION

These thermistors have a negative temperature coefficient and are mounted in a glass envelope.

QUICK REFERENCE DATA

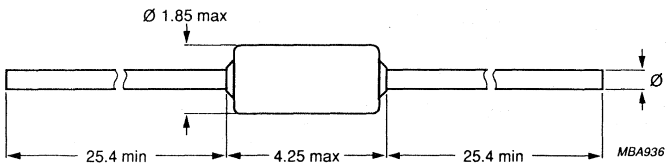
Resistance at 25 °C	10 kΩ to 30 kΩ
Standard selection tolerance on R_{25}	±5 and ±10 %
Rated dissipation	100 mW
Dissipation factor (for information only)	2.5 mW/K
Thermal time constant (for information only)	6 s
Response time (for information only)	0.9 s
Rated temperature range at $P_{max.}$	0 to 55 °C
Weight 633 5.... 633 8....	 0.03 g 0.14 g
Climatic category 633 5.... 633 8....	 40/155/56 40/200/56

PACKAGING INFORMATION

CODE NUMBERS	PACKAGING	
	S.P.Q.	P.Q.
2322 633 5....	1000	12000
2322 633 8....	1000	12000

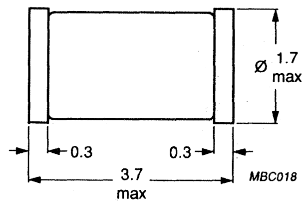
NTC thermistor, SOD27 and SOD80 ranges

2322 633 5..../8....



Dimensions in mm.

Fig.1 Outline for 2322 633 8.... (SOD27).



Dimensions in mm.

Fig.2 Outline for 2322 633 5.... (SOD80).

CHARACTERISTICS

PARAMETER	CONDITIONS
$B_{25/85}$ values	see Table 1
Tolerance on B value	see Table 1
Ratio R_T/R_{25}	see Table 2
Deviation in resistance value due to B tolerance	see Table 2
Temperature coefficient	see Table 2

ELECTRICAL DATA

Table 1

CODE NUMBER 2322 633 5..../8....		R_{25} (kΩ)	$B_{25/85}$	
R_{25} ±5%	R_{25} ±10%	K		
3103	2103	10	3977	±1.3%
3203	2203	20	3977	±1.3%
3303	2303	30	3977	±1.3%

NTC thermistor, SOD27 and SOD80 ranges

2322 633 5..../8....

RESISTANCE VALUES AT INTERMEDIATE TEMPERATURES

Table 2

TEMP. (Note 1) (°C)	RATIO R_T/R_{25}	DEVIATION IN R DUE TO B TOLERANCE (%)	TEMP. COEFF. (%/K)	RESISTANCE VALUE FOR 2322 633 5..../8.... (Note 2) (kΩ)		
				.103	.203	.303
−40	33.06	4.65	6.59	330.6	661.2	991.8
−35	23.9	4.21	6.37	239.0	478.1	717.1
−30	17.47	3.79	6.16	174.7	349.4	524.1
−25	12.9	3.38	5.96	129.0	258.0	387.0
−20	9.621	2.99	5.77	96.21	192.4	288.6
−15	7.242	2.61	5.59	72.42	144.8	217.3
−10	5.501	2.24	5.41	55.01	110.0	165.0
−5	4.214	1.89	5.24	42.14	84.28	126.4
0	3.255	1.55	5.08	32.55	65.09	97.64
5	2.534	1.22	4.93	25.34	50.67	76.01
10	1.987	0.9	4.78	19.87	39.74	59.62
15	1.570	0.59	4.64	15.70	31.40	47.1
20	1.249	0.29	4.51	12.49	24.98	37.46
25	1.0	0.0	4.38	10.0	20.0	30.0
30	0.8059	0.28	4.25	8.059	16.12	24.18
35	0.6534	0.55	4.13	6.534	13.07	19.6
40	0.5329	0.82	4.02	5.329	10.66	15.99
45	0.4371	1.08	3.91	4.371	8.742	13.11
50	0.3604	1.34	3.8	3.604	7.209	10.81
55	0.2988	1.58	3.7	2.988	5.976	8.963
60	0.2489	1.82	3.6	2.489	4.978	7.467
65	0.2084	2.06	3.51	2.084	4.168	6.251
70	0.1753	2.29	3.42	1.753	3.505	5.258
75	0.1481	2.51	3.33	1.481	2.961	4.442
80	0.1256	2.73	3.24	1.256	2.512	3.769
85	0.107	2.95	3.16	1.07	2.141	3.211
90	0.09156	3.16	3.08	0.9156	1.831	2.747
95	0.07862	3.36	3.01	0.7862	1.572	2.359
100	0.06777	3.56	2.93	0.6777	1.355	2.033
105	0.05863	3.76	2.86	0.5863	1.173	1.759
110	0.05089	3.95	2.79	0.5089	1.018	1.527
115	0.04433	4.13	2.73	0.4433	0.8865	1.330
120	0.03873	4.32	2.66	0.3873	0.7747	1.162
125	0.03395	4.5	2.6	0.3395	0.6791	1.019

TEMP. (Note 1) (°C)	RATIO R_T/R_{25}	DEVIATION IN R DUE TO B TOLERANCE (%)	TEMP. COEFF. (%/K)	RESISTANCE VALUE FOR 2322 633 5..../8.... (Note 2) (kΩ)		
				.103	.203	.303
130	0.02985	4.67	2.54	0.2985	0.5971	0.8956
135	0.02633	4.84	2.49	0.2633	0.5265	0.7898
140	0.02328	5.01	2.43	0.2328	0.4656	0.6984
145	0.02065	5.17	2.38	0.2065	0.4129	0.6194
150	0.01836	5.33	2.32	0.1836	0.3671	0.5507
155	0.01636	5.49	2.27	0.1636	0.3273	0.4909
160	0.01455	5.65	2.23	0.1455	0.2910	0.4365
165	0.01303	5.80	2.18	0.1303	0.2606	0.3909
170	0.01169	5.95	2.14	0.1169	0.2339	0.3508
175	0.01052	6.1	2.09	0.1052	0.2104	0.3156
180	0.00948	6.24	2.05	0.09484	0.1897	0.2845
185	0.00857	6.38	2.01	0.08569	0.1714	0.2571
190	0.00776	6.52	1.97	0.07757	0.1551	0.2327
195	0.00704	6.66	1.93	0.07037	0.1407	0.2111
200	0.00640	6.79	1.89	0.06396	0.1279	0.1919

Notes

1. The values belonging to temperatures higher than 155 °C refer to 2322 633 8.... only.
2. Replace the dot in the code numbers by one of the following, depending on the tolerance required for R_{25} value: 3 for a tolerance of ±5% and 2 for a tolerance of ±10%.

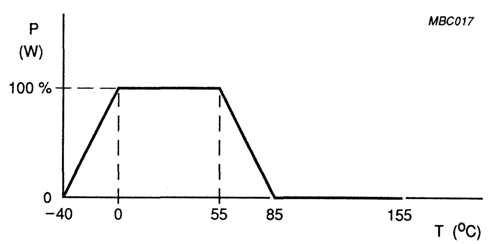


Fig.3 Derating curve for 2322 633 5....

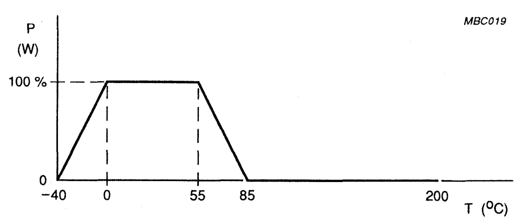


Fig.4 Derating curve for 2322 633 8....

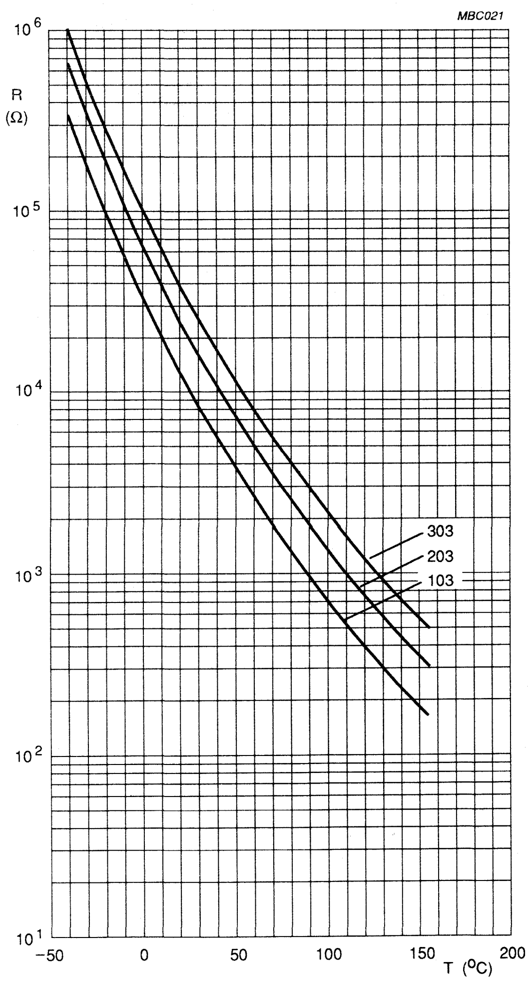


Fig.5 Typical resistance/temperature characteristic for 2322 633 5....

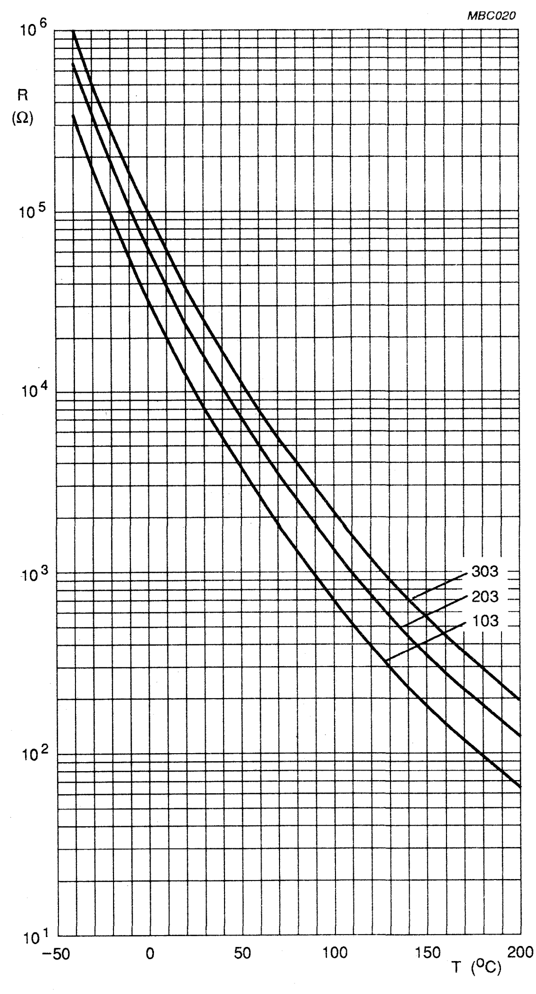


Fig.6 Typical resistance/temperature characteristic for 2322 633 8....

NTC THERMISTORS

glass encapsulated miniature bead

Features

- Small diameter
- Quick response to changes in temperature
- High stability over long time periods
- High temperature operation
- Resistant to aggressive environments
- High degree of isolation between tip and environment

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value at 25 °C	1 kΩ to 1 MΩ
Tolerance on R_{25} value	± 5%, ± 10%
$B_{25/85}$ value	2075 to 4100 K
Tolerance on $B_{25/85}$ value	± 5%
Response time	1 s approx.
Thermal time constant	10 s approx.
Dielectric withstanding voltage (RMS)	1500 V min.
Operating temperature range	
at zero power	−55 to 200 °C, or −55 to 300 °C
at maximum power	0 to 55 °C

APPLICATION

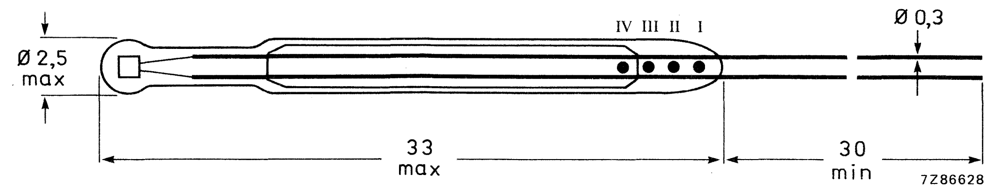
Temperature measurement and control up to 300 °C in 'aggressive' environments. Also level sensing.

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned dumet (CuNiFe) wires.

MECHANICAL DATA

Outlines



Maximum bow in the centre of the glass envelope is 1 mm.

Fig.1 Component outline.

Marking
Four colour dots on the glass envelope, see Table 1 for colour code.

Mass
0.27 g approximately.

Mounting
In any position by soldering.

Soldering

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

Inflammability
Uninflammable.

Impact

Free fall	100 mm

Robustness of terminations

Tensile strength	2.5 N
Bending	1.25 N
Resistance to solvents	in accordance with IEC 68-2-45, resistant to R113 at T_{amb}.

PACKAGING

100 thermistors in a cardboard boax.

ELECTRICAL DATA

Unless otherwise specified, measured in accordance with IEC publication 539.

Maximum dissipation at + 55 °C	100 mW
Dissipation factor	1.2 mW/K approx.
Thermal time constant	10 s approx.
Response time (see note 1)	1 s approx.
Operating temperature range (see Fig.2 and Table 1)	
at zero power	−55 to + 200 °C, or + 300 °C
at maximum power	0 to + 55 °C
Dielectric withstanding voltage (RMS) between terminals and glass envelope	min. 1500 V
Insulation resistance between terminals and glass envelope at 100 V (DC)	min. 100 MΩ

Note

1. Response time in silicone oil MS 200/50. The response time in silicone oil is the time necessary to change of 63.2% of the total difference between the initial and the final body temperature, when subjected to a step function change in ambient temperature. Step change: initial temperature: air at 25 °C; final temperature: oil (MS 200/50) at 85 °C.

Table 1 Catalogue number 2322 626 1 ....

suffix of the catalogue number		R_{25}	$B_{25/85}$-value ± 5%	temperature coefficient at 25 °C	colour code*		
tol. ± 5%	tol. ± 10%	kΩ	K	%/K	I	II	III
3102	2102	1	2075	−2.3	brown	black	red
3222	2222	2.2	2285	−2.6	red	red	red
3472	2472	4.7	2485	−2.8	yellow	violet	red
3103	2103	10	3750	−4.2	brown	black	orange
3223	2223	22	3560	−4.0	red	red	orange
3473	2473	47	3750	−4.2	yellow	violet	orange
3104	2104	100	3900	−4.4	brown	black	yellow
3224	2224	220	3860	−4.3	red	red	yellow
3474	2474	470	3950	−4.5	yellow	violet	yellow
3105	2105	1000	4100	−4.6	brown	black	green

* Thermistors with 5% tolerance have a gold dot IV; 10% tolerance is identified by a silver dot IV (Fig.1).

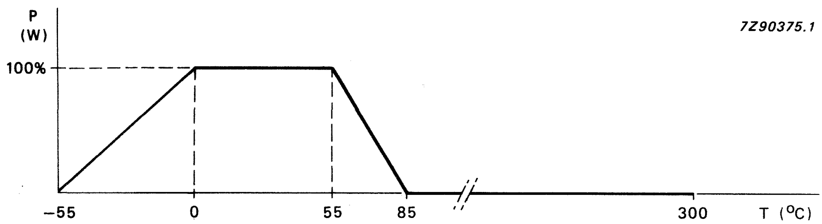


Fig.2 Derating curve.

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.1%
	68-2-1	endurance	−40 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen	endurance	100 mW, 55 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.5%
	68-2-2	dry heat, steady state	125 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	ΔR/R < 3%	ΔR/R = −0.2%
C2 4.14	68-2-14	rapid change of temperature	−40 °C to 125 °C, 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%

* Typical drift based on sample products with $B_{25/85}$ value of 3797 K.

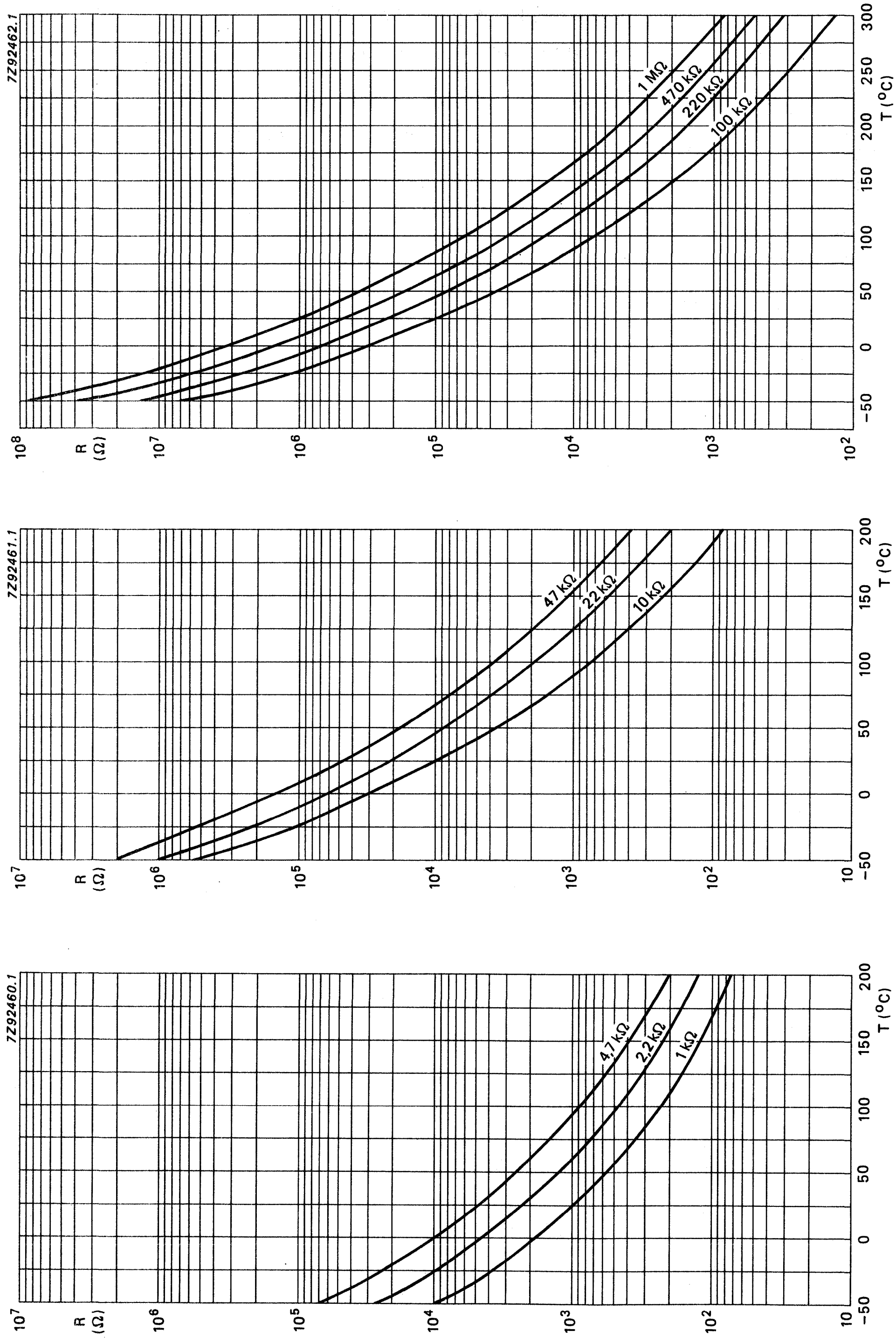


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTORS

glass encapsulated miniature bead

Features

- Small diameter
- Quick response to changes in temperature
- Very high long term stability
- High temperature uses
- Resistant to aggressive environments

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value at 25 °C	1 kΩ to 1 MΩ
Tolerance on R_{25} value	± 5%, ± 10%
Tolerance on $B_{25/85}$ value	± 5%
Thermal time constant	7.5 s approx.
Response time	0.85 s approx.
Operating temperature range	
at zero power	−55 to 200 °C, or −55 to 300 °C
at maximum power	0 to 55 °C

APPLICATION

Temperature measurement and control up to 300 °C. Also level sensing.

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned dumet (CuNiFe) wires.

MECHANICAL DATA

Outlines

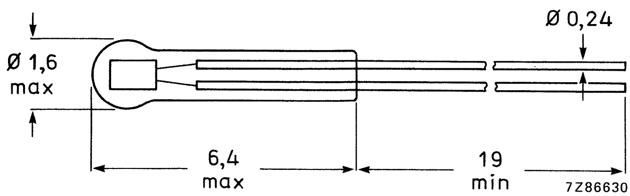


Fig.1 Component outline.

Marking

None

Mass

33 mg approximately

Mounting

In any position by soldering

Soldering

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

Inflammability

Uninflammable

Impact

Free fall 100 mm

Robustness of terminations

Tensile strength 1.0 N

PACKAGING

100 thermistors in a cardboard box

ELECTRICAL DATA

Unless otherwise specified, measured according to IEC publication 539

Table 1 Catalogue number 2322 626 2....

suffix of the catalogue number		R_{25}	$B_{25/85}$-value ± 5%	T_{max}	temperature coefficient at 25 °C
tol. ± 5%	tol. ± 10%	kΩ	K	°C	%/K
3102	2102	1	2075	200	–2.3
3222	2222	2,2	2285	200	–2.6
3472	2472	4,7	2485	200	–2.8
3103	2103	10	3750	200	–4.2
3223	2223	22	3560	200	–4.0
3473	2473	47	3750	200	–4.2
3104	2104	100	3900	300	–4.4
3224	2224	220	3860	300	–4.3
3474	2474	470	3950	300	–4.5
3105	2105	1000	4100	300	–4.6

Maximum dissipation at + 55 °C — 100 mW

Dissipation factor — 0.8 mW/K approx.

Thermal time constant — 7.5 s approx.

Response time (see note) — 0.85 s approx.

Operating temperature range (Fig. 2 and Table 1)
- at zero power — –55 to + 200 °C, or + 300 °C
- at maximum power — 0 to + 55 °C

Dielectric withstanding voltage (RMS)
- between terminals and glass envelope — min. 100 V

Insulation resistance between terminals
- and glass envelope at 10 V (DC) — min. 10 MΩ

Note: Response time in silicone oil MS 200/50. The response time in silicone oil is the time necessary to change of 63.2 % of the total difference between the initial and the final body temperature, when subjected to a step function change in ambient temperature. Step change: initial temperature: air at 25 °C; final temperature: oil (MS 200/50) at 85 °C.

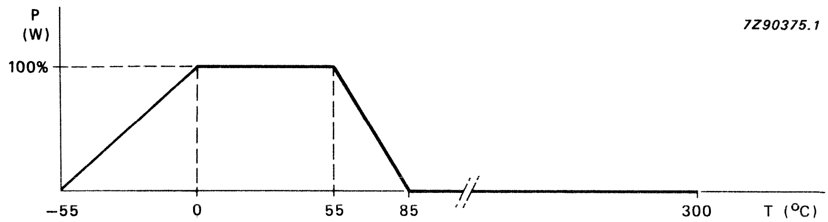
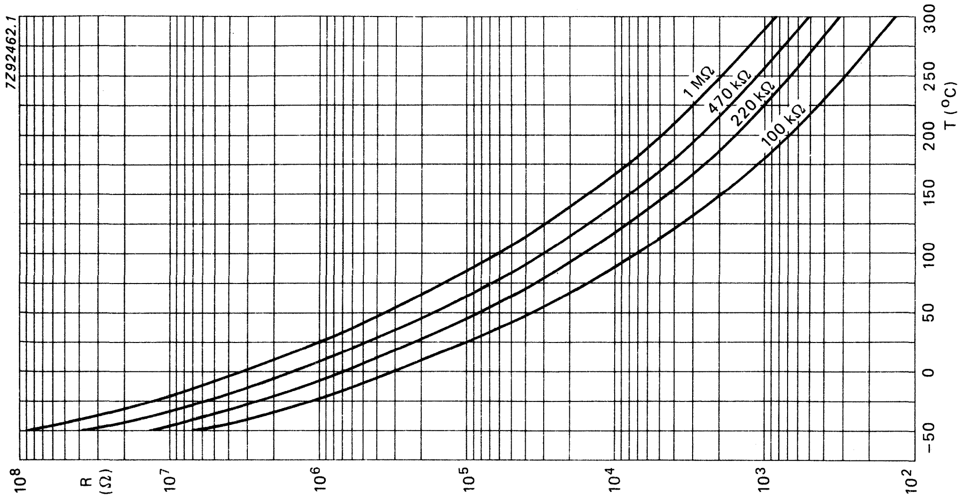


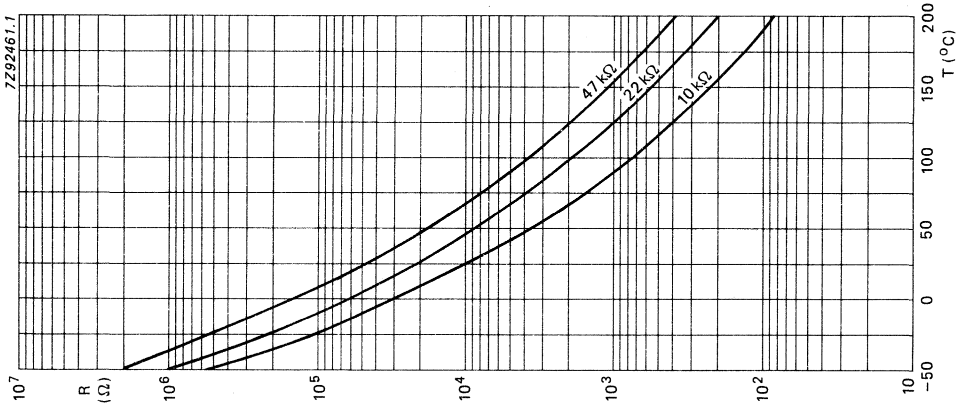
Fig.2 Derating curve.

Table 2 Stability data

CECC	IEC	test	procedure	drift (requirement)	drift (typical)*
D3 4.20.1		endurance	25 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.1%
	68-2-1	endurance	−40 °C, 1000 hours	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen	endurance	100 mW, 55 °C 1000 hours	ΔR/R < 3%	ΔR/R = 0.5%
	68-2-2	dry heat, steady state	125 °C, 1000 hours	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	68-2-3	damp heat, steady state	56 days at 40 °C, 90-95% RH	ΔR/R < 3%	ΔR/R = −0.2%
C2 4.14	68-2-14	rapid change of temperature	−40 °C to 125 °C 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%

* Typical drift based on sample products with $B_{25/75}$ value of 3965 K.





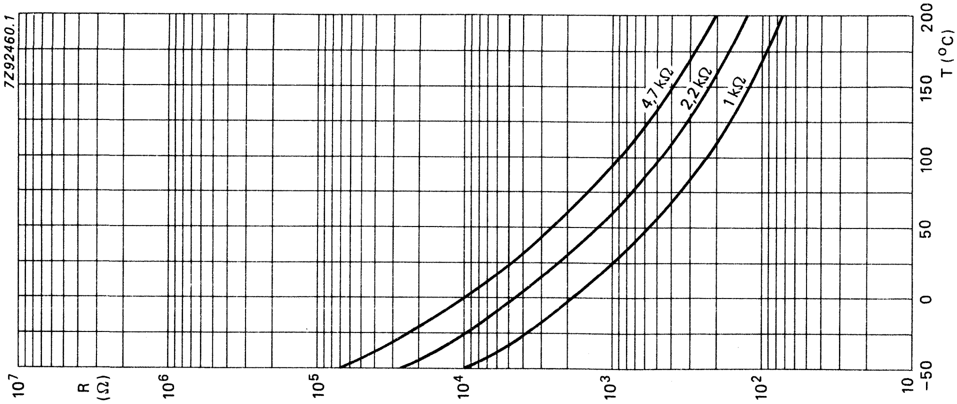


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTOR
naked disc range

Features

- Low price
- Proven quality

TEMPERATURE SENSING AND CONTROL

QUICK REFERENCE DATA

Resistance value	see Table 1
$B_{25/85}$ value	see Table 1
Temperature coefficient	see Table 1
Dissipation factor	see Table 1

APPLICATION

Temperature sensing of coolant in motor cars. The thermistors are normally used under power on conditions (power causing self-heating of the NTC).

DESCRIPTION

Disc thermistors (without leads) having a negative temperature coefficient.

MECHANICAL DATA

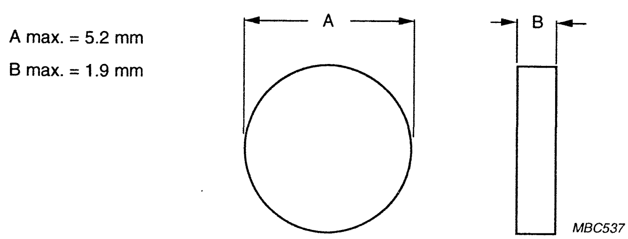


Fig.1 Component outline; see Table 1 for dimensions.

RANGE INFORMATION

Climatic category	25/125/56
Packaging	1000 pieces

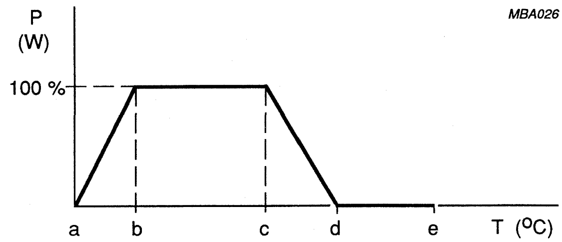


Fig.2 Derating curve; see Table 1 for curve values.

Table 1 Type information 2322 611 900 . .

Resistance at (Ω)	90027	90028	90035	90039	90048
−20 °C					
0 °C					
20 °C					
25 °C	930 ± 10%		2577 (*)	930 (*)	1042
40 °C		304.5 ± 8.8%			
54.5 °C			754.5 ± 5%		
60 °C				268 ± 9.5%	299 ± 9.5%
90 °C					
100 °C	84.5 ± 7%	39.6 ± 5%		84.5 ± 7%	95 ± 7%
110 °C			121.6 ± 3%		
120 °C		23 ± 8%			
140 °C					
$B_{25/85}$ (K)	3500 (*)	3950 (*)	4093 (*)	3500 (*)	3500 (*)
Temperature coefficient (approx.) (%/K)	−4.05	−4.44	−4.6	−4	−4
Derating curve max. dissipation (W)	0.25	0.25	0.5	0.25	0.25
a (°C)	−25	−30	−55	−25	−25
b (°C)	−25	−25	−25	−25	−25
c (°C)	55	55	55	55	55
d (°C)	85	85	85	85	85
e (°C)	125	155	125	125	125
Weight (approx.) (grams)	0.15	0.14	0.1	0.1	0.1
Outline A (mm)	4.7 ± 0.2	4.7 ± 0.2	5.2 − 0.3	4.4 ± 0.3	4.4 ± 0.3
Outline B (mm)	1.4 ± 0.6	1.7 to 2.2	1.14 to 1.9	1.3 ± 0.3	1.4 ± 0.3
Dissipation factor (approx.) (mW/K)	4.8	6.6			
Marking	orange stripe	none	yellow stripe	none	none

* for information only.

GENERAL

Surge currents occurring when electrical appliances are switched on can cause serious problems. Circuit components can easily be damaged and high starting torques can quickly wear out belts and moving parts. However, surges can be prevented using just one small component, the negative temperature coefficient (NTC) surge current limiter.

Fig.1 shows a typical mains input circuit with an NTC surge current limiter in the input line. At switch-on, the cold resistance of the surge current limiter is high enough to limit the surge current to a safe level but after a few milliseconds, during which time the surge current has been suppressed, the surge current limiter has heated up and its resistance has fallen to a value that allows normal operation of the equipment (Fig.2). A period of 30 to 60 seconds must be allowed between switching-off and switching-on again allowing it to cool down, otherwise only partial transient protection may be provided.

The low-power 610 series are a low-cost solution to general-purpose surge current limiting. They are lacquered and colour-coded for identification.

The new higher-power 653 to 656 series offer very high maximum withstanding current. The body is lacquer-insulated and marked. They are pin-compatible with devices from other manufacturers.

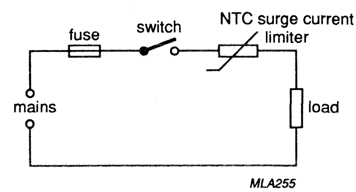


Fig.1 Typical mains input circuit with an NTC surge current limiter in the input line.

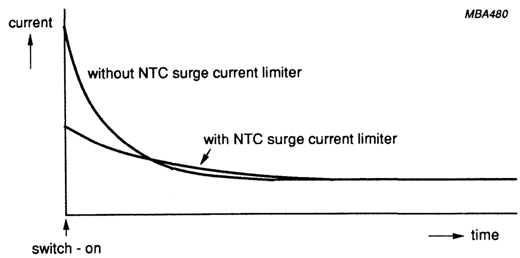


Fig.2 Current/time characteristic showing the suppression effect of the NTC surge current limiter.

APPLICATIONS

Our surge current limiters are ideal for protecting switch contacts and are used for:

- Power supplies, AC and DC motors, transformers, power-factor capacitors, relays, filament lamps, projector lamps, street lighting , personal computers, video monitors, chain-saws, power drills, vacuum cleaners, solariums, microwave cookers, and numerous other applications
- Limiting surge currents to national standard levels of mains pollution
- Protecting semiconductor devices from surges
- Preventing fuse-blowing at switch on
- Preventing excessive wearout of belts and moving parts by reducing starting torque
- Increasing lifetime of projector and other lamps, particularly where long life is important and access is difficult (e.g. swimming pools, street lamps).

APPLICATION EXAMPLE

Fig.3 shows how our higher-power (653-656) NTC surge current limiter is used in the input line to protect a power supply.

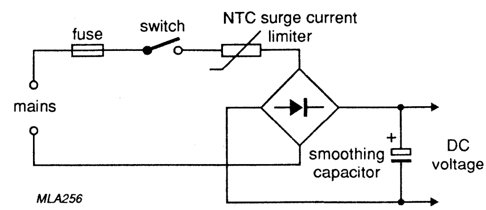


Fig.3 Typical mains input circuit with a higher-power (653-656) NTC surge current limiter.

NTC THERMISTORS

low power 1 Watt range

Features

- Cost effective
- Thermistor for surge current limiting under low power dissipation conditions

SURGE CURRENT LIMITING

QUICK REFERENCE DATA

Resistance value at +25 °C	4 to 33 Ω
$B_{25/85}$-value	2800 to 3250 K
Maximum dissipation	1 W
Dissipation factor	10 mW/K
Thermal time constant	60 s approx.
Operating temperature range	
at zero power	−25 to +125 °C
at maximum power	0 to +55 °C

DESCRIPTION

Disc thermistor with negative temperature coefficient with two tinned copper wires. It is not lacquered, not insulated and has a colour code.

MECHANICAL DATA

Outlines

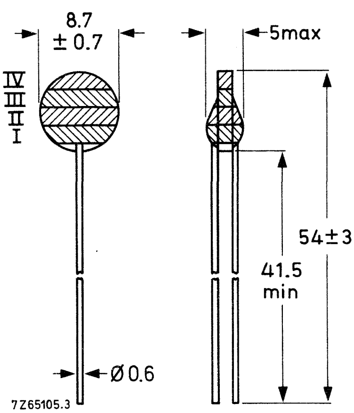


Fig.1 Component outline.

Marking

The thermistors are marked with three colour bands showing their resistance value (R_{25}) in code as indicated in Table 1. Thermistors with a tolerance on R_{25} of 10% have a fourth band coloured silver.

Mass

1.0 to 1.3 grams

Mounting

In any position by soldering.

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

PACKAGING

250 thermistors in a cardboard box.

ELECTRICAL DATA

Maximum dissipation *	1 W
Dissipation factor *	10 mW/K approx.
Thermal time constant *	60 s approx.
Heat capacity *	0.6 J/K approx.
Operating temperature	
at zero power	−25 to + 125 °C
at maximum power	0 to + 55 °C

* Measurements made in still air, between two phosphor-bronze wires (ϕ 1.3 mm).

Table 1 Catalogue numbers 2322 610 1.....

suffix of catalogue number		R_{25}	$B_{25/85}$ ± 5%	temperature coefficient	colour code		
tol. ± 10%	tol. ± 20%	Ω	K	%/K	I	II	III
2408	1408	4	2800	−3.15	yellow	black	gold
2808	1808	8	2900	−3.25	grey	black	gold
2159	1159	15	3125	−3.40	brown	green	black
2339	1339	33	3250	−3.65	orange	orange	black

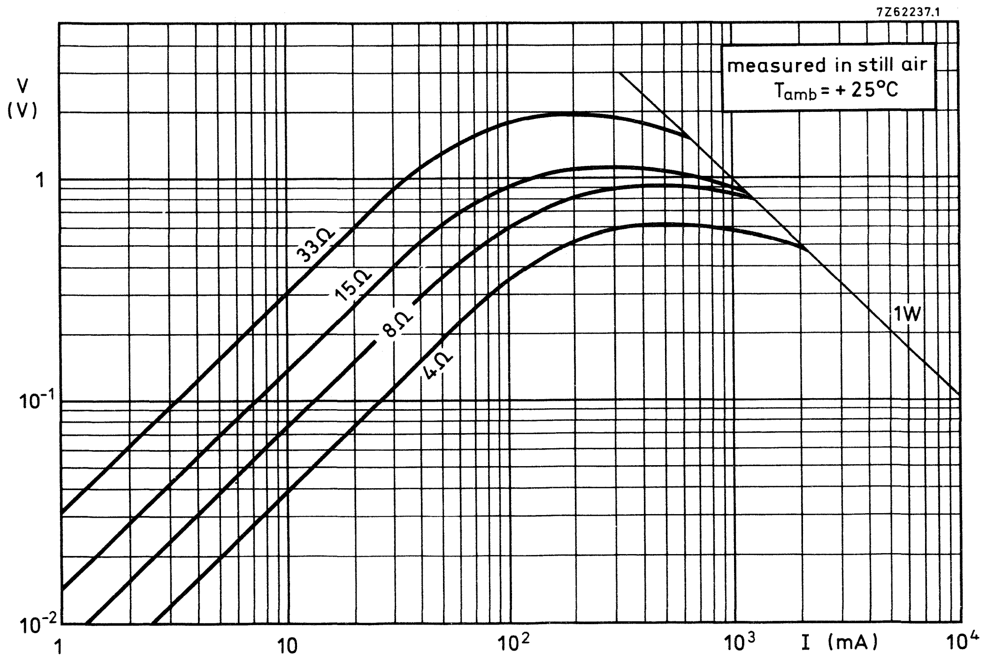


Fig.2 Typical voltage/current characteristics.

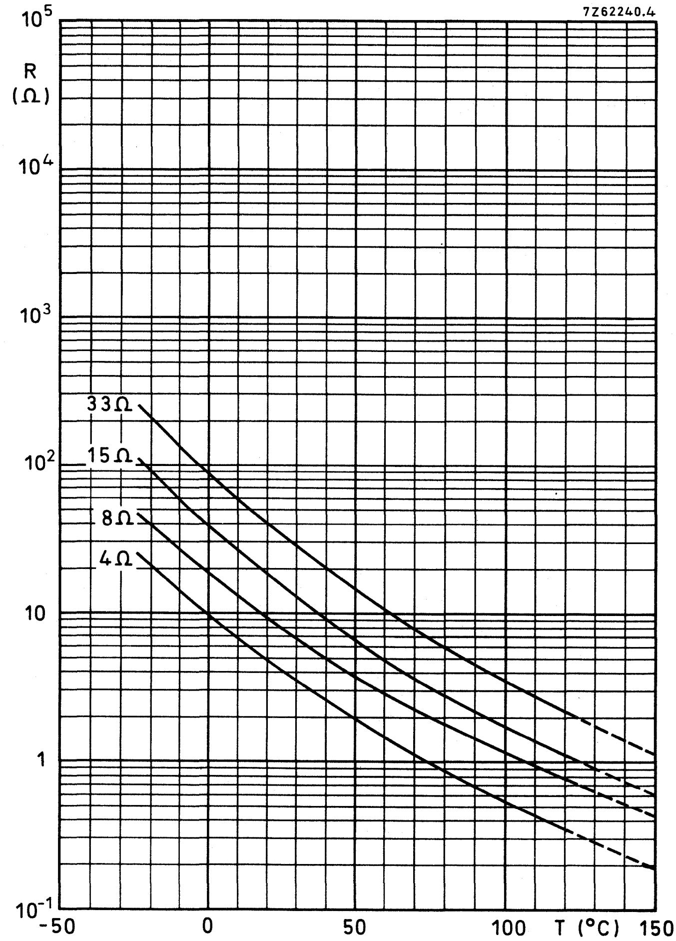


Fig.3 Typical resistance/temperature characteristics.

NTC THERMISTORS

higher power range

SURGE CURRENT LIMITING

Features

- large variety of products
- high cold resistance - negligible resistance in continuous current condition

QUICK REFERENCE DATA

Resistance value at 25 °C	2.5 Ω to 20 Ω
$B_{25/85}$ value	2950 to 3600 K
Maximum current (RMS)	2.2 to 15 A
Operating temperature range	
at zero power	−25 to 155 °C
at maximum current	0 to 55 °C

APPLICATION

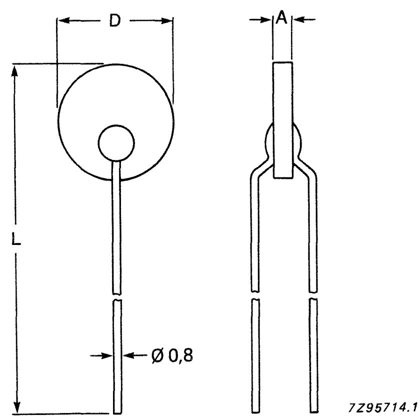
For limiting inrush current surges, preventing the blowing of fuses, provision of soft start of motors and switch protection.

DESCRIPTION

The thermistor has a negative temperature coefficient. It consists of a disc with two tinned copper wires. The thermistor body may be lacquered, depending on type (see Fig.1).

MECHANICAL DATA

Outlines



Non-lacquered types

2322 644 90005 2322 644 90013
2322 644 90008 2322 644 90025

For dimensions A and D, refer to Table 1.

Fig.1 Outline of components.

MECHANICAL DATA (continued)

Marking: none

Mass: see Table 1

Mounting: in any position by soldering

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

Impact

Free fall	1 m

Inflammability

The thermistors are non-flammable, in accordance with IEC Publication 695-2-2 (1980, needle flame)

PACKING

The thermistors are packed in cardboard boxes; the smallest packing quantities per type are shown in Table 1.

ELECTRICAL DATA

Unless otherwise specified, all measurements are in accordance with IEC Publication 539.

Operating temperature range

at zero power	–25 to 155 °C
at maximum power	0 to 55 °C

Table 1 Electrical data

catalogue number 2322 644	R_{25} value ± 25% Ω	tolerance %	δ approx. mW/K	τ approx. s	I_{max} (RMS) A	R value at I_{max} approx. Ω	mass approx. grams	D_{max} mm	A mm	L mm	temp. coeff. %/K	$B_{25/85}$ value approx. K	smallest packing quantity
90005	⩾ 15	–	17	148	2.2	⩽ 1		16	4 ± 1	59 ± 3	–3.75	3350	100
90008	20	25			5		7.5	23.8	4 ± 1	62 ± 3	–4	3600	25
90013	20	25			6		7.5	23.8	4 ± 1	62 ± 3	–3.9	3450	25
90025	20	25			5		7.5	23.8	3.5 ± 1	60 ± 2	–4	3600	25

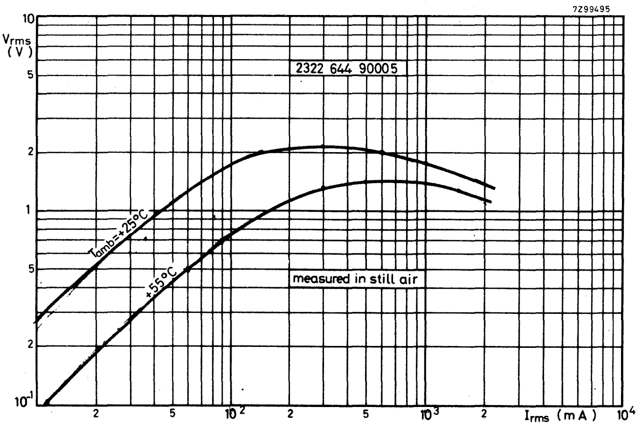


Fig.2 Typical voltage/current characteristics, type 90005; measured in still air at 25 °C.

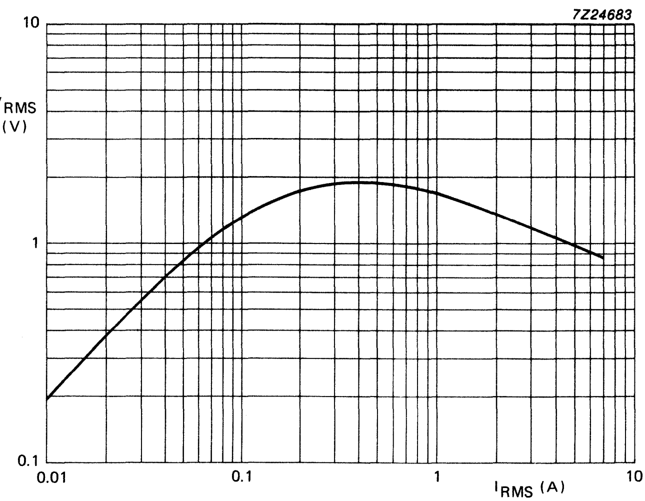


Fig.3 Typical voltage/current characteristics, type 90008; measured in still air at 25 °C.

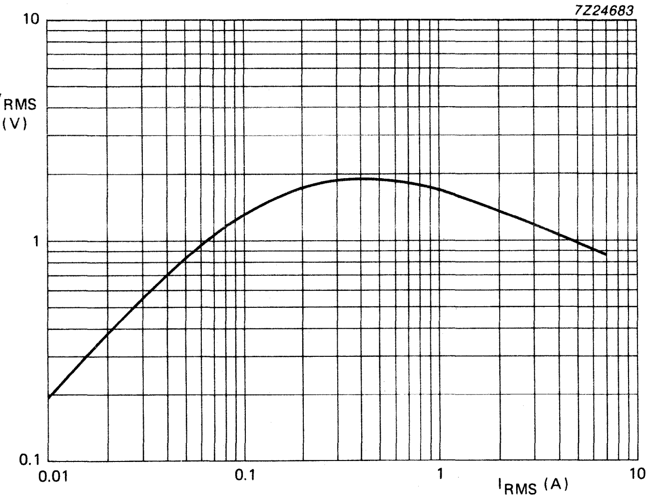


Fig.4 Typical voltage/current characteristics, type 90025; measured in still air at 25 °C.

NTC THERMISTOR

disc without leads

SURGE CURRENT LIMITING

Features

- high cold resistance - negligible resistance in continuous current condition.

QUICK REFERENCE DATA

Resistance value at +25 °C	5 Ω ± 20%
Resistance value at I_{RMS} = 2.2 A	max. 0.5 Ω
$B_{25/85}$-value	2975 K
Maximum current (RMS)	8 A
Operating temperature range	
at zero power	−25 to +155 °C
at maximum power	0 to +55 °C

APPLICATION

For limitation of surge current.

DESCRIPTION

Disc thermistor with negative temperature coefficient, provided with reinforced contacts.

MECHANICAL DATA

Outline drawing

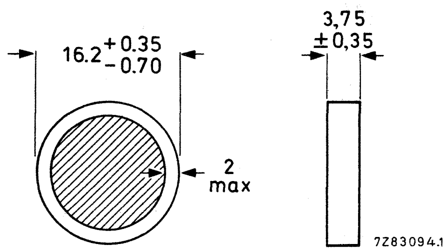


Fig. 1. Component outline.

Marking	red dot in the centre of both faces, see Fig.1.
Mass	4.2 g approximately.
Mounting	In any position by clamping.
Impact	Free fall, 0.1 m.
Inflammability	Uninflammable

PACKAGING

10 preformed sheets of polystyrene containing 75 items in a cardboard box. Resistance value and catalogue number are printed on the box.

ELECTRICAL DATA

Unless otherwise specified, measured according to IEC publication 539.

Resistance value at +25 °C	5 Ω ± 20%
Resistance value at I_{RMS} = 2.2 A	max. 0.5 Ω
$B_{25/85}$-value	2975 K
Temperature coefficient	−3.35%/K
Maximum current (RMS)	8 A
Operating temperature range	
at zero power	−25 to +155 °C
at maximum power	0 to +55 °C

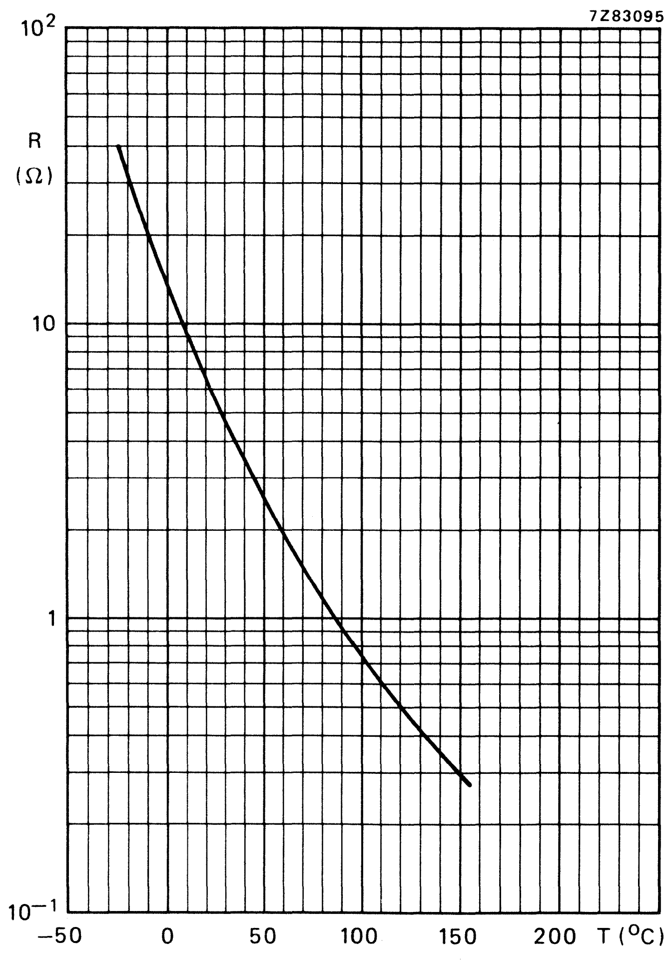


Fig. 2 Typical resistance/temperature characteristic.

NTC inrush surge current limiters 3e pitch — 2322 653/4/5/6

FEATURES

- Wide variety of resistance and steady state current
- High cold resistance and negligible during continuous operation.

APPLICATIONS

- Fuse blowing prevention
- Motor soft start provision
- Increase life span of incandescent lamps.

DESCRIPTION

These thermistors have a negative temperature coefficient and are specially dedicated to the protection of power supplies circuitry against exceedingly high current surge at turn-on. They consist of a specially formulated metal-oxide ceramic disc, with two tinned copper wires and are lacquered.

MOUNTING

In any position by soldering.

WARNING

Under steady state conditions, surge current limiters become hot. However, the long leads prevent overheating of printed board tracks. Fig.2 shows typical measured temperatures under various currents for type number 2322 654 61508.

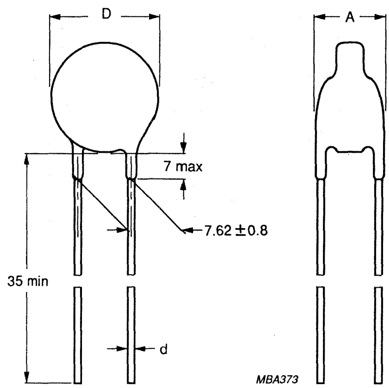
QUICK REFERENCE DATA

Resistance values at 25 °C	2 to 20 Ω
Tolerance on R_{25}	±20%
$B_{25/85}$	2950 to 3125 K
Maximum current (RMS)	2.5 to 15 A
Operating temperature range at zero power at maximum current	 −25 to 155 °C 0 to 55 °C
Climatic category	25/155/56

PACKAGING INFORMATION

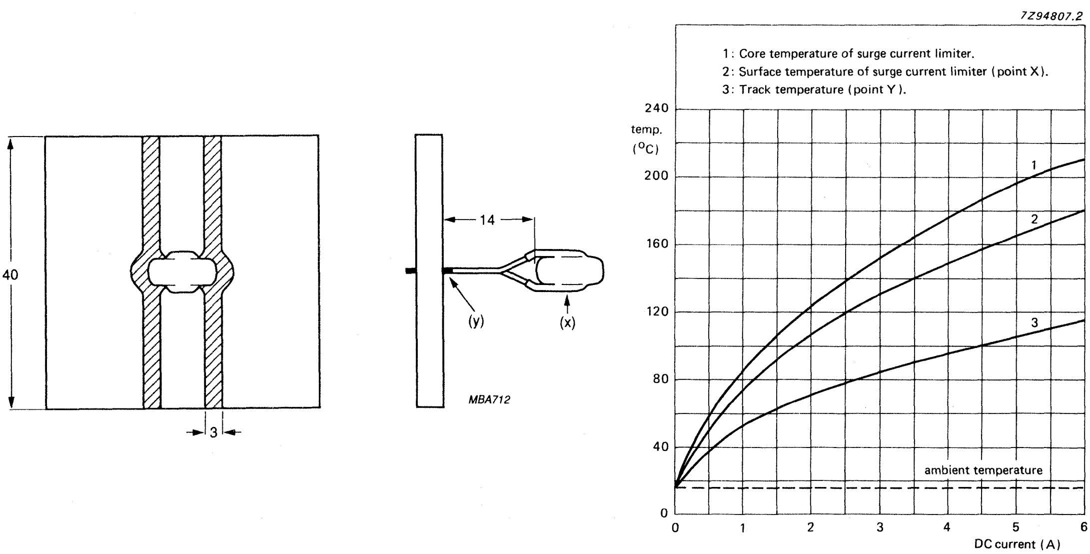
CODE NUMBERS	PACKAGING	
	S.P.Q.	P.Q.
2322 653 61508	100	2000
2322 653 61109	100	2000
2322 653 61159	100	2000
2322 653 61209	100	2000
2322 654 61258	100	2000
2322 654 61408	100	2000
2322 654 61508	100	2000
2322 654 61708	100	2000
2322 655 61508	50	1000
2322 655 61109	50	1000
2322 656 61208	25	500
2322 656 61258	25	500

NTC inrush surge current limiters 3e pitch 2322 653/4/5/6



Dimensions in mm.

Fig.1 Component outline.



Mounting method.
Dimensions in mm.

Fig.2 Core temperature as a function of DC current.

NTC inrush surge current limiters 3e pitch 2322 653/4/5/6

MECHANICAL DATA

Table 1

CODE NUMBER	D MAX. (mm)	A MAX. (mm)	d (mm)	P ±1 (mm)	APPROX. WEIGHT (g)
2322 653 61508	11.5	8	0.8	7.8	2.0
2322 653 61109	11.5	8	0.8	7.8	2.2
2322 653 61159	11.5	8	0.8	7.8	2.0
2322 653 61209	11.5	8	0.8	7.8	2.5
2322 654 61258	14	8	1	8	2.3
2322 654 61408	14	8	1	8	2.8
2322 654 61508	14	8	1	8	3.3
2322 654 61708	14	8	1	8	3.3
2322 655 61508	18	8	1	8	4.6
2322 655 61109	18	8	1	8	5.2
2322 656 61208	24.5	8	1	8	7.8
2322 656 61258	24.5	8	1	8	8.0

ELECTRICAL DATA

Table 2

CODE NUMBER	R_{25} ±20% (Ω)	$I_{MAX.}$ (RMS) (A)	R at $I_{MAX.}$ (Ω)	$B_{25/85}$ (note 1) (K)	TEMP. COEFF. (%/K)	DISS. FACTOR (nW/K)	THERMAL TIME (s)
2322 653 61508	5	4	0.17	3010	3.3	13.5	80
2322 653 61109	10	3	0.30	3010	3.3	13.5	90
2322 653 61159	15	2.5	0.42	3125	3.4	13.5	80
2322 653 61209	20	2	0.68	2950	3.25	13.5	95
2322 654 61258	2.5	8	0.06	3010	3.3	17	90
2322 654 61408	4	7	0.08	3010	3.3	17	95
2322 654 61508	5	6	0.10	3010	3.3	17	105
2322 654 61708	7	5	0.15	2950	3.25	17	105
2322 655 61508	5	8	0.08	3010	3.3	20	145
2322 655 61109	10	6	0.15	3100	3.4	20	155
2322 656 61208	2	15	0.03	3010	3.3	27	200
2322 656 61258	2.5	13	0.04	3010	3.3	27	230

Note

1. For information only

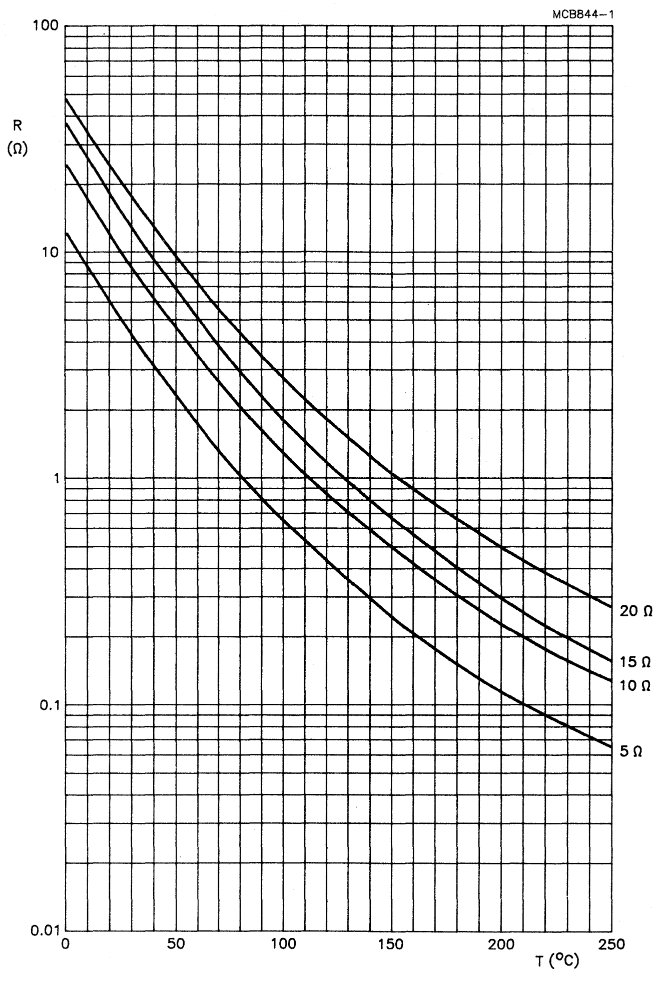


Fig.3 Typical resistance/temperature characteristic for type 653.

NTC inrush surge current limiters 3e pitch 2322 653/4/5/6

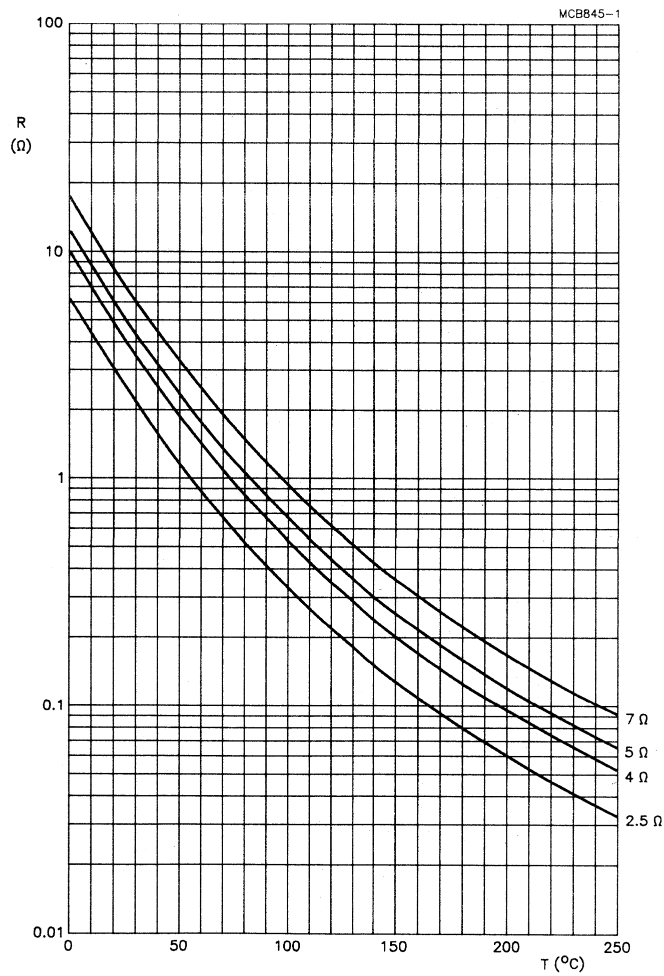


Fig.4 Typical resistance/temperature characteristic for type 654.

NTC inrush surge current limiters 3e pitch

2322 653/4/5/6

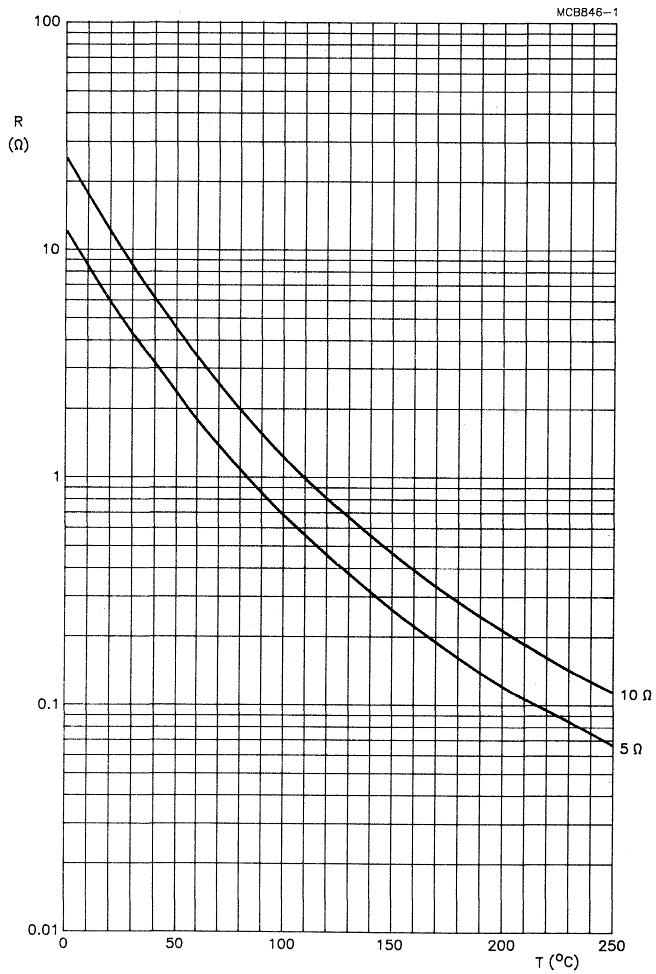


Fig.5 Typical resistance/temperature characteristic for type 655.

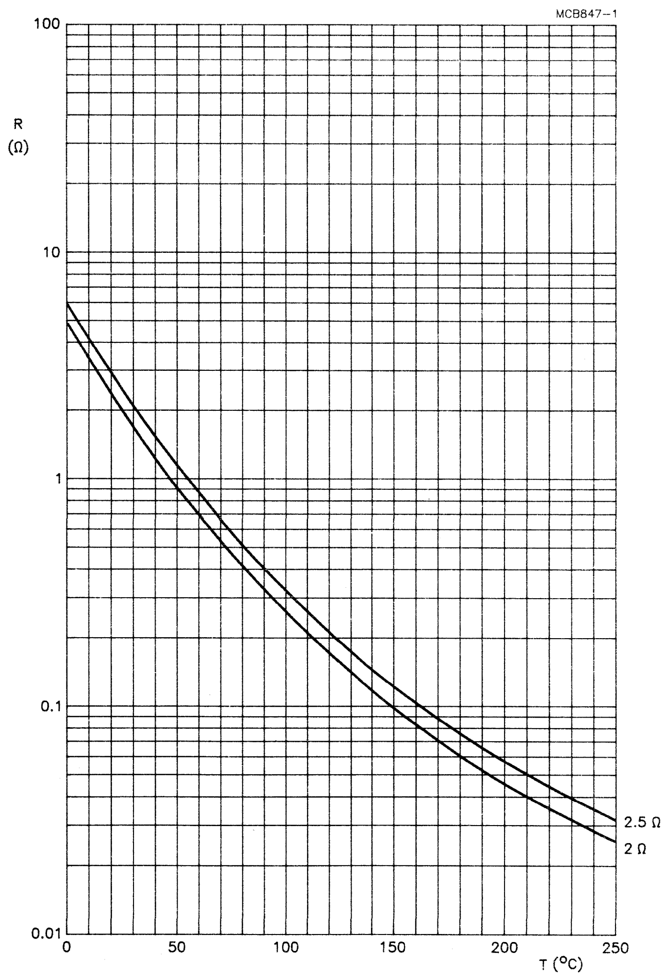


Fig.6 Typical resistance/temperature characteristic for type 656.

NTC inrush surge current limiters 3e pitch

2322 653/4/5/6

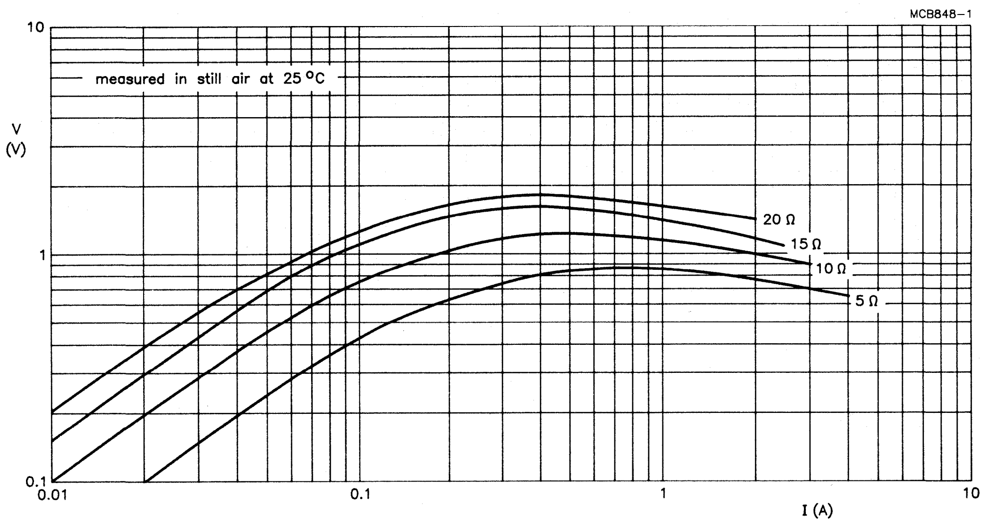


Fig.7 Typical voltage/current characteristic for type 653.

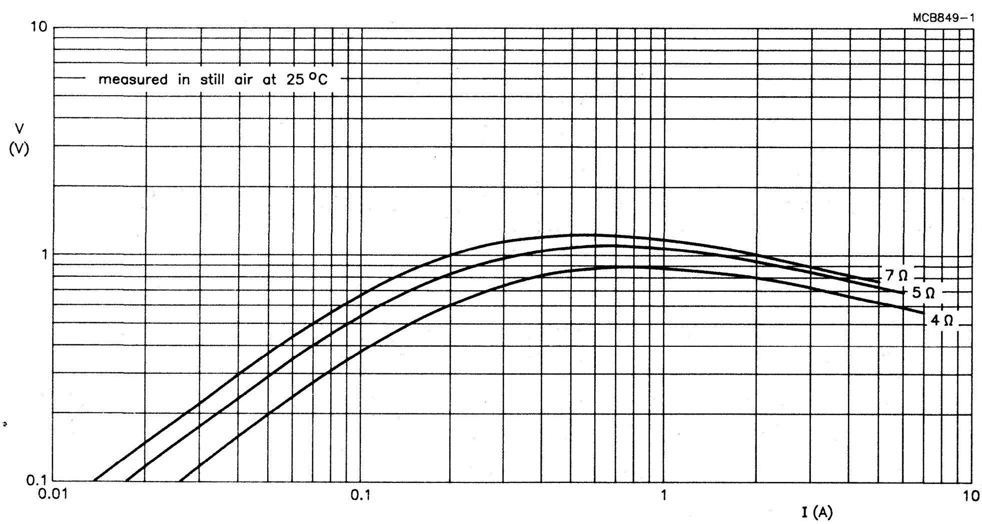


Fig.8 Typical voltage/current characteristic for type 654.

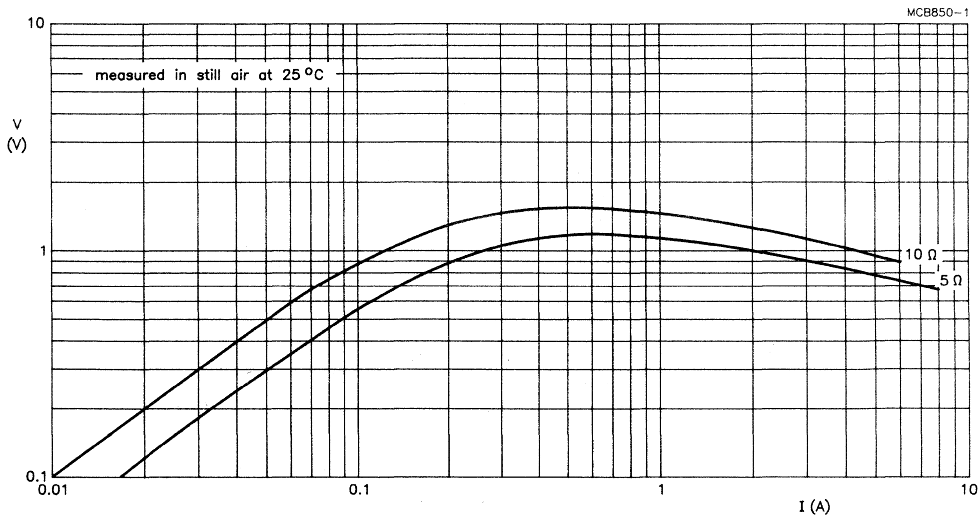


Fig.9 Typical voltage/current characteristic for type 655.

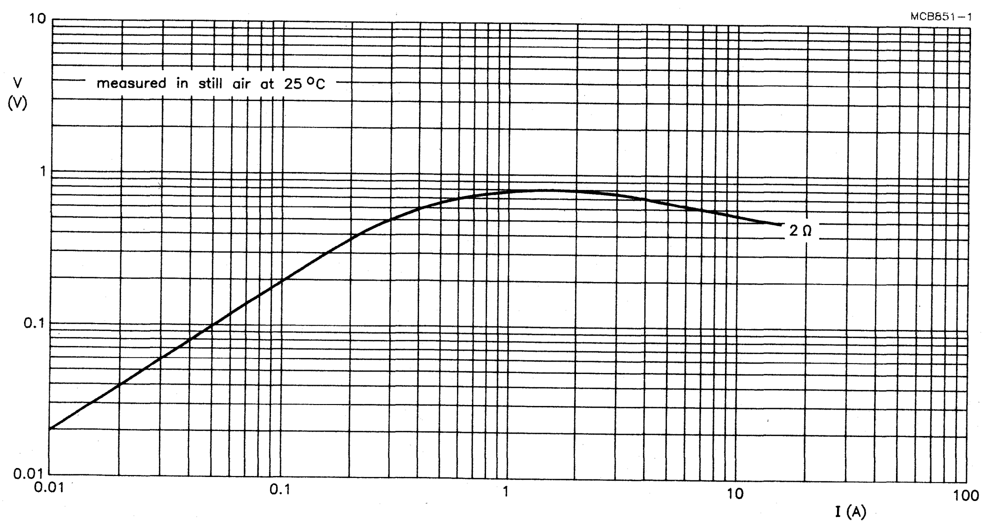


Fig.10 Typical voltage/current characteristic for type 656.

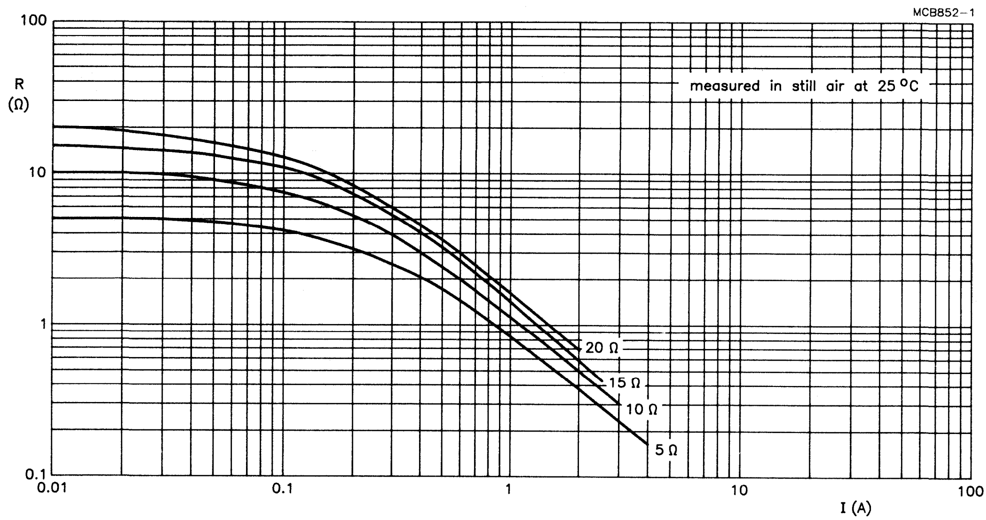


Fig.11 Typical resistance/current characteristic for type 653.

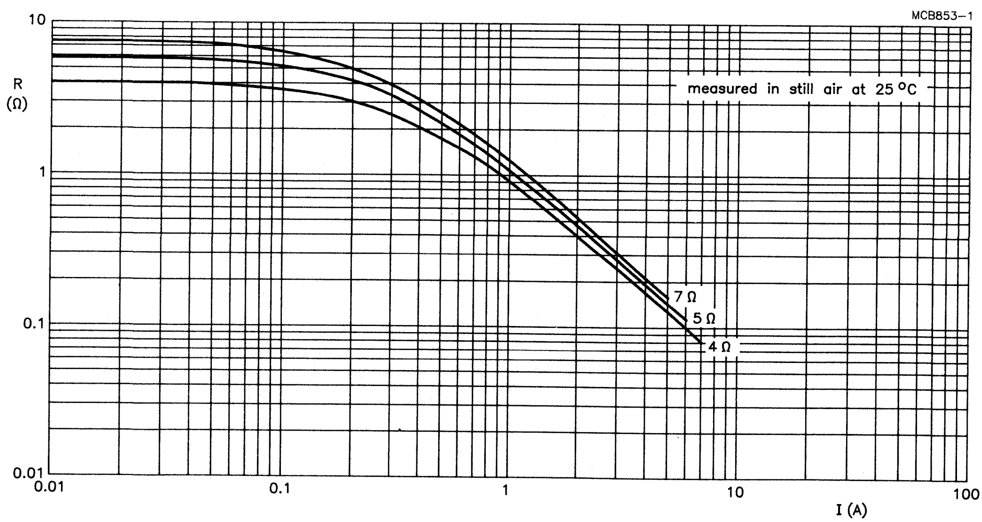


Fig.12 Typical resistance/current characteristic for type 654.

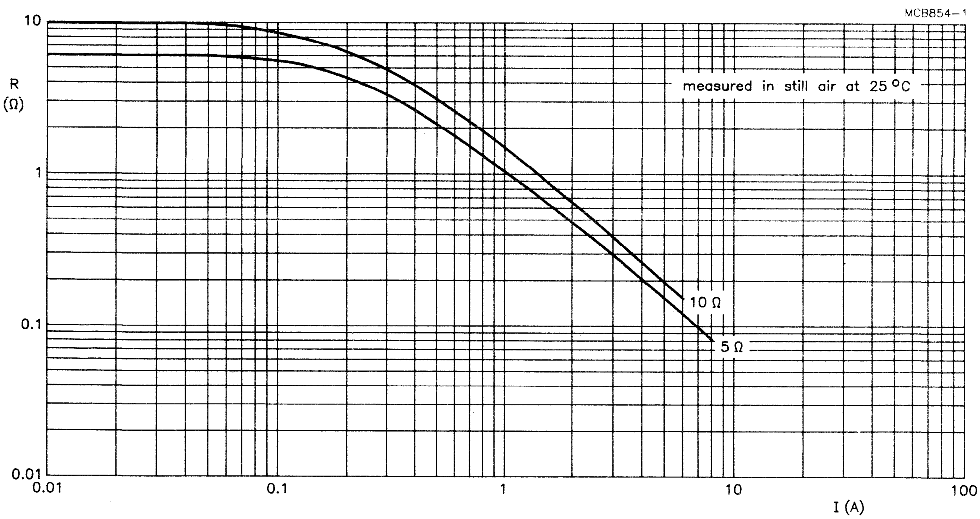


Fig.13 Typical resistance/current characteristic for type 655.

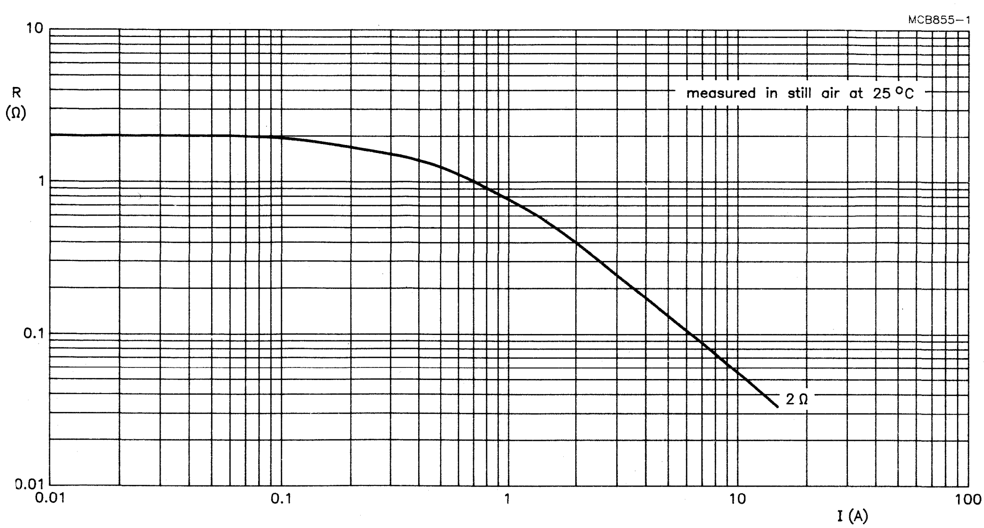


Fig.14 Typical resistance/current characteristic for type 656.

NTC Thermistors

Introduction to NTC temperature compensation

FEATURES

- Low-cost solution to stability problems in electronic circuitry
- Wide range of resistance values makes selection easy
- 5 and 10% tolerances on R_{25} available
- Maximum power dissipation 0.5 W
- Temperature range −25 to +125 °C.

APPLICATIONS

- Consumer applications
- Industrial electronics
- Electronic data processing.

DESCRIPTION

The output current of an electronic circuit such as the amplifier shown in Fig.1 can be compensated for the effect of temperature by connecting an NTC thermistor in the input bias chain.

MECHANICAL OPTIONS

- Taped on reel, 1e pitch (642 4....) and 2e pitch (642 3....).

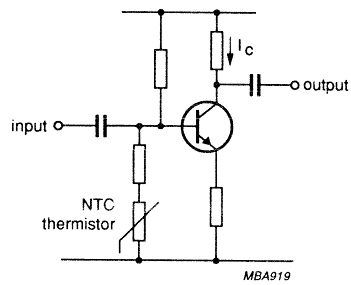


Fig.1 Temperature compensation of an amplifier circuit.

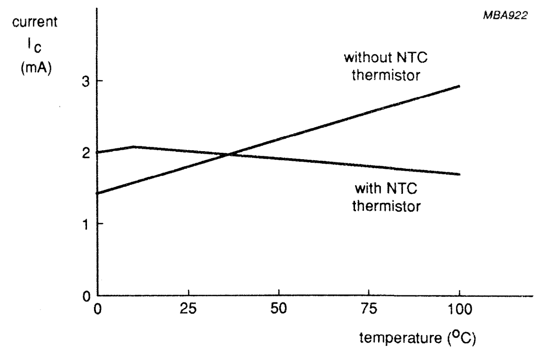


Fig.2 Typical current/temperature compensation characteristic.

NTC THERMISTORS
low resistance range

Features

- Cost effective range with low resistance values at 25 °C

TEMPERATURE SENSING AND CONTROL
TEMPERATURE COMPENSATION

QUICK REFERENCE DATA

Resistance value at + 25 °C	3.3 Ω to 1.5 kΩ
$B_{25/85}$ value	2675 to 3975 K
Maximum dissipation	0.5 W
Dissipation factor	8.5 mW/K
Thermal time constant	17 s approx.
Operating temperature range	
at zero power	−25 to + 125 °C
at maximum power	0 to + 55 °C

APPLICATION

Temperature compensation and temperature sensing.

DESCRIPTION

The thermistor has a negative temperature coefficient, it consists of a disc with two tinned copper wires. It is grey lacquered and colour coded, but not insulated.

MECHANICAL DATA

Outlines

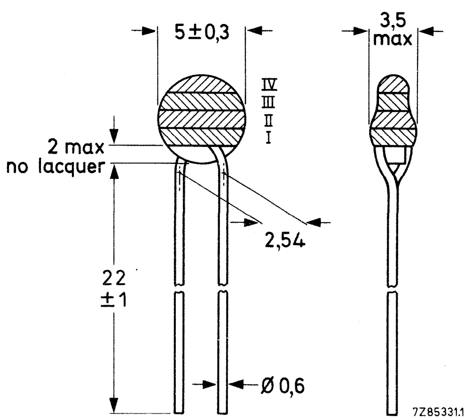


Fig.1 Component outline.

PACKAGING

500 thermistors in a cardboard box. They can be supplied on tape on request.

Marking

The thermistors are marked with three or four colour bands in accordance with Fig. 1 and Table 1.

Mass

0.25 g approximately.

Mounting

In any position by soldering.

Robustness of terminations

Tensile strength	10 N
Bending	5 N

Soldering

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

Impact

Free fall	1 m

Flammability

Not inflammable in accordance with IEC as described by TC50 (1979), needle flame.

Resistance to solvents

In accordance with IEC 68-2-45, resistant to R113 at T_{amb}.

ELECTRICAL DATA

Unless otherwise specified, measured in accordance with IEC publication 539.

Resistance at 25 °C	see Table 1
$B_{25/85}$ values	see Table 1
Temperature coefficient	see Table 1
Maximum dissipation*	0.5 W
Dissipation factor *	8.5 mW/K approx.
Thermal time constant*	17 s approx.
Operating temperature range	
at zero power	−25 to + 125 °C
at maximum power, see Fig. 2	0 to + 55 °C

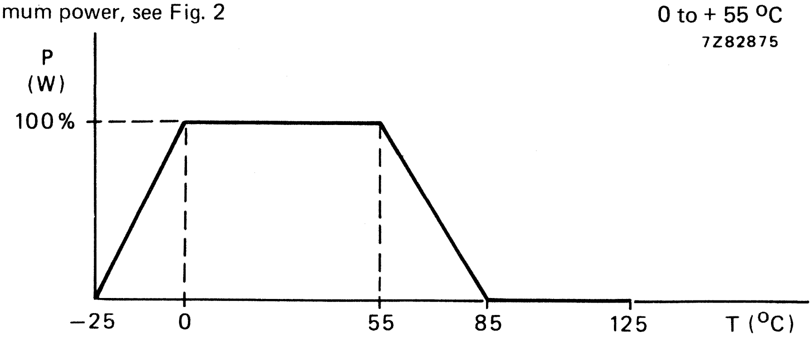


Fig. 2 Derating curve.

* Measured in the measuring set described in the French norm NF C93-271, and clamped at 10 mm from the body.

Table 1 Catalogue number 2322 642 6....

suffix of catalogue number	R_{25} Ω	$B_{25/85}$ ± 5% K	temperature coefficient %/K	colour code (see Marking) I	II	III	* IV
.338	3,3	2675	−3,0	orange	orange	gold	
.478	4,7	2750	−3,1	yellow	violet	gold	
.688	6,8	2800	−3,2	blue	grey	gold	
.109	10	2875	−3,2	brown	black	black	
.159	15	2950	−3,3	brown	green	black	
.229	22	3025	−3,4	red	red	black	
.339	33	3100	−3,5	orange	orange	black	
.479	47	3150	−3,5	yellow	violet	black	
.689	68	3225	−3,6	blue	grey	black	
.101	100	3300	−3,7	brown	black	brown	
.151	150	3375	−3,8	brown	green	brown	
.221	220	3475	−3,9	red	red	brown	
.331	330	3575	−4,0	orange	orange	brown	
.471	470	3650	−4,1	yellow	violet	brown	
.681	680	3725	−4,2	blue	grey	brown	
.102	1 000	3825	−4,3	brown	black	red	
.152	1 500	3975	−4,5	brown	green	red	

* Replace dot in catalogue number (9th digit) by:
2 for a tolerance of 10% on R_{25}, band IV is silver.
3 for a tolerance of 5% on R_{25}, band IV is gold.

VARISTORS (VDR)

INTRODUCTION

Varistors provide reliable and economical protection against high voltage transients and surges which may be produced, for example, by lightning, switching or electrical noise on AC or DC power lines. They have the advantage over transient suppressor diodes in as much as they can absorb much higher transient energies and can suppress positive and negative transients.

When a transient occurs, the varistor resistance changes from a very high standby value to a very low conducting value. The transient is thus absorbed and clamped to a safe level, protecting sensitive circuit components.

The main features of our varistor range are:

- wide voltage range selection - from 14 V to 550 V RMS. This allows easy selection of the correct component for the specific application
- high energy absorption capability with respect to size of component
- response times of less than 20 ns, clamping the transient the instant it occurs
- low standby power - virtually no current is used in the standby condition
- low capacitance values, making the varistors suitable for the protection of digital switching circuitry
- high body insulation - an ochre coating provides protection up to 2500 V, preventing short circuits to adjacent components or tracks
- available on tape with accurately defined dimensional tolerances, making the varistors ideal for automatic insertion
- approved to Underwriter Laboratory (UL) E-98144 Vol. 1, Sec. 1, and manufactured using UL approved flame retardent materials
- completely non flammable, in accordance with IEC, even under severe loading conditions
- non porous lacquer making the varistors safe for use in humid or toxic evironments. The lacquer is also resistant to cleaning solvents in accordance with IEC 68-2-45
- CECC qualification has been granted for the current range of varistors in production.

VARISTOR MANUFACTURING PROCESS

In order to guarantee top performance and maximum reliability, close in line control is maintained over the automated manufacturing techniques. Figure 1 shows each step of the manufacturing process, clearly indicating the emphasis placed on in line control.

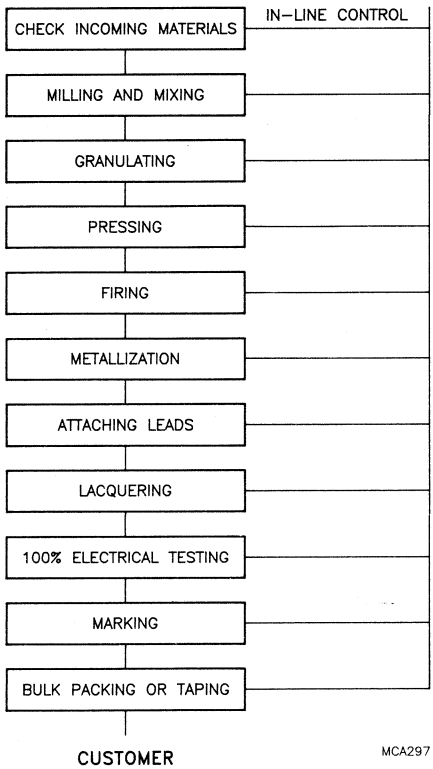


Fig.1 Manufacturing process flow chart.

Each major step in the manufacturing process shown in Fig.1 is described in the following paragraphs:

- **Milling and mixing**
  Incoming materials are checked, weighed, milled and mixed for several hours to make a homogeneous mixture.

- **Granulation**
  A binder is added to produce larger granules for processing.

- **Pressing**
  The surface area and thickness of the disc help to determine the final electrical characteristics of the varistor, therefore pressing is a very important stage in the manufacturing process. The granulated powder is fed into dies and formed into discs using a high speed rotary press.

- **Firing**
  The pressed products are first pre-fired to burn out the binder. They are then fired for a controlled period and temperature until the required electrical characteristics are obtained. Regular visual and electrical checks are made on the fired batch.

- **Metallization**
  The fired ceramic discs are metallized on both faces to produce good electrical contacts. Metallization is achieved by evaporation in a vacuum. Visual checks are made regularly and a solderability test is carried out in each production batch.

- **Attaching leads**
  Leads are automatically soldered to the metallized faces and regular tensile strength tests are made. Three types of lead configuration are available; one with straight leads, one with straight leads with flange, and one with kinked leads.

- **Lacquering**
  The components are coated by immersing them in a special non flammable ochre epoxy lacquer. Two coats are applied and the lacquer is cured. Regular tests to check the coating thickness are made.

- **100% electrical testing**
  The voltage of each component is checked, normally at 1 mA, but any other current may be specified. Any rejects are automatically separated for further evaluation.

- **Marking**
  All components are laser marked.

Varistors are manufactured from a non-homogeneous material, giving a rectifying action at the contact points of two particles. Many series and parallel connections determine the voltage rating and the current capability of the varistor.

Figure 2 shows the structure of a varistor.

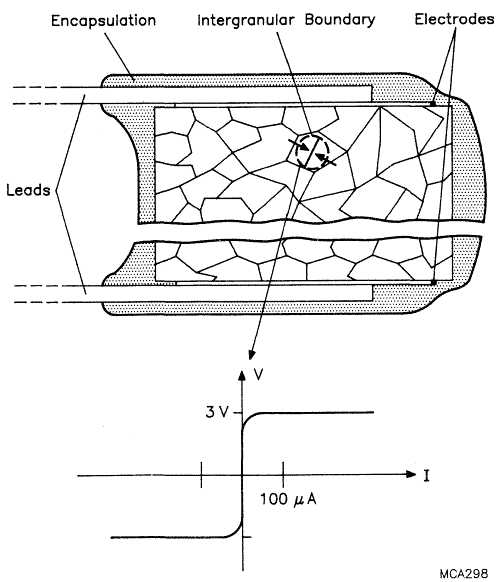


Fig.2 Structure of a varistor.

QUALITY

Approvals
- CECC 42 201-802 of 1992
- UL E98144
- VDE 53 138 E (for 60 - 460 V ranges)

The term 'QUALITY ASSESSMENT' is defined as the continuous surveillance by the manufacturer of a product to ensure that it conforms to the requirements of the specification to which it was made.

- **Product and process release**
  Recognized reliability criteria are designed into each new product and process from the beginning. Evaluation goes far beyond target specifications and heavy emphasis is placed upon reliability. Before production release, new varistors must successfully complete an extended series of life tests under extreme conditions.

- **Monitoring incoming materials**
  Apart from carrying out physical and chemical checks on incoming raw materials, a very close liaison with materials suppliers is maintained. Incoming inspection and production results are gradually fed back to them, so ensuring that they also maintain the highest quality standards.

- **In-line control**
  The manufacturing centre operates in accordance with the requirements of CECC 42 000 and IEC 40 (Secretariat) 538. Each operator is actively engaged in quality checking. In addition, in-line inspectors make daily spot checks on process and product quality, the results of which are fed into the production process.

- **Final inspection and test (100%)**
  At the end of production, each varistor is inspected and tested prior to packing.

- **Lot testing**
  Before any lot is released, it undergoes a series of special lot tests under the supervision of the Quality Department.

- **Periodic sample testing**
  Component samples are periodically sent to the Quality Laboratory for rigorous climatic and endurance tests to CECC requirements. Data from these tests provide a valuable means of exposing long term trends that might otherwise pass unnoticed. The results of these tests are further used to improve the production process.

- **Field information**
  The most accurate method of assessing quality is monitoring performance of the devices in the field. Customer feedback is actively encouraged and the information is used to study how the components may be further improved. This close relationship with customers is based on mutual trust built up over many years of co-operation.

DEFINITIONS

Maximum continuous voltage
The maximum voltage which may be applied continuously between the terminals of the component. For all types of AC voltages, the voltage level determination is given by the crest voltage x 0.707.

Voltage at 1 mA, or varistor voltage
The voltage across a varistor when a current of 1 mA is passed through the component. The measurement shall be made in as short a time as possible to avoid heat perturbation.

The varistor voltage is essentially a point on the V-I characteristic permitting easy comparison between models and types.

Maximum clamping voltage
The maximum voltage between two terminals when a standard impulse current of rise time 8 μs and decreasing time 20 μs (8/20 μs) is applied through the varistor (in accordance with IEC 60-2, section 6).

The specified current for this measurement is the class current.

Maximum non repetitive surge current
The maximum peak current allowable through the varistor is dependent on pulse shape, duty cycle and number of pulses. In order to characterize the ability of the varistor to withstand impulse currents, it is generally allowed to warrant a 'maximum non repetitive surge current'. This is given for one pulse characterized by the shape of the impulse current of 8/20 μs following IEC 60-2, with such an amplitude that the varistor voltage measured at 1 mA changes by ± 10% maximum.

If more than one impulse is applied when the impulse is of a longer duration, derating curves are applied (see relevant information in the data sheet); these curves guarantee a maximum varistor voltage change of ± 10% by 1 mA measurement.

Maximum energy
During the application of one impulse of current, a certain energy will be dissipated by the varistor. The quantity of dissipated energy is a function of:

- the amplitude of the current
- the voltage corresponding to the peak current
- the rise time of the impulse
- the decrease time of the impulse; most of the energy is dissipated during the time corresponding to between 100% and 50% of the peak current
- the non-linearity of the varistor.

In order to calculate the energy dissipated during a pulse, reference is generally made to a standardized wave of current. The wave prescribed by IEC 60-2 section 6 has a shape which increases from zero to a peak value in a short time, and thereafter decreases to zero either at an approximate exponential rate, or in the manner of a heavily damped sinusoidal curve. This curve is defined by the virtual lead time (t_1) and the virtual time to half value (t_2) as shown in Fig.3.

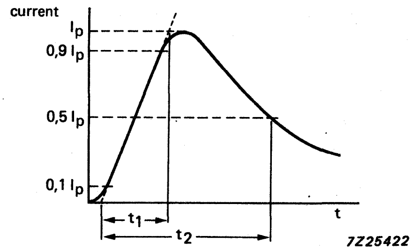


Fig.3 Maximum energy curve.

The calculation of energy during application of such a pulse is given by the formula

$$E = V_P I_P \left(\frac{t_1}{\beta + 2} + \frac{t_2 - t_1}{(\beta + 1)\ln 2}\right)$$

Where:

I_P = peak current

V_P = voltage at peak current

β = given for $I_P = \sqrt{2}$ to I_P

It can be ascertained that the low value of β, corresponds to the low value of dissipated energy for a given peak current and wave shape.

The published maximum energy does not then represent the quality of the varistor, but can be a valuable indication to compare the different series of components having the same varistor voltage. The published maximum energy is valid for a standard impulse of duration 10/1000 μs giving a maximum varistor voltage change of ± 10% at 1 mA.

When more than one pulse is applied, the duty cycle must be so that the rated average dissipation is not exceeded. Values of the rated dissipations are:

0.1 W for series 592
0.25 W for series 593
0.4 W for series 594
0.6 W for series 595.

ELECTRICAL CHARACTERISTICS

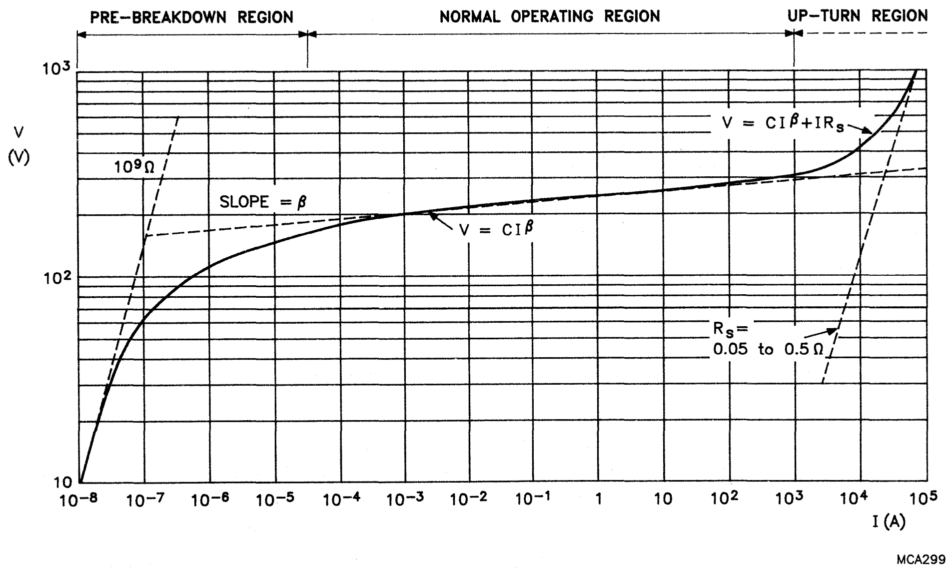
Typical V/I characteristic of a Zn0 varistor

The relationship between voltage and current of a varistor can be approximated to:

$$V = CI^{\beta}$$

Where:

V = voltage
C = varistor voltage at 1 Amp
I = actual working current
β = tangent of angle curve deviating from the horizontal



Pre-breakdown region: V = 10.I approximately; highly temperature dependent

Normal operating region: $V = C \,.\, I^{\beta}$

Upturn region: $V = C \,.\, I^{\beta} + IR_s$

Fig. 4 Typical V/I curve.

Example:
C = 230 V at 1 A
β = 0.035 (Zn0)
I = 0.001 or 100 A

$V = CI^{\beta}$;

for current of 0.001 A; $V = 230.(10^{-3})^{0.035} = 180$ V

for current of 100 A; $V = 230.(10^{2})^{0.035} = 270$ V

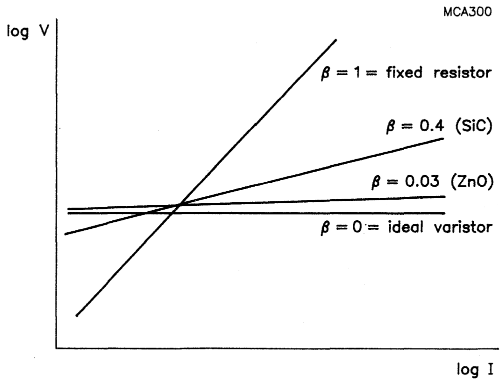


Fig. 5 Varistor characteristics using different β values.

Specification of a varistor curve

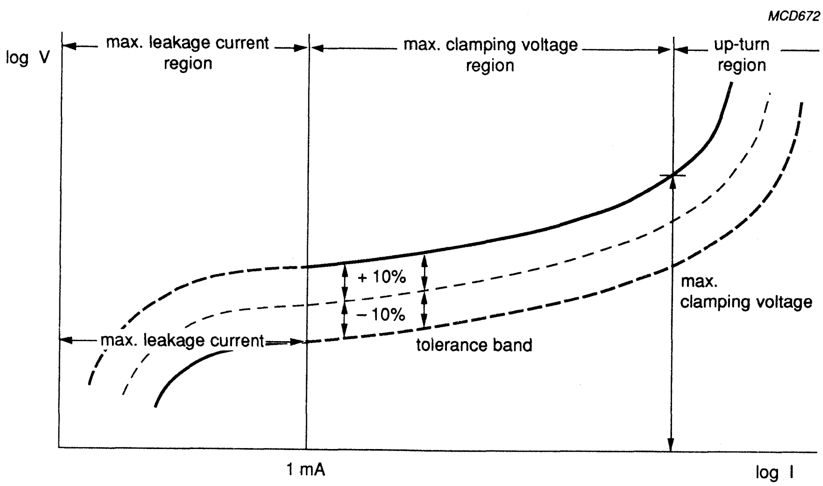


Fig.6 Working points on a varistor curve.

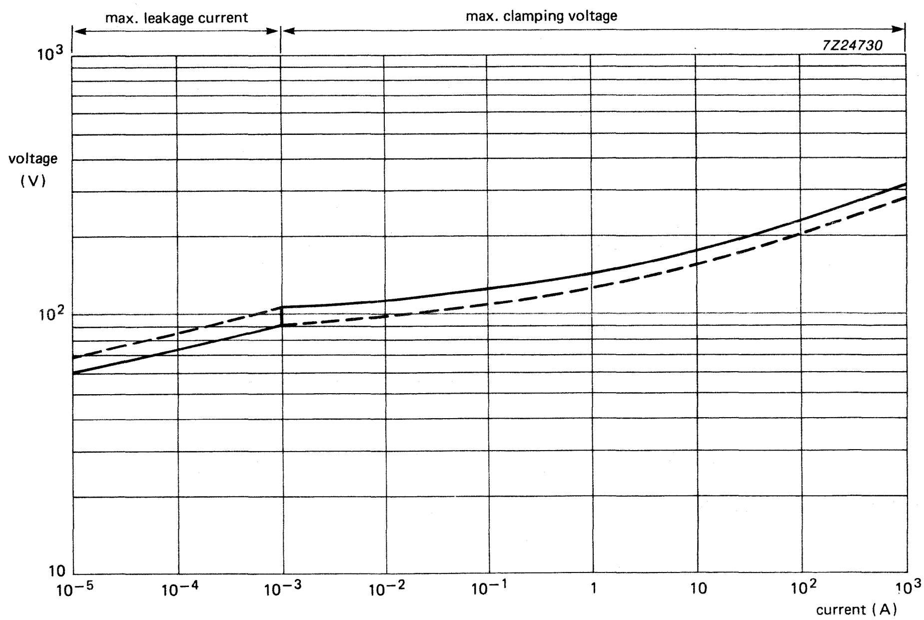


Fig.7 Curve for varistor type 2322 593 .6006

Figure 7 shows the various working points on the varistor curve using the series 2322 593 ..... 60 V type as an example, the values being as follows:

Maximum RMS voltage:	60 V
Maximum DC working voltage:	85 V = $60.\sqrt{2}$
Varistor voltage:	100 V ± 10 %
Maximum clamping voltage at 10 A:	165 V
Maximum non repetitive current:	1200 A
Leakage current at 85 V DC:	10^{-5} A to 5.10^{-4}
Transient energy:	10/1000 µs: 5.4 J

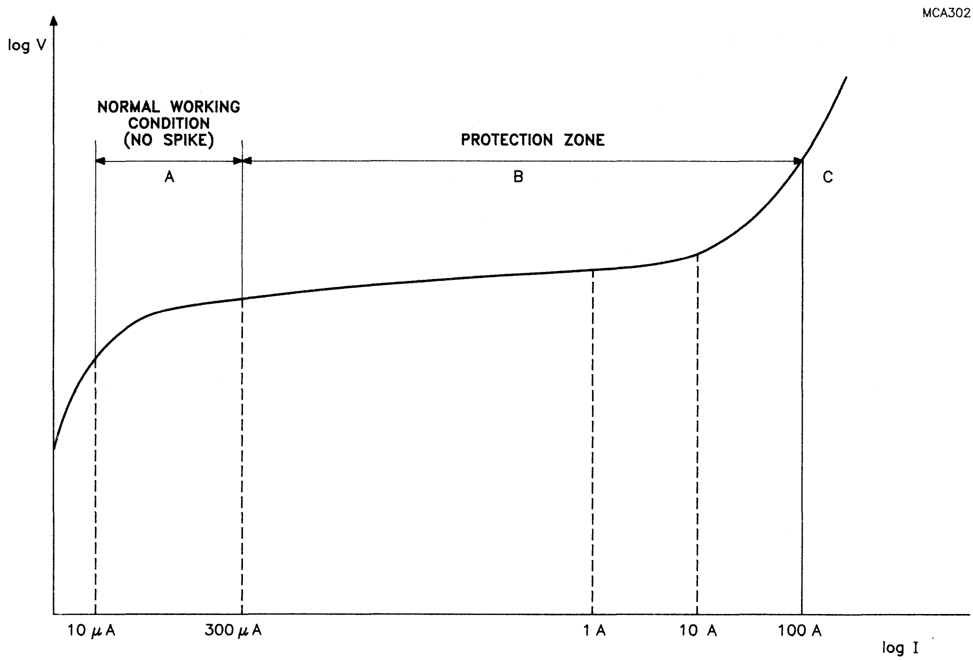


Fig.8 Definitions of the varistor curve.

The points shown on the curve in Fig. 8 are defined as follows:

A: **Normal working zone** - current is kept as low as possible in order to have low dissipation during continuous operation (between 10 - 300 μA)

B: **Maximum clamping voltage** - the maximum voltage for a given (class) current (peak current based upon statistical probability determined by standardization authorities)

C: **Maximum withstanding surge current** - the maximum peak current that the varistor can withstand (only) once in its ifetime.

TRANSIENT VOLTAGE LIMITATION WITH ZN0 VARISTORS

Principles of voltage limitation

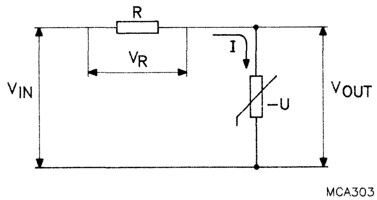


Fig.9 Voltage limitation using a varistor.

In Fig. 9, the supply voltage V_{IN} is derived by the resistance R (e.g. the line resistance) and the Varistor (-U) selected for the application.

$$V_{IN} = V_R + V_{OUT}$$

$$V_{IN} = RI + CI^{\beta}$$

If the supply voltage varies by an amount of V_{IN} the current variation is I and the supply voltage may be expressed as:

$$(V_{IN} + \Delta V_{IN}) = R(I + \Delta I) + C(I + \Delta I)^{\beta}$$

Given the very small value of β (0.03 to 0.05), it is evident that the modification of CI^{β} will be very small compared to the variation of RI when V_{IN} is increased to $V_{IN} + \Delta V_{IN}$. A large increase of V_{IN} will induce a large increase of V_R and a small increase of V_{OUT}.

Example:

If the varistor is a typical component of the series 2322 592 52716 (C = 520, $\beta = 0.04$) and if R = 250 Ω,

for $V_{IN} = 315$ V (crest voltage of the 220 V supply voltage);

$I = 10^{-5}$ A, $V_R = 2.5 \times 10^{-3}$ V, and $V_{OUT} = 315$ V.

for $V_{IN} = 500$ V;

$I = 10^{-1}$ A, $V_R = 25$ V, and $V_{OUT} = 475$ V.

for $V_{IN} = 1000$ V;

$I = 1.88$ A, $V_R = 470$ V, and $V_{OUT} = 530$ V.

Figure 10 shows the influence of different values of series resistors on the varistor.

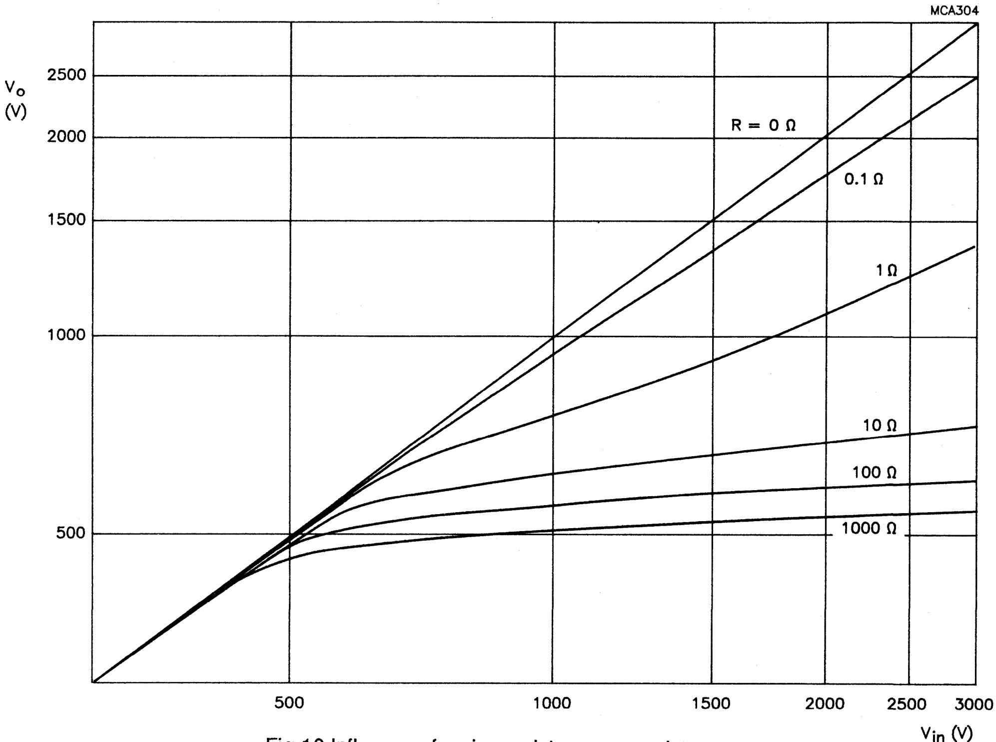


Fig.10 Influence of series resistance on varistor.

By drawing the load line, it is also possible to estimate the variation of the voltages V_R and V_{OUT} when V_{IN} is increased to 500 V or 1000 V. This effect is shown in Figs 11 and 12 respectively.

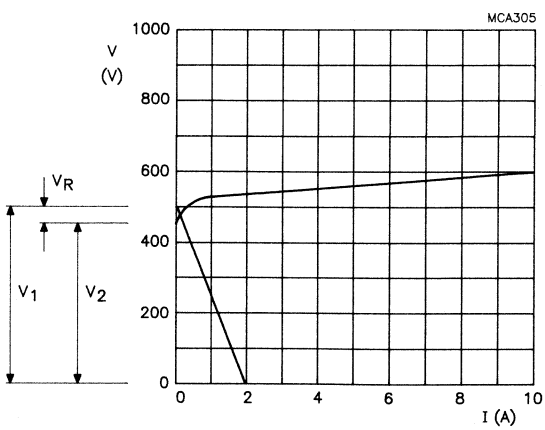


Fig.11 Influence on varistor when V_{IN} is 500 V (R = 250 Ω).

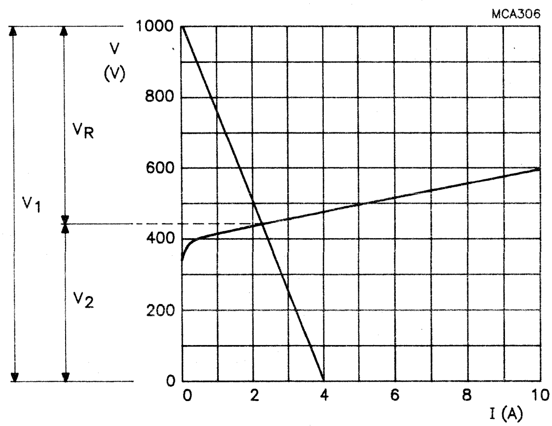


Fig.12 Influence on varistor when V_{IN} is 1000 V (R = 250 Ω).

Equivalent circuit model

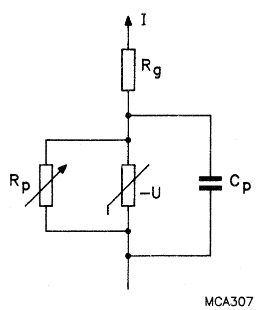


Fig.13 Equivalent circuit model.

A simple equivalent circuit representing a metal oxide varistor as a capacitance in parallel with a voltage dependent resistor is shown in Fig. 13. Cp and Rp are the capacitance and resistance of the intergranular layer respectively; Rg is the Zn0 grain resistance. For low values of applied voltages, Rp behaves as an ohmic loss.

Capacitance

Depending on area and thickness of the device, the capacitance of the varistors increases with the diameter of the disc, and decreases with its thickness.

In DC circuits, the capacitance of the varistors remains approximately constant provided the applied voltage does not rise to the conduction zone, and drops abruptly near the rated maximum continuous DC voltage.

In AC circuits, the capacitance can affect the parallel resistance in the leakage region of the V-I characteristic. The relationship is approximately linear with the frequency and the resulting parallel resistance can be calculated from $1/\omega C$ as for a usual capacitor.

Nevertheless, due to the structural characteristics of the zinc oxide varistors, the capacitance itself decreases slightly with an increase in frequency. This phenomenon is emphasized when the frequency reaches approximately 100 kHz. Figure 14 shows the effect of HF alternating current on the varistor.

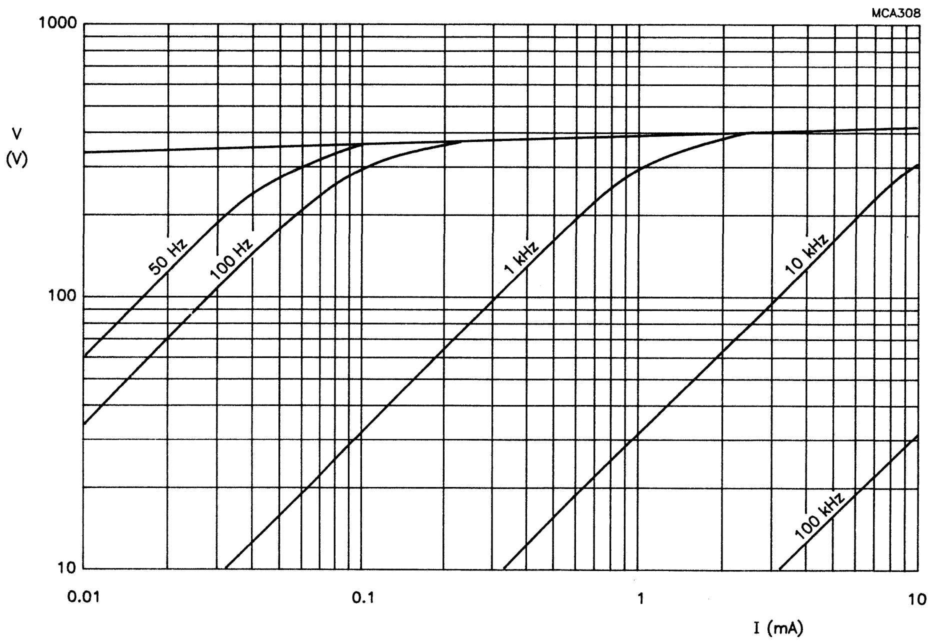


Fig.14 Effect of HF alternating current on varistor, type 2322 595 52516, C = 480 pF.

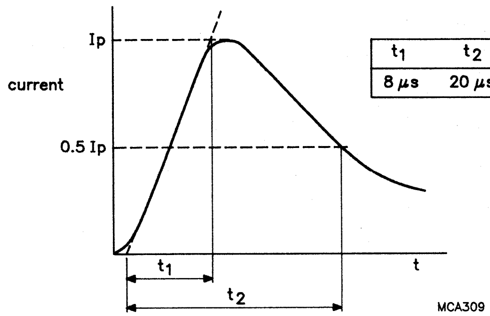
Energy handling

Maximum allowable peak current and maximum allowable energy are standardized using defined pulses.

- peak current (amperes); 8/20 µs - 1 pulse
- energy (joules); 10/1000 µs - 1 pulse

Surge life rating - curves (number of surges allowed as a function of pulsetime and maximum current).

Internationally accepted test pulses



t_1	t_2
8 µs	20 µs

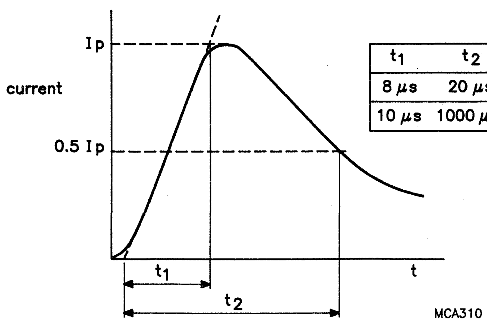
Max. allowable peak current
(one time only)

<u>Examples</u>

593 52516 (250V) = 1200 A
593 53006 (30V) = 250 A
595 52516 (250V) = 4500 A
595 53006 (30V) = 1000 A

Fig.15 Standard impulse current following IEC publication 60-2, paragraph 16.1.

Pulse life time rating of 593 60V-type



t_1	t_2
8 µs	20 µs
10 µs	1000 µs

Energie capability : $E = K.V_p.I_pt_2$

1 pulse 8/20 µs: 1200 A = 1 x 8 J
10 pulses 8/20 µs: 300 A = 10 x 1.45 J
1 pulse 10/1000 µs: 33 A = 1 x 8.3 J
10 pulses 10/1000 µs: 11 A = 10 x 2.5 J

After test: (ΔV/V) 1 mA ≤ 10%

I_p = pulse current
V_p = corresponding clamping voltage

Fig.16 Examples of energy capabilities for different levels of current amplitude or impulse duration.

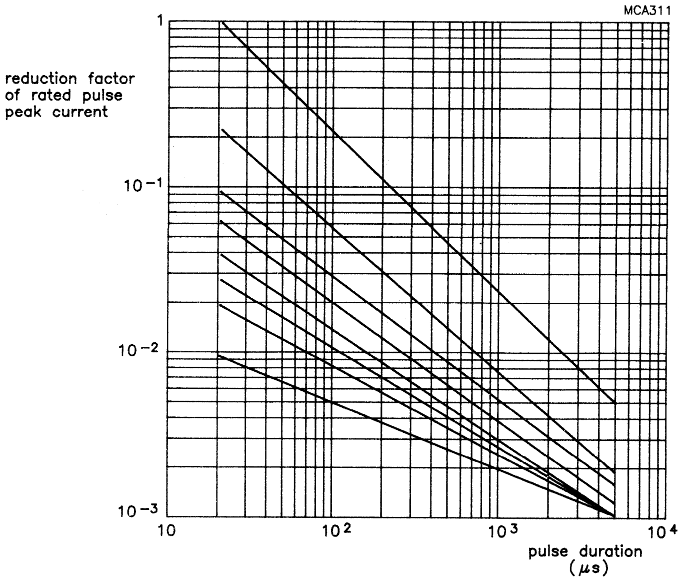
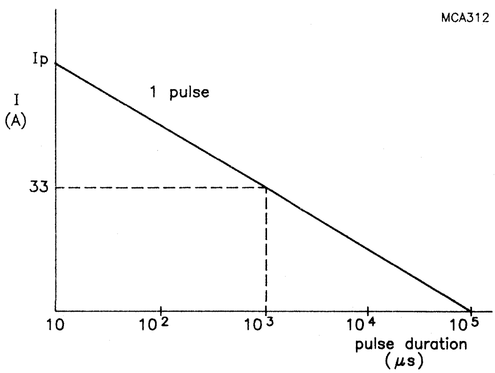


Fig.17 Maximum peak current for various number of pulses as a function of pulse duration.

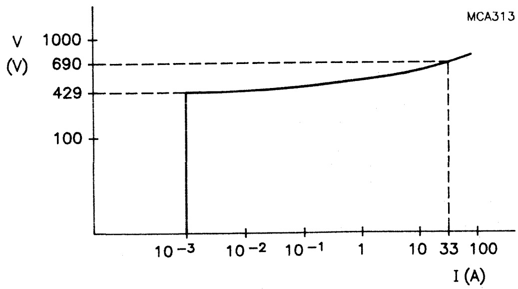


Maximum energy (10 x 1000 µs)

Example

593 52516 (250 V)

Fig. 18 Example of selection of the maximum peak current as a function of pulse duration.



$$E = K \times Vp \times Ip \times t_2$$
$$= 1.4 \times 700 \times 33 \times 10^{-3} = 32 \text{ joules}$$

Fig. 19 Example of calculation of energy for a 2322 593 52516 type, 1 impulse at the maximum peak current (33A) for a duration t_2 = 1000 µs (k = 1.4).

DISSIPATED POWER

DC dissipation

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

$$W = I.V = CI^{\beta+1} \text{ or } KV^{\alpha+1}$$

When the coefficient $\alpha = 30$ ($\beta = 0.033$), the power dissipated by the varistor is proportional to the 31st power of the voltage. A voltage increase of only 2.26% 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, otherwise the permissible rating will be exceeded.

This is even more cogent as the varistors have a negative temperature coefficient, which means that at higher dissipation (and accordingly at a higher temperature) the resistance value will decrease and the dissipated power will increase even more.

AC dissipation

When a sinusoidal alternating voltage is applied to a varistor, the dissipation cannot be calculated from the same formula as in a DC application. The calculation requires an integration of the V.I product.

The instantaneous dissipated power is given by:

$$P_{INST} = V.I = V(K.V^{\alpha}) = K.V^{\alpha+1}$$

In the above equation, the value $V = V_{PEAK}.\sin \omega t$.

During a half cycle, the dissipated power is then given by:

$$P_{RMS} = \frac{1}{\pi} \int_0^{\pi} K.V_{PEAK}{}^{\alpha+1} \ (\sin \omega t)^{\alpha+1}.dt$$

Since $V_{PEAK} = V_{RMS} \times \sqrt{2}$

$$P_{RMS} = \frac{1}{\pi} .K.V_{RMS}{}^{\alpha+1}.(\sqrt{2})^{\alpha+1} \int_0^{\pi} (\sin \omega t)^{\alpha+1}.dt$$

This integration is not easy to solve because of the exponent $\alpha + 1$ of sin ωt.

It is generally easier to use the quotient of the AC power on the DC power:

$P = P_{AC}/P_{DC}$.

This quotient depends only from the value of α and not more of the K value as shown in the formula:

$$P = \frac{\frac{1}{\pi}.K.V_{RMS}{}^{\alpha+1}.2^{(\alpha+1)/2} \int_0^{\pi} (\sin \omega t)^{\alpha+1}.dt}{KV^{\alpha+1}}$$

$$P = \frac{1}{\pi}.2^{(\alpha+1)/2} \int_0^{\pi} (\sin \omega t)^{\alpha+1}.dt$$

P has been calculated by successive application of a reduction formula, and is tabulated below:

Table 1 Power ratios

α	P	α	P	α	P	α	P	α	P
1	1.00	11	14.4	21	344	31	9.135	41	255.646
2	1.20	12	19.6	22	477	32	12.776	42	358.778
3	1.50	13	26.8	23	658	33	17.734	43	499.673
4	1.92	14	36.7	24	915	34	24.822	44	701.611
5	2.50	15	50.3	25	1264	35	34.482	45	977.622
6	3.29	16	69.0	26	1763	36	48.301	46	1373.365
7	4.375	17	95.0	27	2439	37	67.149	47	1914.510
8	5.85	18	131	28	3404	38	94.126	48	2690.675
9	7.875	19	180	29	4715	39	130.941	49	3752.439
10	10.64	20	249	30	6587	40	183.660	50	5275.834

Temperature coefficient

In the 'leakage current' region of the V/I characteristic, the normal equation $V = CI^{\beta}$ of the varistor becomes less applicable.

This is due to a parallel resistance which shows a very important temperature coefficient, created by thermal conduction. This temperature coefficient decreases when the current density increases. Then, the temperature coefficient at 1 mA is higher for a large varistor than for a small varistor.

This phenomena induces an increase in leakage current when the varistor is used at high temperature. The relationship between the temperature can be expressed by:

$I = I_0.e^{KT}$

where:

I_0 is the limiting current at 0 ° Kelvin

K is a constant including the band gap energy of the zinc oxide and the Boltzmann's constant.

Practically, the maximum temperature coefficient is guaranteed on the voltage for a current of 1 mA, in % by K.

SURGE PROTECTION

Varistors provide protection against surges which may be generated in the following ways:

- **Electromagnetic energy**

  Atmospheric - lightning

  Switching of inductive loads - relays
  pumps
  actuators
  spot welders
  thermostats
  fluorescent chokes
  discharge lamps
  motors
  transformers
  air conditioning units
  fuses.

- **Electrostatic discharges**

  For example, discharges caused by synthetic carpets (approximately 50 kV).

Source of transient

The energy dissipated by switching of an inductive load is completely transferred in the capacitance of the coil which is generally very low.

$E = 1/2\ (LI^2) = 1/2\ (CV^2)$

Examples, using the following values

Mains voltage = 220 V RMS (allowable peak voltage = 340 V)
Line inductance = 20 μH (2.10^{-5} H)
Line capacitance = 1 μF (10^{-6} F)
Line resistance = 0.34 Ω

1. In the event of a short circuit:

   Load current $I_L = V/R = 340\ V/0.34\ \Omega = 1000\ A$

   Energy stored $E = 1/2\ (2 \times 10^{-5})\ .\ 10^6 = 10$ Joules (W.s)

2. In the event of a fuse going open circuit:

   The energy goes from inductance L towards line capacitance

   $V_C = \sqrt{2E/C} = 2 \times 10/10^{-6} = 20 \times 10^6 = 4472\ V$

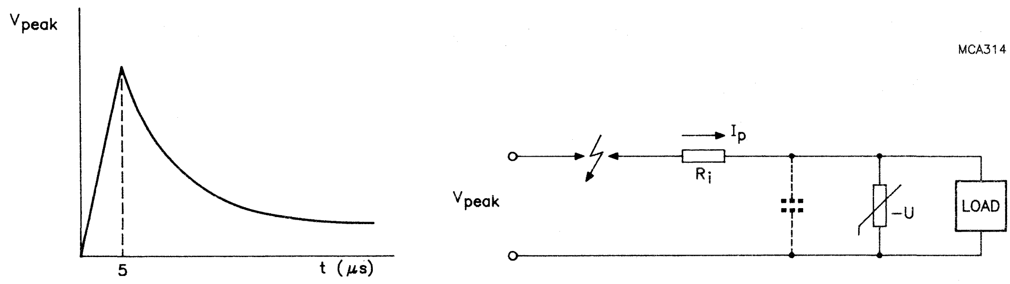


Fig.20 Source of transient.

The line impedance becomes high when the fuse goes open circuit (resistance against high voltage peak in a very short time).

$R_l = 1/\omega C = 1/2\ (\pi f C)$

Since the rise time of the pulse is 5 μs, the frequency f = 0.2 MHz.

$R_l = 1/6.28 \times 0.2\ .\ 10^{-6} \times 10^{-8} = 80\ \Omega$

$I_p = 48$ A

$V_{Rl} = 80 \times 48 = 3820$ V

$V_{VDR} = 652\ V = V_{LOAD}$

VARISTOR APPLICATIONS

Varistors may be used in many applications, including:

- computers
- timers
- amplifiers
- oscilloscopes
- medical analysis equipment
- street lightning
- tuners
- televisions
- controllers
- industrial power plant
- telecommunications
- automotive
- gas and petrol appliances
- electronic home appliances
- relays
- broadcasting
- traffic facilities
- electromagnetic valves
- railway distribution/vehicles
- agriculture
- power supplies
- line ground (earth protection)
- microwave ovens
- toys, etc.

Application examples

1. For suppression of mains-borne transients in domestic appliances and industrial equipment.

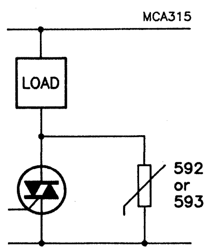


Fig. 21 Suppression via load.

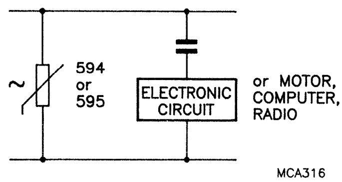


Fig. 22 Suppression directly across mains.

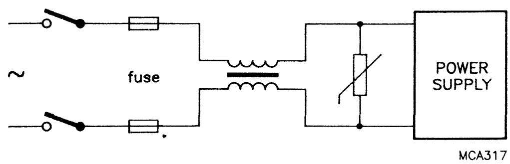


Fig. 23 Switched-mode power supply protection.

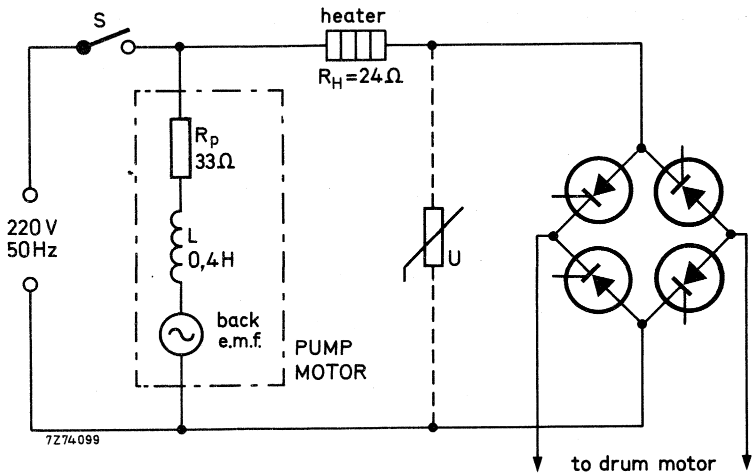


Fig. 24 Protection of a thyristor bridge in a washing machine.

Behaviour of the circuit without varistor protection

The measured peak current through the pump motor when S is closed is 1 A. The energy expended in establishing the electromagnetic field in the inductance of the motor is therefore:

$I^2L/2 = 0.4/2 = 200$ mJ.

Without varistor protection, an initial current of 1 A will flow through the thyristor bridge when S is opened, and a voltage sufficient to damage or destroy the thyristors will be developed. Arcing will occur across the opening contacts of the switch.

Behaviour of the circuit with varistor 2322 593 52516 inserted

On opening switch S, the peak voltage developed across the varistor is:

$$V = C_{MAX} I^{\beta} = 600\,V$$

The thyristors in the bridge can withstand this voltage without damage.

The total energy returned to the circuit is 200 mJ. Of this 200 mJ, 15.1 mJ is dissipated in the heater, and 184.3 mJ is dissipated in the varistor. The varistor can withstand more than 10^5 transients containing this amount of energy.

2. For suppression of internally generated spikes in electronic circuits.

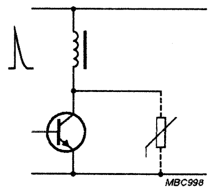


Fig. 25 Varistor used across a transistor or coil in a television circuit.

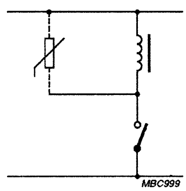


Fig. 26 Varistor used across a switch or coil.

In both examples shown above, type 2322 592 should be used for up to approximately 200 A, and type 2322 593 should be used up to approximately 500 A.

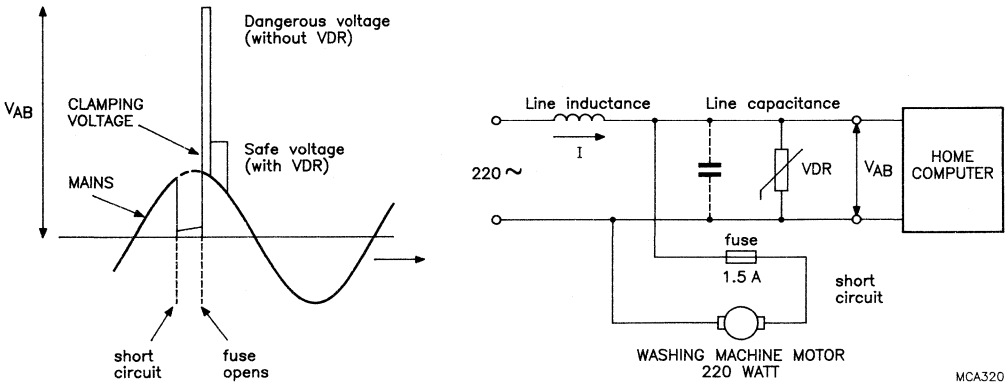


Fig. 27 Influence of a transient on the mains voltage.

SELECTION OF THE CORRECT VARISTOR TYPE

In order to select a Zn0 varistor for a specific application, the following points must first be considered:

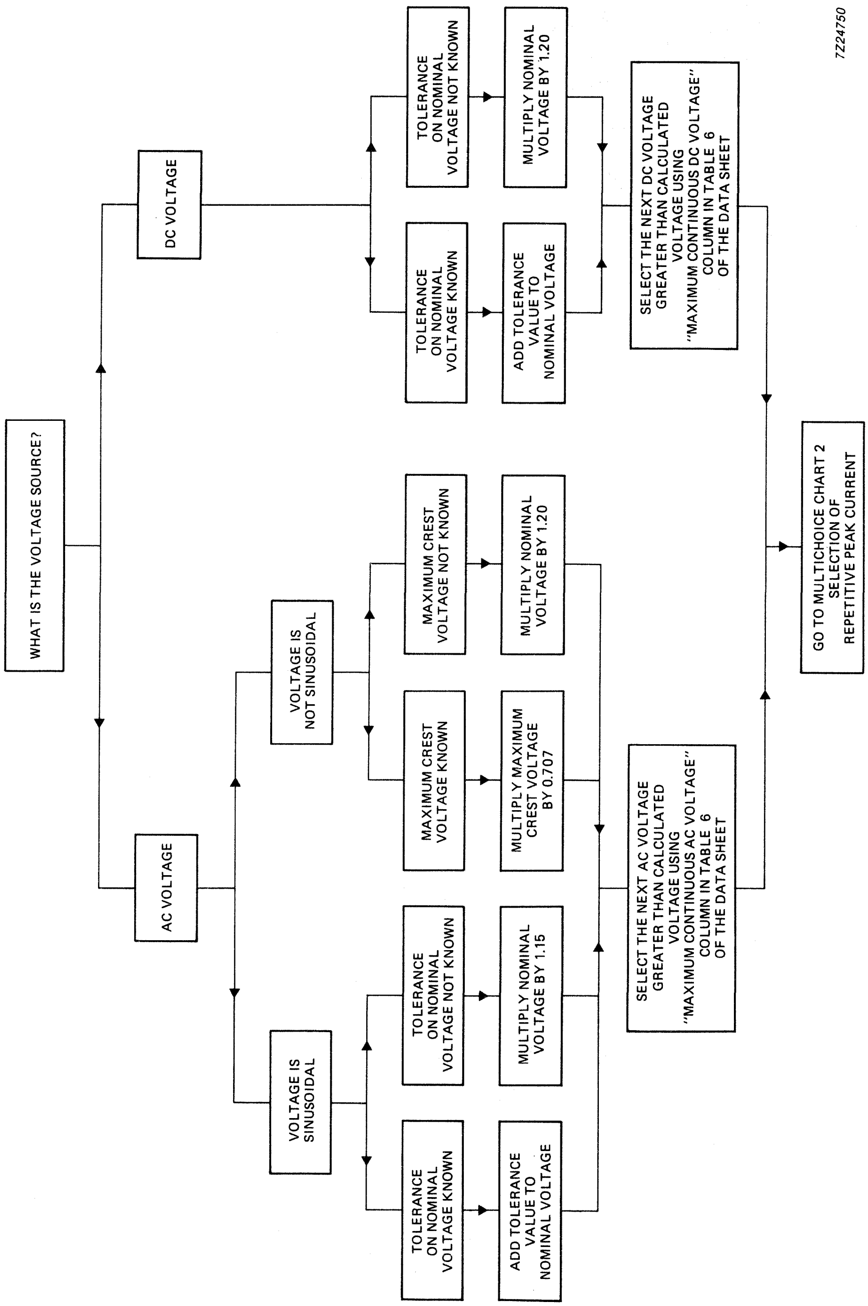
1.The normal operating conditions of the apparatus or system

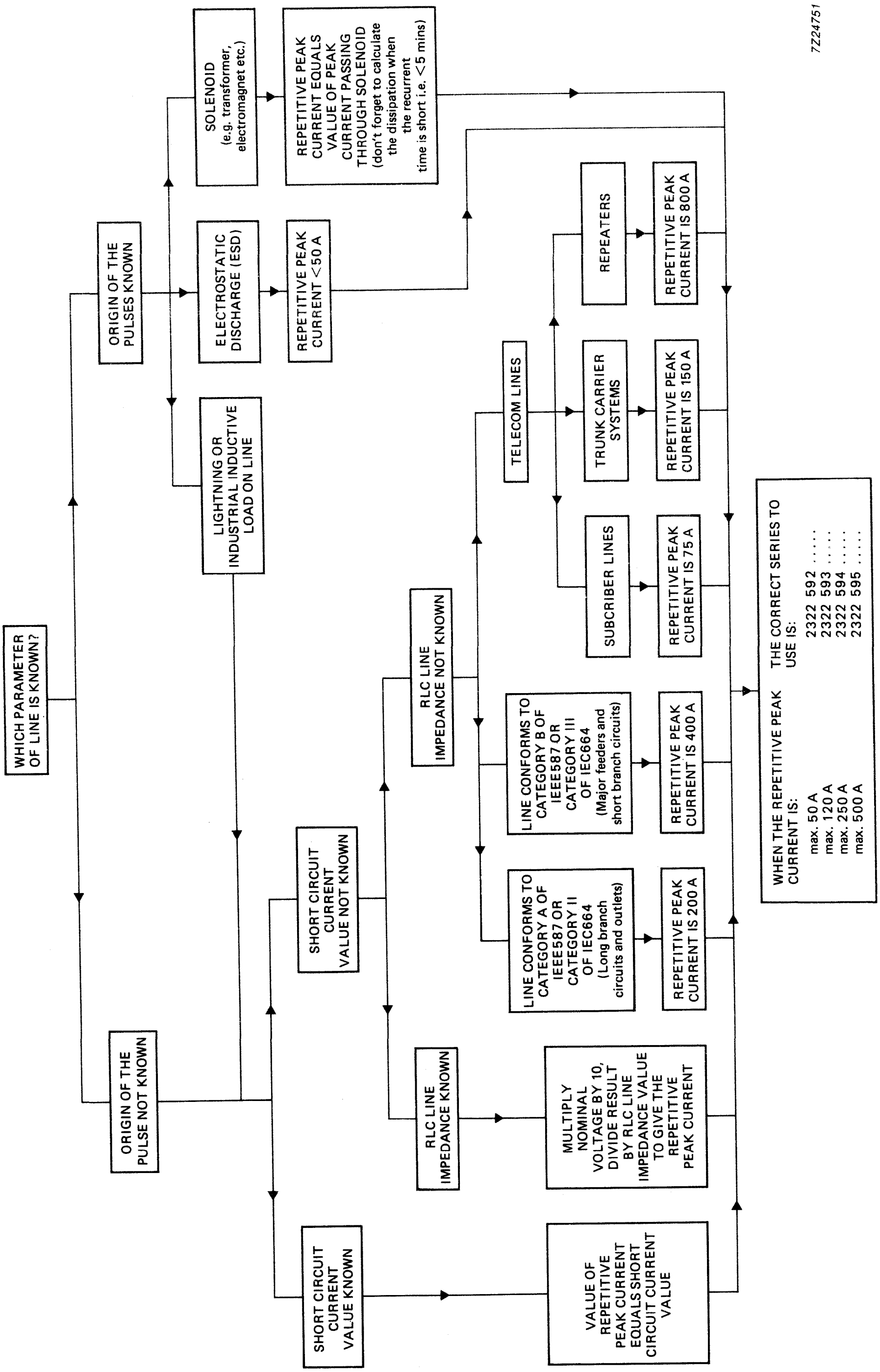
- AC voltage ?
- DC voltage ?

2.What is the maximum RMS or DC voltage?

To ensure correct selection of varistor type, two multichoice selection charts have been prepared:

Chart 1 determines the necessary steady state voltage rating (i.e. working voltage), and chart 2 determines the correct size (i.e. correct energy absorption). These charts can be found on the following pages.


WHAT IS THE VOLTAGE SOURCE?
DC VOLTAGE
AC VOLTAGE
TOLERANCE ON NOMINAL VOLTAGE NOT KNOWN
MULTIPLY NOMINAL VOLTAGE BY 1.20
TOLERANCE ON NOMINAL VOLTAGE KNOWN
ADD TOLERANCE VALUE TO NOMINAL VOLTAGE
SELECT THE NEXT DC VOLTAGE GREATER THAN CALCULATED VOLTAGE USING "MAXIMUM CONTINUOUS DC VOLTAGE" COLUMN IN TABLE 6 OF THE DATA SHEET
VOLTAGE IS NOT SINUSOIDAL
MAXIMUM CREST VOLTAGE NOT KNOWN
MULTIPLY NOMINAL VOLTAGE BY 1.20
MAXIMUM CREST VOLTAGE KNOWN
MULTIPLY MAXIMUM CREST VOLTAGE BY 0.707
VOLTAGE IS SINUSOIDAL
TOLERANCE ON NOMINAL VOLTAGE NOT KNOWN
MULTIPLY NOMINAL VOLTAGE BY 1.15
TOLERANCE ON NOMINAL VOLTAGE KNOWN
ADD TOLERANCE VALUE TO NOMINAL VOLTAGE
SELECT THE NEXT AC VOLTAGE GREATER THAN CALCULATED VOLTAGE USING "MAXIMUM CONTINUOUS AC VOLTAGE" COLUMN IN TABLE 6 OF THE DATA SHEET
GO TO MULTICHOICE CHART 2 SELECTION OF REPETITIVE PEAK CURRENT
7Z24750


7Z24751
WHICH PARAMETER OF LINE IS KNOWN?
ORIGIN OF THE PULSES KNOWN
ORIGIN OF THE PULSE NOT KNOWN
SOLENOID (e.g. transformer, electromagnet etc.)
REPETITIVE PEAK CURRENT EQUALS VALUE OF PEAK CURRENT PASSING THROUGH SOLENOID (don't forget to calculate the dissipation when the recurrent time is short i.e. <5 mins)
ELECTROSTATIC DISCHARGE (ESD)
REPETITIVE PEAK CURRENT <50 A
LIGHTNING OR INDUSTRIAL INDUCTIVE LOAD ON LINE
SHORT CIRCUIT CURRENT VALUE NOT KNOWN
SHORT CIRCUIT CURRENT VALUE KNOWN
RLC LINE IMPEDANCE NOT KNOWN
RLC LINE IMPEDANCE KNOWN
TELECOM LINES
REPEATERS
REPETITIVE PEAK CURRENT IS 800 A
TRUNK CARRIER SYSTEMS
REPETITIVE PEAK CURRENT IS 150 A
SUBCRIBER LINES
REPETITIVE PEAK CURRENT IS 75 A
LINE CONFORMS TO CATEGORY B OF IEEE587 OR CATEGORY III OF IEC664 (Major feeders and short branch circuits)
REPETITIVE PEAK CURRENT IS 400 A
LINE CONFORMS TO CATEGORY A OF IEEE587 OR CATEGORY II OF IEC664 (Long branch circuits and outlets)
REPETITIVE PEAK CURRENT IS 200 A
MULTIPLY NOMINAL VOLTAGE BY 10, DIVIDE RESULT BY RLC LINE IMPEDANCE VALUE TO GIVE THE REPETITIVE PEAK CURRENT
VALUE OF REPETITIVE PEAK CURRENT EQUALS SHORT CIRCUIT CURRENT VALUE
WHEN THE REPETITIVE PEAK CURRENT IS:
max. 50 A
max. 120 A
max. 250 A
max. 500 A
THE CORRECT SERIES TO USE IS:
2322 592 .....
2322 593 .....
2322 594 .....
2322 595 .....

VARISTORS

zinc oxide disc, epoxy coated

QUICK REFERENCE DATA

Maximum AC voltage (RMS)	14 to 550 V
Maximum DC voltage	18 to 745 V
Maximum non-repetitive transient current (8/20 μs)	100 to 4500 A
Climatic category	40/125/56
Specification	based on CECC 42 000
Packaging	
2322 592 and 2322 593	on tape on reel on tape in 'ammopack' and in bulk
2322 594 and 2322 595	on tape on reel and in bulk

APPLICATION

Suppression of transients to increase contact life and improve electronic equipment reliability.

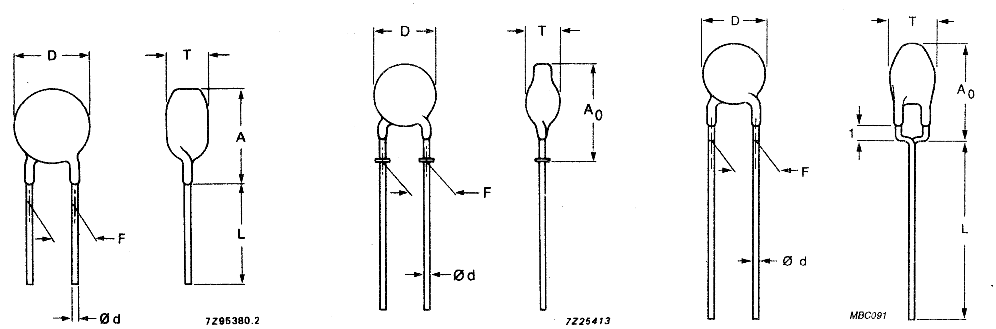
DESCRIPTION

The varistors consist of a disc of low-β ceramic material with two tinned solid copper wires. They are coated with layers of ochre-coloured epoxy, which provides electrical, mechanical and climatic protection. The encapsulation is resistant to all cleaning solvents in accordance with IEC 68-2-45.
Three types of lead configuration are available:

- straight leads
- straight leads with flange (592, 593 series only)
- kinked leads (592, 593 series only)

MECHANICAL DATA

Outlines



Straight leads — Straight leads with flange — Kinked leads

Fig.1 Survey of component outlines; see Table 1 for details.

MECAHNICAL DATA (continued)

Table 1 Component dimensions

catalogue number	D max. mm	A max. mm	A_O max. mm	L min. mm	d mm	F mm	therm. res. K/W approx.	max. diss. mW
2322 592	7	9	11	27	0.6 ± 0.06	5 + 0.6/−0.1	80	100
2322 593	9	11	13	27	0.6 ± 0.06	5 + 0.6/−0.1	70	250
2322 594	13.5	15.5		17	0.8 − 0.02	7.5 ± 1	60	400
2322 595	17	19		16	0.8 − 0.02	7.5 ± 1	50	600

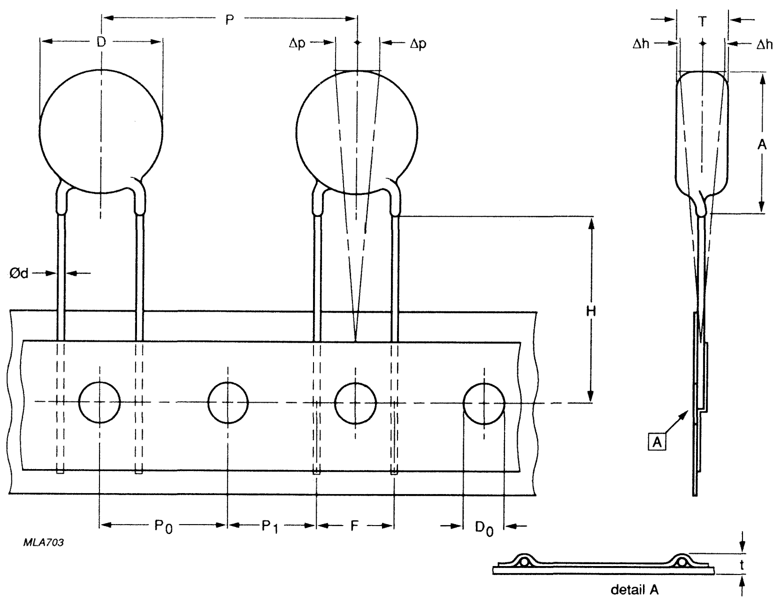


Fig.2 Taped version with straight leads; see Table 2 for details, (only for 594 and 595).

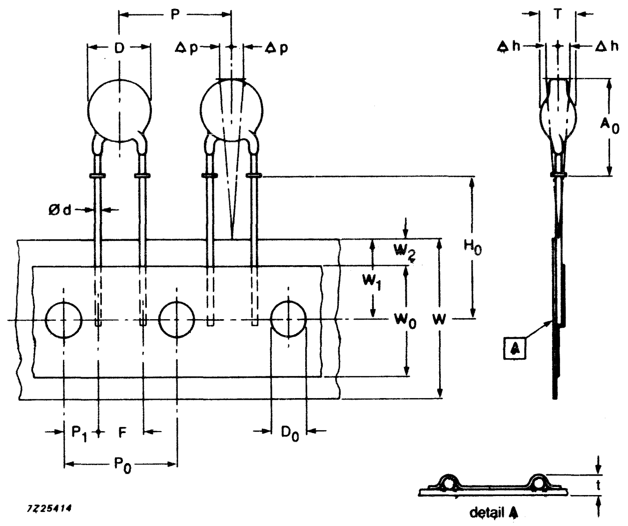


Fig.3 Taped version with flanged leads; see Table 2 for details, (only for 592 and 593).

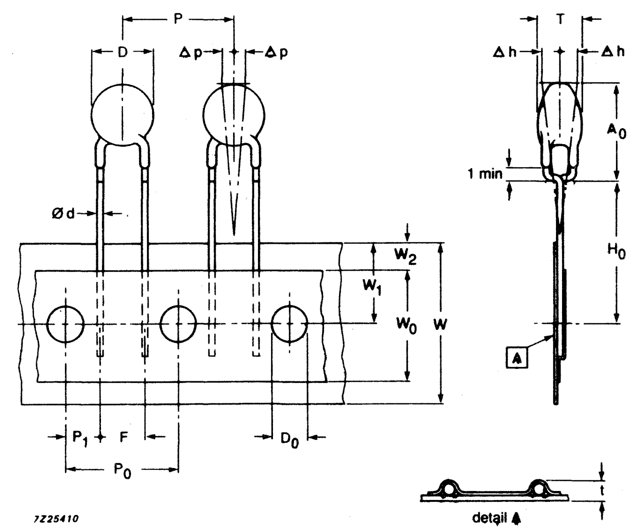


Fig.4 Taped version with kinked leads; see Table 2 for details.

Table 2 Taping data (based on IEC 286-2)

parameter	symbol	nominal dimensions mm	tolerance	remarks
body diameter	D	see Table 1		
total thickness	T	see Table 6		
mounting height	$A_0 - A$	see Table 1		
lead wire diameter	d	see Table 1		
lead to lead distance	F	see Table 1		guaranteed between component and tape
component pitch	P	12.7/25.4 mm	± 1 mm	
feed hole pitch	P_0	12.7	± 0.3	cumulative pitch error = ± 1 mm/20 pitches
feed hole centre to lead centre	P_1	3.81/8.89	± 0.7	guaranteed between component and tape
component alignment	ΔP	0	± 1.3	
component alignment	Δh	0	± 2.0	
tape width	W	18	+ 1/–0.5	
hold down tape width	W_0	12.5 min.		
hole position	W_1	9	± 0.5	
hold down tape position	W_2	3 max.		
height between component and tape centre	H	20	+ 2/–0	straight lead versions
lead wire clinch height	H_0	16/18.25	± 0.5	flanged and kinked lead versions
feed hole diameter	D_0	4	± 0.2	
total tape thickness	t	2 max.		cardboard tape 0.5 ± 0.1
AQL - mechanical level II			± 1%	

MECHANICAL DATA (continued)

Mounting

The varistors are suitable for processing on automatic insertion, and cutting and bending equipment.

Versions with flanged leads provide better positioning on the PCB and more accurate control over component height. This is important for hand mounting and automatic insertion techniques (see Fig.5).

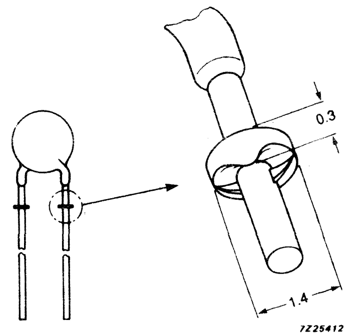


Fig.5 Varistor with flanged lead.

Soldering

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

Impact

Free fall	1 m

Robustness of terminations

Tensile strength	10 N

Inflammability

The varistors are non-flammable

Marking

The varistors are marked with the following information:

- maximum continuous RMS voltage
- series number (i.e. 592, 593, 594 or 595)
- manufacturer's logo
- date of manufacture

ORDERING INFORMATION

Packaging

The varistors are available in a number of packing options:

- on tape on reel
- on tape in 'ammopack'
- bulk packing

The basic ordering code for each option is given in Tables 3 to 5 inclusive. To complete the catalogue number consult Table 6, Electrical Data, to determine the required operating parameters.

Table 3 Varistors available on tape on reel

	2322 592 (ϕ 7 mm) 14 - 460 V	2322 593 (ϕ 10 mm) 14 - 460 V	2322 594 (ϕ 13.5 mm) 14 - 550 V	2322 595 (ϕ 17 mm) 14 - 550 V
packing quantity	1500	1500	750	750
straight leads; H = 20 (see Fig.2)	0 . . . 6	0 . . . 6	0 . . . 6	0 . . . 6
straight leads with flange; H_0 = 16 (see Fig.3)	1 . . . 6	1 . . . 6		
straight leads with flange; H_0 = 18.25 (see Fig.3)	2 . . . 6	2 . . . 6		
kinked leads; H_0 = 18.25 (see Fig.4)	3 . . . 6	3 . . . 6		
kinked leads; H_0 = 16 (see Fig.4)	8 . . . 6	8 . . . 6		

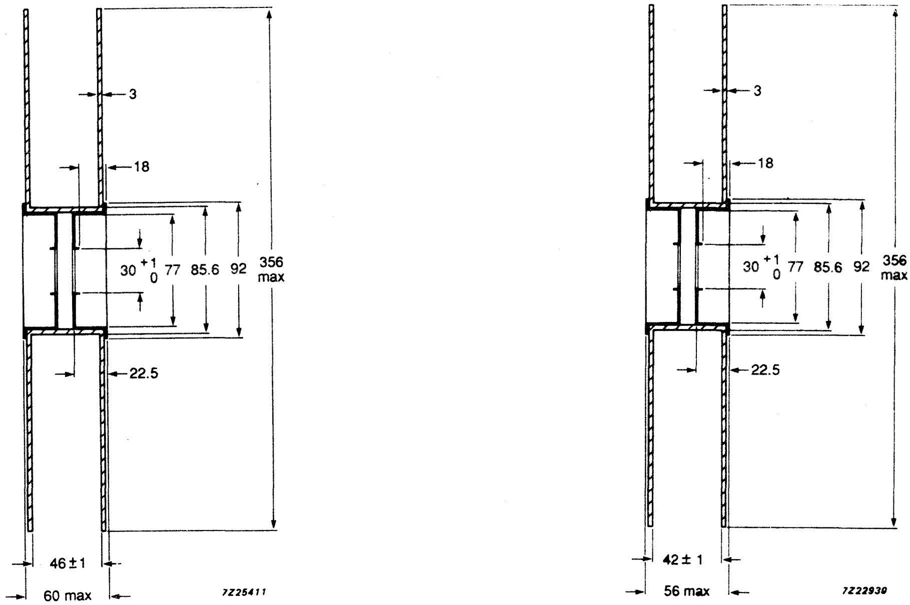


Fig.6 Dimensions of reels.

Table 4 Varistors available on tape in 'ammopack'

	2322 592 (ϕ 7 mm)		2322 593 (ϕ 10 mm)	
	14 V to 175 V	230 V to 460 V	14 V to 175 V	230 V to 460 V
packing quantity	1500	1000	1500	1000
straight leads; H = 20 (see Fig.2)	0 . . . 7	0 . . . 7	0 . . . 7	0 . . . 7
straight leads with flange; H_0 = 16 (see Fig.3)	1 . . . 7	1 . . . 7	1 . . . 7	1 . . . 7
straight leads with flange; H_0 = 18.25 (see Fig.3)	2 . . . 7	2 . . . 7	2 . . . 7	2 . . . 7
kinked leads; H_0 = 18.25 (see Fig.4)	3 . . . 7	3 . . . 7	3 . . . 7	3 . . . 7
kinked leads; H_0 = 16 (see Fig.4)	8 . . . 7	8 . . . 7	8 . . . 7	8 . . . 7

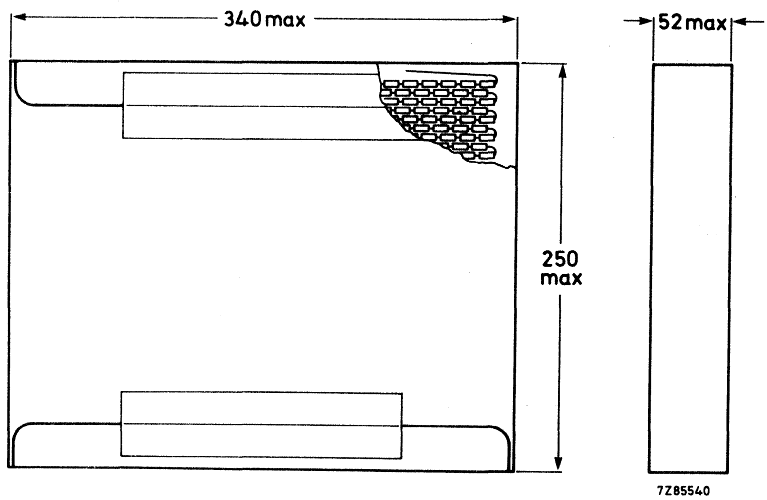


Fig.7 Dimensions of 'ammopack'.

Table 5 Varistors available in bulk

	2322 592 (ϕ 7 mm) 14 - 460 V	2322 593 (ϕ 10 mm) 14 - 460 V	2322 594 (ϕ 13.5 mm) 14 - 550 V	2322 595 (ϕ 17 mm) 14 - 550 V
packing quantity	250	250	250	100/250
straight leads; (see Fig.1)	5 . . . 6	5 . . . 6	5 . . . 6	5 . . . 6
straight leads with flange; (see Fig.1)	7 . . . 6	7 . . . 6		
kinked leads; (see Fig.1)	6 . . . 6	6 . . . 6		

ELECTRICAL DATA

Climatic category	40/125/56
Maximum continuous voltage	
RMS	14 to 550 V
DC	18 to 745 V
Maximum withstanding surge current (8 x 20 μs)	
2322 592	100 or 400 A
2322 593	250 or 1200 A
2322 594	500 or 2500 A
2322 595	1000 or 4500 A
Temperature coefficient of voltage at 1 mA max.	–0.065 %/K
Insulation voltage	2500 V

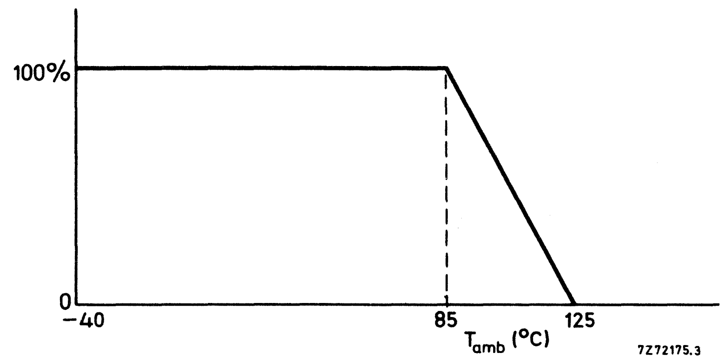


Fig.8 Derating curve.

Table 6 Electrical parameters

catalogue number 2322 . . . . followed by	maximum continuous voltage		voltage at 1 mA (note 2)		maximum voltage at stated current (8 x 20 μs) (note 3)		maximum energy (10 x 1000 μs) (note 4)	maximum non-repetitive surge current (8 x 20 μs)	typical capacitance at 1 kHz	maximum thickness
	V (RMS) (note 1)	V (DC)	V (min.)	V (max.)	V	A	J	A	pF	T (mm)
592 . 140 6	14	18	20	24	48	1	0.5	100	1300	4.5
593 . 140 6					43	2.5	1.7	250	2800	4.6
594 . 140 6					43	5	4.3	500	6000	4.7
595 . 140 6					43	10	5.4	1000	15000	4.7
592 . 170 6	17	22	24	30	60	1	0.7	100	1050	4.5
593 . 170 6					53	2.5	2.0	250	2000	4.7
594 . 170 6					53	5	5.3	500	4000	4.8
595 . 170 6					53	10	6.9	1000	10000	4.8
592 . 200 6	20	26	30	36	73	1	0.8	100	900	4.5
593 . 200 6					65	2.5	2.5	250	1500	4.9
594 . 200 6					65	5	6.5	500	3000	5.0
595 . 200 6					65	10	8.8	1000	7500	5.0
592 . 250 6	25	31	35	43	86	1	0.9	100	500	4.5
593 . 250 6					77	2.5	3.0	250	1350	4.9
594 . 250 6					77	5	7.7	500	2600	5.1
595 . 250 6					77	10	9.4	1000	6500	5.1
592 . 300 6	30	38	42	52	96	1	1.1	100	700	4.1
593 . 300 6					93	2.5	3.6	250	1600	4.1
594 . 300 6					93	5	9.2	500	2700	4.4
595 . 300 6					90	10	12	1000	6000	4.4
592 . 350 6	35	45	50	62	123	1	1.4	100	560	4.1
593 . 350 6					115	2.5	4.4	250	1300	4.1
594 . 350 6					110	5	11	500	2200	4.4
595 . 350 6					105	10	14	1000	4800	4.4
592 . 400 6	40	56	61	75	145	1	1.6	100	460	4.1
593 . 400 6					135	2.5	5.2	250	1000	4.1
594 . 400 6					130	5	13	500	1800	4.4
595 . 400 6					130	10	17	1000	3800	4.4

Replace last digit of catalogue number with a '7' for ordering on tape in ammopack (592, 593 series only).

catalogue number 2322 . . . . followed by	maximum continuous voltage		voltage at 1 mA (note 2)		maximum voltage at stated current (8 x 20 μs) (note 3)		maximum energy (10 x 1000 μs) (note 4)	maximum non-repetitive surge current (8 x 20 μs)	typical capacitance at 1 kHz	maximum thickness
	V (RMS) (note 1)	V (DC)	V (min.)	V (max.)	V	A	J	A	pF	T (mm)
592 . 500 6	50	65	74	90	145	5	2.6	400	370	4.1
593 . 500 6					140	10	7.0	1200	900	4.1
594 . 500 6					140	25	12	2500	1500	4.4
595 . 500 6					140	50	21	4500	3100	4.4
592 . 600 6 *	60	85	90	110	165	5	2.9	400	290	4.1
593 . 600 6 *					165	10	8.3	1200	700	4.1
594 . 600 6 *					165	25	15	2500	1200	4.4
595 . 600 6 *					165	50	24	4500	2300	4.4
592 . 750 6 *	75	100	108	132	190	5	3.4	400	240	4.1
593 . 750 6 *					200	10	10	1200	530	4.1
594 . 750 6 *					200	25	18	2500	1000	4.4
595 . 750 6 *					200	50	29	4500	1900	4.4
592 . 950 6 *	95	125	135	165	230	5	4.1	400	180	4.1
593 . 950 6 *					250	10	13	1200	450	4.1
594 . 950 6 *					250	25	22	2500	800	4.4
595 . 950 6 *					250	50	37	4500	1500	4.4
592 . 131 6 *	130	170	185	225	310	5	5.5	400	130	4.1
593 . 131 6 *					340	10	17	1200	320	4.1
594 . 131 6 *					340	25	30	2500	580	4.6
595 . 131 6 *					340	50	56	4500	1050	4.6
592 . 141 6	140	180	192	242	350	5	6.3	400	120	4.4
593 . 141 6					370	10	21	1200	290	4.4
594 . 141 6					370	25	33	2500	540	4.8
595 . 141 6					370	50	57	4500	950	4.8
592 . 151 6 *	150	200	216	264	395	5	7.1	400	110	4.4
593 . 151 6 *					400	10	20	1200	270	4.4
594 . 151 6 *					400	25	36	2500	490	4.8
595 . 151 6 *					400	50	59	4500	850	4.8

Replace last digit of catalogue number with a '7' for ordering on tape in ammopack (592, 593 series only).
*CECC approved types

catalogue number 2322 . . . . followed by V	maximum continuous voltage V (RMS) (note 1)	maximum continuous voltage V (DC)	voltage at 1 mA (note 2) V (min.)	voltage at 1 mA (note 2) V (max.)	maximum voltage at stated current (8 x 20 μs) (note 3) V	maximum voltage at stated current (8 x 20 μs) (note 3) A	maximum energy (10 x 1000 μs) (note 4) J	maximum non-repetitive surge current (8 x 20 μs) A	typical capacitance at 1 kHz pF	maximum thickness T (mm)
592 . 171 6 *	175	225	247	303	410	5	7.3	400	90	4.6
593 . 171 6 *					455	10	23	1200	230	4.6
594 . 171 6 *					455	25	41	2500	430	5.0
595 . 171 6 *					455	50	67	4500	750	5.0
592 . 231 6 *	230	300	324	396	560	5	10	400	70	4.9
593 . 231 6 *					600	10	30	1200	170	4.9
594 . 231 6 *					600	25	54	2500	320	5.4
595 . 231 6 *					600	50	88	4500	540	5.4
592 . 251 6 *	250	320	351	429	600	5	11	400	60	4.9
593 . 251 6 *					650	10	33	1200	160	4.9
594 . 251 6 *					650	25	58	2500	300	5.4
595 . 251 6 *					650	50	96	4500	480	5.4
592 . 271 6 *	275	350	387	473	695	5	12	400	55	4.9
593 . 271 6 *					710	10	36	1200	140	4.9
594 . 271 6 *					710	25	63	2500	270	5.4
595 . 271 6 *					710	50	104	4500	440	5.4
592 . 301 6 *	300	385	423	517	750	5	13	400	50	5.3
593 . 301 6 *					800	10	40	1200	130	5.3
594 . 301 6 *					800	25	71	2500	240	5.9
595 . 301 6 *					800	50	117	4500	400	5.9
592 . 321 6	320	420	459	561	800	5	15	400	45	5.5
593 . 321 6					850	10	44	1200	120	5.5
594 . 321 6					850	25	77	2500	220	6.2
595 . 321 6					850	50	120	4500	370	6.2
592 . 381 6	385	505	558	682	1000	5	18	400	40	5.8
593 . 381 6					1025	10	51	1200	95	5.8
594 . 381 6					1025	25	67	2500	180	6.6
595 . 381 6					1025	50	110	4500	280	6.6

Replace last digit of catalogue number with a '7' for ordering on tape in ammopack (592, 593 series only).

*CECC approved types

Table 6 (continued)

catalogue number 2322 . . . . followed by	maximum continuous voltage		voltage at 1 mA (note 2)		maximum voltage at stated current (8 x 20 μs) (note 3)		maximum energy (10 x 1000 μs) (note 4)	maximum non-repetitive surge current (8 x 20 μs)	typical capacitance at 1 kHz	maximum thickness
	V (RMS) (note 1)	V (DC)	V (min.)	V (max.)	V	A	J	A	pF	T (mm)
592 . 421 6 *	420	560	612	748	1100	5	20	400	35	5.9
593 . 421 6 *					1120	10	56	1200	85	5.9
594 . 421 6 *					1120	25	73	2500	165	6.6
595 . 421 6 *					1120	50	120	4500	250	6.6
592 . 461 6 *	460	615	675	825	1200	5	21	400	30	6.0
593 . 461 6 *					1240	10	63	1200	75	6.0
594 . 461 6 *					1240	25	82	2500	150	6.6
595 . 461 6 *					1240	50	135	4500	225	6.6
594 . 511 6	510	670	738	902	1355	25	89	2500	135	6.9
595 . 511 6					1355	50	145	4500	220	6.9
594 . 551 6	550	745	819	1001	1500	25	98	2500	120	7.0
595 . 551 6					1500	50	160	4500	180	7.0

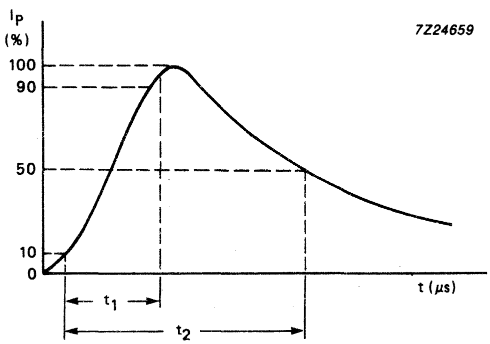
Replace last digit of catalogue number with a '7' for ordering on tape in ammopack (592, 593 series only).
*CECC approved types

Notes to Table 6

1. The sinusoidal voltage is assumed as the normal operating condition. If a non-sinusoidal voltage is present, type selection should be based on multiplying the peak voltage by a factor of 0.707.
2. The voltage measured at 1 mA meets the requirements of para. 4.3 of CECC specification 42 000.
3. A current wave of 8 x 20 μs (requirement of para. B.2.10.1 of CECC specification 42 000) is used as a standard for impulse current and clamping voltage ratings. The maximum non-repetitive surge current is given for one impulse applied during the life of the component.
4. High energy surges are generally of longer duration. The maximum energy for one impulse of 10 x 1000 μs is given as a reference for long duration impulses. This impulse can be characterised by peak current (I_p) and impulse width t_2 (virtual time of half I_p value, following IEC 60-2, Section 6). If V_p is the clamping voltage corresponding to I_p, the energy absorbed in the VDR is determined by the formula:

   $$E = K \cdot V_p \cdot I_p \cdot t_2$$

   K is dependent on the value of t_2 when the value of t_1 is between 8 and 10 μs (see Fig.9).



t_2 (μs)	K
20	1
50	1.2
100	1.3
1000	1.4

Fig.9 Peak current (I_p) as a function of impulse width (t_2).

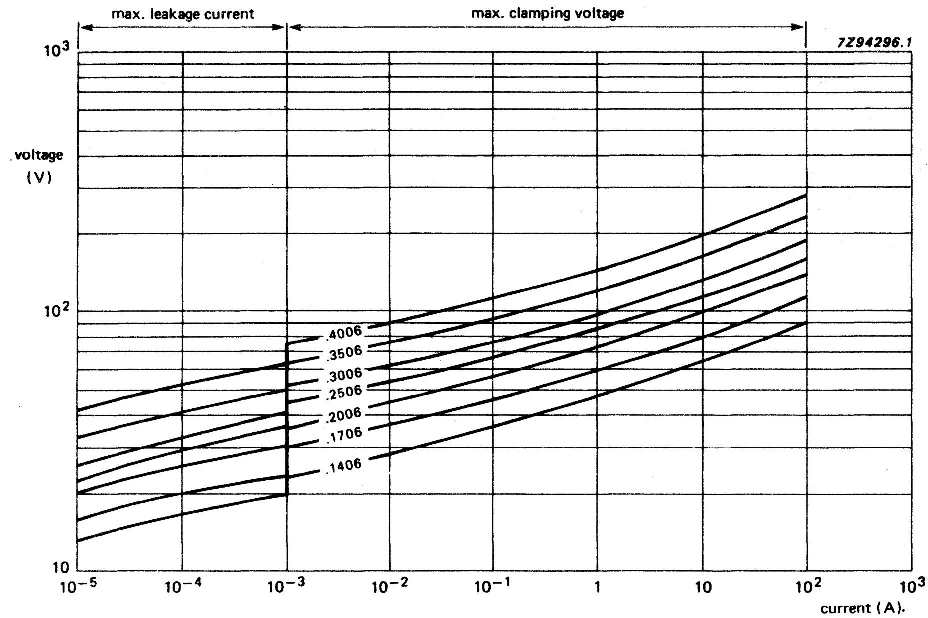


Fig.10 V/I characteristics, 14/40 V; 2322 592 series.

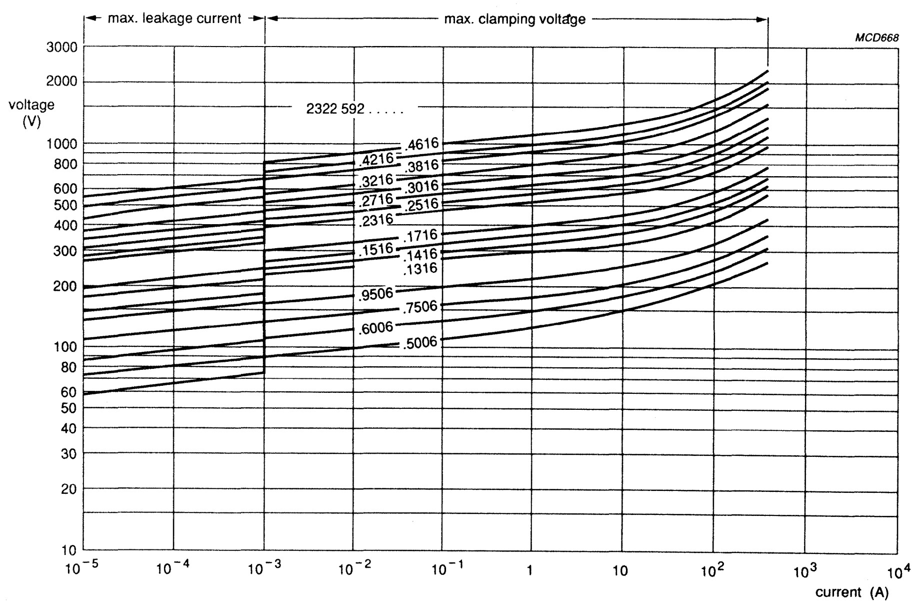


Fig.11 V/I characteristics, 50/460 V; 2322 592 series.

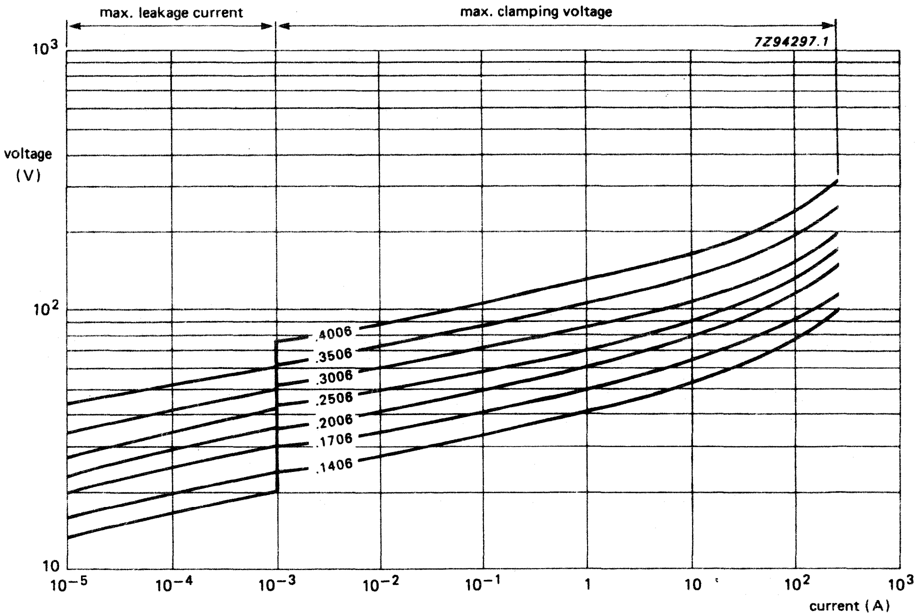


Fig.12 V/I characteristics, 14/40 V; 2322 593 series.

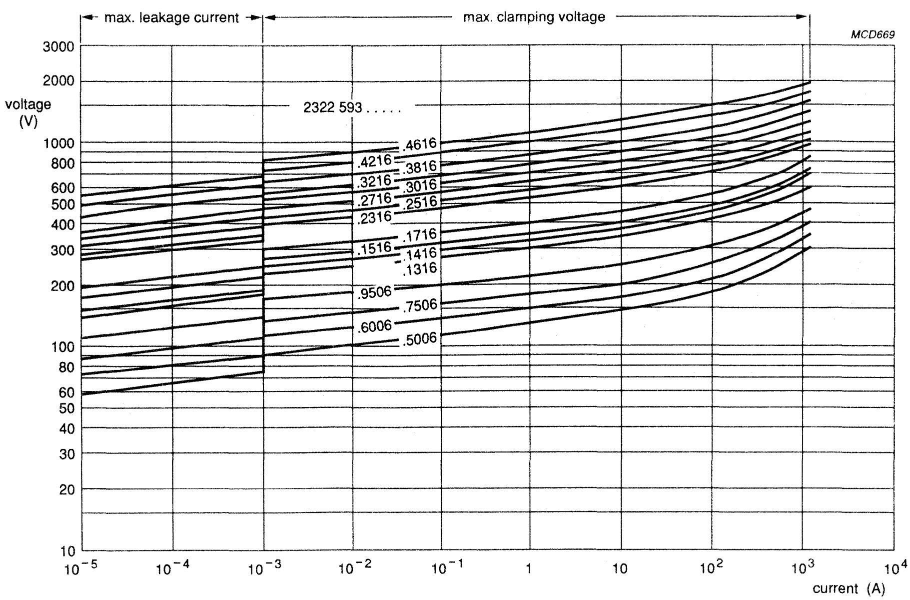


Fig.13 V/I characteristics, 50/460 V; 2322 593 series.

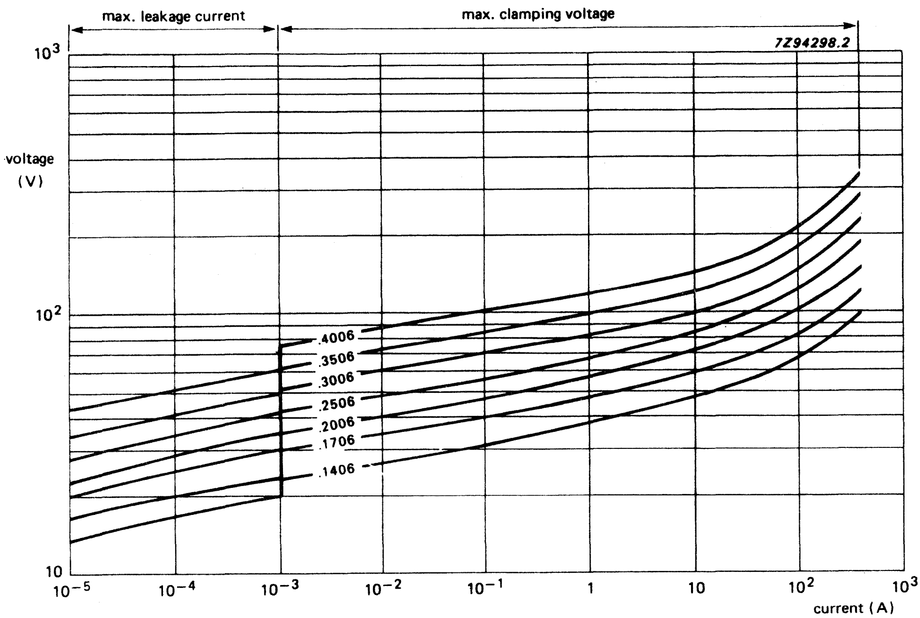


Fig.14 V/I characteristics, 14/40 V; 2322 594 series.

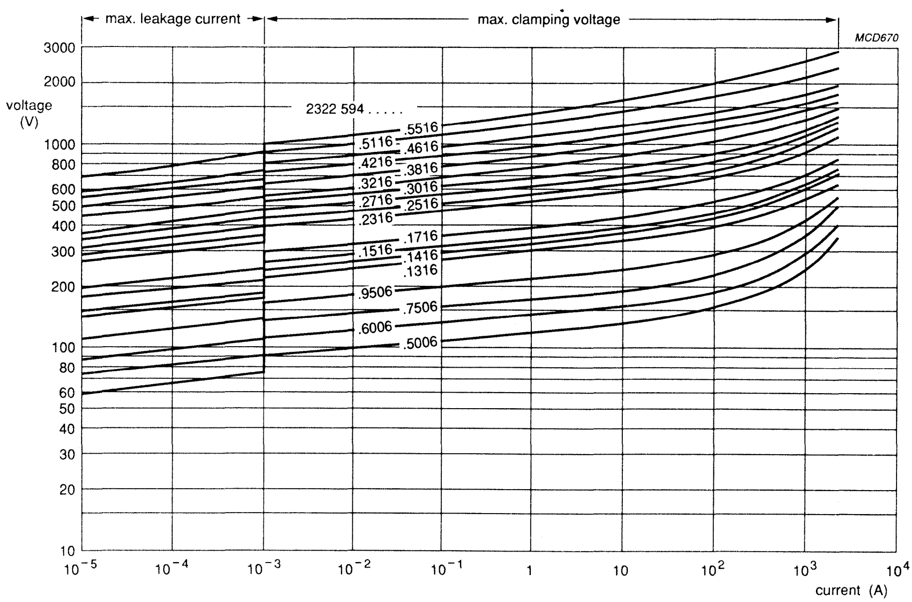


Fig.15 V/I characteristics, 50/550 V; 2322 594 series.

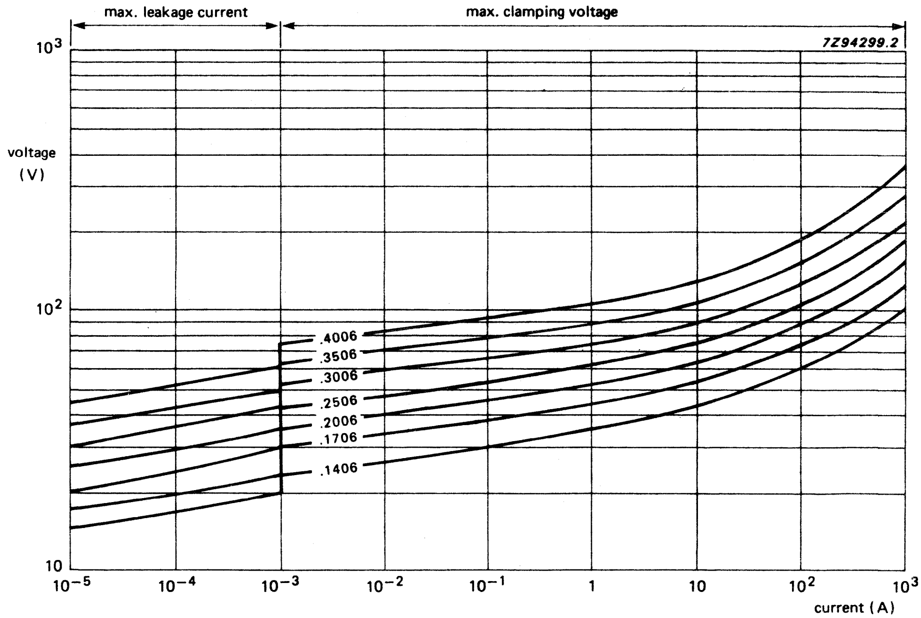


Fig.16 V/I characteristics, 14/40 V; 2322 595 series.

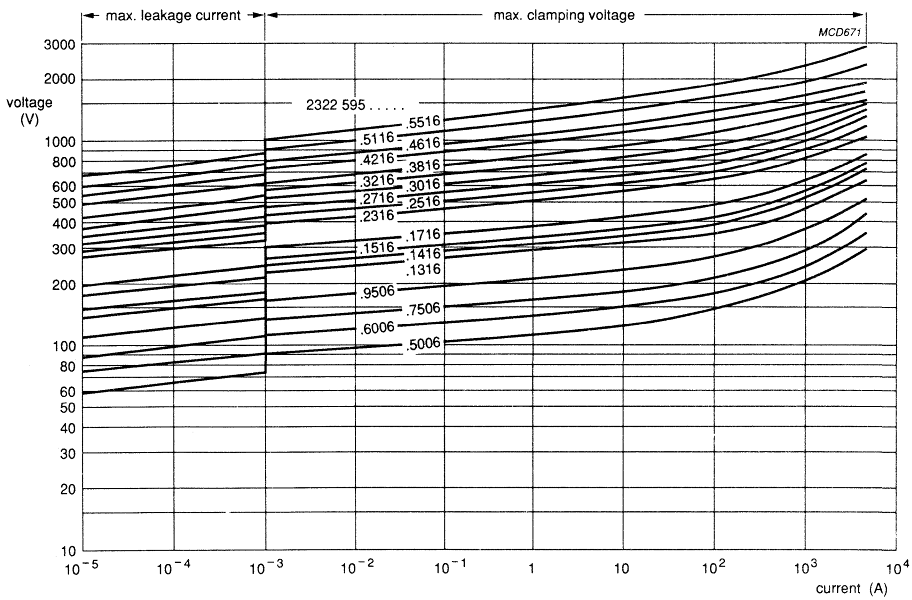


Fig.17 V/I characteristics, 50/550 V; 2322 595 series.

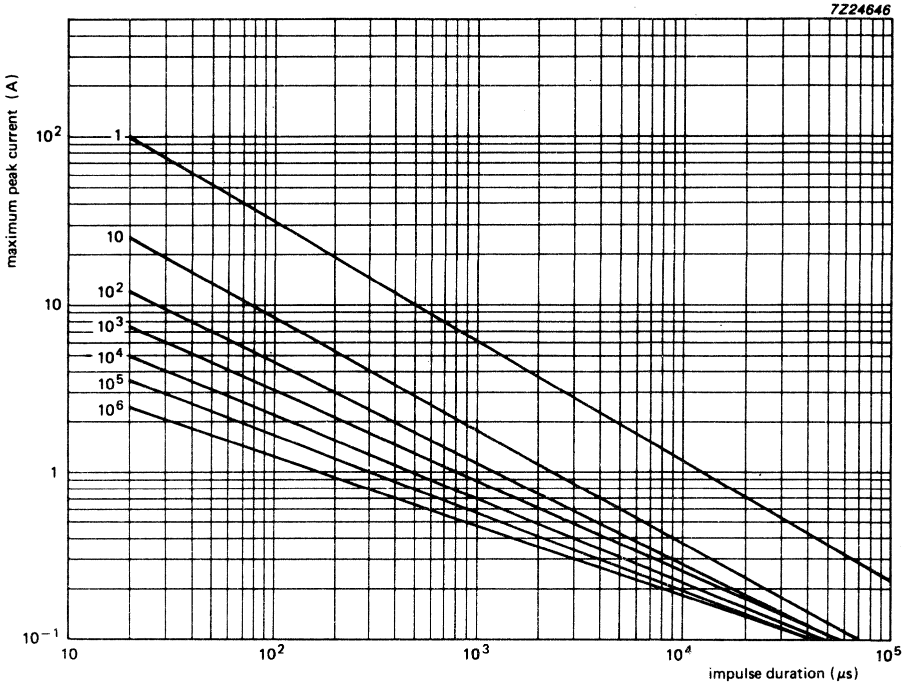


Fig.18 Maximum applicable transient current as a function of impulse duration, 14/40 V; 2322 592 series.

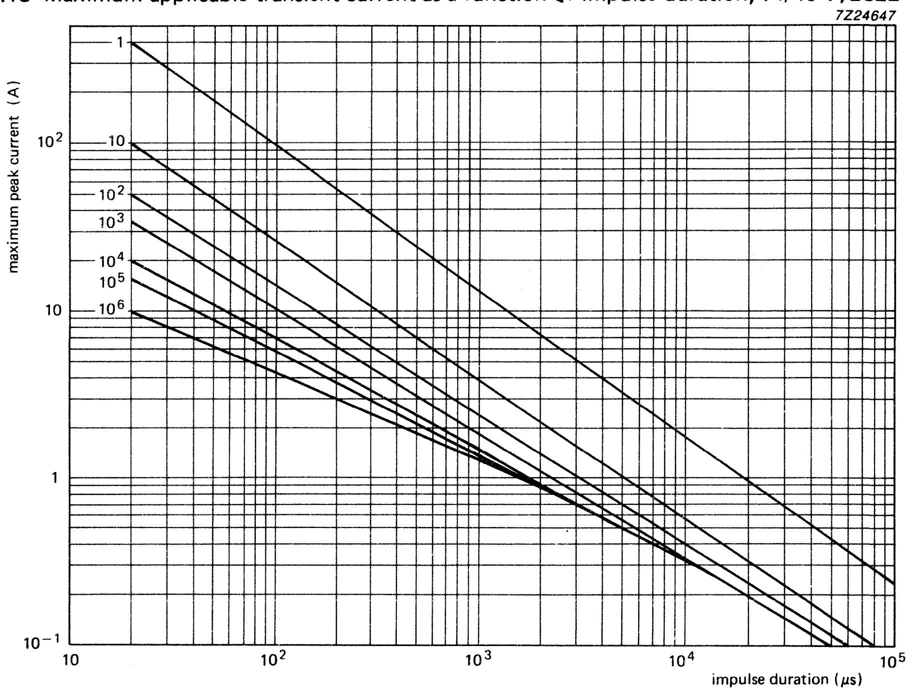


Fig 19 Maximum applicable transient current as a function of impulse duration, 50/460 V; 2322 592 series.

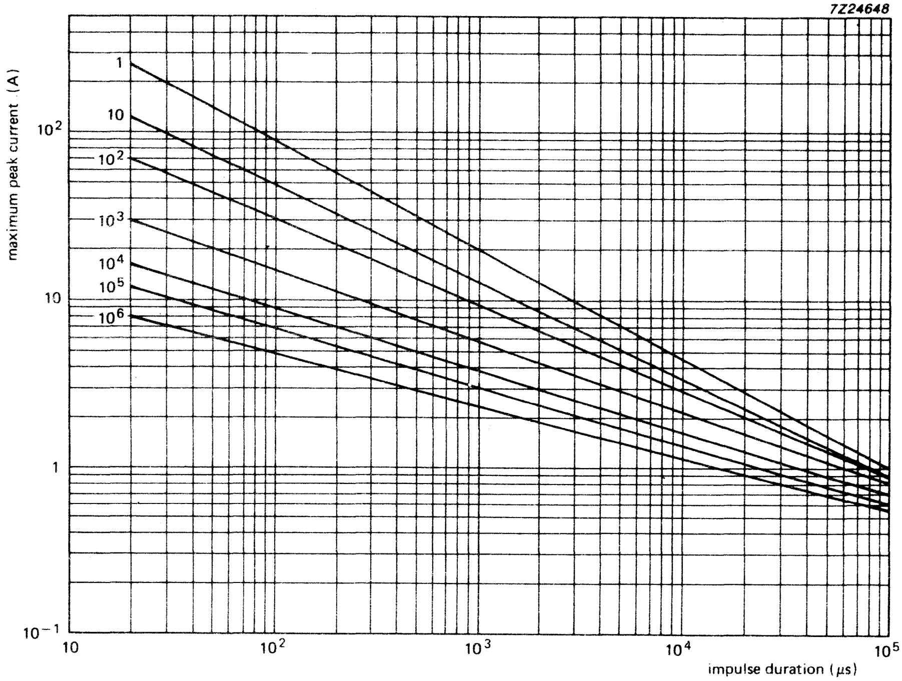


Fig.20 Maximum applicable transient current as a function of impulse duration, 14/40 V; 2322 593 series.

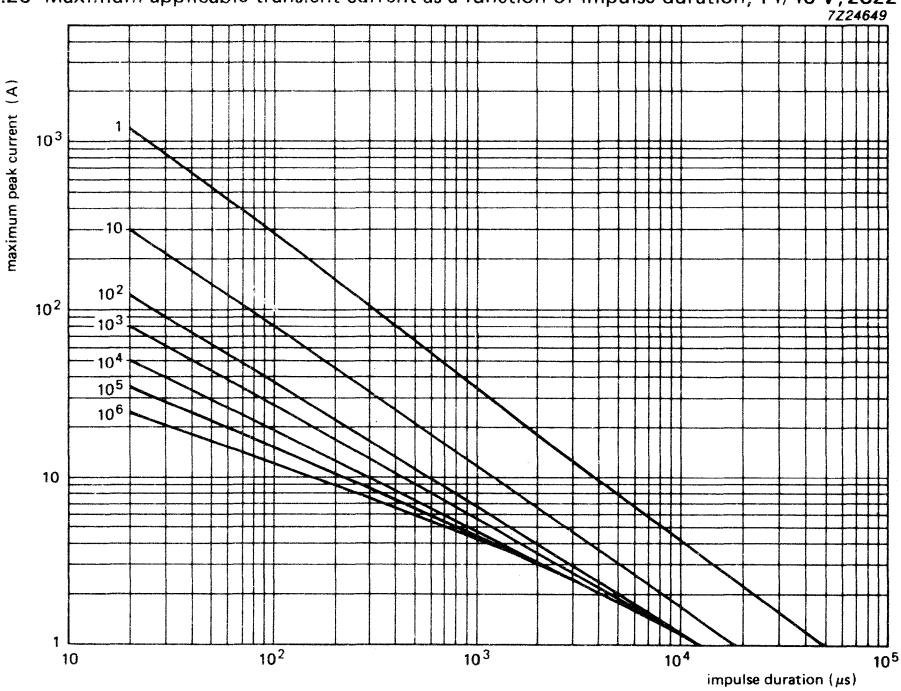


Fig.21 Maximum applicable transient current as a function of impulse duration, 50/460 V; 2322 593 series.

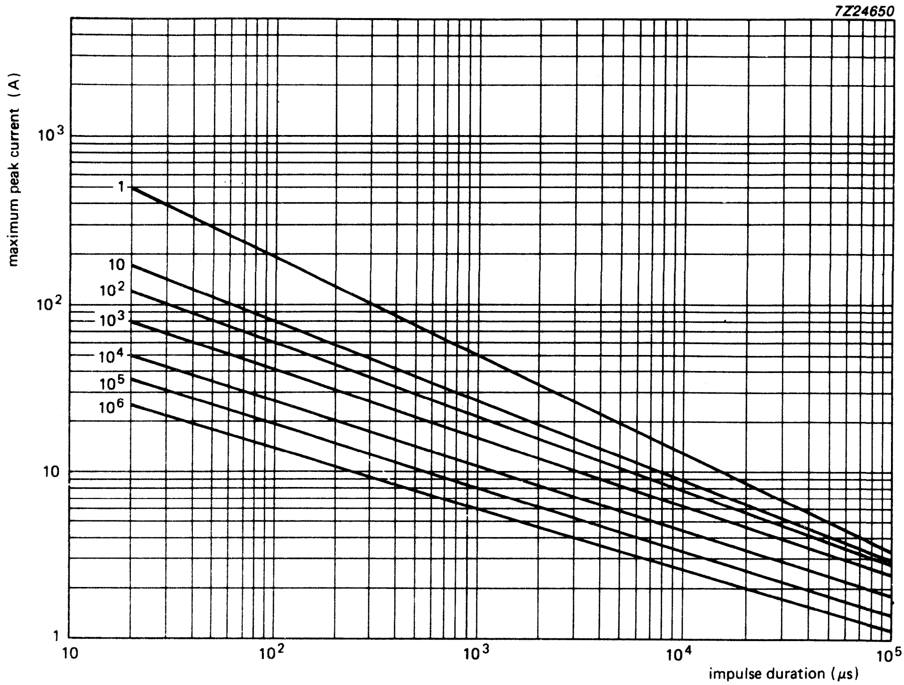


Fig.22 Maximum applicable transient current as a function of impulse duration, 14/40 V; 2322 594 series.

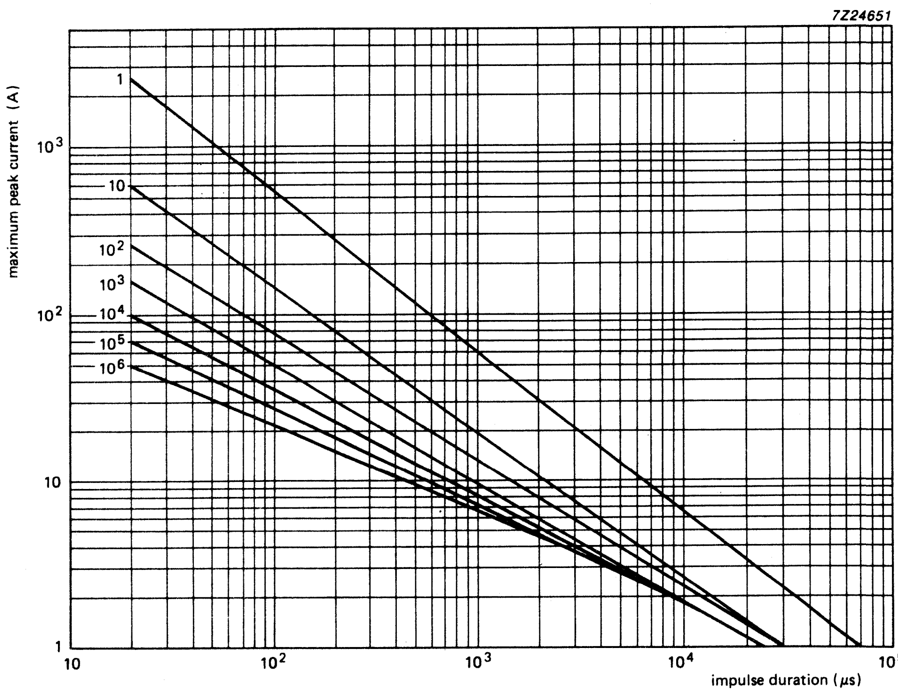


Fig.23 Maximum applicable transient current as a function of impulse duration, 50/300 V; 2322 594 series.

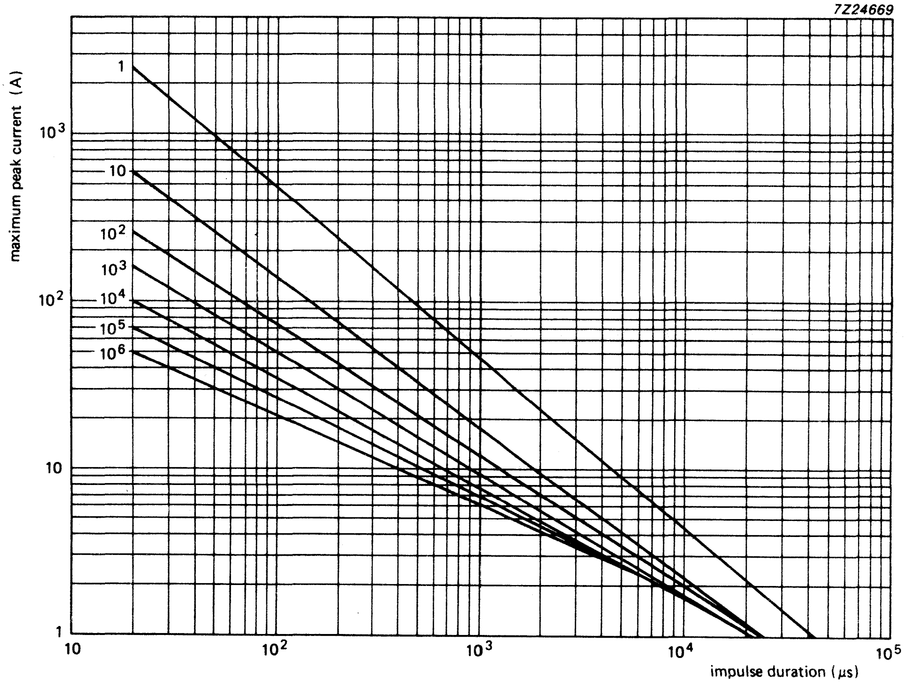


Fig.24 Maximum applicable transient current as a function of impulse duration, 385/550 V; 2322 594 series.

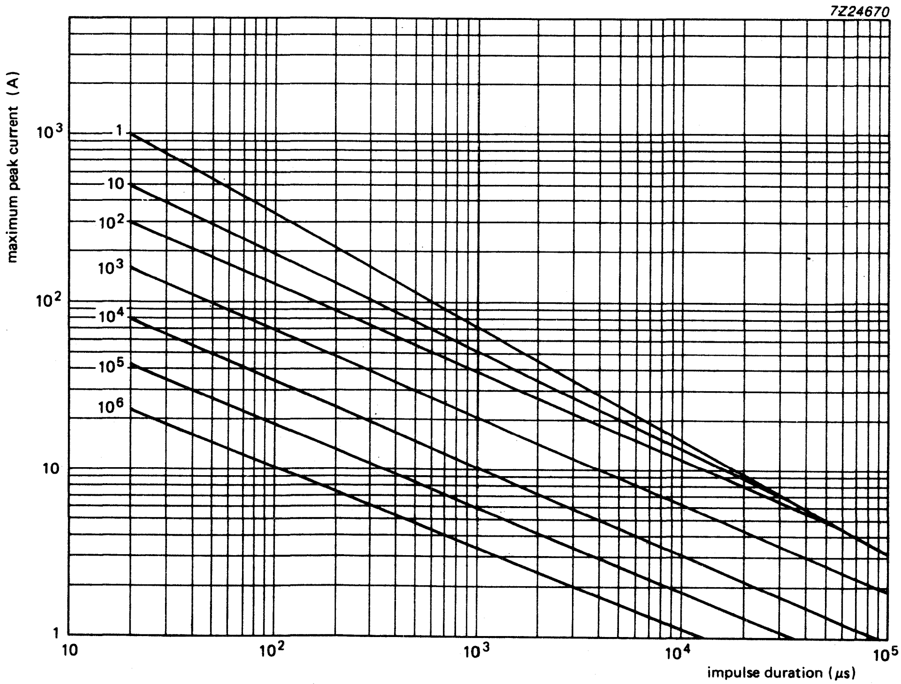


Fig.25 Maximum applicable transient current as a function of impulse duration, 14/40 V; 2322 595 series.

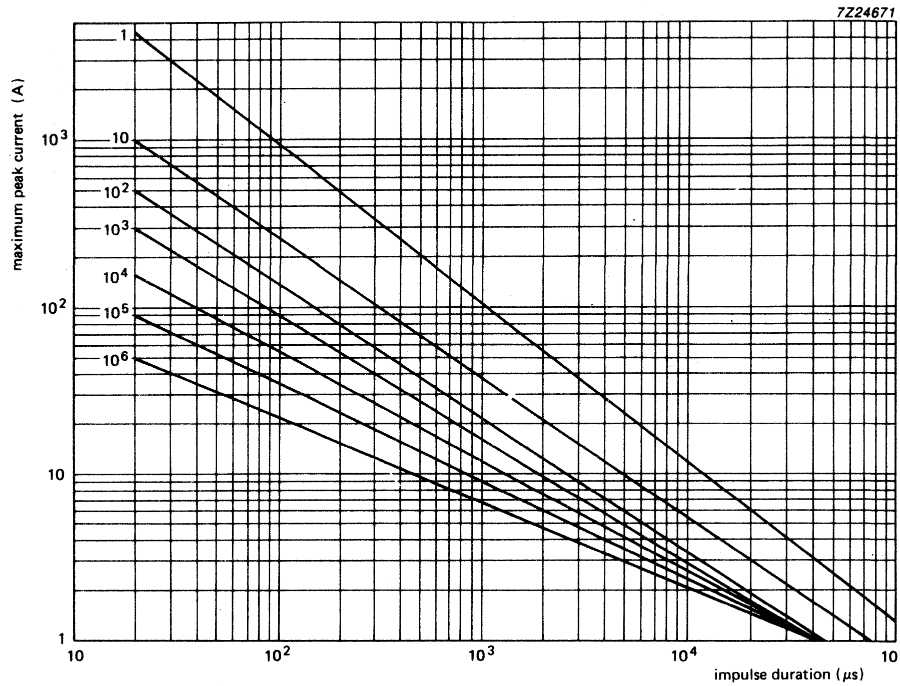


Fig.26 Maximum applicable transient current as a function of impulse duration, 50/300 V; 2322 595 series.

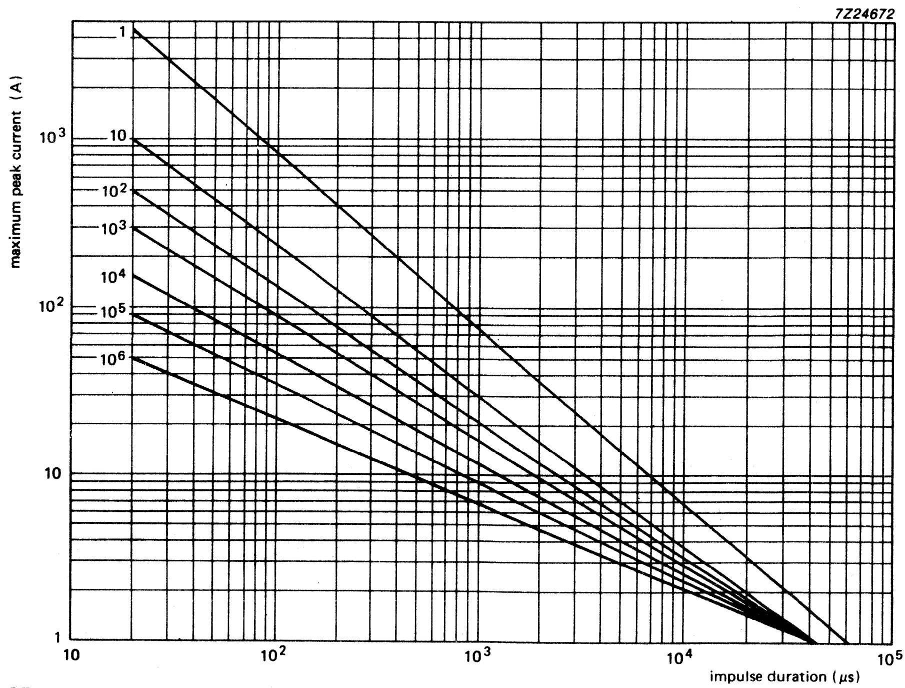


Fig.27 Maximum applicable transient current as a function of impulse duration, 385/550 V; 2322 595 series.

HUMIDITY SENSOR

HUMIDITY SENSOR

QUICK REFERENCE DATA

Humidity range	10 to 90% R.H.
Capacitance at +25 °C, 43% R.H. and 100 kHz	122 pF ± 15%
Sensitivity between 12 and 75% R.H.	0,4 ± 0,05 pF/% R.H.
Frequency range	1 kHz to 1 MHz
Maximum AC or DC voltage	15 V
Storage humidity range	0 to 100% R.H.
Ambient temperature range	
Operating	0 to +85 °C
Storage	−25 to +85 °C

APPLICATION

For humidity measurements in electronic hygrometers for domestic use, self-regulating air humidifiers, etc.

DESCRIPTION

This capacitive atmospheric humidity sensor consists of a non-conductive foil, which is covered on both sides with a layer of gold. The dielectric constant of the foil changes as a function of the relative humidity of the ambient atmosphere and, accordingly, the capacitance value of the sensor is a measure for relative humidity. The foil is clamped between contact springs and assembled in a plastic housing. It is provided with two connecting pins fitting printed-wiring boards with a grid pitch of 2,54 mm, provision is also made for fastening with 3 mm bolts. The characteristics are not affected by an incidental condensation of water on the sensor foil. It should not be exposed to acetone vapour, nor to chlorine vapours.

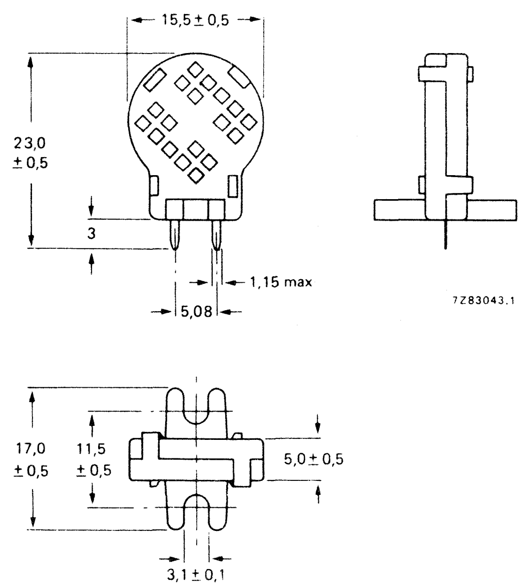


Fig. 1 Dimensions in mm.

MECHANICAL DATA

Outlines

See Fig. 1

Marking	PHILIPS H1
Mass	1,3 g approximately

Mounting

The item can be soldered directly onto a printed-wiring board or can be fastened with 3 mm bolts.

Soldering	
Solderability	max. 240 °C, max. 4 s
Resistance to heat	max. 240 °C, max. 4 s
Robustness of terminations	
Tensile strength	10 N
Impact	
Free fall	1 m
Inflammability	uninflammable

ELECTRICAL DATA

Humidity range	10 to 90% R.H.
Capacitance at +25 °C. 43% R.H., 100 kHz	122 pF ± 15%
Tan δ at +25 °C, 100 kHz and 43% R.H.	$\leqslant$ 0.035
Sensitivity between 12 and 75% R.H.	0,4 ± 0,05 pF/% R.H.
Frequency range	1 kHz to 1 MHz
Temperature dependence	0,1% R.H./K
Response time (to 90% of indicated R.H. change at +25 °C, in circulating air)	
between 10 and 43% R.H.	< 3 min.
between 43 and 90% R.H.	< 5 min.
Hysteresis (for R.H. excursion of 10 to 90 to 10%)	3% approximately
Maximum a.c. or d.c. voltage	15 V
Storage humidity range	0 to 100% R.H.
Ambient temperature range	
Operating	0 to +85 °C
Storage	−25 to +85 °C

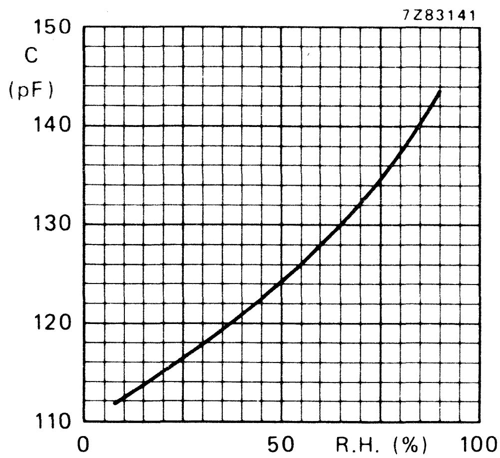


Fig. 2 Typical capacitance/relative humidity characteristic.

QUALITY LEVEL

Sampling and data evaluation for quality level according to MIL-STD-105D.

A.Q.L. 0,25% – Inoperatives
A.Q.L. 1% – Electrical
A.Q.L. 1,5% – Mechanical

PACKAGING

500 pieces per box.

NOTES

DATA HANDBOOK SYSTEM

Data handbook system

INTRODUCTION

Our data handbook system comprises more than 65 books with subjects including electronic components, subassemblies and magnetic products. The handbooks are classified into seven series:

INTEGRATED CIRCUITS;
DISCRETE SEMICONDUCTORS;
DISPLAY COMPONENTS;
PASSIVE COMPONENTS;
PROFESSIONAL COMPONENTS;
MAGNETIC PRODUCTS;
LIQUID CRYSTAL DISPLAYS.

Data handbooks contain all pertinent data available at the time of publication and each is revised and reissued regularly.

Loose data sheets are sent to subscribers to keep them up-to-date on additions or alterations made during the lifetime of a data handbook.

Catalogues are available for selected product ranges (some catalogues are also on floppy discs).

For more information about data handbooks, catalogues and subscriptions, contact one of the organizations listed on the back cover of this handbook. Product specialists are at your service and enquiries are answered promptly.

INTEGRATED CIRCUITS

IC01	Semiconductors for Radio and Audio Systems
IC02	Semiconductors for Television and Video Systems
IC03	Semiconductors for Telecom Systems
IC04	CMOS HE4000B Logic Family
IC05	Advanced Low-power Schottky (ALS) Logic Series
IC06	High-speed CMOS Logic Family
IC08	ECL 100K ECL Logic Family
IC10	Memories
IC11	General Purpose/Linear ICs
IC12	Display Drivers and Microcontroller Peripherals

INTEGRATED CIRCUITS (continued)

IC13	Programmable Logic Devices (PLD)
IC14	8048-based 8-bit Microcontrollers
IC15	FAST TTL Logic Series
IC16	ICs for Clocks and Watches
IC18	Semiconductors for In-Car Electronics and General Industrial Applications
IC19	Semiconductors for Datacom: LANs, UARTs, Multi-Protocol Controllers and Fibre Optics
IC20	8051-based 8-bit Microcontrollers
IC21	68000-based 16-bit Microcontrollers
IC22	ICs for Multi-Media Systems
IC23	QUBIC Advanced BiCMOS Interface Logic ABT, MULTIBYTE™
IC24	Low Voltage CMOS Logic

DISCRETE SEMICONDUCTORS

SC01	Diodes
SC02	Power Diodes
SC03	Thyristors and Triacs
SC04	Small Signal Transistors
SC05	Low-frequency Power Transistors and Hybrid IC Power Modules
SC06	High-voltage and Switching Power Transistors
SC07	Small-signal Field-effect Transistors
SC08a	RF Power Bipolar Transistors
SC08b	RF Power MOS Transistors
SC09	RF Power Modules
SC10	Surface Mounted Semiconductors
SC12	Optocouplers
SC13	PowerMOS Transistors
SC14	Wideband Transistors and Wideband Hybrid IC Modules
SC15	Microwave Transistors
SC16	Wideband Hybrid IC Modules
SC17	Semiconductor Sensors

Data handbook system

DISPLAY COMPONENTS

DC01	Colour Display Components Colour TV Picture Tubes and Assemblies Colour Monitor Tube Assemblies
DC02	Monochrome Monitor Tubes and Deflection Units
DC03	Television Tuners, Coaxial Aerial Input Assemblies
DC04	Loudspeakers
DC05	Flyback Transformers, Mains Transformers and General-purpose FXC Assemblies

PASSIVE COMPONENTS

PA01	Electrolytic Capacitors
PA02	Varistors, Thermistors and Sensors
PA03	Potentiometers and Switches
PA04	Variable Capacitors
PA05	Film Capacitors
PA06	Ceramic Capacitors
PA07	Quartz Crystals for Special and Industrial Applications
PA08	Fixed Resistors
PA10	Quartz Crystals for Automotive and Standard Applications
PA11	Quartz Oscillators

PROFESSIONAL COMPONENTS

PC01	High-power Klystrons and Accessories
PC02	Cathode-ray Tubes
PC03	Geiger-Müller Tubes
PC04	Photo Multipliers
PC05	Plumbicon Camera Tubes and Accessories
PC06	Circulators and Isolators
PC07	Vidicon and Newvicon Camera Tubes and Deflection Units
PC08	Image Intensifiers
PC09	Dry-reed Switches
PC11	Solid-state Image Sensors and Peripheral Integrated Circuits
PC12	Electron Multipliers

MAGNETIC PRODUCTS

MA01	Soft Ferrites
MA02	Permanent Magnets
MA03	Piezoelectric Ceramics

LIQUID CRYSTAL DISPLAYS

LCD01	Liquid Crystal Displays and Driver ICs for LCDs

Philips Components – a worldwide company

Argentina: PHILIPS ARGENTINA S.A., Div. Philips Components, Vedia 3892, 1430 BUENOS AIRES, Tel. (01) 541-4261.
Australia: PHILIPS COMPONENTS PTY Ltd, 34 Waterloo Road, NORTH RYDE NSW 2113, Tel. (02) 805 4455. Fax. (02) 805 4466.
Austria: ÖSTERREICHISCHE PHILIPS INDUSTRIE G.m.b.H., UB Bauelemente, Triester Str. 64, 1101 WIEN, Tel. (0222) 60 101-820.
Belgium: N.V PHILIPS PROF. SYSTEMS – Components Div., 80 Rue Des Deux Gares, B-1070 BRUXELLES, Tel. (02) 52 56 111.
Brazil: PHILIPS COMPONENTS, Av. Francisco Monteiro 702, RIBEIRAO PIRES-SP, CEP 09400, Tel. (011) 459-8211. Fax. (011) 459-8282.
Canada: PHILIPS ELECTRONICS LTD., Philips Components, 601 Milner Ave., SCARBOROUGH, Ontario, M1B 1M8, Tel. (416) 292-5161.
Chile: PHILIPS CHILENA S.A., Av. Santa Maria 0760, SANTIAGO, Tel. (02) 77 38 16.
Colombia: IPRELENSO LTDA., Carrera 21 No. 56-17, BOGOTA, D.E., P.O. Box 77621, Tel. (01) 249 7624.
Denmark: PHILIPS COMPONENTS A/S, Prags Boulevard 80, P.O. Box 1919, DK-2300 COPENHAGEN S, Tel. 32-88 33 33.
Finland: PHILIPS COMPONENTS, Sinikalliontie 3, SF-2630 ESPOO, Tel. 358-0-50 261.
France: PHILIPS COMPOSANTS, 117 Quai du Président Roosevelt, 92134 ISSY-LES-MOULINEAUX Cedex, Tel. (01) 40 93 80 00, Fax. 01 40 93 83 22.
Germany: PHILIPS COMPONENTS UB der Philips G.m.b.H., Burchardstrasse 19, D-2 HAMBURG 1, Tel. (040) 3296-0, Fax. (040) 329 69 12.
Greece: PHILIPS HELLENIQUE S.A., Components Division, No. 15, 25th March Street, GR 17778 TAVROS, Tel. (01) 4894 339/4894 911.
Hong Kong: PHILIPS HONG KONG LTD., Components Div., 15/F Philips Ind. Bldg., 24-28 Kung Yip St., KWAI CHUNG, Tel. (0)-42 45 121. Fax. (0) 480 69 60.
India: PEICO ELECTRONICS & ELECTRICALS LTD., Components Dept., Shivsagar Estate 'A' Block, P.O. Box 6598, 254-D Dr. Annie Besant Rd., BOMBAY – 40018, Tel. (022) 4921 500-4921 515. Fax. (022) 494 190 63.
Indonesia: P.T. PHILIPS DEVELOPMENT CORPORATION, Philips House, 4th floor, JL. H.R. Rasuna Said Kav. 3-4, P.O. Box 4252, JAKARTA 12950, Tel. (021) 520 11 22, Fax. (021) 520 51 89.
Ireland: PHILIPS ELECTRONICS (IRELAND) LTD., Components Division, Newstead, Clonskeagh, DUBLIN 14, Tel. (01) 69 33 55.
Italy: PHILIPS S.p.A., Philips Components, Piazza IV Novembre 3, I-20124 MILANO, Tel. (02) 6752.1, Fax. (02) 675 226 42.
Japan: PHILIPS JAPAN LTD., Components Division, Philips Bldg 13-37, Kohnan 2-chome, Minato-ku, TOKYO 108, Tel. (03) 813-3740-5030. Fax. 03 813 3740 0570.
Korea (Republic of): PHILIPS ELECTRONICS (KOREA) LTD. Components Division, Philips House, 260-199 Itaewon-dong, Yongsan-ku, SEOUL, Tel. (02) 794-5011.
Malaysia: PHILIPS MALAYSIA SDN BHD, Components Div., 3 Jalan SS15/2A SUBANG, 47500 PETALING JAYA, Tel. (03) 734 5511.
Mexico: PHILIPS COMPONENTS, Paseo Triunfo de la Republica, No 215 Local 5, Cd Juarez CHI HUA HUA 32340 MEXICO Tel. (16) 18-67-01/02.
Netherlands: PHILIPS NEDERLAND B.V., Marktgroep Philips Components, Postbus 90050, 5600 PB EINDHOVEN, Tel. (040) 78 37 49.
New Zealand: PHILIPS NEW ZEALAND LTD., Components Division, 2 Wagener Place, C.P.O. Box 1041, AUCKLAND, Tel. (09) 894-160, Fax. (09) 897-811.
Norway: NORSK A/S PHILIPS, Philips Components, Box 1, Manglerud 0612, OSLO, Tel. (02) 74 80 00.
Pakistan: PHILIPS ELECTRICAL CO. OF PAKISTAN LTD., Philips Markaz, M.A. Jinnah Rd., KARACHI-3, Tel. (021) 72 57 72.
Peru: CADESA, Carretera Central 6.500, LIMA 3, Apartado 5612, Tel. 51-14-35 00 59.
Philippines: PHILIPS SEMICONDUCTORS PHILIPPINES Inc., 106 Valero St. Salcedo Village, P.O. Box 911, MAKATI, Metro MANILA, Tel. (63-2) 810-0161. Fax. 63 2 817 3474.
Portugal: PHILIPS PORTUGUESA S.A.R.L., Av. Eng. Duarte Pacheco 6, 1009 LISBOA Codex, Tel. (019) 68 31 21.
Singapore: PHILIPS SINGAPORE, PTE LTD., Components Div., Lorong 1, Toa Payoh, SINGAPORE 1231, Tel. 35 02 000.
South Africa: S.A. PHILIPS PTY LTD., Components Division, 195-215 Main Road, JOHANNESBURG 2000, P.O. Box 7430, Tel. (011) 470-5434. Fax. (011) 470 54 94.
Spain: PHILIPS COMPONENTS, Balmes 22, 08007 BARCELONA, Tel. (03) 301 63 12. Fax. (03) 301 42 43.
Sweden: PHILIPS COMPONENTS, A.B., Tegeluddsvägen 1, S-11584 STOCKHOLM, Tel. (0)8-78 21 000.
Switzerland: PHILIPS COMPONENTS A.G., Components Dept., Allmendstrasse 140-142, CH-8027 ZÜRICH, Tel. (01) 488 22 11.
Taiwan: PHILIPS TAIWAN LTD., 581 Min Sheng East Road, P.O. Box 22978, TAIPEI 10446, Taiwan, Tel. 886-2-509 76 66. Fax. 886 2 500 58 99.
Thailand: PHILIPS ELECTRICAL CO. OF THAILAND LTD., 283 Silom Road, P.0. Box 961, BANGKOK, Tel. (02) 233-6330-9.
Turkey: TÜRK PHILIPS TICARET A.S., Philips Components, Talatpasa Cad. No. 5, 80640 LEVENT/ISTANBUL, Tel. (01) 179 27 70.
United Kingdom: PHILIPS COMPONENTS LTD., Philips House, Torrington Place, LONDON WC1E 7HD, Tel. (071) 580 6633, Fax. (071) 436 21 96.
United States: (Colour picture tubes – Monochrome & Colour Display Tubes) PHILIPS DISPLAY COMPONENTS COMPANY, 1600 Huron Parkway, P.O. Box 963, ANN ARBOR, Michigan 48106, Tel. 313-996 9400. Fax. 313-761 2886. (Passive Components, Discrete Semiconductors, Materials and Professional Components & LCD) PHILIPS COMPONENTS, Discrete Products Division, 2001 West Blue Heron Blvd., P.O. Box 10330, RIVIERA BEACH, Florida 33404, Tel. (407) 881-3200.
Uruguay: PHILIPS COMPONENTS, Coronel Mora 433, MONTEVIDEO, Tel. (02) 70-4044.
Venezuela: MAGNETICA S.A., Calle 6, Ed. Las Tres Jotas, CARACAS 1074A, App. Post. 78117, Tel. (02) 241 75 09.
Zimbabwe: PHILIPS ELECTRICAL (PVT) LTD., 62 Mutare Road, HARARE, P.O. Box 994, Tel. 47211.

For all other countries apply to: Philips Components, Marketing Communications, P.O. Box 218, 5600 MD EINDHOVEN, The Netherlands, Telex 35000 phtcnl, Fax. +31-40-724825

Printed in The Netherlands Date of release: 05-'92 9398 182 90011

Philips Components

PHILIPS

PHILI

ELE
BUS
UNI
DAT