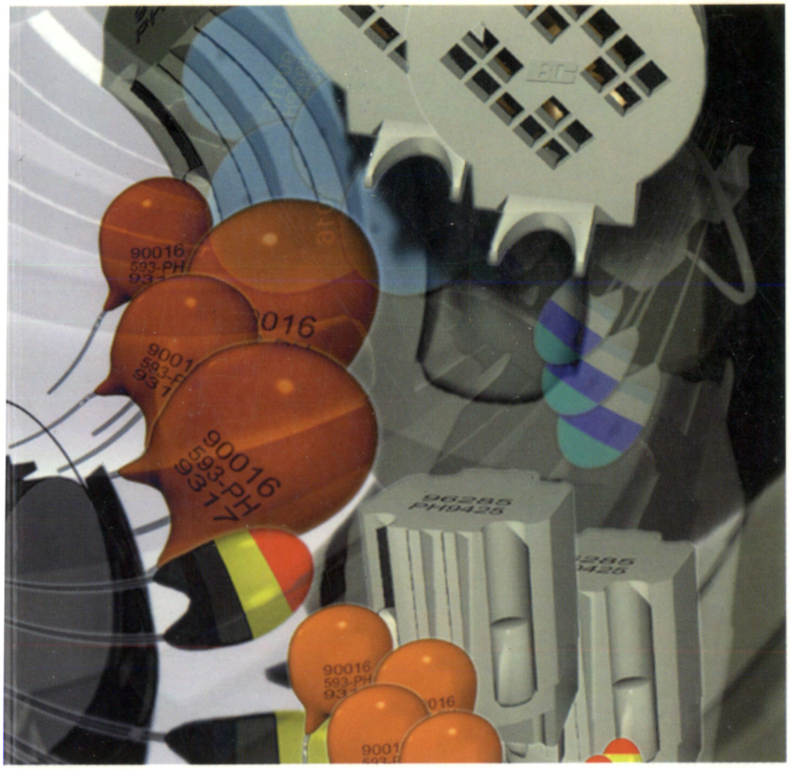

Varistors, Thermistors and Sensors

Data Handbook BC02
1999

BEYSCHLAG
CENTRALAB
COMPONENTS

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.

NOTICE

By 1 January 1999 BC Components was set up as an independent company, formerly belonging to Philips Components. As a consequence it may initially happen that logos on products, documentation and packaging are not corresponding. This situation will solve itself.

We thank you for your understanding.

BC Components.

Varistors, Thermistors and Sensors

CONTENTS

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.	

LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Customers of BC Components who are using or selling these products for use in such applications do so at their own risk and agree to fully indemnify BC Components for any damages resulting from such improper use or sale.

SELECTION GUIDE

NEGATIVE TEMPERATURE COEFFICIENT (NTC) THERMISTORS

PRODUCT FUNCTION	RANGE	OUTLINE	CATALOGUE NUMBERS	PAGE
Temperature sensing and control	accuracy line	radial leads; 2.2 kΩ to 470 kΩ	2322 640 5....	26
		radial leads; 3.3 Ω to 470 kΩ	2322 640 6....	36
		radial leads; 5 kΩ to 10 kΩ	2322 645 0....	59
	special accuracy	radial leads; two-point sensors	2322 640 10...	63
	SMD	surface mount device	2322 615 1....	68
		surface mount device	2322 615 2....	91
	miniature accuracy line	long radial non-insulated leads	2322 645 90028	98
		long radial insulated leads	2322 640 90059	101
		long radial non-insulated leads	2322 645 10...	104
		long radial insulated leads	2322 645 20...	104
	high temperature sensors	SOD80; glass-encapsulated	2322 633 5....	107
		SOD27; axial nickel leads	2322 633 7....	107
		SOD27; axial tin leads	2322 633 8....	107
	naked chips	naked chips; 1 kΩ to 470 kΩ	2322 640 0....	119
	moulded sensors	radial leads	2322 641 6....	129
	special, long leads	water-resistant; insulated leads	2338 640 7....	136
		brass-pipe; insulated leads	2338 640 8....	136
		epoxy-coated; insulated leads	2338 640 9....	136
	glass encapsulated miniature beads	radial leads	2322 626 1....	143
		radial leads	2322 626 2....	146
		axial leads	2322 633 0....	149
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	housing	screw; 2.2 kΩ to 470 kΩ	2322 640 7....	155
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	moulded sensors (maintenance types)	moulded	2322 640 90004	161
		moulded with metal strip	2322 640 98004	161
		moulded	2322 640 90005	163
		moulded with metal strip	2322 640 98005	163

POSITIVE TEMPERATURE COEFFICIENT (PTC) THERMISTORS

PRODUCT FUNCTION	RANGE	OUTLINE	CATALOGUE NUMBERS	PAGE
Overload protection, naked and leaded	T_s = 120 °C; V_{oper} = 56 V	naked disc	2322 66. 0...1	184
		leaded, bulk	2322 66. 1...1	184
		leaded, on tape	2322 66. 3...1	184
	T_s = 120 °C; V_{oper} = 265 V	naked disc	2322 66. 0...3	184
		leaded, bulk	2322 66. 1...3	197
		leaded, on tape	2322 66. 3...3	197
	T_s = 140 °C; V_{oper} = 30 V	naked disc	2322 66. 4...1	197
		leaded, bulk	2322 66. 5...1	197
		leaded, on tape	2322 66. 6...1	197
	T_s = 140 °C; V_{oper} = 145 V	naked disc	2322 66. 4...2	197
		leaded, bulk	2322 66. 5...2	197
		leaded, on tape	2322 66. 6...2	197
	T_s = 140 °C; V_{oper} = 265 V	naked disc	2322 66. 4...3	197
		leaded, bulk	2322 66. 5...3	197
		leaded, on tape	2322 66. 6...3	197
	telecommunications		2322 66. 9....	218
	SMD	surface mount device	2322 661 97...	222
	lighting		2322 66. 9....	232
	instrumentation		2322 66. 9....	235
Temperature protection	T_n = 60 °C to 170 °C	chip size 1.5 × 1.5 mm	2322 671 91052 to 91067	240
		chip size 1.7 × 1.7 mm	2322 671 91002 to 91014	240
		radial leads	2322 671 91102 to 91114	240

PRODUCT FUNCTION	RANGE	OUTLINE	CATALOGUE NUMBERS	PAGE
Degaussing	standard inrush	plastic housing	2322 662 96.09	208
		plastic housing	2322 662 96.11	208
		plastic housing	2322 662 96.16	208
		plastic housing	2322 662 96.24	208
		plastic housing	2322 662 96.02	208
		plastic housing	2322 662 96.13	208
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		plastic housing	2322 662 96.26	208
	high inrush	plastic housing	2322 662 96706	208
		plastic housing	2322 662 96705	208
	mono	plastic housing	2322 662 96281	208
		plastic housing	2322 662 96682	208
		plastic housing	2322 662 96683	208
		plastic housing	2322 662 96684	208
		plastic housing	2322 662 96285	208
		plastic housing	2322 662 96686	208
		plastic housing	2322 662 96687	208
		plastic housing	2322 662 96688	208

VARISTORS (VDR)

PRODUCT FUNCTION	OUTLINE	VOLTAGE (V)	CATALOGUE NUMBERS	PAGE
Transient suppression	straight leads	14 to 460	2322 592 .....; 2322 593	306
		14 to 550	2322 594 .....; 2322 595	
	kinked leads	14 to 460	2322 592 .....; 2322 593	306
		14 to 550	2322 594 .....; 2322 595	
	flanged leads	14 to 460	2322 592 .....; 2322 593	306

HUMIDITY SENSOR

PRODUCT FUNCTION	OUTLINE	MAX. VOLTAGE AC or DC (V)	CATALOGUE NUMBERS	PAGE
Sensing	plastic housing	15	2322 691 90001	330

NEGATIVE TEMPERATURE COEFFICIENT (NTC) THERMISTORS

Page

INTRODUCTION TO NTCs

APPLICATIONS

Motor vehicles

NTC temperature sensors are widely used in motor vehicles. For example:

- Inlet air-temperature control
- Transmission oil temperature control
- Engine temperature control
- Airco systems
- Airbag electronic systems
- Temperature detection of laser diode in CD players for cars
- Frost sensors
- ABS.

Domestic appliances

NTC temperature sensors are in virtually all equipment in the home where temperature plays a role. This includes:

- Fridges and freezers
- Cookers and deep-fat fryers
- Washing machines and dish washers
- Central-heating systems
- Air conditioning
- Fire alarms.

Industrial, telecommunications, consumer

In switching, measuring and detection systems

- Process control
- Heating and ventilation
- Air conditioning
- Temperature protection in battery management/charging systems
- LCD contrast control in flat-panel displays, mobile phones and camcorders
- Temperature compensation of quartz oscillator frequency in, for example, mobile phones
- Ink-jet printer head temperature detection
- Video and audio equipment.

SELECTION CHART

PRODUCT RANGE	OPERATING TEMP. RANGE (°C)	R_{25} TOL. (±%)	B TOL. (±%)	RESP. TIME (s)	MAX. ∅ (mm)	LEAD ∅ (mm)	LEAD L (mm)	LEAD MATERIAL	PAGE
Accuracy line:									
640 5....	−40 to +125	1, 2, 3	0.75 to 1.5	1.7	3.4	0.4	38 min.	tinned nickel	26
640 6....		2, 3, 5, 10	0.5 to 3.0	1.2	3.8	0.6	17 min.	tinned copper	36
645 0....		5	0.75	1.2	3.3	0.6	17 min.	tinned copper	59
Special accuracy line:									
640 10...	−40 to +125	0.5	two-point sensors	1.2	3.3	0.6	17 min.	tinned copper	63
SMD versions:									
615 1....	−55 to +150	5, 10	1 to 3	–	–	–	–	–	68
615 2....	−55 to +150	3, 5, 10	3	–	–	–	–	–	91
Miniature accuracy line:								nickel:	
645 20...	−40 to +125	–	1.2	2.5	2.4	AWG30	38	insulated	104
645 10...		–	1.2	1.24	2.4	0.3	38	non-insulated	104
High temperature:									
633 5....	−40 to +200	5, 10	1.3	0.9	1.7	–	–	nickel plated copper-clad iron	107
633 8....	−40 to +200	5, 10	1.3	0.9	1.85	0.56 max.	25.4 min.		107
633 7....	+25 to +300	5, 10	1.3	0.9	1.85	0.56 max.	25.4 min.		107
Naked chips:									
640 0....	−40 to +125	1, 2, 3, 5	0.75 to 2.5	<1.2	2.4	–	–	–	119
Moulded:									
641 6....	−40 to +125	3	0.75 to 2.0	2.7	4 ±0.2	0.06	21 ±1	tinned copper	129
Special long-leaded (UL2468 PVC insulation):								tinned copper:	
640 7....	−40 to +85	3	0.75 to 3	15	6	AWG24	–	water-resistant	136
640 8....		3	0.75 to 3	10	6	AWG24	–	brass-pipe	136
640 9....		3	0.75 to 3	7	6	AWG24	–	epoxy-coated	136
Glass encap. miniature beads:									
626 1....	−55 to +200 or −55 to +300	5, 10	5	1	2.5	0.3	30 min.	copper/nickel tinned iron	143
626 2....		5, 10	5	0.85	1.6	0.24	19 min.		146
633 1....	−55 to +200	5, 10	5	0.5	0.7 to 1	0.06	5 min.		149
633 2....		5, 10	5	6	3	0.24	20 min		152

RANGE SUMMARY

- **Accuracy Line**
  - 2322 640 5.... and 640 6....

    The flagship of our ranges. The Accuracy Line sensors offer real value for money. They have low tolerances (as low as ±1% on the R_{25}-value and ±0.5% on the B-value) and an operating temperature range from –40 to +125 °C. In addition, they are very stable over a long life.
  - 2322 645 ..... series

    This range is our American standard line with an excellent accuracy over a wide temperature range (±0.75% on the B-value). Sensors are available with R_{25}-values from 5 kΩ to 10 kΩ with an operating temperature range from –40 to +125 °C.
- **surface mount temperature sensors**
  - 2322 615 1.....

    Our recently-introduced 0805 surface mount NTC sensors for temperature sensing and compensation embody all the qualities of Philips' NTC technology. The sensors come in a full range of R_{25}-values from 100 Ω to 470 kΩ with standard tolerances of 5% and 10%. Sensors with narrower tolerances are also available on special request.
- **High-temperature sensors**
  - 2322 633 5...., 633 7.... and 633 8....

    This range of high-quality glass-encapsulated NTC temperature sensors are price-competitive for general use. Not only can these sensors be used at up to 300 °C, but their glass encapsulation makes them ideal for use in corrosive atmospheres and harsh environments, even down to –40 °C. This makes them an attractive alternative to other more expensive sensing methods. In addition, they are very small. Two types of tiny glass envelopes are available: SOD27 for sensors with leads, and SOD80 'MELF' execution) for leadless, surface mount sensors.
- **Glass-encapsulated miniature beads**
  - 2322 626 ..... and 633 .....

    These ranges pack extremely high performance in very small size. They are fast and stable in the temperature range from as low as –55 °C to as high as +300 °C.
- **Chips**
  - 2322 640 0....

    When leaded components cannot be used, there is always the possibility of mechanical fixing. For this purpose we supply metallized square chips with R_{25}-values from 2.2 to 470 kΩ and five types of circular disc sensors.
- **Moulded sensors**
  - 2322 641 6....

    Designed for harsh environments, our moulded sensors are ideal where good surface contact is essential. The range has recently been enhanced, and can be extended further on customer request, based on the 2322 640 0.... series.
- **Miniature accuracy line**
  - 2322 645 10... and 645 20...

    These sensors combine the features of the Accuracy Line with long non-insulated or insulated leads for remote sensing applications.
- **Special long-leaded sensors**
  - 2322 640 7...., 8.... and 9.....

    For special applications we can supply three types of long-leaded sensors: water-resistant sensors for permanent immersion in water, pipe sensors for use in corrosive atmospheres and epoxy-coated sensors for general use.

HOW NTC TEMPERATURE SENSORS WORK

NTC temperature sensors are made from a mixture of metal oxides which are subjected to a sintering process that gives them a negative electrical resistance versus temperature (R/T) relationship such as that shown in Fig.1.

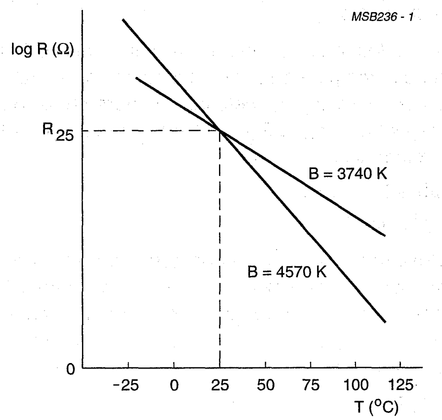


Fig.1 Typical resistance as a function of temperature for an NTC temperature sensor.

The relatively large gradient means that even small temperature changes cause a significant change in electrical resistance which makes the NTC sensor ideal for accurate temperature measurement and control.

The main electrical characteristics of an NTC ceramic temperature sensor are expressed by three important parameters and their tolerances (see Table 1).

Table 1 Important NTC parameters

PARAMETER	DESCRIPTION
R_{25}	the resistance of the sensor in Ω at a reference temperature of 25 °C
B-value	a material constant
α	the temperature coefficient of resistance expressed in %/K

Resistance R_{25} at 25 °C (298.15 K)

The resistance at 25 °C (substantially at room temperature) provides a convenient reference point for thermistors. Tolerances on R_{25} are due mainly to variations in ceramic material manufacture and tolerances on chip dimensions. Through the use of highly homogeneous material compositions and proprietary ceramic sawing techniques allowing precise control of chip dimensions, products are available with tolerances on R_{25} lower than 1%.

Material constant B

B is a material constant that controls the slope of the R-T characteristic (see Fig.1) which can, at least to a first approximation, be represented by the formula:

$$R_T = R_{25} \exp\left\{B\left(\frac{1}{T} - \frac{1}{298.15}\right)\right\} \quad (1)$$

Where T is the absolute temperature of the sensor.

In practice, B varies somewhat with temperature and is therefore defined between two temperatures 25 °C and 85 °C by the formula:

$$B_{25/85} = \log_e\left(\frac{R_{85}}{R_{25}}\right) \Big/ \left(\frac{1}{358.15} - \frac{1}{298.15}\right) \quad (2)$$

$B_{25/85}$ (expressed in K) is normally used to characterize and compare different ceramics. Tolerance on B (or $B_{25/85}$) is caused mainly by material composition tolerances and sintering conditions. The latest materials offer tolerances as low as ±0.5% on a B of 3528 K, i.e. ΔB = 17 K.

In most cases, better fitting curves than pure expoential are required to measure the temperature accurately; see formula (1). That is why each NTC material curve is defined by a 3rd order polynominal, as shown below:

$$R_T = R_{25}\varepsilon\left[A + B/T + C/T^2 + D/T^3\right] \quad (3)$$

or inversely expressing T as a function of R_T:

$$T = \frac{1}{\left[A_1 + B_1 l_n\left(\frac{R_T}{R_{25}}\right) + C_1 l_n^2\left(\frac{R_T}{R_{25}}\right) + D_1 l_n^3\left(\frac{R_T}{R_{25}}\right)\right]} \quad (4)$$

The two approximations (3) and (4) represent the real material curves with an error lower than 0.1% at any given temperature.

The values of the coefficients A, B, C, D, A_1, B_1, C_1 and D_1 are given in the specifications of data sheet *"640 6...."*

Sensor tolerances

The total tolerances of the NTC sensor over its operating temperature range is a combination of the tolerances on R_{25} and on B-value given by the formula:

$$\frac{\Delta R}{R} = \frac{\Delta R_{25}}{R_{25}} + \Delta B \left| \frac{1}{T} - \frac{1}{298.15} \right| \quad (5)$$

Figure 2 is a graphical representation of this formula which shows a minimum at 25 °C since this is the temperature at which the sensor is calibrated. Above and below this temperature, the tolerances increase due to the increasing tolerances on B-value, giving the graph a 'butterfly' shape.

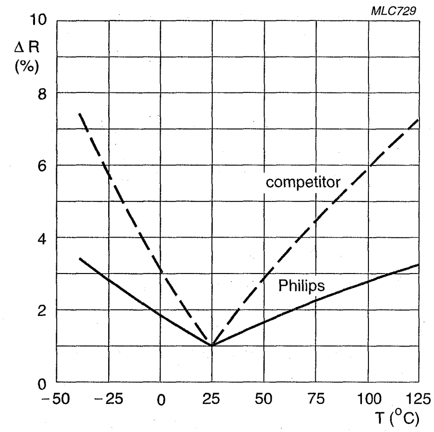


Fig.2 Typical resistance change as a function of temperature for a 1% Philips NTC temperature sensor compared to a competitor sensor.

The exceptionally low ΔB-value of the Philips sensor compared with those of typical competitors (see Fig.2) gives a flatter ΔR/R 'butterfly' curve which means you can get more accurate temperature measurement using Philips NTC temperature sensors.

Temperature coefficient of resistance

The temperature coefficient of resistance α expresses the sensitivity of a sensor to temperature changes. It is defined as:

$$\alpha = \frac{1}{R} \times \frac{\Delta R}{\Delta T} \quad (6)$$

Using formula (1) to eliminate R this can be re-expressed as:

$$\alpha = -\frac{B}{T^2} \quad (7)$$

Which means that the relative tolerance on α is equal to the relative tolerance on B-value.

Thermal stability

The stability of an NTC temperature sensor is expressed in terms of the maximum shift in its electrical properties, R_{25} and B-values after it has been subjected to an extended period at its maximum operating temperature. Figure 3, for example, shows the long-term deviation of R_{25} and B-value for a standard lacquered component from the 640 6 series with an R_{25} of 10 kΩ.

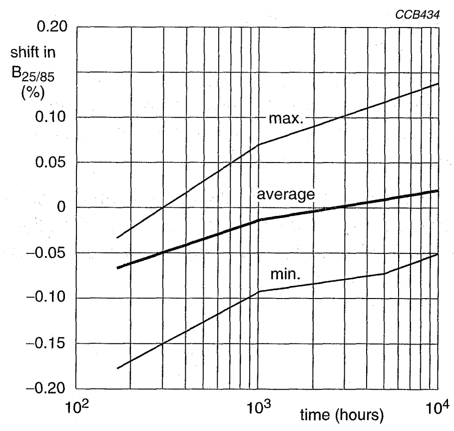


Fig.3 Ageing characteristics (dry heat at 150 °C) of a 640 6.... series NTC temperature sensor with an R_{25} of 10 kΩ.

Temperature cycling

Another important criterion for assessing the performance of an NTC sensor throughout its operational life is its resistance to thermal cycling. To assess this, products are subjected to rapid temperature variations covering the extremes over which they are expected to operate until failure is induced.

These tests fully demonstrate the high reliability of our products: our soldered types (for example 645 20 types) withstanding more than 5000 cycles, and our glass encapsulated types (633 series) more than 100 000 cycles without failure.

Thermal time constant and response time

The speed of response of an NTC sensor is characterized by its time constant. This is the time for the sensor's temperature to change by 63.2% (i.e. 1 to 1/e) of the total change that occurs when the sensor is subjected to a very rapid change in temperature.

The conditions under which the time constant is measured are important. Two are normally considered:

- Ambient change: the component is initially in still air at 25 °C then quickly immersed in a fluid at 85 °C. The fluid is usually silicone oil but other fluids, e.g. water for washing machine applications, air for tumble dryers can also be specified.
- Power-on/power-off conditions: the component is heated by dissipation of electrical power in still air to a temperature of 85 °C after which electrical power is removed.

Figure 4 represents the typical voltage variation of a boiler sensor experiencing a transition from air at 25 °C to the temperature of boiling water. The graph shows a response time of about 4 seconds.

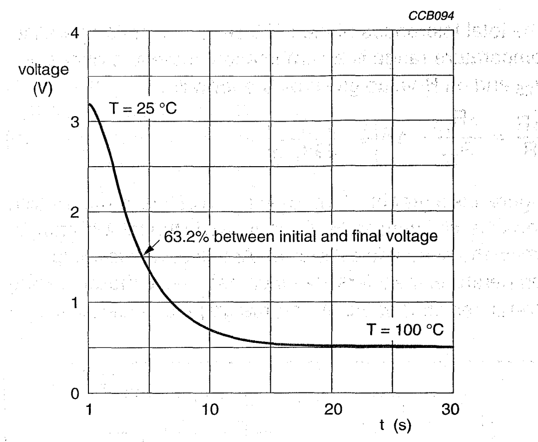


Fig.4 Typical output of a boiler sensor undergoing a sudden temperature transition from 25 to 100 °C.

ADVANCED DEVELOPMENT AND HIGH-TECHNOLOGY MANUFACTURE

The high accuracy of our NTC temperature sensor series is principally a result of advanced development and high-technology manufacture.

Advanced development

Audits of our factory by major customers especially in the automotive industry regularly award us top marks. This is the result of strong commitment to development and heavy investment in personnel and equipment. Only by such commitment have we been able to develop new and better materials with B-value tolerances as low as 0.75%.

High-technology manufacture

Our most significant improvement in NTC temperature sensor manufacture has come through the use of precision sawing. This gives much better control over R_{25}-value than the earlier pressing technique and has allowed us to achieve R_{25} tolerances lower than 1%. After manufacture, we electrically test every one of our NTC temperature sensors.

COMPONENT QUALITY, OUR GUARANTEE OF EXCELLENCE

As you expect from a world-class electronic components manufacturer, quality is an integral part of our company's make-up. It's reflected in our ISO9001/9002 approved organizations, all of which operate according to the principles of TQM (Total Quality Management). It's reflected too in the way we act, think and do business. Quality, in fact, is the essence of what we have to offer: not just in our products but in our customer service and customer relations as well.

Our Quality Assurance system is based on the following principles:

- Total quality management involving careful design and thorough investigation of conformance and reliability before release of new products and processes.
- Careful control of purchased materials and manufacturing process steps. This is mainly achieved by strict implementation of Statistical Process Control (SPC) to detect and eliminate adverse manufacturing trends before they become significant.
- Electrical inspection of significant characteristics with a target of zero defects in our delivered sensors.
- Statistical inspection of outgoing batches and periodic reliability checks aimed at collecting trend information, which is steered towards Quality improvement.

Quality assurance at BC Components goes further, however. Batch tests under extreme climatic conditions are designed to test our sensors to destruction. Results clearly indicate that Philips NTC sensors provide reliable performance over a long lifetime. A fact that has been verified by ppm figures obtained from many years of close cooperation with major customers in all sectors of industry. Proving conclusively that Philips NTC temperature sensors offer unsurpassed levels of quality and reliability in the field.

SELECTING AN NTC TEMPERATURE SENSOR

Step 1

Decide on the sensor series you need from the "Selection chart".

Your choice depends on the operating temperature range and other criteria such as:

- Accuracy
- Product size
- Required mechanical execution i.e. naked chip, SMD, epoxy coated, moulded or glass sealed
- Lead length or diameter.

Step 2

Decide on the value of R_{25} you need. Refer to the R/T characteristics of the sensor series you chose in Step 1. In these characteristic curves, each sensor in the series is distinguished by its R_{25}-value. Choose an R_{25}-value to give a resistance at your average temperature of operation of between 1 kΩ and 100 kΩ.

Step 3

Determine the tolerance on R_{25}. Generally, you will know the accuracy of ΔT at which the temperature should be measured in your application. The relative tolerance ($\Delta R/R$) on sensor resistance is then: $\frac{\Delta R}{R} \times \alpha \Delta T$ in which 'α' is the temperature coefficient of resistance; see section "Temperature coefficient of resistance". To calculate the relative tolerance on R_{25} ($\Delta R_{25}/R_{25}$), simply subtract from $\Delta R/R$ the ΔR tolerance due to B-value.

Step 4

Using the tables in the 'Device Data' of this *"Data Handbook"*, select the sensor from the series meeting your requirements on ΔR_{25} calculated in Step 3.

Step 5

For other important requirements such as response time and length of component, refer to the "Selection chart".

Although the standard range gives the narrowest tolerances at 25 °C, we can on special request, adapt our manufacturing processes to provide products with the narrowest tolerance at any temperature of your choice. Please pass your request through your local BC Components sales organization.

EXAMPLES ON HOW TO SELECT

Example 1

A leaded NTC sensor is required for sensing temperatures in refrigerator and freezer compartments with a temperature accuracy of 0.5 °C over the whole temperature range of −25 °C to +10 °C. Over this temperature range, the circuit design requires that the resistance should be maintained between 2 kΩ and 30 kΩ.

STEP 1

Choose the execution. Since temperature has to be measured with high accuracy, nickel leads are recommended. Their low heat conductivity effectively isolates the component from the outside world, enabling it to accurately monitor the temperature of the freezing compartments. From the "Selection chart" it can be seen that 640 5 series components are the most suitable choice.

STEP 2

Refer to the 640 5 series specifications in this *"Data Handbook"*. The component meeting the requirement that the resistance should be maintained between 2 kΩ to 30 kΩ is a 640 5x222 type (x indicating the tolerance).

STEP 3

Calculate the required tolerance on R_{25}. Knowing that $\Delta T = \pm 0.5$ K and taking values for α at −25 °C and 10 °C from the 640 5 specifications:

$$\frac{\Delta R}{R} = 5.95 \times 0.5 = 3\% \text{ at } -25\ °C$$

$$\frac{\Delta R}{R} = 4.78 \times 0.5 = 2.4\% \text{ at } +10\ °C$$

To calculate the relative tolerance on R_{25} ($\Delta R_{25}/R_{25}$), simply subtract from $\Delta R/R$ the ΔR tolerance due to B-value at these two temperatures obtained from this *"Data Handbook"*.

$$\frac{\Delta R_{25}}{R_{25}} = 3\% - 1.94\% = 1.06\% \text{ at } -25\ °C$$

$$\frac{\Delta R_{25}}{R_{25}} = 2.4\% - 0.52\% = 1.92\% \text{ at } +10\ °C$$

Take the minimum which gives an R_{25} tolerance of ±1%. The selected component is therefore 640 55222.

STEP 4

Not applicable.

STEP 5

Suppose now that the required $\Delta R_{25}/R_{25}$ had been less than 1%. Though no standard product meets that requirement, it's nevertheless possible to specify custom products with a different reference point, e.g. 0 °C instead of 25 °C, that meet narrower tolerance specifications.

Example 2

Designing a fast-charging circuit for nickel hydride cells. During fast charging, the rate of temperature rise of the cells must be monitored. If this reaches 1 K/min with a tolerance of ±10%, the circuit must switch from fast charging to trickle charge. Ambient temperature must be between 10 °C to 45 °C to allow fast charging and the backup cut-off temperature (above which charging is completely switched off) is fixed at 60 °C. Temperatures are expected to be measured with an accuracy of ±2 °C.

STEP 1

Surface mount products can be used for this application. Since SMDs for relatively low temperatures are needed, refer to the 615 series rather than 633 5 (MELF) series.

STEP 2

Choose the R_{25} of the component. From the R/T specifications of the 615 series, it can be seen that a type with an R_{25} = 100 kΩ is suitable i.e. 2322 615 1x104.

STEP 3

It is possible to choose a component with 5% or 10% tolerance. The temperature measurement range is from 10 to +60 °C. Referring to the data on the 2322 615 1x104 series, the maximum ΔT in this range (i.e. at 60 °C) for a 5% tolerance type is 1.92 °C and 3.45 °C for a 10% tolerance type. Therefore a 5% tolerance type must be chosen.

STEP 4

The sensor to choose is therefore the 2322 615 13104.

STEP 5

Verify now that the selected component fulfils the requirement with regard to rate of temperature rise (dT/dt), from section "Temperature coefficient of resistance":

$$\frac{\Delta R}{\Delta T} = \alpha R \frac{\Delta T}{\Delta T}$$

So to assure a maximum rate of temperature rise of 1 K/min we get (taking the α and R-values at 60 °C from the specifications):

$$\frac{\Delta R}{\Delta T} = -\frac{3.31}{100} \times 27952.66 \times 1 \text{ K/min} = -925 \times \Omega\text{/min}$$

This is verified by measuring the rate of change of voltage (dV/dt) across the sensor at constant current I. The rate of change of resistance dR/dt can then be determined (= 1/I dV/dt).

At the same temperature, an NTC sensor with R and B-values at the extremes set by the sensor tolerances will have:

a resistance of 27952.66 × (1 −6.35/100) = 26180 Ω

an α of −3.31 × (1−1/100) = −3.28%/K (tolerance on α = tolerance on $B_{25/85}$).

So the same dR/dt, i.e. −925 Ω/min in this extreme component will limit the maximum rate of temperature rise dT/dt to 925 × 100/3.28 × 1/26180 = 1.07 K/min which still falls within the tolerance of ±10% allowed on the rate of temperature rise (1 K/min + 10% = 1.1 K/min).

Application grouping

Applications of NTCs 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 subsections:

   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, when 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) characteristic shows a negative slope.

The classifications mentioned are supported by practical examples in Figs 5 to 17.

EXAMPLES

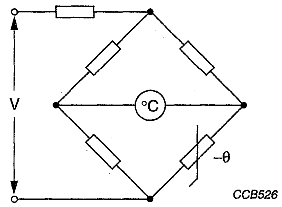


Fig.5 Temperature measurement in industrial and medical thermometers.

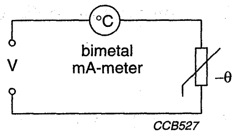


Fig.6 Car cooling water temperature measurement with bimetal.

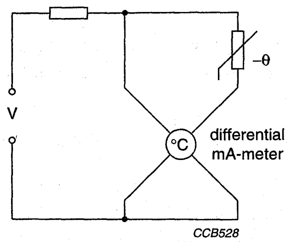


Fig.7 Car cooling water temperature measurement with differential mA-meter.

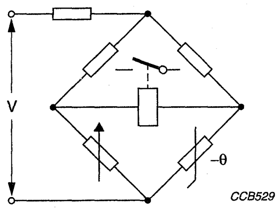


Fig.8 Temperature measurement with a bridge incorporating an NTC thermistor and a relay or a static switching device.

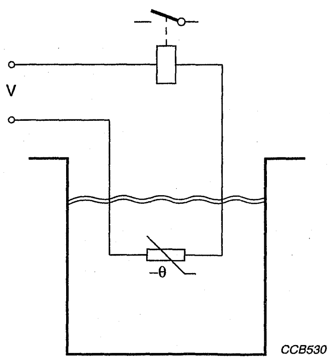


Fig.9 Liquid level control.

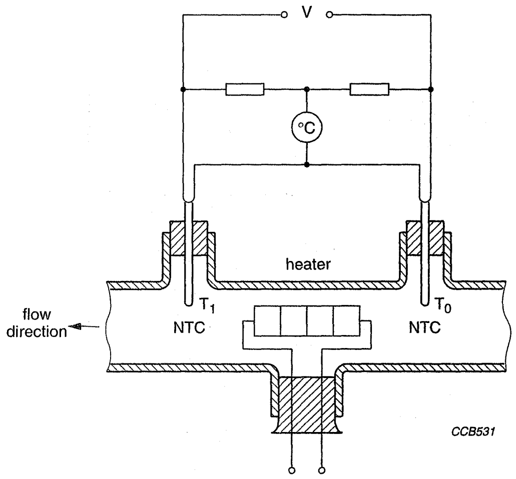


Fig.10 Flow measurement of liquids and gases. The temperature difference between T_1 and T_0 is measured for the velocity of the fluid.

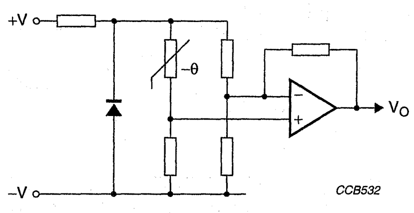


Fig.11 Temperature sensing bridge with op-amp which acts as differential amplifier. The sensitivity can be very high.

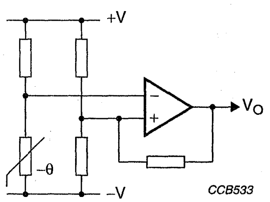


Fig.12 Basic temperature sensing configuration. The op-amp (e.g. NE532) acts as a Schmitt-trigger. The transfer characteristic is shown in Fig.13.

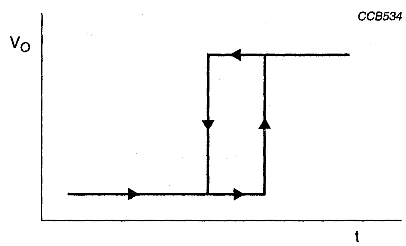


Fig.13 Transfer characteristic of the circuit shown in Fig.12.

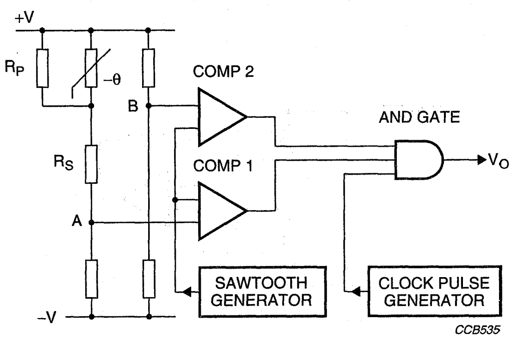


Fig.14 Temperature sensing bridge with 0 °C offset and ADC. Due to R_P and R_S the voltage at A varies linearly with the NTC thermistor temperature. The voltage at B is equal to that at A when the NTC thermistor temperature is 0 °C. Both voltages are fed to the comparator circuit. See also Fig.15.

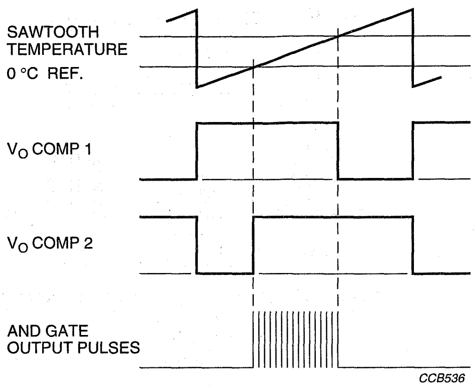


Fig.15 Pulses occurring at various points in the circuit shown in Fig.14.

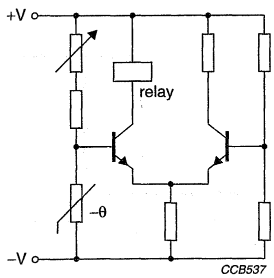


Fig.16 Simple thermostat.

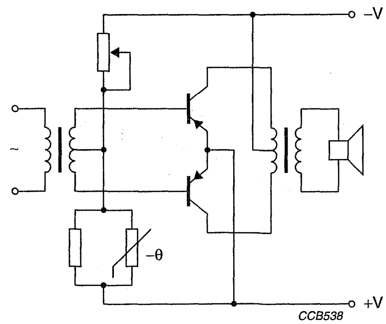


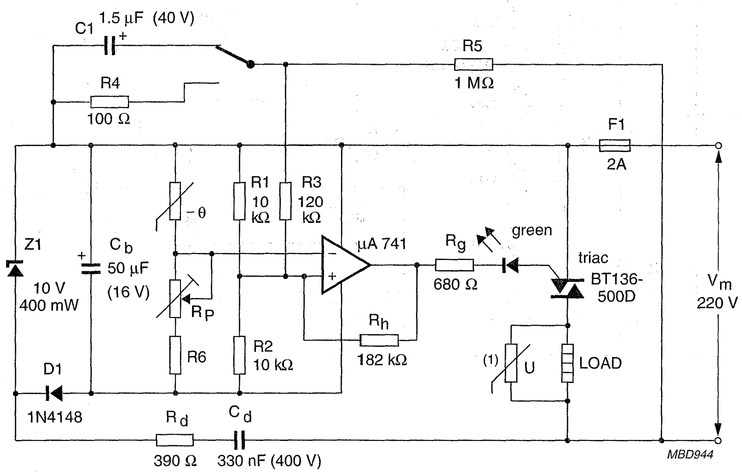
Fig.17 Temperature compensation in transistor circuits. Push-pull compensation.

NTC temperature sensors used as a thermal switch

A common use of an NTC temperature sensor is in one of the bridge arms of a thermal switch circuit using an operational amplifier such as the μA741. Figure 18 shows a typical thermal switch circuit for a refrigerator thermostat.

The circuit consists of a 10 V (DC) zener diode 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.

TEMPERATURE SENSING IN REFRIGERATORS



(1) Catalogue number: 2322 593 32312.
All resistors are 0.25 W.

Fig.18 Refrigerator thermostat using an NTC temperature sensor.

HEAT DETECTION IN FIRE ALARMS

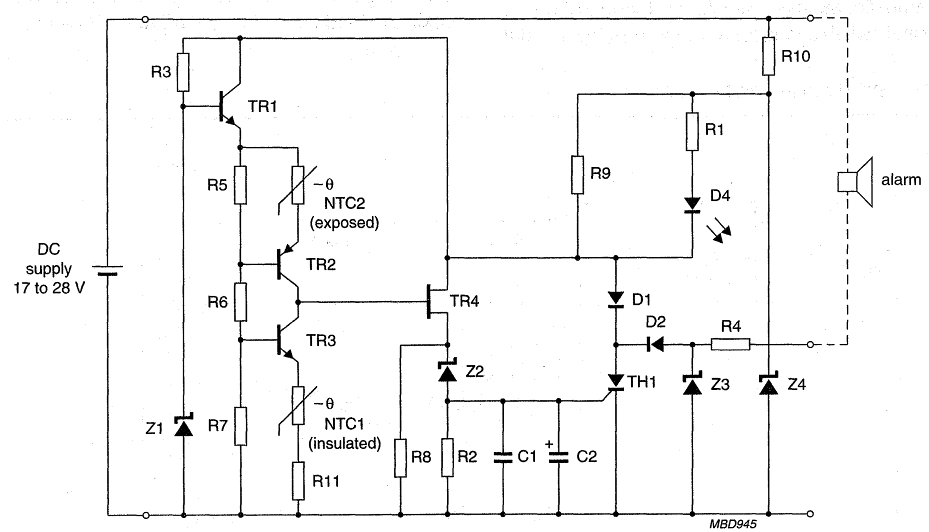


Fig.19 Circuit diagram of a typical heat detector using a matched pair of NTC thermistors.

NTC temperature protection of rechargeable batteries

Figure 20 shows the circuit diagram of an 'intelligent' charger designed to charge, within 1 hour, a NiCd or NiMH battery pack containing up to six AA-type cells. The TEA110X allows any type of power regulator to be used. In Fig.20, the unregulated 12 V (DC) supply is passed through a linear power regulator to charge the batteries under the control and management of the TEA110X. The BYD13D diode inhibits further charge (and prevents discharge) when the battery pack is full.
For further information refer to *"Application Note NTC temperature protection of rechargeable batteries, code number 9398 082 91011"*.

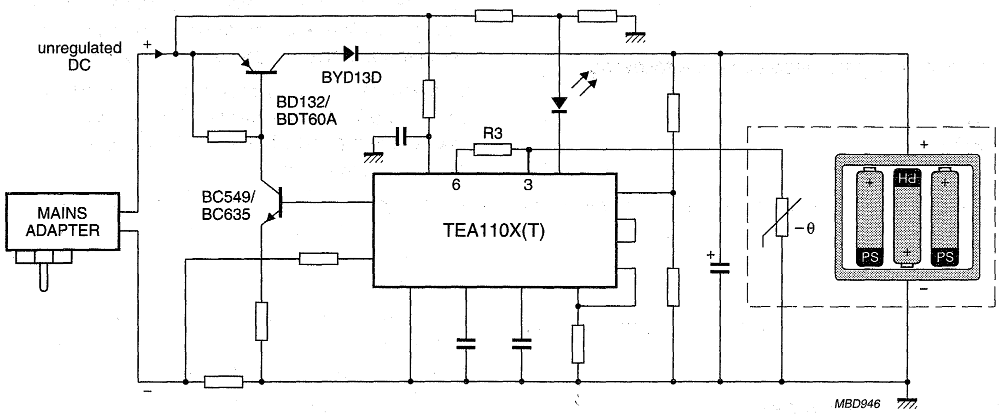


Fig.20 'Intelligent' charger based on the TEA110X with NTC battery temperature sensing.

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 respectively.

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.

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 the measurement at 25 °C and that 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 measurements 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 fluid 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.

PREFERRED TYPES

NTC thermistors for temperature sensing

For specific details refer to the relevant section in this data handbook.

R_{25} (kΩ)	NOMINAL B-VALUE (K)	CATALOGUE NUMBER 2322 ... .
2322 640 6.... 5% tolerance		
0.47	3560 ±0.75%	3471
1	3528 ±0.5%	3102
1.5	3528 ±0.5%	3152
2	3528 ±0.5%	3202
2.2	3977 ±0.75%	3222
3.3	3977 ±0.75%	3332
4.7	3977 ±0.75%	3472
6.8	3977 ±0.75%	3682
10	3977 ±0.75%	3103
15	3740 ±2%	3153
22	3740 ±2%	3223
33	4090 ±1.5%	3333
47	4090 ±1.5%	3473
68	4190 ±1.5%	3683
100	4190 ±1.5%	3104
150	4370 ±2.5%	3154
220	4370 ±2.5%	3224
470	4570 ±1.5%	3474
2322 640 6.... 3% tolerance		
2.7	3977 ±0.75%	6272
4.7	3977 ±0.75%	6472
10	3977 ±0.75%	6103
47	4090 ±1.5%	6473
100	4190 ±1.5%	6104
470	4570 ±1.5%	6474

R_{25} (kΩ)	NOMINAL B-VALUE (K)	CATALOGUE NUMBER 2322 ... .
2322 640 5.... 2% tolerance		
10	3977 ±0.75%	4103
47	4090 ±1.5%	4473
100	4190 ±1.5%	4104
2322 640 5.... 1% tolerance		
10	3977 ±0.75%	5103
47	4090 ±1.5%	5473
100	4190 ±1.5%	5104
2322 633 ..... 5% tolerance		
SMD VERSION		
10	3977 ±1.3%	53103
20	3977 ±1.3%	53203
30	3977 ±1.3%	53303
100	3977 ±1.3%	53104
LEADED VERSION		
100	3977 ±1.3%	73104; nickel-plated
10	3977 ±1.3%	83103; tinned-copper
20	3977 ±1.3%	83203; tinned-copper
30	3977 ±1.3%	83303; tinned-copper
100	3977 ±1.3%	83104; tinned-copper
2322 641 6.... moulded		
2.7 kΩ ±3%	3977 K ±0.75%	6272
12 kΩ ±3%	3740 K ±2%	6123
15 kΩ ±3%	3740 K ±2%	6153
22 kΩ ±3%	3740 K ±2%	6223
100 kΩ ±3%	4190 K ±1.5%	6104
470 kΩ ±3%	4190 K ±1.5%	6474

R_{25} (kΩ)	NOMINAL B-VALUE (K)	CATALOGUE NUMBER 2322 ... .
2322 615 1.... SMD 5% tolerance		
0.10	2880	3101
0.22	2990	3221
0.33	3041	3331
0.47	3136	3471
0.68	3270	3681
1	3390	3102
2.2	3680	3222
3.3	3830	3332
4.7	3560	3472
5	3560	3502
10	3620	3103
15	3528	3153
22	3930	3223
33	3960	3333
47	4090	3473
68	3740	3683
100	3650	3104
150	3807	3154
330	4015	3334
470	4130	3474

R_{25} (kΩ)	NOMINAL B-VALUE (K)	CATALOGUE NUMBER 2322 ... .
2322 615 1.... SMD 10% tolerance		
0.10	2880	2101
0.22	2990	2221
0.33	3041	2331
0.47	3136	2471
0.68	3270	2681
1	3390	2102
2.2	3680	2222
3.3	3830	2332
4.7	3560	2472
5	3560	2502
10	3620	2103
15	3528	2153
22	3930	2223
33	3960	2333
47	4090	2473
68	3740	2683
100	3650	2104
150	3807	2154
330	4015	2334
470	4130	2474

NTC thermistors for temperature sensing (continued)

CATALOGUE NUMBER 2338 640			R_{25} (kΩ)	$B_{25/85}$-VALUE (K)
EPOXY-COATED TYPE	WATER-RESISTANT TYPE	BRASS-PIPE TYPE		
90102	70106	80102	2.2 kΩ ±3%	3977 K ±0.75%
90104	70105	–	5 kΩ ±3%	3977 K ±0.75%
90106	70104	80106	10 kΩ ±3%	3977 K ±0.75%
90452	70452	–	47 kΩ ±3%	4090 K ±2%
90504	70504	80504	100 kΩ ±3%	4190 K ±1.5%

NTC thermistors, accuracy line 2322 640 5....

FEATURES

- Accurate over a wide temperature range (tolerance on B-value between 2.5% and 0.75%)
- Good stability over a long life
- Excellent price/performance ratio
- Flexible leads
- Low heat conductivity through 0.4 mm diameter Ni-leads.

APPLICATION

Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two tinned Ni-leads. The device is colour coded.

PACKAGING

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

MECHANICAL DATA

Marking

The thermistors are marked with coloured bands; see Fig.1 and Table 1.

Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	2 to 470 kΩ
Tolerance on R_{25}-value	±5%; ±3%; ±2%; ±1%
Tolerance on $B_{25/85}$-value	±2.5 to ±0.75%
Maximum dissipation	100 mW
Response time	≈1.7 s
Operating temperature range at:	
zero dissipation (continuously)	−40 to +125 °C
zero dissipation (for short periods)	≤150 °C
maximum dissipation (100 mW)	0 to +55 °C
Climatic category	40/125/56
Mass	≈0.11 g

Outline

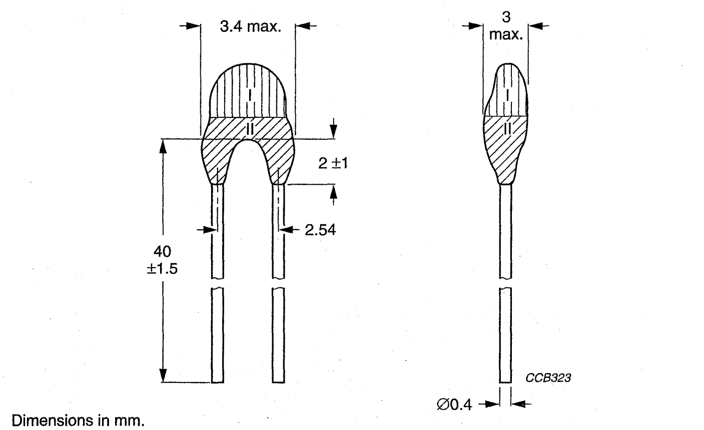


Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, catalogue numbers and coding; note 1

The thermistors have a 12-digit catalogue number starting with 2322 640 5. The subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	CATALOGUE NUMBER 2322 640 5....				CODING (see Fig.1)	
		R_{25} ±5%	R_{25} ±3%	R_{25} ±2%	R_{25} ±1%	I	II
2	3528 K ±0.5%	3202	6202	4202	5202	orange	orange
2.7	3977 K ±0.75%	3272	6272	4272	5272	red	red
4.7	3977 K ±0.75%	3472	6472	4472	5472	green	green
5	3977 K ±0.75%	3502	6502	4502	5502	black	white
10	3977 K ±0.75%	3103	6103	4103	5103	blue	blue
12	3740 K ±2%	3123	6123	4123	–	yellow	yellow
22	3740 K ±2%	3223	6223	4223	–	white	white
47	4090 K ±1.5%	3473	6473	4473	–	black	black
68	4190 K ±1.5%	3683	6683	4683	–	grey	grey
100	4190 K ±1.5%	3104	6104	4104	5104	brown	brown
470	4570 K ±1.5%	3474	6474	4474	–	violet	violet

Note

1. Extended range available on request.

Table 2 Resistance values at intermediate temperatures with R_{25} at 2 kΩ; see also Table 1

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω)
				2322 640 .....; see Table 7, note 1
				5.202
−40	23.3402	1.65	−6.06	46684
−35	17.3347	1.49	−5.84	34672
−30	13.0166	1.34	−5.62	26035
−25	9.8764	1.19	−5.42	19754
−20	7.5682	1.05	−5.23	15138
−15	5.8541	0.92	−5.05	11709
−10	4.5688	0.79	−4.87	9138
−5	3.5961	0.66	−4.71	7193
0	2.8533	0.54	−4.55	5707
5	2.2815	0.43	−4.40	4563
10	1.8376	0.31	−4.26	3675
15	1.4904	0.21	−4.12	2981
20	1.2169	0.10	−3.99	2434
25	1.0000	0.00	−3.87	2000
30	0.8266	0.10	−3.75	1653
35	0.6873	0.19	−3.63	1375
40	0.5746	0.28	−3.53	1149
45	0.4827	0.37	−3.42	965.0
50	0.4073	0.46	−3.32	814.7
55	0.3452	0.54	−3.23	690.5
60	0.2937	0.62	−3.14	587.5
65	0.2508	0.70	−3.05	501.7
70	0.2149	0.78	−2.97	429.8
75	0.1847	0.85	−2.89	369.5
80	0.1593	0.92	−2.81	318.6
85	0.1377	0.99	−2.73	275.5
90	0.1194	1.06	−2.66	238.9
95	0.1038	1.13	−2.59	207.6
100	0.09045	1.19	−2.53	180.9
105	0.07900	1.25	−2.46	158.0
110	0.06915	1.31	−2.40	138.3
115	0.06066	1.37	−2.34	121.3
120	0.05332	1.43	−2.29	106.6
125	0.04696	1.49	−2.23	93.9
130	0.04143	1.54	−2.18	82.9
135	0.03662	1.60	−2.13	73.3
140	0.03243	1.65	−2.08	64.9
145	0.02877	1.70	−2.03	57.5
150	0.02556	1.75	−2.33	51.1

Table 3 Resistance values at intermediate temperatures with R_{25} at 2.7 kΩ, 4.7 kΩ, 5 kΩ and 10 kΩ; see also Table 1

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....;see Table 7, note 1			
				5.272	**5.472**	**5.502**	**5.103**
−40	33.21	2.66	6.57	89.67	156.1	166.1	332.1
−35	23.99	2.41	6.36	64.77	112.8	120.0	240.0
−30	17.52	2.17	6.15	47.31	82.35	87.60	175.2
−25	12.93	1.94	5.95	34.91	60.77	64.65	129.3
−20	9.636	1.71	5.76	26.02	45.30	48.18	96.36
−15	7.250	1.50	5.58	19.58	34.08	36.25	72.50
−10	5.505	1.29	5.40	14.86	25.87	27.52	55.05
−5	4.216	1.08	5.24	11.38	19.81	21.08	42.16
0	3.255	0.89	5.08	8.790	15.30	16.28	32.56
5	2.534	0.70	4.92	6.842	11.91	12.67	25.34
10	1.987	0.52	4.78	5.366	9.340	9.936	19.87
15	1.570	0.34	4.64	4.239	7.378	7.849	15.70
20	1.249	0.17	4.50	3.372	5.869	6.244	12.49
25	1.000	0.00	4.37	2.700	4.700	5.000	10.00
30	0.8059	0.16	4.25	2.176	3.788	4.030	8.059
35	0.6535	0.32	4.13	1.764	3.072	3.267	6.535
40	0.5330	0.47	4.02	1.439	2.505	2.665	5.330
45	0.4372	0.62	3.91	1.180	2.055	2.186	4.372
50	0.3605	0.77	3.80	0.973	1.694	1.803	3.606
55	0.2989	0.91	3.70	0.807	1.405	1.494	2.989
60	0.2490	1.05	3.60	0.672	1.170	1.245	2.490
65	0.2084	1.18	3.51	0.562	0.9797	1.042	2.084
70	0.1753	1.31	3.42	0.473	0.8239	0.8765	1.753
75	0.1481	1.44	3.33	0.399	0.6960	0.7405	1.481
80	0.1256	1.57	3.25	0.339	0.5905	0.6282	1.256
85	0.1070	1.69	3.16	0.289	0.5031	0.5352	1.070
90	0.09154	1.81	3.09	0.247	0.4303	0.4577	0.9154
95	0.07860	1.93	3.01	0.212	0.3694	0.3930	0.7860
100	0.06773	2.04	2.94	0.182	0.3183	0.3387	0.6773
105	0.05858	2.15	2.87	0.158	0.2753	0.2929	0.5858
110	0.05083	2.26	2.80	0.137	0.2389	0.2542	0.5083
115	0.04426	2.37	2.73	0.1195	0.2080	0.2213	0.4426
120	0.03866	2.47	2.67	0.1044	0.1817	0.1933	0.3866
125	0.03387	2.57	2.61	0.0915	0.1592	0.1694	0.3387
130	0.02977	2.67	2.55	0.0804	0.1399	0.1488	0.2977
135	0.02624	2.77	2.49	0.0709	0.1233	0.1312	0.2624
140	0.02319	2.86	2.43	0.0626	0.1090	0.1160	0.2319
145	0.02055	2.96	2.38	0.0555	0.0966	0.1028	0.2055
150	0.01826	3.05	2.33	0.0493	0.0858	0.0913	0.1826

Table 4 Resistance values at intermediate temperatures with R_{25} at 12 kΩ and 22 kΩ; see also Table 1

T_{amb} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)	
				2322 640 .....; see Table 7, note 1	
				5.123	**5.223**
−40	25.78	6.81	6.09	309.4	567.2
−35	19.13	6.16	5.89	229.5	420.8
−30	14.32	5.53	5.70	171.8	315.0
−25	10.82	4.93	5.52	129.8	238.0
−20	8.245	4.35	5.35	98.93	181.4
−15	6.335	3.80	5.19	76.02	139.4
−10	4.907	3.26	5.03	58.88	107.9
−5	3.830	2.74	4.88	45.95	84.25
0	3.011	2.24	4.73	36.13	66.24
5	2.384	1.76	4.60	28.60	52.45
10	1.900	1.30	4.46	22.80	41.81
15	1.525	0.85	4.34	18.30	33.55
20	1.231	0.42	4.21	14.77	27.09
25	1.000	0.00	4.10	12.00	22.00
30	0.8170	0.41	3.98	9.804	17.97
35	0.6712	0.80	3.88	8.054	14.77
40	0.5543	1.19	3.77	6.652	12.20
45	0.4602	1.57	3.67	5.522	10.12
50	0.3839	1.94	3.57	4.607	8.447
55	0.3219	2.30	3.48	3.862	7.081
60	0.2710	2.65	3.39	3.252	5.963
65	0.2293	2.99	3.30	2.751	5.044
70	0.1947	3.33	3.22	2.337	4.284
75	0.1661	3.66	3.14	1.993	3.654
80	0.1422	3.98	3.06	1.707	3.129
85	0.1223	4.29	2.99	1.467	2.690
90	0.1055	4.60	2.92	1.266	2.321
95	0.09135	4.90	2.85	1.096	2.010
100	0.07937	5.19	2.78	0.9524	1.746
105	0.06919	5.48	2.71	0.8302	1.522
110	0.06050	5.76	2.65	0.7260	1.331
115	0.05307	6.04	2.59	0.6369	1.168
120	0.04670	6.31	2.53	0.5604	1.027
125	0.04121	6.57	2.47	0.4945	0.9065

Table 5 Resistance values at intermediate temperatures with R_{25} at 47 kΩ; see also Table 1

T_{amb} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)
				2322 640 .....; see Table 7, note 1
				5.473
−40	33.81	5.55	6.55	1589
−35	24.50	5.02	6.34	1151
−30	17.93	4.52	6.15	842.8
−25	13.25	4.03	5.96	622.6
−20	9.875	3.56	5.78	464.1
−15	7.425	3.10	5.61	349.0
−10	5.630	2.67	5.45	264.6
−5	4.304	2.24	5.29	202.3
0	3.315	1.84	5.14	155.8
5	2.573	1.44	4.99	120.9
10	2.011	1.07	4.85	94.53
15	1.583	0.70	4.72	74.40
20	1.254	0.34	4.59	58.95
25	1.000	0.00	4.46	47.00
30	0.8024	0.33	4.34	37.71
35	0.6474	0.66	4.23	30.43
40	0.5255	0.98	4.12	24.70
45	0.4288	1.28	4.01	20.15
50	0.3518	1.59	3.91	16.53
55	0.2901	1.88	3.81	13.63
60	0.2403	2.17	3.71	11.30
65	0.2001	2.45	3.62	9.404
70	0.1674	2.72	3.53	7.865
75	0.1406	2.99	3.44	6.607
80	0.1186	3.25	3.36	5.573
85	0.1004	3.51	3.28	4.721
90	0.08542	3.76	3.20	4.015
95	0.07292	4.00	3.13	3.427
100	0.06248	4.24	3.06	2.936
105	0.05372	4.47	2.98	2.525
110	0.04635	4.70	2.92	2.179
115	0.04013	4.93	2.85	1.886
120	0.03485	5.15	2.79	1.638
125	0.03037	5.36	2.73	1.427
130	0.02654	5.57	2.67	1.247
135	0.02326	5.78	2.61	1.093
140	0.02044	5.98	2.55	0.9608
145	0.01802	6.18	2.50	0.8468
150	0.01592	6.37	2.44	0.7483

NTC thermistors, accuracy line 2322 640 5....

Table 6 Resistance values at intermediate temperatures with R_{25} at 68 kΩ and 100 kΩ; see also Table 1

T_{amb} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)	
				2322 640 .....; see Table 7, note 1	
				6.683	**6.104**
−40	36.66	5.69	6.70	2493	3666
−35	26.38	5.15	6.49	1794	2638
−30	19.17	4.63	6.29	1303	1917
−25	14.06	4.13	6.10	956.2	1406
−20	10.41	3.65	5.92	708.0	1041
−15	7.779	3.18	5.74	528.9	777.9
−10	5.861	2.73	5.57	398.5	586.1
−5	4.453	2.30	5.41	302.8	445.3
0	3.409	1.88	5.26	231.8	340.9
5	2.631	1.48	5.11	178.9	263.1
10	2.044	1.09	4.97	139.0	204.4
15	1.600	0.72	4.83	108.8	160.0
20	1.261	0.35	4.70	85.74	126.1
25	1.000	0.00	4.57	68.00	100.0
30	0.7981	0.34	4.45	54.27	79.81
35	0.6408	0.67	4.35	43.57	64.08
40	0.5175	1.00	4.22	35.19	51.74
45	0.4202	1.32	4.11	28.57	42.02
50	0.3431	1.63	4.00	23.33	34.31
55	0.2816	1.93	3.90	19.15	28.16
60	0.2322	2.22	3.80	15.79	23.22
65	0.1925	2.51	3.71	13.09	19.25
70	0.1602	2.79	3.62	10.90	16.03
75	0.1340	3.06	3.53	9.114	13.40
80	0.1126	3.33	3.45	7.655	11.26
85	0.09496	3.59	3.36	6.457	9.496
90	0.08042	3.85	3.28	5.469	8.042
95	0.06837	4.10	3.21	4.649	6.837
100	0.05835	4.35	3.13	3.968	5.835
105	0.04998	4.59	3.06	3.399	4.998
110	0.04296	4.82	2.99	2.921	4.296
115	0.03705	5.05	2.92	2.519	3.705
120	0.03206	5.28	2.86	2.180	3.206
125	0.02783	5.50	2.80	1.892	2.783

NTC thermistors, accuracy line 2322 640 5....

Table 7 Resistance values at intermediate temperatures with R_{25} at 470 kΩ; see also Table 1

T_{amb} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; note 1 6.474
−40	48.62	6.22	7.13	22850
−35	34.19	5.63	6.91	16068
−30	24.28	5.06	6.71	11413
−25	17.42	4.51	6.52	8185
−20	12.61	3.98	6.33	5926
−15	9.211	3.47	6.15	4329
−10	6.788	2.98	5.98	3190
−5	5.045	2.51	5.82	2371
0	3.781	2.06	5.66	1776
5	2.855	1.62	5.50	1342
10	2.173	1.19	5.36	1021
15	1.666	0.78	5.22	783.0
20	1.286	0.38	5.08	604.6
25	1.000	0.00	4.95	470.0
30	0.7825	0.37	4.82	367.8
35	0.6163	0.74	4.70	289.6
40	0.4883	1.09	4.59	229.5
45	0.3892	1.44	4.47	182.9
50	0.3120	1.77	4.36	146.7
55	0.2515	2.10	4.26	118.2
60	0.2038	2.43	4.15	95.80
65	0.1660	2.74	4.06	78.03
70	0.1359	3.05	3.96	63.88
75	0.1118	3.35	3.87	52.55
80	0.09240	3.64	3.78	43.43
85	0.07670	3.93	3.69	36.05
90	0.06395	4.21	3.61	30.06
95	0.05354	4.48	3.53	25.16
100	0.04501	4.75	3.45	21.15
105	0.03798	5.01	3.37	17.85
110	0.03218	5.27	3.30	15.12
115	0.02736	5.52	3.23	12.86
120	0.02335	5.77	3.16	10.97
125	0.01999	6.01	3.09	9.396

Note to Tables 2 through 7

1. Replace dot in last 5 digits of catalogue number by a number according to the following details and depending on tolerance on required R_{25}-value: 4 for a tolerance of ±2%; 6 for a tolerance of ±3%; 3 for a tolerance of ±5%; 2 for a tolerance of ±10%.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%; ±3%; ±2%; ±1%
Climatic category	40/125/56
Maximum dissipation	100 mW
Dissipation factor δ	2.2 mW/K
Response time; note 1	1.7 s
Thermal time constant τ	13 s
Operating temperature range (see Fig.2):	
at zero dissipation (continuously)	−40 to +125 °C
at zero dissipation (for short periods); note 2	≤150 °C
at maximum dissipation	0 to +55 °C

Notes

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.
2. Valid for all types with the exception of 2322 640 5.474.

Derating

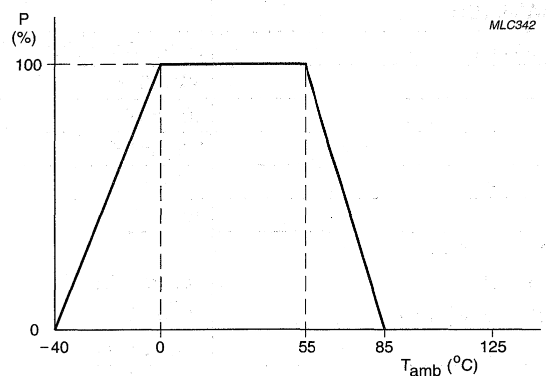
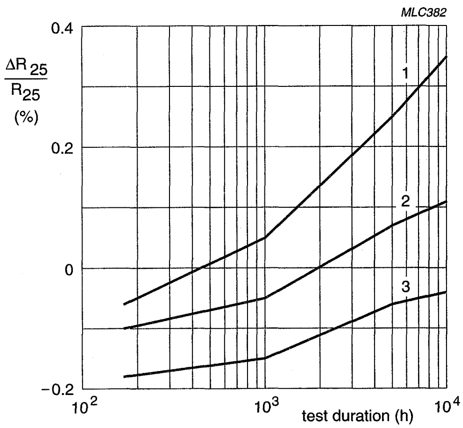


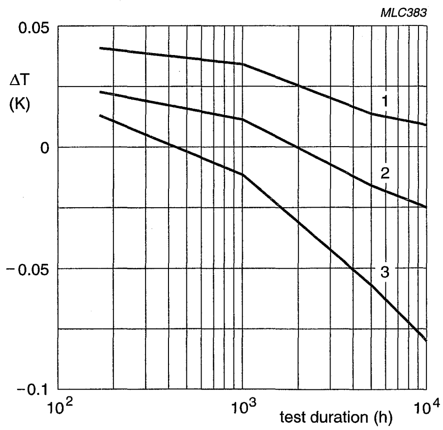
Fig.2 Power derating curve.

Long term stability



Curves valid for 2.2 to 10 kΩ.
Curve 1: maximum deviation.
Curve 2: average deviation.
Curve 3: minimum deviation.

Fig.3 Long term stability of R_{25} as a function of test duration at maximum temperature (150 °C).



Curves valid for 2.2 to 10 kΩ.
Curve 1: minimum deviation.
Curve 2: average deviation.
Curve 3: maximum deviation.

Fig.4 Long term stability of T as a function of test duration at maximum temperature (150 °C).

NTC thermistors, accuracy line 2322 640 6....

FEATURES

- Accuracy over a wide temperature range
- High stability over a long life
- Excellent price/performance ratio.

APPLICATION

- Temperature sensing and control.

DESCRIPTION

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

MARKING

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

MOUNTING

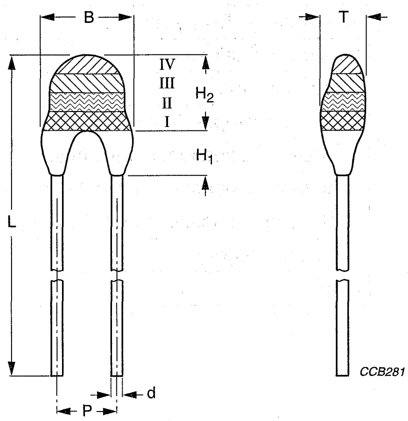
By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	3.3 Ω to 470 kΩ
Tolerance on R_{25}-value	±2%; ±3%; ±5%; ±10%
Tolerance on $B_{25/85}$-value	±0.5% to ±3%
Maximum dissipation	500 mW
Response time	1.2 s
Operating temperature range:	
at zero dissipation; continuously	−40 to +125 °C
at zero dissipation; for short periods	≤150 °C
at maximum dissipation (500 mW)	0 to 55 °C
Climatic category	40/125/56
Mass	≈0.22 g

MECHANICAL DATA

Outline



For dimensions see Table 1.

Fig.1 Component outline 2322 640 6.331 to 6.474.

Table 1 Physical dimensions for relevant type; see Fig.1

CODE NUMBER 2322 640	B_{max} (mm)	d (mm)	H_1 (mm)		$H_{2\,max}$ (mm)	L (mm)	P (mm)	T_{max} (mm)
			MIN.	MAX.				
6.331 to 6.474	3.3 ±0.5	0.6 ±0.06	–	2.0 ±1.0	6.0	24 ±1.5	2.54	3.0
6.338 to 6.221	5.0	0.6 ±0.06	1.0	4.0	6.0	24 ±1.5	2.54	4.0

ORDERING INFORMATION

Table 2 Code numbers and relevant packaging quantities

PARAMETER	BULK	TAPE AND REEL[1] 1e pitch	TAPE AND REEL[1] 2e pitch
	2322 640 6....	2322 640 4....	2322 640 3....
Quantity	500	1500 per reel, 2 reels per box	1500 per reel, 2 reels per box

Note

1. The maximum number of empty places per reel shall not exceed 0.5% of the total number of components per reel. No more than three consecutive positions may be vacant.

Table 3 R_{25}-values, catalogue numbers and coding

R_{25} (Ω)	$B_{25/85}$-VALUE	CATALOGUE NUMBER 2322 640 6....				COLOUR CODE (see Fig.1 and note 1)		
		R_{25} ±2%	R_{25} ±3%	R_{25} ±5%	R_{25} ±10%	I	II	III
3.3	2880 K ±3%	4338	6338	3338	2338	orange	orange	gold
4.7	2880 K ±3%	4478	6478	3478	2478	yellow	violet	gold
6.8	2880 K ±3%	4688	6688	3688	2688	blue	grey	gold
10	2990 K ±3%	4109	6109	3109	2109	brown	black	black
15	3041 K ±3%	4159	6159	3159	2159	brown	green	black
22	3136 K ±3%	4229	6229	3229	2229	red	red	black
33	3390 K ±3%	4339	6339	3339	2339	orange	orange	black
47	3390 K ±3%	4479	6479	3479	2479	yellow	violet	black
68	3390 K ±3%	4689	6689	3689	2689	blue	grey	black
100	3560 K ±0.75%	4101	6101	3101	2101	brown	black	brown
150	3560 K ±0.75%	4151	6151	3151	2151	brown	green	brown
220	3560 K ±0.75%	4221	6221	3221	2221	red	red	brown
330	3560 K ±0.75%	4331	6331	3331	2331	orange	orange	brown
470	3560 K ±0.5%	4471	6471	3471	2471	yellow	violet	brown
680	3560 K ±0.5%	4681	6681	3681	2681	blue	grey	brown
1000	3528 K ±0.5%	4102	6102	3102	2102	brown	black	red
1500	3528 K ±0.5%	4152	6152	3152	2152	brown	green	red
2000	3528 K ±0.5%	4202	6202	3202	2202	red	black	red
2200	3977 K ±0.75%	4222	6222	3222	2222	red	red	red

R_{25} (Ω)	$B_{25/85}$-VALUE	CATALOGUE NUMBER 2322 640 6....				COLOUR CODE (see Fig.1 and note 1)		
		R_{25} ±2%	R_{25} ±3%	R_{25} ±5%	R_{25} ±10%	I	II	III
2700	3977 K ±0.75%	4272	6272	3272	2272	red	violet	red
3300	3977 K ±0.75%	4332	6332	3332	2332	orange	orange	red
4700	3977 K ±0.75%	4472	6472	3472	2472	yellow	violet	red
6800	3977 K ±0.75%	4682	6682	3682	2682	blue	grey	red
10000	3977 K ±0.75%	4103	6103	3103	2103	brown	black	orange
12000	3740 K ±2%	4123	6123	3123	2123	brown	red	orange
15000	3740 K ±2%	4153	6153	3153	2153	brown	green	orange
22000	3740 K ±2%	4223	6223	3223	2223	red	red	orange
33000	4090 K ±1.5%	4333	6333	3333	2333	orange	orange	orange
47000	4090 K ±1.5%	4473	6473	3473	2473	yellow	violet	orange
68000	4190 K ±1.5%	4683	6683	3683	2683	blue	grey	orange
100000	4190 K ±1.5%	4104	6104	3104	2104	brown	black	yellow
150000	4370 K ±2.5%	4154	6154	3154	2154	brown	green	yellow
220000	4370 K ±2.5%	4224	6224	3224	2224	red	red	yellow
330000	4570 K ±1.5%	4334	6334	3334	2334	orange	orange	yellow
470000	4570 K ±1.5%	4474	6474	3474	2474	yellow	violet	yellow

Note

1. Dependent upon R_{25}-tolerance, the band IV is coloured as follows:
   a) for R_{25} ±2%, band IV is coloured red
   b) for R_{25} ±3%, band IV is coloured orange
   c) for R_{25} ±5%, band IV is coloured gold
   d) for R_{25} ±10%, band IV is coloured silver.

R_T value and tolerance

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 Tables 5 through 17, together with a formula to calculate the characteristics with a high precision.

Formulae to determine nominal resistance values(1)

The resistance values at intermediate temperatures, or the operating temperature values, can be calculated using the following interpolation laws (extended *"Steinhart and Hart"*):

$$R\,(T) = R_{ref} \times e^{A + B/T + C/T^2 + D/T^3} \qquad (1)$$

$$T\,(R) = \left(A_1 + B_1 \ln\frac{R}{R_{ref}} + C_1 \ln^2\frac{R}{R_{ref}} + D_1 \ln^3\frac{R}{R_{ref}}\right)^{-1} \qquad (2)$$

where:

A, B, C, D, A_1, B_1, C_1 and D_1 are constant values depending on the material concerned; see Table 4.

R_{ref} is the resistance value at a reference temperature (in this event 25 °C).

T is the temperature in K.

(1) Formulae numbered (1) and (2) are interchangeable with an error of max. 0.005 °C in the range 25 °C to 125 °C and max. 0.015 °C in the range −40 °C to +25 °C.

Determination of the resistance/temperature deviation from nominal value

The total resistance deviation is obtained by combining the 'R_{25}-tolerance' and the 'resistance deviation due to B-tolerance'.

When:

X = R_{25}-tolerance

Y = resistance deviation due to B-tolerance

Z = complete resistance deviation,

then: $$Z = \left[\left(1 + \frac{X}{100}\right) \times \left(1 + \frac{Y}{100}\right) - 1\right] \times 100\%$$

or $Z \approx X + Y$.

When:

TC = temperature coefficient

ΔT = temperature deviation,

then: $$\Delta T = \frac{Z}{TC}$$

The temperature tolerances are plotted in Figs 3, 4, 5, 6, 7 and 8.

Example: at 0 °C, assume X = 5%, Y = 0.89% and TC = 5.08%/K (see Table 12), then:

$$Z = \left\{\left[1 + \frac{5}{100}\right] \times \left[1 + \frac{0.89}{100}\right] - 1\right\} \times 100\%$$

$$= \{1.05 \times 1.0089 - 1\} \times 100\% = 5.9345\% \ (\approx 5.93\%)$$

$$\Delta T = \frac{Z}{TC} = \frac{5.93}{5.08} = 1.167\ °C \ (\approx 1.17\ °C)$$

A NTC with a R_{25}-value of 10 kΩ has a value of 32.56 kΩ between −1.17 and +1.17 °C.

Table 4 Parameters for determining nominal resistance values

$B_{25/85}$-VALUE (K)	A	B (K)	C (10^5K^2)	D (10^6K^3)	A_1 (10^{-3})	B_1 ($10^{-4}K^{-1}$)	C_1 ($10^{-6}K^{-2}$)	D_1 ($10^{-7}K^{-3}$)
2880	−9.094	2251.74	229098	−27.4482	3.354016	3.495020	2.095959	4.260615
2990	−10.2296	2887.62	132336	−25.0251	3.354016	3.415560	4.955455	4.364236
3041	−11.1334	3658.73	−102895	0.516652	3.354016	3.349290	3.683843	7.050455
3136	−12.4493	4702.74	−402687	31.96830	3.354016	3.243880	2.658012	−2.70156
3390	−12.6814	4391.97	−232807	15.09643	3.354016	2.993410	2.135133	−8.05672
3528	−12.060	3.688	−0.076	−5.915	3.354016	2.909670	1.632136	0.719220
3528	−21.095	11.930	−25.139	248.120	3.354016	2.933908	3.494314	−7.71269
3560	−13.072	4.191	−0.472	−11.993	3.354016	2.884193	4.118032	1.786790
3740	−13.897	4.558	−0.983	−7.522	3.354016	2.744032	3.666944	1.375492
3977	−14.634	4.792	−1.153	−3.731	3.354016	2.569355	2.626311	0.675278
4090	−15.532	5.230	−1.605	−5.414	3.354016	2.519107	3.510939	1.105179
4190	−16.035	5.459	−1.911	−3.328	3.354016	2.460382	3.405377	1.034240
4370	−16.872	5.759	−1.943	−6.869	3.354016	2.367720	3.585140	1.255349
4570	−17.644	6.023	−2.032	−7.184	3.354016	2.264097	3.278184	1.097628

Table 5 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 640 .....; see Table 17, note 1		
				6.338	**6.478**	**6.688**
−40	13.6364	8.08	−4.97	45.00	64.09	92.73
−35	10.6806	7.30	−4.80	35.25	50.20	72.63
−30	8.4350	6.55	−4.64	27.84	39.64	57.36
−25	6.7148	5.84	−4.48	22.16	31.56	45.66
−20	5.3866	5.15	−4.33	17.78	25.32	36.63
−15	4.3532	4.49	−4.19	14.37	20.46	29.60
−10	3.5432	3.85	−4.05	11.69	16.65	24.09
−5	2.9035	3.24	−3.92	9.58	13.65	19.74
0	2.3950	2.65	−3.79	7.90	11.26	16.29
5	1.9880	2.08	−3.66	6.56	9.34	13.52
10	1.6602	1.54	−3.55	5.48	7.80	11.29
15	1.3944	1.01	−3.43	4.60	6.55	9.48
20	1.1777	0.49	−3.32	3.89	5.54	8.01
25	1.0000	0.00	−3.22	3.30	4.70	6.80
30	0.8534	0.48	−3.12	2.82	4.01	5.80
35	0.7319	0.94	−3.02	2.42	3.44	4.98
40	0.6307	1.39	−2.93	2.08	2.96	4.29
45	0.5459	1.82	−2.84	1.80	2.57	3.71
50	0.4746	2.24	−2.76	1.57	2.23	3.23
55	0.4143	2.65	−2.68	1.37	1.95	2.82
60	0.3631	3.04	−2.60	1.20	1.71	2.47
65	0.3194	3.43	−2.52	1.05	1.50	2.17
70	0.2820	3.80	−2.45	0.93	1.33	1.92
75	0.2499	4.16	−2.38	0.82	1.17	1.70
80	0.2222	4.51	−2.32	0.73	1.04	1.51
85	0.1982	4.85	−2.25	0.65	0.93	1.35
90	0.1774	5.19	−2.19	0.59	0.83	1.21
95	0.1592	5.51	−2.13	0.53	0.75	1.08
100	0.1433	5.82	−2.07	0.47	0.67	0.97
105	0.1294	6.13	−2.02	0.43	0.61	0.88
110	0.1171	6.43	−1.97	0.39	0.55	0.80
115	0.1063	6.72	−1.92	0.35	0.50	0.72
120	0.0967	7.00	−1.87	0.32	0.45	0.66
125	0.0882	7.28	−1.82	0.29	0.41	0.60
130	0.0806	7.55	−1.77	0.27	0.38	0.55
135	0.0739	7.81	−1.73	0.24	0.35	0.50
140	0.0678	8.07	−1.69	0.22	0.32	0.46
145	0.0624	8.32	−1.65	0.21	0.29	0.42
150	0.0575	8.56	−1.61	0.19	0.27	0.39

NTC thermistors, accuracy line 2322 640 6....

Table 6 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω)
				2322 640 .....; see Table 17, note 1
				6.109
−40	13.675	8.39	−4.86	136.75
−35	10.763	7.58	−4.72	107.63
−30	8.5318	6.81	−4.58	85.32
−25	6.8097	6.06	−4.44	68.10
−20	5.4717	5.35	−4.31	54.72
−15	4.4253	4.66	−4.18	44.25
−10	3.6017	4.00	−4.06	36.02
−5	2.9494	3.37	−3.94	29.49
0	2.4295	2.75	−3.82	24.30
5	2.0128	2.16	−3.71	20.13
10	1.6767	1.59	−3.60	16.77
15	1.4042	1.04	−3.50	14.04
20	1.1821	0.51	−3.39	11.82
25	1.0000	0.00	−3.30	10.00
30	0.8500	0.50	−3.20	8.50
35	0.7259	0.98	−3.11	7.26
40	0.6226	1.44	−3.03	6.23
45	0.5363	1.89	−2.94	5.36
50	0.4639	2.33	−2.86	4.64
55	0.4029	2.75	−2.78	4.03
60	0.3512	3.16	−2.71	3.51
65	0.3073	3.56	−2.64	3.07
70	0.2698	3.95	−2.57	2.70
75	0.2377	4.32	−2.50	2.38
80	0.2101	4.69	−2.43	2.10
85	0.1864	5.04	−2.37	1.86
90	0.1658	5.38	−2.31	1.66
95	0.1479	5.72	−2.25	1.48
100	0.1323	6.05	−2.20	1.32
105	0.1187	6.36	−2.14	1.19
110	0.1068	6.67	−2.09	1.07
115	0.0964	6.98	−2.04	0.96
120	0.0871	7.27	−1.99	0.87
125	0.0790	7.56	−1.94	0.79
130	0.0717	7.84	−1.90	0.72
135	0.0653	8.11	−1.85	0.65
140	0.0596	8.37	−1.81	0.60
145	0.0545	8.63	−1.77	0.55
150	0.0500	8.89	−1.73	0.50

Table 7 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω)
				2322 640 .....; see Table 17, note 1
				6.159
−40	17.042	8.53	−5.54	255.63
−35	12.993	7.71	−5.31	194.90
−30	10.017	6.92	−5.10	150.26
−25	7.8037	6.17	−4.90	117.06
−20	6.1382	5.44	−4.71	92.07
−15	4.8719	4.74	−4.53	73.08
−10	3.8996	4.07	−4.37	58.49
−5	3.1461	3.42	−4.22	47.19
0	2.5571	2.80	−4.07	38.36
5	2.0930	2.20	−3.94	31.40
10	1.7245	1.62	−3.81	25.87
15	1.4298	1.06	−3.69	21.45
20	1.1924	0.52	−3.57	17.89
25	1.0000	0.00	−3.47	15.00
30	0.8431	0.50	−3.36	12.65
35	0.7144	0.99	−3.26	10.72
40	0.6083	1.47	−3.17	9.12
45	0.5203	1.92	−3.08	7.80
50	0.4470	2.37	−3.00	6.70
55	0.3856	2.80	−2.92	5.78
60	0.3339	3.21	−2.84	5.01
65	0.2903	3.62	−2.76	4.35
70	0.2533	4.01	−2.69	3.80
75	0.2218	4.39	−2.62	3.33
80	0.1948	4.77	−2.56	2.92
85	0.1717	5.13	−2.50	2.58
90	0.1518	5.48	−2.44	2.28
95	0.1346	5.82	−2.38	2.02
100	0.1196	6.15	−2.32	1.79
105	0.1067	6.47	−2.27	1.60
110	0.0954	6.79	−2.22	1.43
115	0.0855	7.09	−2.17	1.28
120	0.0768	7.39	−2.12	1.15
125	0.0691	7.69	−2.07	1.04
130	0.0624	7.97	−2.03	0.94
135	0.0565	8.25	−1.98	0.85
140	0.0512	8.52	−1.94	0.77
145	0.0465	8.78	−1.90	0.70
150	0.0423	9.04	−.86	0.63

Table 8 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 640 .....; see Table 17, note 1 6.229
−40	17.042	8.80	−5.54	374.92
−35	12.993	7.95	−5.31	285.85
−30	10.017	7.14	−5.10	220.38
−25	7.8037	6.36	−4.90	171.68
−20	6.1382	5.61	−4.71	135.04
−15	4.8719	4.89	−4.53	107.18
−10	3.8996	4.20	−4.37	85.79
−5	3.1461	3.53	−4.22	69.21
0	2.5571	2.89	−4.07	56.26
5	2.0930	2.27	−3.94	46.05
10	1.7245	1.67	−3.81	37.94
15	1.4298	1.10	−3.69	31.45
20	1.1924	0.54	−3.57	26.23
25	1.0000	0.00	−3.47	22.00
30	0.8431	0.52	−3.36	18.55
35	0.7144	1.02	−3.26	15.72
40	0.6083	1.51	−3.17	13.38
45	0.5203	1.98	−3.08	11.45
50	0.4470	2.44	−3.00	9.83
55	0.3856	2.88	−2.92	8.48
60	0.3339	3.32	−2.84	7.35
65	0.2903	3.73	−2.76	6.39
70	0.2533	4.14	−2.69	5.57
75	0.2218	4.53	−2.62	4.88
80	0.1948	4.91	−2.56	4.29
85	0.1717	5.29	−2.50	3.78
90	0.1518	5.65	−2.44	3.34
95	0.1346	6.00	−2.38	2.96
100	0.1196	6.34	−2.32	2.63
105	0.1067	6.68	−2.27	2.35
110	0.0954	7.00	−2.22	2.10
115	0.0855	7.32	−2.17	1.88
120	0.0768	7.62	−2.12	1.69
125	0.0691	7.93	−2.07	1.52
130	0.0624	8.22	−2.03	1.37
135	0.0565	8.50	−1.98	1.24
140	0.0512	8.78	−1.94	1.13
145	0.0165	9.06	−1.90	1.02
150	0.0423	9.32	−1.86	0.93

Table 9 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 640 .....; see Table 17, note 1		
				6.339	**6.479**	**6.689**
−40	21.4241	9.51	−5.94	707.00	1006.93	1456.84
−35	16.0147	8.59	−5.70	528.48	752.69	1089.00
−30	12.1074	7.72	−5.49	399.54	569.05	823.30
−25	9.2511	6.87	−5.28	305.29	434.80	629.07
−20	7.1395	6.06	−5.09	235.60	335.56	485.49
−15	5.5619	5.29	−4.90	183.54	261.41	378.21
−10	4.3715	4.54	−4.73	144.26	205.46	297.26
−5	3.4647	3.82	−4.57	114.33	162.84	235.60
0	2.7678	3.12	−4.42	91.34	130.09	188.21
5	2.2276	2.45	−4.27	73.51	104.70	151.48
10	1.8057	1.81	−4.13	59.59	84.87	122.79
15	1.4735	1.18	−4.00	48.63	69.26	100.20
20	1.2102	0.58	−3.88	39.94	56.88	82.29
25	1.0000	0.00	−3.76	33.00	47.00	68.00
30	0.8311	0.56	−3.64	27.43	39.06	56.51
35	0.6946	1.11	−3.54	22.92	32.64	47.23
40	0.5835	1.63	−3.43	19.26	27.42	39.68
45	0.4927	2.14	−3.34	16.26	23.16	33.50
50	0.4180	2.64	−3.24	13.79	19.65	28.42
55	0.3563	3.12	−3.15	11.76	16.74	24.23
60	0.3050	3.58	−3.07	10.06	14.33	20.74
65	0.2622	4.03	−2.98	8.65	12.32	17.83
70	.02263	4.47	−2.90	7.47	10.64	15.39
75	0.1961	4.90	−2.83	6.47	9.22	13.33
80	0.1705	5.31	−2.76	5.63	8.02	11.60
85	0.1489	5.71	−2.69	4.91	7.00	10.12
90	0.1304	6.11	−2.62	4.30	6.13	8.86
95	0.1146	6.49	−2.55	3.78	5.38	7.79
100	0.1010	6.86	−2.49	3.33	4.75	6.87
105	0.0893	7.22	−2.43	2.95	4.20	6.07
110	0.0792	7.57	−2.37	2.61	3.72	5.38
115	0.0704	7.91	−2.32	2.32	3.31	4.79
120	0.0628	8.24	−2.26	2.07	2.95	4.27
125	0.0561	8.57	−2.21	1.85	2.64	3.82
130	0.0503	8.88	−2.16	1.66	2.37	3.42
135	0.0452	9.19	−2.11	1.49	2.13	3.07
140	0.0407	9.49	−2.07	1.34	1.91	2.77
145	0.0368	9.79	−2.02	1.21	1.73	2.50
150	0.0333	10.08	−1.98	1.10	1.56	2.26

Table 10 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1					
				6.101	**6.151**	**6.221**	**6.331**	**6.471**	**6.681**
−40	21.9261	2.50	−5.75	2192.6	2388.9	4823.7	7236	10503	14910
−35	16.5224	2.26	−5.57	1652.2	2478.4	3634.9	5452	7766	11235
−30	12.5583	2.03	−5.40	1255.8	1883.7	2762.8	4144	5902	8540
−25	9.62492	1.80	−5.24	962.5	1443.7	2117.5	3176	4524	6545
−20	7.43618	1.59	−5.08	743.6	1115.4	1636.0	2454	3495	5057
−15	5.78976	1.39	−4.93	579.0	868.5	1273.7	1911	2721	3937
−10	4.54158	1.19	−4.78	454.2	681.2	999.1	1499	1235	3088
−5	3.58813	1.00	−4.64	358.8	538.2	789.4	1184	1686	2440
0	2.85449	0.82	−4.51	285.4	428.2	628.0	942.0	1342	1941
5	2.28599	0.64	−4.38	228.6	342.9	502.9	754.4	1074	1554
10	1.84245	0.47	−4.25	184.2	276.4	405.3	608.0	865.9	1253
15	1.49414	0.31	−4.13	149.4	224.1	328.7	493.1	702.2	1016
20	1.21887	0.15	−4.01	121.9	182.8	268.2	402.2	572.9	828.8
25	1.000	0.00	−3.90	100.0	150.0	220.0	330.0	470.0	680.0
30	0.82494	0.15	−3.80	82.5	123.7	181.5	272.2	387.7	561.0
35	0.68413	0.29	−3.69	68.4	102.6	150.5	225.8	321.5	465.2
40	0.57025	0.43	−3.59	57.0	85.5	125.5	188.2	268.0	387.8
45	0.47765	0.56	−3.50	47.8	71.6	105.1	157.6	224.5	324.8
50	0.40198	0.69	−3.40	40.2	60.3	88.4	132.7	188.9	273.3
55	0.33984	0.82	−3.31	34.0	51.0	74.8	112.1	159.7	231.1
60	0.28856	0.94	−3.23	28.9	43.3	63.5	95.23	135.6	196.2
65	0.24606	1.06	−3.15	24.6	36.9	54.1	81.20	115.6	167.3
70	0.21067	1.17	−3.07	21.1	31.6	46.3	69.52	99.00	143.3
75	0.18108	1.29	−2.99	18.1	27.2	39.8	59.76	85.11	123.1
80	0.15623	1.39	−2.91	15.6	23.4	34.4	51.56	73.43	106.2
85	0.13529	1.50	−2.84	13.5	20.3	29.8	44.65	63.59	92.00
90	0.11757	1.60	−2.77	11.8	17.6	25.9	38.80	55.26	79.95
95	0.10251	1.70	−2.71	10.3	15.4	22.6	33.83	48.18	69.71
100	0.08968	1.80	−2.64	8.97	13.5	19.7	29.59	42.15	60.98
105	0.07871	1.89	−2.58	7.87	11.8	17.3	25.97	36.99	53.52
110	0.06928	1.99	−2.52	6.93	10.4	15.2	22.86	32.56	47.11
115	0.06117	2.08	−2.46	6.12	9.18	13.5	20.19	28.75	41.60
120	0.05416	2.16	−2.41	5.42	8.12	11.9	17.87	25.46	36.83
125	0.04809	2.25	−2.35	4.81	7.21	10.6	15.87	22.60	32.70
130	0.04282	2.33	−2.30	4.28	6.42	9.42	14.13	20.12	29.11
135	0.03822	2.41	−2.25	3.82	5.73	8.41	12.61	17.96	25.99
140	0.03420	2.49	−2.20	3.42	5.13	7.52	11.29	16.07	23.25
145	0.03068	2.57	−2.15	3.07	4.60	6.75	10.12	14.42	20.86
150	0.02758	2.65	−2.10	2.76	4.14	6.07	9.10	12.96	18.76

Table 11 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 640 .....; see Table 17, note 1		
				6.102	**6.152**	**6.202**
−40	23.3402	1.65	−6.06	23342	35013	46684
−35	17.3347	1.49	−5.84	17336	26004	34672
−30	13.0166	1.34	−5.62	13018	19526	26035
−25	9.8764	1.19	−5.42	9877	14816	19754
−20	7.5682	1.05	−5.23	7569	11353	15138
−15	5.8541	0.92	−5.05	5855	8782	11709
−10	4.5688	0.79	−4.87	4569	6854	9138
−5	3.5961	0.66	−4.71	3596	5395	7193
0	2.8533	0.54	−4.55	2854	4280	5707
5	2.2815	0.43	−4.40	2282	3422	4563
10	1.8376	0.31	−4.26	1838	2457	3675
15	1.4904	0.21	−4.12	1491	2236	2981
20	1.2169	0.10	−3.99	1217	1826	2434
25	1.0000	0.00	−3.87	1000	1500	2000
30	0.8266	0.10	−3.75	826.7	1240	1653
35	0.6873	0.19	−3.63	687.4	1031	1375
40	0.5746	0.28	−3.53	574.6	861.9	1149
45	0.4827	0.37	−3.42	482.7	724.1	965.0
50	0.4073	0.46	−3.32	407.4	611.0	814.7
55	0.3452	0.54	−3.23	345.2	517.8	690.5
60	0.2937	0.62	−3.14	293.7	440.6	587.5
65	0.2508	0.70	−3.05	250.8	376.2	501.7
70	0.2149	0.78	−2.97	214.9	322.4	429.8
75	0.1847	0.85	−2.89	184.8	277.1	369.5
80	0.1593	0.92	−2.81	159.3	238.9	318.6
85	0.1377	0.99	−2.73	137.7	206.6	275.5
90	0.11942	1.06	−2.66	119.4	179.1	238.9
95	0.10380	1.13	−2.59	103.8	155.7	207.6
100	0.09045	1.19	−2.53	90.46	135.7	180.9
105	0.07900	1.25	−2.46	79.00	118.5	158.0
110	0.06915	1.31	−2.40	69.16	103.7	138.3
115	0.06066	1.37	−2.34	60.66	90.99	121.3
120	0.05332	1.43	−2.29	53.32	79.98	106.6
125	0.04696	1.49	−2.23	46.96	70.44	93.9
130	0.04143	1.54	−2.18	41.44	62.15	82.9
135	0.03662	1.60	−2.13	36.63	54.94	73.3
140	0.03243	1.65	−2.08	32.43	48.65	64.9
145	0.02877	1.70	−2.03	28.77	43.16	57.5
150	0.02556	1.75	−1.98	25.56	38.34	51.1

Table 12 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1					
				6.222	6.272	6.332	6.472	6.682	6.103
−40	33.21	2.66	6.57	73.06	89.67	109.6	156.1	225.8	332.1
−35	23.99	2.41	6.36	52.78	64.77	79.17	112.8	163.1	240.0
−30	17.52	2.17	6.15	38.55	47.31	57.82	82.35	119.1	175.2
−25	12.93	1.94	5.95	28.44	34.91	42.67	60.77	87.92	129.3
−20	9.636	1.71	5.76	21.20	26.02	31.80	45.30	65.53	96.36
−15	7.250	1.50	5.58	15.95	19.58	23.93	34.08	49.30	72.50
−10	5.505	1.29	5.40	12.11	14.86	18.16	25.87	37.43	55.05
−5	4.216	1.08	5.24	9.275	11.38	13.91	19.81	28.67	42.16
0	3.255	0.89	5.08	7.162	8.790	10.74	15.30	22.14	32.56
5	2.534	0.70	4.92	5.575	6.842	8.362	11.91	17.23	25.34
10	1.987	0.52	4.78	4.372	5.366	6.558	9.340	13.51	19.87
15	1.570	0.34	4.64	3.454	4.239	5.181	7.378	10.67	15.70
20	1.249	0.17	4.50	2.747	3.372	4.121	5.869	8.492	12.49
25	1.000	0.00	4.37	2.200	2.700	3.300	4.700	6.800	10.00
30	0.8059	0.16	4.25	1.773	2.176	2.660	3.788	5.480	8.059
35	0.6535	0.32	4.13	1.438	1.764	2.156	3.072	4.444	6.535
40	0.5330	0.47	4.02	1.173	1.439	1.759	2.505	3.624	5.330
45	0.4372	0.62	3.91	0.9618	1.180	1.443	2.055	2.972	4.372
50	0.3605	0.77	3.80	0.7932	0.973	1.190	1.694	2.451	3.606
55	0.2989	0.91	3.70	0.6575	0.807	0.9863	1.405	2.032	2.989
60	0.2490	1.05	3.60	0.5478	0.672	0.8217	1.170	1.693	2.490
65	0.2084	1.18	3.51	0.4586	0.562	0.6879	0.9797	1.417	2.084
70	0.1753	1.31	3.42	0.3857	0.473	0.5785	0.8239	1.192	1.753
75	0.1481	1.44	3.33	0.3258	0.399	0.4887	0.6960	1.007	1.481
80	0.1256	1.57	3.25	0.2764	0.339	0.4146	0.5905	0.8544	1.256
85	0.1070	1.69	3.16	0.2355	0.289	0.3532	0.5031	0.7278	1.070
90	0.09154	1.81	3.09	0.2014	0.247	0.3021	0.4303	0.6225	0.9154
95	0.07860	1.93	3.01	0.1729	0.212	0.2594	0.3694	0.5345	0.7860
100	0.06773	2.04	2.94	0.1490	0.182	0.2235	0.3183	0.4607	0.6773
105	0.05858	2.15	2.87	0.1289	0.158	0.1933	0.2753	0.3983	0.5858
110	0.05083	2.26	2.80	0.1118	0.137	0.1677	0.2389	0.3457	0.5083
115	0.04426	2.37	2.73	0.0974	0.1195	0.1461	0.2080	0.3010	0.4426
120	0.03866	2.47	2.67	0.0851	0.1044	0.1276	0.1817	0.2629	0.3866
125	0.03387	2.57	2.61	0.0745	0.0915	0.1118	0.1592	0.2303	0.3387
130	0.02977	2.67	2.55	0.0655	0.0804	0.0982	0.1399	0.2024	0.2977
135	0.02624	2.77	2.49	0.0577	0.0709	0.0866	0.1233	0.1784	0.2624
140	0.02319	2.86	2.43	0.0510	0.0626	0.0765	0.1090	0.1577	0.2319
145	0.02055	2.96	2.38	0.0452	0.0555	0.0678	0.0966	0.1398	0.2055
150	0.01826	3.05	2.33	0.0402	0.0493	0.0603	0.0858	0.1242	0.1826

NTC thermistors, accuracy line 2322 640 6....

Table 13 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1		
				6.123	**6.153**	**6.223**
−40	25.78	6.81	6.09	309.4	386.8	567.2
−35	19.13	6.16	5.89	229.5	286.9	420.8
−30	14.32	5.53	5.70	171.8	214.8	315.0
−25	10.82	4.93	5.52	129.8	162.3	238.0
−20	8.245	4.35	5.35	98.93	123.7	181.4
−15	6.335	3.80	5.19	76.02	95.03	139.4
−10	4.907	3.26	5.03	58.88	73.60	107.9
−5	3.830	2.74	4.88	45.95	57.44	84.25
0	3.011	2.24	4.73	36.13	45.16	66.24
5	2.384	1.76	4.60	28.60	35.76	52.45
10	1.900	1.30	4.46	22.80	28.50	41.81
15	1.525	0.85	4.34	18.30	22.87	33.55
20	1.231	0.42	4.21	14.77	18.47	27.09
25	1.000	0.00	4.10	12.00	15.00	22.00
30	0.8170	0.41	3.98	9.804	12.26	17.97
35	0.6712	0.80	3.88	8.054	10.07	14.77
40	0.5543	1.19	3.77	6.652	8.315	12.20
45	0.4602	1.57	3.67	5.522	6.903	10.12
50	0.3839	1.94	3.57	4.607	5.759	8.447
55	0.3219	2.30	3.48	3.862	4.828	7.081
60	0.2710	2.65	3.39	3.252	4.067	5.963
65	0.2293	2.99	3.30	2.751	3.439	5.044
70	0.1947	3.33	3.22	2.337	2.921	4.284
75	0.1661	3.66	3.14	1.993	2.492	3.654
80	0.1422	3.98	3.06	1.707	2.134	3.129
85	0.1223	4.29	2.99	1.467	1.834	2.690
90	0.1055	4.60	2.92	1.266	1.583	2.321
95	0.09135	4.90	2.85	1.096	1.370	2.010
100	0.07937	5.19	2.78	0.9524	1.190	1.746
105	0.06919	5.48	2.71	0.8302	1.038	1.522
110	0.06050	5.76	2.65	0.7260	0.9075	1.331
115	0.05307	6.04	2.59	0.6369	0.7961	1.168
120	0.04670	6.31	2.53	0.5604	0.7005	1.027
125	0.04121	6.57	2.47	0.4945	0.6181	0.9065

Table 14 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1	
				6.333	**6.473**
−40	33.81	5.55	6.55	1116	1589
−35	24.50	5.02	6.34	808.6	1151
−30	17.93	4.52	6.15	591.7	842.8
−25	13.25	4.03	5.96	437.1	622.6
−20	9.875	3.56	5.78	325.9	464.1
−15	7.425	3.10	5.61	245.0	349.0
−10	5.630	2.67	5.45	185.8	264.6
−5	4.304	2.24	5.29	142.0	202.3
0	3.315	1.84	5.14	109.4	155.8
5	2.573	1.44	4.99	84.91	120.9
10	2.011	1.07	4.85	66.37	94.53
15	1.583	0.70	4.72	52.24	74.40
20	1.254	0.34	4.59	41.39	58.95
25	1.000	0.00	4.46	33.00	47.00
30	0.8024	0.33	4.34	26.47	37.71
35	0.6474	0.66	4.23	21.37	30.43
40	0.5255	0.98	4.12	17.34	24.70
45	0.4288	1.28	4.01	14.15	20.15
50	0.3518	1.59	3.91	11.61	16.53
55	0.2901	1.88	3.81	9.572	13.63
60	0.2403	2.17	3.71	7.931	11.30
65	0.2001	2.45	3.62	6.603	9.404
70	0.1674	2.72	3.53	5.522	7.865
75	0.1406	2.99	3.44	4.639	6.607
80	0.1186	3.25	3.36	3.913	5.573
85	0.1004	3.51	3.28	3.315	4.721
90	0.08542	3.76	3.20	2.819	4.015
95	0.07292	4.00	3.13	2.406	3.427
100	0.06248	4.24	3.06	2.062	2.936
105	0.05372	4.47	2.98	1.773	2.525
110	0.04635	4.70	2.92	1.530	2.179
115	0.04013	4.93	2.85	1.342	1.886
120	0.03485	5.15	2.79	1.150	1.638
125	0.03037	5.36	2.73	1.002	1.427
130	0.02654	5.57	2.67	0.8757	1.247
135	0.02326	5.78	2.61	0.7675	1.093
140	0.02044	5.98	2.55	0.6746	0.9608
145	0.01802	6.18	2.50	0.5945	0.8468
150	0.01592	6.37	2.44	0.5254	0.7483

Table 15 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1	
				6.683	**6.104**
−40	36.66	5.69	6.70	2493	3666
−35	26.38	5.15	6.49	1794	2638
−30	19.17	4.63	6.29	1303	1917
−25	14.06	4.13	6.10	956.2	1406
−20	10.41	3.65	5.92	708.0	1041
−15	7.779	3.18	5.74	528.9	777.9
−10	5.861	2.73	5.57	398.5	586.1
−5	4.453	2.30	5.41	302.8	445.3
0	3.409	1.88	5.26	231.8	340.9
5	2.631	1.48	5.11	178.9	263.1
10	2.044	1.09	4.97	139.0	204.4
15	1.600	0.72	4.83	108.8	160.0
20	1.261	0.35	4.70	85.74	126.1
25	1.000	0.00	4.57	68.00	100.0
30	0.7981	0.34	4.45	54.27	79.81
35	0.6408	0.67	4.35	43.57	64.08
40	0.5175	1.00	4.22	35.19	51.74
45	0.4202	1.32	4.11	28.57	42.02
50	0.3431	1.63	4.00	23.33	34.31
55	0.2816	1.93	3.90	19.15	28.16
60	0.2322	2.22	3.80	15.79	23.22
65	0.1925	2.51	3.71	13.09	19.25
70	0.1602	2.79	3.62	10.90	16.03
75	0.1340	3.06	3.53	9.114	13.40
80	0.1126	3.33	3.45	7.655	11.26
85	0.09496	3.59	3.36	6.457	9.496
90	0.08042	3.85	3.28	5.469	8.042
95	0.06837	4.10	3.21	4.649	6.837
100	0.05835	4.35	3.13	3.968	5.835
105	0.04998	4.59	3.06	3.399	4.998
110	0.04296	4.82	2.99	2.921	4.296
115	0.03705	5.05	2.92	2.519	3.705
120	0.03206	5.28	2.86	2.180	3.206
125	0.02783	5.50	2.80	1.892	2.783

Table 16 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 .....; see Table 17, note 1	
				6.154	6.224
−40	41.02	10.10	6.89	6153	9024
−35	29.29	9.12	6.68	4394	6444
−30	21.12	8.18	6.48	3168	4646
−25	15.37	7.28	6.29	2305	3381
−20	11.28	6.42	6.11	1693	2483
−15	8.358	5.59	5.93	1254	1839
−10	6.242	4.80	5.76	936.4	1373
−5	4.700	4.03	5.60	705.0	1034
0	3.567	3.30	5.44	535.0	784.7
5	2.727	2.59	5.29	409.1	600.0
10	2.101	1.90	5.15	315.1	462.1
15	1.629	1.25	5.01	244.4	358.4
20	1.272	0.61	4.88	190.8	279.9
25	1.000	0.00	4.75	150.0	220.0
30	0.7910	0.59	4.62	118.6	174.0
35	0.6295	1.18	4.51	94.42	138.5
40	0.5039	1.74	4.39	75.58	110.9
45	0.4056	2.30	4.28	60.85	89.24
50	0.3283	2.84	4.17	49.25	72.24
55	0.2672	3.37	4.07	40.08	58.78
60	0.2185	3.89	3.97	32.78	48.08
65	0.1796	4.40	3.87	26.94	39.51
70	0.1483	4.90	3.78	22.25	32.63
75	0.1231	5.39	3.69	18.46	27.07
80	0.1025	5.86	3.60	15.38	22.56
85	0.08582	6.33	3.52	12.87	18.88
90	0.07213	6.79	3.44	10.82	15.87
95	0.06086	7.24	3.36	9.129	13.39
100	0.05155	7.68	3.28	7.732	11.34
105	0.04383	8.11	3.21	6.574	9.642
110	0.03740	8.53	3.14	5.610	8.228
115	0.03203	8.94	3.07	4.804	7.046
120	0.02752	9.35	3.00	4.128	6.054
125	0.02372	9.75	2.94	3.559	5.219

Table 17 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)	
				2322 640 .....; see note 1	
				6.334	**6.474**
−40	48.62	6.22	7.13	16044	22850
−35	34.19	5.63	6.91	11282	16068
−30	24.28	5.06	6.71	8013	11413
−25	17.42	4.51	6.52	5747	8185
−20	12.61	3.98	6.33	4161	5926
−15	9.211	3.47	6.15	3040	4329
−10	6.788	2.98	5.98	2240	3190
−5	5.045	2.51	5.82	1665	2371
0	3.781	2.06	5.66	1248	1776
5	2.855	1.62	5.50	942.3	1342
10	2.173	1.19	5.36	717.1	1021
15	1.666	0.78	5.22	549.8	783.0
20	1.286	0.38	5.08	424.5	604.6
25	1.000	0.00	4.95	330.0	470.0
30	0.7825	0.37	4.82	258.2	367.8
35	0.6163	0.74	4.70	203.4	289.6
40	0.4883	1.09	4.59	161.1	229.5
45	0.3892	1.44	4.47	128.4	182.9
50	0.3120	1.77	4.36	103.0	146.7
55	0.2515	2.10	4.26	83.00	118.2
60	0.2038	2.43	4.15	67.26	95.80
65	0.1660	2.74	4.06	54.79	78.03
70	0.1359	3.05	3.96	44.86	63.88
75	0.1118	3.35	3.87	36.90	52.55
80	0.09240	3.64	3.78	30.49	43.43
85	0.07670	3.93	3.69	25.31	36.05
90	0.06395	4.21	3.61	21.10	30.06
95	0.05354	4.48	3.53	17.67	25.16
100	0.04501	4.75	3.45	14.85	21.15
105	0.03798	5.01	3.37	12.53	17.85
110	0.03218	5.27	3.30	10.70	15.12
115	0.02736	5.52	3.23	9.029	12.86
120	0.02335	5.77	3.16	7.704	10.97
125	0.01999	6.01	3.09	6.597	9.396

Note to Tables 5 through 17

1. Replace dot in last 5 digits of catalogue number by a number according to the following details and depending on tolerance on required R_{25}-value: 4 for a tolerance of ±2%; 6 for a tolerance of ±3%; 3 for a tolerance of ±5%; 2 for a tolerance of ±10%.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*, see also Table 3. Stability is in accordance with *"CECC 43 000"* and *"IEC 60068-2"*, see Table 18.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±2%; ±3%; ±5% and ±10%
Climatic category	40/125/56
Maximum dissipation	500 mW
Dissipation factor δ (for information only)	7 mW/K
Response time (for information only); note 1	1.2 s
Thermal time constant τ (for information only)	11 s
Operating temperature range:	
at zero dissipation; continuously	−40 to +125 °C
at zero dissipation	≤150 °C
at maximum dissipation	0 to +55 °C

Note

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

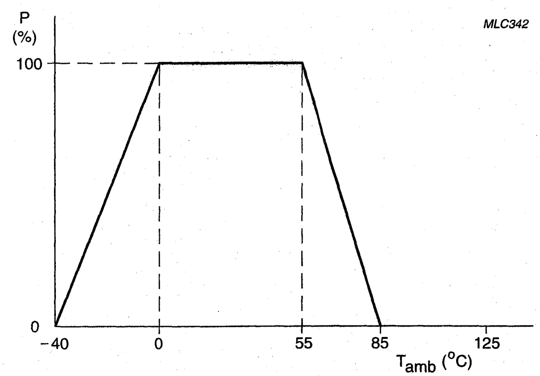
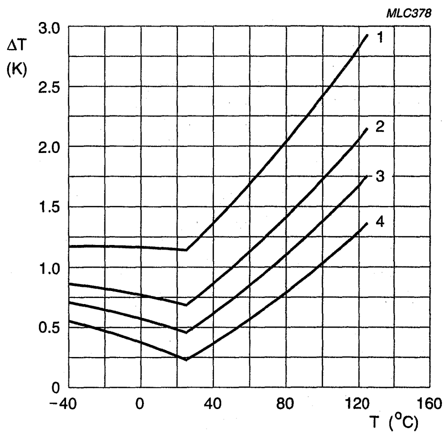
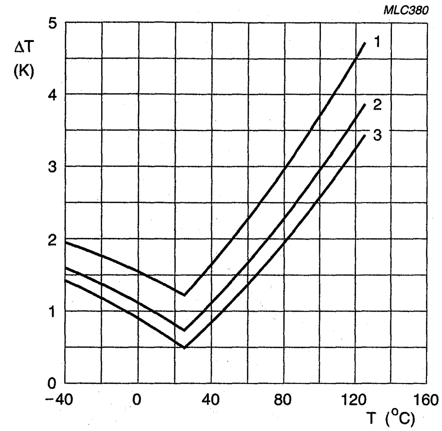


Fig.2 Power derating curve.



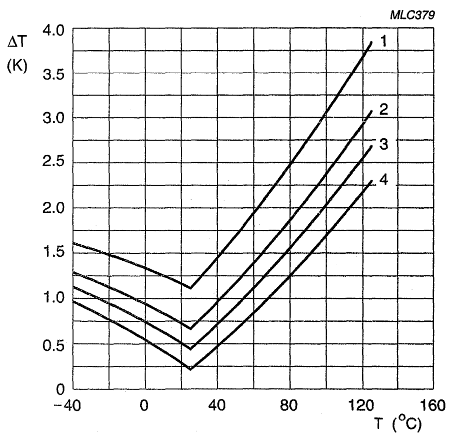
Curves valid for 2.2 to 10 kΩ.
Curve 1: $\Delta R_{25}/R_{25}$ = 5%.
Curve 2: $\Delta R_{25}/R_{25}$ = 3%.
Curve 3: $\Delta R_{25}/R_{25}$ = 2%.
Curve 4: $\Delta R_{25}/R_{25}$ = 1% (for 2322 640 5.... series only).

Fig.3 Temperature deviation as a function of the ambient temperature.



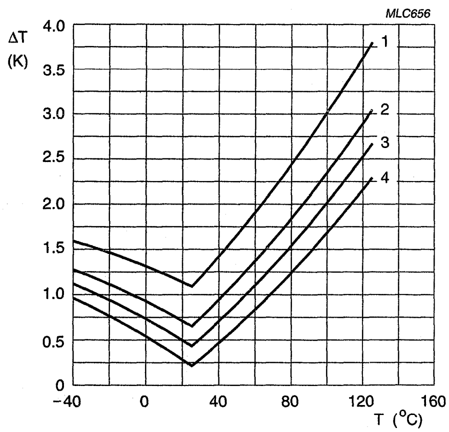
Curves valid for 12 to 22 kΩ.
Curve 1: $\Delta R_{25}/R_{25}$ = 5%.
Curve 2: $\Delta R_{25}/R_{25}$ = 3%.
Curve 3: $\Delta R_{25}/R_{25}$ = 2%.

Fig.4 Temperature deviation as a function of the ambient temperature.



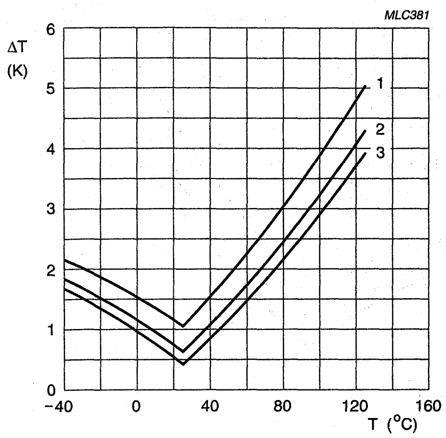
Curves valid for 33 to 47 kΩ.
Curve 1: $\Delta R_{25}/R_{25}$ = 5%.
Curve 2: $\Delta R_{25}/R_{25}$ = 3%.
Curve 3: $\Delta R_{25}/R_{25}$ = 2%.
Curve 4: $\Delta R_{25}/R_{25}$ = 1% (for 2322 640 5.... series only).

Fig.5 Temperature deviation as a function of the ambient temperature.



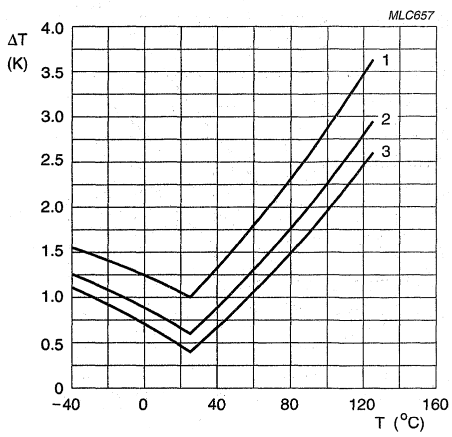
Curves valid for 68 to 100 kΩ.
Curve 1: $\Delta R_{25}/R_{25}$ = 5%.
Curve 2: $\Delta R_{25}/R_{25}$ = 3%.
Curve 3: $\Delta R_{25}/R_{25}$ = 2%.
Curve 4: $\Delta R_{25}/R_{25}$ = 1% (for 2322 640 5.... series only).

Fig.6 Temperature deviation as a function of the ambient temperature.



Curves valid for 150 to 220 kΩ.
Curve 1: $\Delta R_{25}/R_{25} = 5\%$.
Curve 2: $\Delta R_{25}/R_{25} = 3\%$.
Curve 3: $\Delta R_{25}/R_{25} = 2\%$.

Fig.7 Temperature deviation as a function of the ambient temperature.



Curves valid for 330 to 470 kΩ.
Curve 1: $\Delta R_{25}/R_{25} = 5\%$.
Curve 2: $\Delta R_{25}/R_{25} = 3\%$.
Curve 3: $\Delta R_{25}/R_{25} = 2\%$.

Fig.8 Temperature deviation as a function of the ambient temperature.

TESTS AND REQUIREMENTS

Essentially all tests are carried out in accordance with *"IEC publication 60068-2; Environmental testing"*, except where indicated.

Table 18 Stability tests

CECC 32 100 CLAUSE	IEC 60068-2 TEST METHOD	TEST	PROCEDURE	REQUIREMENTS
D3; 4.20.1		endurance	25 °C; 1000 hours	ΔR/R < 1%
	1	endurance	−40 °C; 1000 hours	ΔR/R < 1%
	539	endurance	500 mW; 55 °C; 1000 hours	ΔR/R < 3% (note 1)
	2	dry heat, (steady state)	125 °C; 1000 hours	ΔR/R < 3%
D1; 4.19	3	damp heat (steady state)	56 days at 40 °C; 90 to 95% RH	ΔR/R < 3%
C2; 4.14	14	rapid change of temperature	−40 °C to +125 °C; 50 cycles	ΔR/R < 2%
Other applicable tests				
	21	robustness of leads: tensile strength bending	 loading force 10 N loading force 5 N	ΔR/R ≤ 1%
	58	soldering: solderability resistance to heat	 240 °C max.; duration 4 s max. 265 °C max.; duration 5 s max.	ΔR/R ≤ 1% (note 2)
	27	impact	free fall; 1 m	ΔR/R ≤ 1%
	29	shock	490 m/s; half sinewave	ΔR/R ≤ 1%
	45	resistance to solvent (isopropanol)	ambient temp for 5 min; 5 N with hydrophylic cotton wool	no traces of lacquer on cotton wool
	6	vibration	1.5 mm peak to peak: 10 to 58 Hz 10 gp: 50 to 500 Hz 1 octave/min. 2 hours in each direction in three orthogonal directions	no visible damage ΔR/R < 1%
	2	inflammability	1980, needle flame test	non-flammable

Notes

1. For R_{25} ≥ 100 kΩ the drift requirement is ΔR/R < 5%.
2. For R_{25} from 2.2 kΩ to 10 kΩ, requirement is ±2% max.

FEATURES

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

APPLICATIONS

- Temperature sensing and control up to 150 °C
- Temperature compensation.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two tinned solid copper leads. 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 and the choice of R_{25}-values is based on the American standard. The thermistors have a non-flammable coating of protective lacquer which, in accordance with *"IEC 60068-2-45"*, is resistant to most commonly used cleaning solvents.

PACKAGING

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

MECHANICAL DATA

Marking

Grey lacquered.

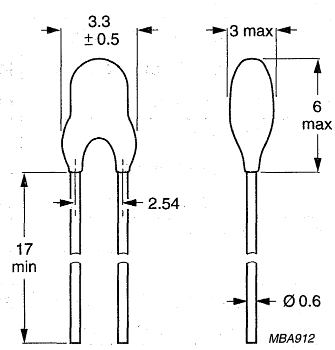
Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	5 to 10 kΩ
$B_{25/75}$-value	3965 K
Tolerance on $B_{25/75}$-value	±0.75%
Maximum dissipation	100 mW
Response time (for information only)	1.2 s
Operating temperature range:	
at zero dissipation	−40 to +125 °C
for short periods	≤150 °C
at maximum dissipation	0 to +55 °C
Climatic category	40/125/56
Mass	≈0.22 g

Outline



Dimensions in mm.

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values and catalogue numbers

R_{25}-VALUE ±5% (kΩ)	CATALOGUE NUMBER 2322 645 0....
5	03502
6	03602
8	03802
10	03103

R_T-value and tolerance

These thermistors have a narrow tolerance on the B-value, 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 3, together with a formula to calculate the characteristics with a high precision.

Formulae to determine nominal resistance values

The resistance values at intermediate temperatures, or at the operating temperature values, can be calculated using the following interpolation laws (extended *"Steinhart and Hart"*):

$$R(T) = R_{ref} \times e^{A + B/T + C/T^2 + D/T^3}$$

$$T(R) = \left(A_1 + B_1 \ln\frac{R}{R_{ref}} + C_1 \ln^2\frac{R}{R_{ref}} + D_1 \ln^3\frac{R}{R_{ref}}\right)^{-1}$$

where:

A, B, C, D, A_1, B_1, C_1 and D_1 are constant values depending on the material concerned; see Table 2.

R_{ref} is the resistance value at a reference temperature (in this event 25 °C).

T is the temperature in K.

Determination of the resistance/temperature deviation from nominal value

The total resistance deviation is obtained by combining the 'R_{25}-tolerance' and the 'resistance deviation due to B-tolerance'.

When:

X = R_{25}-tolerance

Y = resistance deviation due to B-tolerance

Z = complete resistance deviation,

then:

$$Z = \left[\left(1 + \frac{X}{100}\right) \times \left(1 + \frac{Y}{100}\right) - 1\right] \times 100\%$$

or $Z \approx X + Y$

When:

TC = temperature coefficient

ΔT = temperature deviation,

then:

$$\Delta T = \frac{Z}{TC}$$

EXAMPLE

At 0 °C, assume X = 5%, Y = 0.89% and TC = 5.08%/K (see Table 3), then:

$$Z = \left\{\left[1 + \frac{5}{100}\right] \times \left[1 + \frac{0.89}{100}\right] - 1\right\} \times 100\%$$

$$= \{1.05 \times 1.0089 - 1\} \times 100\% = 5.9345\% \ (\approx 5.93\%)$$

$$\Delta T = \frac{Z}{TC} = \frac{5.93}{5.08} = 1.167\ °C \ (\approx 1.17\ °C)$$

A NTC with a R_{25}-value of 10 kΩ has a value of 32.51 kΩ between −1.17 and +1.17 °C.

Table 2 Parameters for determining nominal resistance values

$B_{25/85}$ (K)	A	B (K)	C (K^2)	D (K^3)	A_1 ($10^{-3}K^{-1}$)	B_1 ($10^{-4}K^{-1}$)	C_1 ($10^{-6}K^{-1}$)	D_1 ($10^{-7}K^{-1}$)
3977	−14.6337	4791.842	−115334	−3730535	3.353832	2.569355	2.626311	0.675278

NTC thermistors, accuracy line 2322 645 0....

Table 3 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 645 .....(1)			
				0.502	**0.602**	**0.802**	**0.103**
−40	33.21	2.66	6.57	166.1	199.3	265.7	332.1
−35	23.99	2.41	6.36	120.0	143.9	191.9	239.9
−30	17.52	2.17	6.15	87.60	105.1	140.2	175.2
−25	12.93	1.94	5.95	64.65	77.57	103.4	129.3
−20	9.636	1.71	5.76	48.18	57.82	77.09	96.36
−15	7.250	1.50	5.58	36.25	43.50	58.00	72.50
−10	5.505	1.29	5.40	27.52	33.03	44.04	55.05
−5	4.216	1.08	5.24	21.08	25.30	33.73	42.16
0	3.255	0.89	5.08	16.28	19.53	26.04	32.56
5	2.534	0.70	4.92	12.67	15.20	20.27	25.34
10	1.987	0.52	4.78	9.936	11.92	15.90	19.87
15	1.570	0.34	4.64	7.849	9.419	12.56	15.70
20	1.249	0.17	4.50	6.244	7.493	9.990	12.49
25	1.000	0.00	4.37	5.000	6.000	8.000	10.00
30	0.8059	0.16	4.25	4.030	4.836	6.447	8.059
35	0.6535	0.32	4.13	3.267	3.921	5.228	6.535
40	0.5330	0.47	4.02	2.665	3.198	4.264	5.330
45	0.4372	0.62	3.91	2.186	2.623	3.497	4.372
50	0.3605	0.77	3.80	1.803	2.163	2.884	3.606
55	0.2989	0.91	3.70	1.494	1.793	2.391	2.989
60	0.2490	1.05	3.60	1.245	1.494	1.992	2.490
65	0.2084	1.18	3.51	1.042	1.251	1.668	2.084
70	0.1753	1.31	3.42	0.8765	1.052	1.402	1.753
75	0.1481	1.44	3.33	0.7405	0.8886	1.185	1.481
80	0.1256	1.57	3.25	0.6282	0.7538	1.005	1.256
85	0.1070	1.69	3.16	0.5352	0.6422	0.8563	1.070
90	0.09154	1.81	3.09	0.4577	0.5493	0.7324	0.9154
95	0.07860	1.93	3.01	0.3930	0.4716	0.6288	0.7860
100	0.06773	2.04	2.94	0.3387	0.4064	0.5419	0.6773
105	0.05858	2.15	2.87	0.2929	0.3515	0.4686	0.5858
110	0.05083	2.26	2.80	0.2542	0.3050	0.4067	0.5083
115	0.04426	2.37	2.73	0.2213	0.2656	0.3541	0.4426
120	0.03866	2.47	2.67	0.1933	0.2320	0.3093	0.3866
125	0.03387	2.57	2.61	0.1694	0.2032	0.2710	0.3387
130	0.02977	2.67	2.55	0.1488	0.1786	0.2382	0.2977
135	0.02624	2.77	2.49	0.1312	0.1574	0.2099	0.2624
140	0.02319	2.86	2.43	0.1160	0.1391	0.1855	0.2319
145	0.02055	2.96	2.38	0.1028	0.1233	0.1644	0.2055
150	0.01826	3.05	2.33	0.0913	0.1096	0.1461	0.1826

Note

1. Replace dot in last 5 digits of catalogue number by 3 for ±5% tolerance on required R_{25}-value.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1.
Stability is in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5 %
Climatic category	40/125/56
Maximum dissipation	100 mW
Dissipation factor δ (for information only)	7 mW/K
Response time (for information only); note 1	1.2 s
Thermal time constant τ (for information only)	11 s
Operating temperature range (see Fig.2):	
at zero dissipation (continuously)	−40 to +125 °C
for short periods	≤150 °C
at maximum dissipation	0 to +150 °C

Note

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

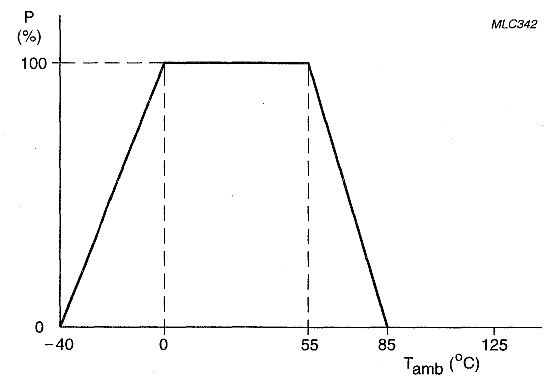


Fig.2 Power derating curve.

NTC thermistors, special accuracy 2322 640 10...

FEATURES

- Excellent accuracy between 25 °C and 85 °C
- High stability over a long life.

APPLICATIONS

- Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two tinned copper-plated leads. It is grey lacquered and not insulated. These thermistors are very accurate over a trajectory from 25 °C to 85 °C.

PACKAGING

The thermistors are packed in cardboard boxes, each box contains 500 units.

MECHANICAL DATA

Marking

Grey lacquered body.

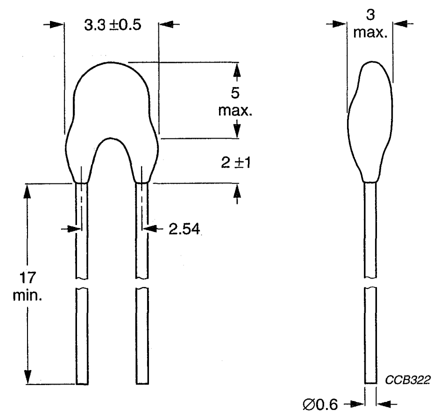
Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	4.7 to 100 kΩ
Tolerance on R_{25}-value	±0.5%
Resistance value at 85 °C (R_{85})	0.5029 to 9.498 kΩ
Tolerance on R_{85}-value	±0.5%
Maximum dissipation	250 mW
Response time (for information only)	1.2 s
Operating temperature range:	
at zero dissipation	−40 to +125 °C
at maximum dissipation	0 to +55 °C
Climatic category	40/125/56
Mass	≈0.22 g

Outline



Dimensions in mm.

Fig.1 Component outline.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*, see also Table 1.

PARAMETER	VALUE
Resistance at 25 °C; note 1	4.7 to 100 kΩ
Tolerance on R_{25}-value	±0.5%
Resistance at 85 °C	0.5029 to 9.498 kΩ
Tolerance on R_{85}-value	±0.5%
Climatic category	40/125/56
Maximum dissipation	250 mW
Dissipation factor δ (for information only)	7 mW/K
Response time (for information only); note 2	1.2 s
Thermal time constant τ (for information only)	11 s
Operating temperature range:	
at zero dissipation (continuously)	−40 to +125 °C
at maximum dissipation	0 to +55 °C

Notes

1. For values of nominal resistance value and tolerance at intermediate temperatures; see Tables 2, 3 and 4.
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 from 25 °C in air to 85 °C in oil.

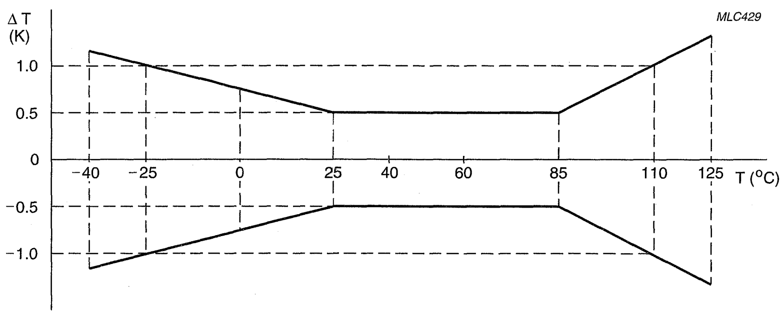


Fig.2 Tolerance curve.

ORDERING INFORMATION

Table 1 R_{25}-values, R_{85}-values, TC-values and catalogue numbers

R_{25}-VALUE ±0.5% (kΩ)	R_{85}-VALUE ±0.5% (Ω)	$B_{25/85}$-VALUE (TYPICAL) (K)	TC at 25 °C (%/K)	CATALOGUE NUMBER 2322 640 .....
4.7	502.9	3977	−4.37	10472
10	1070	3977	−4.37	10103
47	4721	4090	−4.46	10473
100	9498	4190	−4.57	10104

Table 2 Resistance values at intermediate values

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 10472	R_{25} (kΩ) 2322 640 10103
−40	33.21	2.66	6.57	156.1	332.1
−35	23.99	2.41	6.36	112.8	240.0
−30	17.52	2.17	6.15	82.35	175.2
−25	12.93	1.94	5.95	60.77	129.3
−20	9.636	1.71	5.76	45.30	96.36
−15	7.250	1.50	5.58	34.08	72.50
−10	5.505	1.29	5.40	25.87	55.05
−5	4.216	1.08	5.24	19.81	42.16
0	3.255	0.89	5.08	15.30	32.56
5	2.534	0.70	4.92	11.91	25.34
10	1.987	0.52	4.78	9.340	19.87
15	1.570	0.34	4.64	7.378	15.70
20	1.249	0.17	4.50	5.869	12.49
25	1.000	0.00	4.37	4.700	10.00
30	0.8059	0.16	4.25	3.788	8.059
35	0.6535	0.32	4.13	3.072	6.535
40	0.5330	0.47	4.02	2.505	5.330
45	0.4372	0.62	3.91	2.055	4.372
50	0.3605	0.77	3.80	1.694	3.606
55	0.2989	0.91	3.70	1.405	2.989
60	0.2490	1.05	3.60	1.170	2.490
65	0.2084	1.18	3.51	0.9797	2.084
70	0.1753	1.31	3.42	0.8239	1.753
75	0.1481	1.44	3.33	0.6960	1.481
80	0.1256	1.57	3.25	0.5905	1.256
85	0.1070	1.69	3.16	0.5031	1.070
90	0.09154	1.81	3.09	0.4303	0.9154
95	0.07860	1.93	3.01	0.3694	0.7860
100	0.06773	2.04	2.94	0.3183	0.6773
105	0.05858	2.15	2.87	0.2753	0.5858
110	0.05083	2.26	2.80	0.2389	0.5083
115	0.04426	2.37	2.73	0.2080	0.4426
120	0.03866	2.47	2.67	0.1817	0.3866
125	0.03387	2.57	2.61	0.1592	0.3387
130	0.02977	2.67	2.55	0.1399	0.2977
135	0.02624	2.77	2.49	0.1233	0.2624
140	0.02319	2.86	2.43	0.1090	0.2319
145	0.02055	2.96	2.38	0.0966	0.2055
150	0.01826	3.05	2.33	0.0858	0.1826

NTC thermistors, special accuracy 2322 640 10...

Table 3 Resistance values at intermediate values

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)
				2322 640 10473
−40	33.81	5.55	6.55	1589
−35	24.50	5.02	6.34	1151
−30	17.93	4.52	6.15	842.8
−25	13.25	4.03	5.96	622.6
−20	9.875	3.56	5.78	464.1
−15	7.425	3.10	5.61	349.0
−10	5.630	2.67	5.45	264.6
−5	4.304	2.24	5.29	202.3
0	3.315	1.84	5.14	155.8
5	2.573	1.44	4.99	120.9
10	2.011	1.07	4.85	94.53
15	1.583	0.70	4.72	74.40
20	1.254	0.34	4.59	58.95
25	1.000	0.00	4.46	47.00
30	0.8024	0.33	4.34	37.71
35	0.6474	0.66	4.23	30.43
40	0.5255	0.98	4.12	24.70
45	0.4288	1.28	4.01	20.15
50	0.3518	1.59	3.91	16.53
55	0.2901	1.88	3.81	13.63
60	0.2403	2.17	3.71	11.30
65	0.2001	2.45	3.62	9.404
70	0.1674	2.72	3.53	7.865
75	0.1406	2.99	3.44	6.607
80	0.1186	3.25	3.36	5.573
85	0.1004	3.51	3.28	4.721
90	0.08542	3.76	3.20	4.015
95	0.07292	4.00	3.13	3.427
100	0.06248	4.24	3.06	2.936
105	0.05372	4.47	2.98	2.525
110	0.04635	4.70	2.92	2.179
115	0.04013	4.93	2.85	1.886
120	0.03485	5.15	2.79	1.638
125	0.03037	5.36	2.73	1.427
130	0.02654	5.57	2.67	1.247
135	0.02326	5.78	2.61	1.093
140	0.02044	5.98	2.55	0.9608
145	0.01802	6.18	2.50	0.8468
150	0.01592	6.37	2.44	0.7483

Table 4 Resistance values at intermediate values

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)
				2322 640 10104
−40	36.66	5.69	6.70	3666
−35	26.38	5.15	6.49	2638
−30	19.17	4.63	6.29	1917
−25	14.06	4.13	6.10	1406
−20	10.41	3.65	5.92	1041
−15	7.779	3.18	5.74	777.9
−10	5.861	2.73	5.57	586.1
−5	4.453	2.30	5.41	445.3
0	3.409	1.88	5.26	340.9
5	2.631	1.48	5.11	263.1
10	2.044	1.09	4.97	204.4
15	1.600	0.72	4.83	160.0
20	1.261	0.35	4.70	126.1
25	1.000	0.00	4.57	100.0
30	0.7981	0.34	4.45	79.81
35	0.6408	0.67	4.35	64.08
40	0.5175	1.00	4.22	51.74
45	0.4202	1.32	4.11	42.02
50	0.3431	1.63	4.00	34.31
55	0.2816	1.93	3.90	28.16
60	0.2322	2.22	3.80	23.22
65	0.1925	2.51	3.71	19.25
70	0.1602	2.79	3.62	16.03
75	0.1340	3.06	3.53	13.40
80	0.1126	3.33	3.45	11.26
85	0.09496	3.59	3.36	9.496
90	0.08042	3.85	3.28	8.042
95	0.06837	4.10	3.21	6.837
100	0.05835	4.35	3.13	5.835
105	0.04998	4.59	3.06	4.998
110	0.04296	4.82	2.99	4.296
115	0.03705	5.05	2.92	3.705
120	0.03206	5.28	2.86	3.206
125	0.02783	5.50	2.80	2.783

Surface mount NTC thermistors

2322 615 1....

FEATURES

- High sensitivity
- High accuracy over a wide temperature range
- Taped on reel
- Suitable for wave or reflow soldering.

APPLICATION

- Temperature compensation, sensing and protection in, for example:
  - Battery chargers
  - Consumer equipment
  - Office equipment.

DESCRIPTION

Size 0805 chip thermistors with a negative temperature coefficient and silver palladium contacts. The device has no marking.

PACKAGING

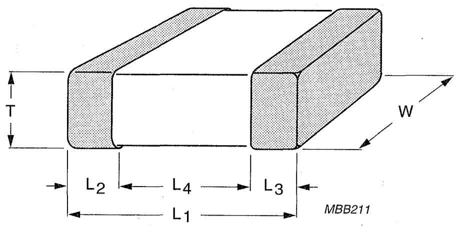
Packaged in punched type paper tape on reel of 4000 units.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	100 Ω to 470 kΩ
Tolerance on R_{25}-value	±5%; ±10%
Tolerance on $B_{25/85}$-value	see Table 2
Maximum dissipation at 25 °C	210 mW
Operating temperature range	−55 to +150 °C
Climatic category	40/125/56
Mass	≈0.015 g

MECHANICAL DATA

Outline



For dimensions see Table 1.

Fig.1 Component outline.

Table 1 Component dimensions; see Fig.1

L_1 (mm)	W (mm)	T MIN. (mm)	T MAX. (mm)	L_2 and L_3 (mm)	L_4 MIN. (mm)
2.0 ±0.2	1.25 ±0.2	0.5	1.25	0.5 ±0.25	0.5

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 2

PARAMETER	VALUE
Tolerance on R_{25}	±5%; ±10%
Tolerance on $B_{25/85}$-value	see Table 2
Climatic category	40/125/56
Maximum dissipation at 25 °C	210 mW
Thermal time constant τ	≈10 s
Operating temperature range	–55 to +150 °C
R/T values	see Tables 13 to 24

Table 2 R_{25}-values, $B_{25/85}$-values and catalogue numbers; see Tables 4 to 24

R_{25} (Ω)	$B_{25/85}$-VALUE (K)	TOLERANCE ON $B_{25/85}$ (%)	CATALOGUE NUMBER 2322 615 1....	
			±5% TOL. ON R_{25}	±10% TOL. ON R_{25}
100	2880	±3	3101	2101
220	2990	±3	3221	2221
330	3041	±3	3331	2331
470	3136	±3	3471	2471
680	3270	±3	3681	2681
1000	3390	±3	3102	2102
2200	3680	±3	3222	2222
3300	3830	±3	3332	2332
4700	3560	±1	3472	2472
5000	3560	±1	3502	2502
10000	3620	±1	3103	2103
15000	3528	±1	3153	2153
22000	3930	±1.5	3223	2223
33000	3960	±3	3333	2333
47000	4090	±1.5	3473	2473
68000	3740	±3	3683	2683
100000	3650	±1	3104	2104
150000	3807	±3	3154	2154
330000	4015	±3	3334	2334
470000	4130	±3	3474	2474

Table 3 Solderability and resistance to soldering heat

IEC 60068-2-20	TEST METHOD	TEST	PROCEDURE	REQUIREMENTS
6	Tc	solderability	3 s at 215 °C; 2 s at 235 °C	ΔR/R < 5%
		resistance to soldering heat	10 s at 260 °C	ΔR/R < 5%

Table 4 Resistance values at intermediate temperatures with R_{25} at 100 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.101						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	13.64	−4.97	1363.6	13.56	2.73	18.97	3.82
−35	10.68	−4.80	1068.1	12.73	2.65	18.10	3.77
−30	8.435	−4.64	843.5	11.94	2.57	17.27	3.72
−25	6.715	−4.48	671.5	11.17	2.49	16.47	3.67
−20	5.387	−4.33	538.7	10.44	2.41	15.70	3.62
−15	4.353	−4.19	535.3	9.74	2.32	14.96	3.57
−10	3.543	−4.05	354.3	9.06	2.24	14.25	3.52
−5	2.904	−3.92	290.4	8.41	2.15	13.57	3.47
0	2.395	−3.79	239.5	7.79	2.06	12.92	3.41
5	1.988	−3.66	198.8	7.19	1.96	12.29	3.35
10	1.660	−3.55	166.0	6.61	1.86	11.69	3.30
15	1.394	−3.43	139.4	6.05	1.76	11.10	3.23
20	1.178	−3.32	117.8	5.52	1.66	10.54	3.17
25	1.000	−3.22	100.0	5.00	1.55	10.00	3.11
30	0.8531	−3.12	85.34	5.50	1.76	10.52	3.37
35	0.7319	−3.02	73.19	5.99	1.98	11.03	3.65
40	0.6307	−2.93	63.07	6.46	2.20	11.53	3.93
45	0.5459	−2.84	54.59	6.92	2.43	12.02	4.23
50	0.4746	−2.76	47.46	7.37	2.67	12.49	4.53
55	0.4143	−2.68	41.43	7.81	2.92	12.95	4.84
60	0.3631	−2.60	36.31	8.24	3.17	13.39	5.15
65	0.3194	−2.52	31.94	8.66	3.43	13.83	5.48
70	0.2820	−2.45	28.20	9.06	3.70	14.26	5.81
75	0.2499	−2.38	24.99	9.46	3.97	14.67	6.16
80	0.2222	−2.32	22.22	9.85	4.25	15.08	6.51
85	0.1982	−2.25	19.82	10.22	4.54	15.47	6.87
90	0.1774	−2.19	17.74	10.59	4.83	15.86	7.24
95	0.1592	−2.13	15.92	10.95	5.14	16.23	7.62
100	0.1433	−2.07	14.33	11.30	5.45	16.60	8.00
105	0.1294	−2.02	12.94	11.64	5.77	16.96	8.40
110	0.1171	−1.97	11.71	11.98	6.09	17.31	8.80
115	0.1063	−1.92	10.63	12.30	6.42	17.65	9.22
120	0.0967	−1.87	9.67	12.62	6.76	17.99	9.64
125	0.0882	−1.82	8.82	12.93	7.11	18.31	10.07
130	0.0806	−1.77	8.06	13.24	7.47	18.63	10.51
135	0.0739	−1.73	7.39	13.54	7.83	18.94	10.96
140	0.0678	−1.69	6.78	13.83	8.20	19.25	11.41
145	0.0624	−1.65	6.24	14.11	8.58	19.55	11.88
150	0.0575	−1.61	5.75	14.39	8.96	19.84	12.36

Surface mount NTC thermistors 2322 615 1....

Table 5 Resistance values at intermediate temperatures with R_{25} at 220 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.221						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	13.68	−4.86	3008.5	18.98	3.91	13.57	2.79
−35	10.76	−4.72	2367.9	18.13	3.84	12.76	2.70
−30	8.532	−4.58	1877.0	17.31	3.78	11.97	2.62
−25	6.810	−4.44	1498.1	16.52	3.72	11.22	2.53
−20	5.472	−4.31	1203.8	15.75	3.66	10.49	2.43
−15	4.425	−4.18	973.6	15.02	3.59	9.79	2.34
−10	3.602	−4.06	792.4	14.31	3.53	9.12	2.25
−5	2.949	−3.94	648.9	13.63	3.46	8.46	2.15
0	2.430	−3.82	534.5	12.97	3.39	7.83	2.05
5	2.013	−3.71	442.8	12.33	3.33	7.23	1.95
10	1.677	−3.60	368.9	11.72	3.26	6.64	1.84
15	1.404	−3.50	308.9	11.13	3.18	6.07	1.74
20	1.182	−3.39	260.1	10.55	3.11	5.53	1.63
25	1.000	−3.30	220.0	10.00	3.03	5.00	1.52
30	0.8500	−3.20	187.0	10.54	3.29	5.51	1.72
35	0.7259	−3.11	159.7	11.06	3.55	6.01	1.93
40	0.6226	−3.03	137.0	11.67	3.83	6.50	2.15
45	0.5363	−2.94	118.0	12.08	4.10	6.98	2.37
50	0.4639	−2.86	102.1	12.56	4.39	7.45	2.60
55	0.4029	−2.78	88.63	13.04	4.69	7.90	2.84
60	0.3512	−2.71	77.26	13.51	4.99	8.35	3.08
65	0.3073	−2.64	67.60	13.96	5.30	8.78	3.33
70	0.2698	−2.57	59.36	14.41	5.62	9.21	3.59
75	0.2377	−2.50	52.30	14.84	5.94	9.62	3.85
80	0.2101	−2.43	46.23	15.27	6.27	10.03	4.12
85	0.1864	−2.37	41.00	15.69	6.62	10.43	4.40
90	0.1658	−2.31	36.47	16.09	6.96	10.82	4.68
95	0.1479	−2.25	32.54	16.49	7.32	11.20	4.97
100	0.1323	−2.20	29.12	16.88	7.69	11.57	5.27
105	0.1187	−2.14	26.12	17.26	8.06	11.93	5.57
110	0.1068	−2.09	23.50	17.63	8.44	12.29	5.88
115	0.0964	−2.04	21.20	18.00	8.83	12.63	6.20
120	0.0871	−1.99	19.17	18.36	9.23	12.98	6.52
125	0.0790	−1.94	17.37	18.71	9.63	13.31	6.85
130	0.0717	−1.90	15.78	19.05	10.04	13.64	7.19
135	0.0653	−1.85	14.37	19.38	10.46	13.96	7.54
140	0.0596	−1.81	13.11	19.71	10.89	14.27	7.89
145	0.0545	−1.77	11.99	20.03	11.33	14.58	8.24
150	0.0500	−1.73	10.99	20.35	11.78	14.88	8.61

Table 6 Resistance values at intermediate temperatures with R_{25} at 330 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.331						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	14.99	−5.16	4945.1	13.88	2.69	19.31	3.74
−35	11.63	−4.98	3838.4	13.02	2.62	18.40	3.70
−30	9.110	−4.80	3006.2	12.20	2.54	17.54	3.65
−25	7.196	−4.64	2374.5	11.40	2.46	16.71	3.60
−20	5.730	−4.48	1890.7	10.65	2.38	15.91	3.55
−15	4.597	−4.33	1517.1	9.92	2.29	15.15	3.50
−10	3.716	−4.19	1226.3	9.22	2.20	14.42	3.44
−5	3.024	−4.05	998.1	8.54	2.11	13.71	3.39
0	2.478	−3.92	817.7	7.90	2.01	13.04	3.32
5	2.043	−3.80	674.2	7.27	1.92	12.38	3.26
10	1.695	−3.68	559.2	6.67	1.81	11.75	3.19
15	1.414	−3.57	466.5	6.10	1.71	11.15	3.12
20	1.186	−3.46	391.3	5.54	1.60	10.56	3.05
25	1.000	−3.36	330.0	5.00	1.49	10.00	2.98
30	0.8475	−3.26	279.7	5.52	1.69	10.55	3.23
35	0.7217	−3.17	238.2	6.03	1.90	11.08	3.50
40	0.6174	−3.08	203.7	6.53	2.12	11.60	3.77
45	0.5305	−2.99	175.1	7.02	2.35	12.11	4.05
50	0.4578	−2.91	151.1	7.49	2.58	12.61	4.34
55	0.3966	−2.83	130.9	7.95	2.81	13.09	4.63
60	0.3450	−2.75	113.8	8.41	3.05	13.57	4.93
65	0.3012	−2.68	99.39	8.85	3.30	14.03	5.24
70	0.2639	−2.61	87.08	9.28	3.56	14.49	5.55
75	0.2320	−2.54	76.56	9.70	3.82	14.93	5.87
80	0.2046	−2.48	67.53	10.12	4.09	15.36	6.20
85	0.1811	−2.41	59.76	10.52	4.36	15.79	6.54
90	0.1608	−2.35	53.05	10.92	4.64	16.20	6.88
95	0.1431	−2.30	47.23	11.31	4.93	16.61	7.23
100	0.1278	−2.24	42.17	11.69	5.22	17.00	7.59
105	0.1144	−2.19	37.75	12.06	5.52	17.39	7.96
110	0.1027	−2.13	33.89	12.42	5.82	17.77	8.33
115	0.0924	−2.08	30.50	12.78	6.13	18.15	8.71
120	0.0834	−2.03	27.51	13.12	6.45	18.51	9.10
125	0.0754	−1.99	24.88	13.47	6.77	18.87	9.49
130	0.0683	−1.94	22.55	13.80	7.10	19.22	9.89
135	0.0621	−1.90	20.49	14.13	7.44	19.56	10.30
140	0.0565	−1.86	18.65	14.45	7.75	19.90	10.72
145	0.0516	−1.82	17.01	14.77	8.13	20.23	11.14
150	0.0471	−1.78	15.55	15.08	8.49	20.56	11.57

Table 7 Resistance values at intermediate temperatures with R_{25} at 470 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.471						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	17.04	−5.54	8009.6	14.32	2.58	19.77	3.57
−35	12.99	−5.31	6106.7	13.40	2.52	18.80	3.54
−30	10.02	−5.10	4708.2	12.52	2.46	17.87	3.51
−25	7.804	−4.90	3667.7	11.68	2.38	16.99	3.47
−20	6.138	−4.71	2885.0	10.87	2.31	16.15	3.43
−15	4.872	−4.53	2289.8	10.11	2.23	15.35	3.39
−10	3.900	−4.37	1832.8	9.38	2.14	14.58	3.34
−5	3.146	−4.22	1478.7	8.67	2.06	13.85	3.28
0	2.557	−4.07	1201.9	8.00	1.96	13.14	3.23
5	2.093	−3.94	983.7	7.35	1.87	12.46	3.17
10	1.725	−3.81	810.5	6.73	1.77	11.81	3.10
15	1.430	−3.69	672.0	6.13	1.66	11.19	3.03
20	1.192	−3.57	560.4	5.56	1.55	10.58	2.96
25	1.000	−3.47	470.0	5.00	1.44	10.00	2.89
30	0.8431	−3.36	396.3	5.54	1.65	10.56	3.14
35	0.7144	−3.26	335.8	6.06	1.86	11.12	3.41
40	0.6083	−3.17	285.9	6.58	2.07	11.65	3.68
45	0.52.3	−3.08	244.5	7.08	2.30	12.18	4.95
50	0.4470	−3.00	210.1	7.57	2.53	12.69	4.24
55	0.3856	−2.92	181.2	8.05	2.76	13.19	4.52
60	0.3339	−2.84	156.9	8.51	3.00	13.68	4.82
65	0.2903	−2.76	136.4	8.97	3.25	14.16	5.12
70	0.2533	−2.69	119.0	9.42	3.50	14.63	5.43
75	0.2218	−2.62	104.2	9.85	3.75	15.08	5.75
80	0.1948	−2.56	91.56	10.28	4.02	15.53	6.07
85	0.1717	−2.50	80.69	10.70	4.29	15.97	6.40
90	0.1518	−2.44	71.33	11.11	4.56	16.40	6.73
95	0.1346	−2.38	63.25	11.51	4.84	16.82	7.07
100	0.1196	−2.32	56.24	11.91	5.13	17.23	7.42
105	0.1067	−2.27	50.14	12.29	5.42	17.64	7.78
110	0.0954	−2.22	44.82	12.67	5.72	18.04	8.14
115	0.0855	−2.17	40.17	13.04	6.02	18.42	8.50
120	0.0768	−2.12	36.09	13.40	6.33	18.80	8.88
125	0.0691	−2.07	32.50	13.76	6.64	19.18	9.26
130	0.0624	−2.03	29.33	14.11	6.96	19.55	9.64
135	0.0565	−1.98	26.53	14.46	7.29	19.91	10.03
140	0.0512	−1.94	24.05	14.79	7.62	20.26	10.43
145	0.0465	−1.90	21.85	15.12	7.95	20.61	10.84
150	0.0423	−1.86	19.89	15.45	8.30	20.95	11.25

Table 8 Resistance values at intermediate temperatures with R_{25} at 680 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.681						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	19.23	−5.77	13073.7	14.74	2.56	20.20	3.50
−35	14.50	−5.53	9858.6	13.77	2.49	19.19	3.47
−30	11.06	−5.31	7519.7	12.85	2.42	18.22	3.43
−25	8.525	−5.10	5797.3	11.97	2.35	17.30	3.39
−20	6.638	−4.91	4514.1	11.14	2.27	16.43	3.35
−15	5.217	−4.73	3547.8	10.33	2.19	15.59	3.30
−10	4.137	−4.56	2812.8	9.57	2.10	14.79	3.24
−5	3.307	−4.40	2248.4	8.84	2.01	14.02	3.19
0	2.664	−4.25	1811.2	8.13	1.91	13.28	3.12
5	1.161	−4.11	1469.7	7.46	1.81	12.57	3.06
10	1.766	−3.98	1200.8	6.81	1.71	11.89	2.99
15	1.452	−3.85	987.5	6.18	1.61	11.24	2.92
20	1.202	−3.73	817.0	5.58	1.50	10.61	2.84
25	1.000	−3.62	680.0	5.00	1.38	10.00	2.77
30	0.8369	−3.51	569.1	5.56	1.59	10.59	3.02
35	0.7041	−3.41	478.8	6.11	1.79	11.16	3.28
40	0.5953	−3.31	404.8	6.65	2.01	11.72	3.55
45	0.5058	−3.21	343.9	7.17	2.23	12.27	3.82
50	0.4317	−3.12	293.5	7.68	2.46	12.81	4.10
55	0.3700	−3.04	251.6	8.18	2.69	13.33	4.39
60	0.3185	−2.96	216.6	8.67	2.93	13.84	4.68
65	0.2752	−2.88	187.2	9.14	3.17	14.34	4.98
70	0.2388	−2.81	162.4	9.61	3.42	14.83	5.29
75	0.2079	−2.73	141.4	10.07	3.68	15.31	5.60
80	0.1816	−2.67	123.5	10.51	3.94	15.78	5.92
85	0.1592	−2.60	108.3	10.95	4.21	16.23	6.24
90	0.1400	−2.54	95.23	11.38	4.49	16.68	6.58
95	0.1236	−2.48	84.02	11.80	4.77	17.12	6.92
100	0.1093	−2.42	74.34	12.21	5.05	17.55	7.26
105	0.0970	−2.36	65.98	12.61	5.34	17.97	7.61
110	0.0863	−2.31	58.71	13.01	5.64	18.39	7.97
115	0.0770	−2.25	52.38	13.39	5.94	18.79	8.34
120	0.0689	−2.20	46.86	13.77	6.25	19.19	8.71
125	0.0618	−2.15	42.02	14.15	6.57	19.58	9.09
130	0.0556	−2.11	37.78	14.51	6.89	19.96	9.47
135	0.0501	−2.06	34.04	14.87	7.21	20.34	9.86
140	0.0452	−2.02	30.74	15.22	7.54	20.71	10.26
145	0.0409	−1.98	27.82	15.57	7.88	21.07	10.67
150	0.0371	−1.93	25.23	15.91	8.22	21.43	11.08

Table 9 Resistance values at intermediate temperatures with R_{25} at 1000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.102						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	21.42	−5.94	21424.1	15.11	2.54	20.57	3.47
−35	16.01	−5.70	16014.7	14.11	2.47	19.54	3.43
−30	12.11	−5.49	12107.4	13.16	2.40	18.55	3.38
−25	9.251	−5.28	9251.1	12.25	2.32	17.59	3.33
−20	7.140	−5.09	7139.5	11.38	2.24	16.68	3.28
−15	5.562	−4.90	5561.9	10.55	2.15	15.81	3.22
−10	4.372	−4.73	4371.5	9.75	2.06	14.98	3.17
−5	3.465	−4.57	3464.7	8.99	1.97	14.18	3.10
0	2.768	−4.42	2767.8	8.26	1.87	13.41	3.04
5	2.228	−4.27	2227.6	7.55	1.77	12.68	2.97
10	1.806	−4.13	1805.7	6.88	1.66	11.97	2.90
15	1.474	−4.00	1473.5	6.23	1.56	11.29	2.81
20	1.210	−3.88	1210.2	5.60	1.45	10.63	2.74
25	1.000	−3.76	1000.0	5.00	1.33	10.00	2.66
30	0.8311	−3.64	831.1	5.58	1.53	10.61	2.91
35	0.6946	−3.54	694.6	6.15	1.74	11.21	3.17
40	0.5835	−3.43	583.5	6.71	1.95	11.79	3.43
45	0.4927	−3.34	492.7	7.25	2.17	12.36	3.71
50	0.4180	−3.24	418.0	7.78	2.40	12.92	3.98
55	0.3563	−3.15	356.3	8.30	2.63	13.46	4.27
60	0.3050	−3.07	305.0	8.81	2.87	13.99	4.56
65	0.2622	−2.98	262.2	9.30	3.12	14.51	4.86
70	0.2263	−2.90	226.3	9.79	3.37	15.01	5.17
75	0.1961	−2.83	196.1	10.26	3.63	15.51	5.48
80	0.1705	−2.76	170.5	10.72	3.89	15.99	5.80
85	0.1489	−2.69	148.9	11.17	4.16	16.47	6.13
90	0.1304	−2.62	130.4	11.62	4.44	16.93	6.47
95	0.1146	−2.55	114.6	12.05	4.72	17.39	6.81
100	0.1010	−2.49	101.0	12.48	5.01	17.83	7.16
105	0.0893	−2.43	89.29	12.89	5.30	18.27	7.51
110	0.0792	−2.37	79.18	13.30	5.60	18.70	7.87
115	0.0704	−2.32	70.41	13.70	5.91	19.11	8.24
120	0.0628	−2.26	62.79	14.09	6.22	19.52	8.62
125	0.0561	−2.21	56.14	14.47	6.54	19.93	9.00
130	0.0503	−2.16	50.32	14.85	6.87	20.32	9.39
135	0.0452	−2.11	45.22	15.22	7.20	20.71	9.79
140	0.0407	−2.07	40.73	15.58	7.53	21.09	10.20
145	0.0368	−2.02	36.77	15.94	7.88	21.46	10.61
150	0.0333	−1.98	33.27	16.29	8.23	21.82	11.02

Table 10 Resistance values at intermediate temperatures with R_{25} at 2000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.202						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	27.23	−6.21	54462.6	15.94	2.57	21.46	3.46
−35	20.06	−6.02	40118.4	14.88	2.47	20.35	3.38
−30	14.92	−5.83	29834.5	13.87	2.38	19.29	3.31
−25	11.20	−5.65	22393.8	12.89	2.28	18.27	3.24
−20	8.481	−5.47	16961.6	11.95	2.19	17.29	3.16
−15	6.480	−5.29	12960.5	11.05	2.09	16.34	3.09
−10	4.994	−5.13	9987.9	10.19	1.99	15.44	3.01
−5	3.880	−4.97	7760.8	9.36	1.89	14.57	2.93
0	3.393	−4.81	6078.6	8.56	1.78	13.73	2.86
5	2.399	−4.66	4797.7	7.79	1.67	12.93	2.78
10	1.908	−4.51	3815.0	7.05	1.56	12.15	2.69
15	1.528	−4.37	3055.3	6.34	1.45	11.41	2.61
20	1.232	−4.24	2463.8	5.66	1.34	10.69	2.52
25	1.000	−4.11	2000.0	5.00	1.22	10.00	2.44
30	0.8170	−3.98	1633.9	5.64	1.42	10.67	2.68
35	0.6715	−3.86	1343.1	6.26	1.62	11.32	2.93
40	0.5553	−3.74	1110.5	6.87	1.83	11.96	3.19
45	0.4618	−3.63	923.5	7.46	2.05	12.58	3.46
50	0.3861	−3.53	772.2	8.04	2.28	13.19	3.74
55	0.3245	−3.42	649.0	8.61	2.51	13.78	4.03
60	0.2742	−3.32	548.3	9.16	2.76	14.35	4.32
65	0.2327	−3.23	465.5	9.69	3.00	14.92	4.62
70	0.1985	−3.14	397.0	10.22	3.26	15.47	4.93
75	0.1701	−3.05	340.2	10.73	3.52	16.00	5.25
80	0.1464	−2.96	292.7	11.23	3.79	16.53	5.58
85	0.1265	−2.88	252.9	11.72	4.07	17.04	5.92
90	0.1097	−2.80	219.4	12.20	4.35	17.54	6.26
95	0.0956	−2.73	191.1	12.66	4.65	18.03	6.61
100	0.0835	−2.65	167.1	13.12	4.95	18.50	6.98
105	0.0733	−2.58	146.6	13.56	5.25	18.97	7.35
110	0.0645	−2.51	129.1	14.00	5.57	19.43	7.73
115	0.0570	−2.45	114.0	14.42	5.89	19.87	8.12
120	0.0505	−2.38	101.0	14.84	6.22	20.31	8.52
125	0.0449	−2.32	89.8	15.24	6.56	20.73	8.92
130	0.0400	−2.26	80.1	15.64	6.91	21.15	9.34
135	0.0358	−2.21	71.6	16.03	7.26	21.55	9.76
140	0.0321	−2.15	64.2	16.41	7.62	21.95	10.20
145	0.0289	−2.10	57.7	16.78	7.99	22.34	10.64
150	0.0260	−2.05	52.1	17.15	8.37	22.72	11.09

Table 11 Resistance values at intermediate temperatures with R_{25} at 2200 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.222						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	27.23	−6.21	59909	15.94	2.57	21.46	3.46
−35	20.06	−6.02	44130	14.88	2.47	20.35	3.38
−30	14.92	−5.83	12818	13.87	2.38	19.29	3.31
−25	11.20	−5.65	24633	12.89	2.28	18.27	3.24
−20	8.481	−5.47	18658	11.95	2.19	17.29	3.16
−15	6.480	−5.29	14257	11.05	2.09	16.34	3.09
−10	4.994	−5.13	10987	10.19	1.99	15.44	3.01
−5	3.880	−4.97	8537	9.36	1.89	14.57	2.93
0	3.393	−4.81	6686	8.56	1.78	13.73	2.86
5	2.399	−4.66	5278	7.79	1.67	12.93	2.78
10	1.908	−4.51	4196	7.05	1.56	12.15	2.69
15	1.528	−4.37	3361	6.34	1.45	11.41	2.61
20	1.232	−4.24	2710	5.66	1.34	10.69	2.52
25	1.000	−4.11	2200	5.00	1.22	10.00	2.44
30	0.8170	−3.98	1797	5.64	1.42	10.67	2.68
35	0.6715	−3.86	1477	6.26	1.62	11.32	2.93
40	0.5553	−3.74	1222	6.87	1.83	11.96	3.19
45	0.4618	−3.63	1016	7.46	2.05	12.58	3.46
50	0.3861	−3.53	849.4	8.04	2.28	13.19	3.74
55	0.3245	−3.42	714.0	8.61	2.51	13.78	4.03
60	0.2742	−3.32	603.2	9.16	2.76	14.35	4.32
65	0.2327	−3.23	512.0	9.69	3.00	14.92	4.62
70	0.1985	−3.14	436.7	10.22	3.26	15.47	4.93
75	0.1701	−3.05	374.2	10.73	3.52	16.00	5.25
80	0.1464	−2.96	322.0	11.23	3.79	16.53	5.58
85	0.1265	−2.88	278.2	11.72	4.07	17.04	5.92
90	0.1097	−2.80	241.4	12.20	4.35	17.54	6.26
95	0.0956	−2.73	210.2	12.66	4.65	18.03	6.61
100	0.0835	−2.65	183.8	13.12	4.95	18.50	6.98
105	0.0733	−2.58	161.3	13.56	5.25	18.97	7.35
110	0.0645	−2.51	142.0	14.00	5.57	19.43	7.73
115	0.0570	−2.45	125.4	14.42	5.89	19.87	8.12
120	0.0505	−2.38	111.2	14.84	6.22	20.31	8.52
125	0.0449	−2.32	98.81	15.24	6.56	20.73	8.92
130	0.0400	−2.26	88.10	15.64	6.91	21.15	9.34
135	0.0358	−2.21	78.78	16.03	7.26	21.55	9.76
140	0.0321	−2.15	70.65	16.41	7.62	21.95	10.20
145	0.0289	−2.10	63.52	16.78	7.99	22.34	10.64
150	0.0260	−2.05	57.26	17.15	8.37	22.72	11.09

Table 12 Resistance values at intermediate temperatures with R_{25} at 3300 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.332						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	32.8313	−6.58	108343.1	15.84	2.41	21.36	3.25
−35	23.7526	−6.37	78383.5	14.80	2.32	20.26	3.18
−30	17.3614	−6.17	57292.8	13.79	2.24	19.21	3.11
−25	12.8173	−5.97	42297.2	12.83	2.15	18.21	3.05
−20	9.5548	−5.78	31530.9	11.91	2.06	17.24	2.98
−15	7.1900	−5.59	23727.1	11.02	1.97	16.31	2.92
−10	5.4600	−5.42	18018.0	10.17	1.88	15.42	2.85
−5	4.1828	−5.24	13803.4	9.35	1.78	14.56	2.78
0	3.2317	−5.08	10664.7	8.56	1.69	13.73	2.70
5	2.5174	−4.92	8307.44	7.80	1.59	12.93	2.63
10	1.9765	−4.76	6522.40	7.06	1.48	12.16	2.55
15	1.5636	−4.61	5159.94	6.35	1.38	11.41	2.47
20	1.2461	−4.47	4112.00	5.66	1.27	10.69	2.39
25	1.0000	−4.33	3300.0	5.00	1.15	10.00	2.31
30	0.8080	−4.20	2666.31	5.64	1.34	10.67	2.54
35	0.6571	−4.07	2168.35	6.26	1.54	11.32	2.78
40	0.5377	−3.95	1774.45	6.86	1.74	11.95	3.03
45	0.4427	−3.83	1460.86	7.44	1.94	12.56	3.28
50	0.3666	−3.72	1209.65	8.01	2.15	13.15	3.54
55	0.3052	−3.61	1007.23	8.55	2.37	13.72	3.80
60	0.2555	−3.50	843.17	9.08	2.59	14.28	4.08
65	0.2150	−3.40	709.47	9.60	2.82	14.82	4.35
70	0.1818	−3.31	599.93	10.10	3.05	15.34	4.64
75	0.1545	−3.21	509.73	10.58	3.29	15.85	4.93
80	0.1318	−3.12	435.07	11.06	3.54	16.34	5.23
85	0.1130	−3.04	372.99	11.51	3.79	16.82	5.54
90	0.0973	−2.95	321.12	11.96	4.05	17.29	5.86
95	0.0841	−2.87	277.60	12.39	4.31	17.74	6.18
100	0.0730	−2.80	240.92	12.81	4.58	18.19	6.51
105	0.0636	−2.72	209.89	13.23	4.86	18.62	6.84
110	0.0556	−2.65	183.52	13.63	5.14	19.04	7.18
115	0.0488	−2.58	161.03	14.02	5.43	19.44	7.54
120	0.0430	−2.51	141.77	14.39	5.73	19.84	7.89
125	0.0379	−2.45	125.23	14.77	6.03	20.23	8.26
130	0.0336	−2.39	110.97	15.13	6.34	20.61	8.63
135	0.0299	−2.33	98.63	15.48	6.65	20.98	9.01
140	0.0266	−2.27	87.92	15.82	6.97	21.34	9.40
145	0.0238	−2.21	78.60	16.16	7.30	21.69	9.80
150	0.0214	−2.16	70.46	16.49	7.63	22.03	10.20

Table 13 Resistance values at intermediate temperatures with R_{25} at 4700 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.472						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	21.9261	−5.75	103053	8.50	1.48	13.66	2.38
−35	16.5224	−5.57	77655	8.16	1.46	13.31	2.39
−30	12.5583	−5.40	59024	7.84	1.45	12.97	2.40
−25	9.62492	−5.24	45237	7.53	1.44	12.65	2.41
−20	7.43618	−5.08	34950	7.23	1.42	12.33	2.43
−15	5.78976	−4.93	27212	6.94	1.41	12.04	2.44
−10	4.54158	−4.78	21345	6.67	1.39	11.75	2.46
−5	3.58813	−4.64	16864	6.40	1.38	11.47	2.47
0	2.85449	−4.51	13416	6.15	1.36	11.20	2.49
5	2.28599	−4.38	10744	5.90	1.35	10.94	2.50
10	1.84245	−4.25	8659.5	5.66	1.33	10.70	2.52
15	1.49414	−4.13	7022.5	5.44	1.32	10.46	2.53
20	1.21887	−4.01	5728.7	5.21	1.30	10.22	2.55
25	1.00	−3.90	4700.0	5.00	1.28	10.00	2.56
30	0.82494	−3.80	3877.2	5.21	1.37	10.22	2.69
35	0.68413	−3.69	3215.4	5.41	1.46	10.43	2.82
40	0.57025	−3.59	2680.2	5.60	1.56	10.63	2.96
45	0.47765	−3.50	2245.0	5.79	1.66	10.83	3.10
50	0.40198	−3.40	1889.3	5.97	1.75	11.02	3.24
55	0.33984	−3.31	1597.2	6.15	1.85	11.20	3.38
60	0.28856	−3.23	1356.2	6.32	1.96	11.38	3.52
65	0.24606	−3.15	1156.5	6.48	2.06	11.55	3.67
70	0.21067	−3.07	990.1	6.64	2.17	11.72	3.82
75	0.18108	−2.99	851.06	6.80	2.28	11.89	3.98
80	0.15623	−2.91	734.29	6.95	2.39	12.05	4.13
85	0.13529	−2.84	635.86	7.10	2.50	12.20	4.29
90	0.11757	−2.77	552.56	7.24	2.61	12.35	4.45
95	0.10251	−2.71	481.81	7.38	2.73	12.50	4.62
100	0.08968	−2.64	421.50	7.52	2.85	12.64	4.78
105	0.07871	−2.58	369.91	7.65	2.97	12.78	4.95
110	0.06928	−2.52	325.64	7.78	3.09	12.91	5.12
115	0.06117	−2.46	287.51	7.91	3.21	13.05	5.30
120	0.05416	−2.41	254.57	8.03	3.34	13.17	5.48
125	0.04809	−2.35	226.03	8.15	3.47	13.30	5.66
130	0.04282	−2.30	201.23	8.27	3.60	13.42	5.84
135	0.03822	−2.25	179.62	8.38	3.73	13.54	6.03
140	0.0342	−2.20	160.73	8.49	3.86	13.66	6.21
145	0.03068	−2.15	144.17	8.60	4.00	13.77	6.40
150	0.02758	−2.10	129.63	8.70	4.14	13.88	6.60

Table 14 Resistance values at intermediate temperatures with R_{25} at 5000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.502						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	21.92609	−5.75	109630	8.50	1.48	13.66	2.38
−35	16.52243	−5.57	82612	8.16	1.46	13.31	2.39
−30	12.55825	−5.40	62791	7.84	1.45	12.97	2.40
−25	9.624924	−5.24	48125	7.53	1.44	12.65	2.41
−20	7.43618	−5.08	37181	7.23	1.42	12.33	2.43
−15	5.789764	−4.93	28949	6.94	1.41	12.04	2.44
−10	4.54158	−4.78	22708	6.67	1.39	11.75	2.46
−5	3.58813	−4.64	17941	6.40	1.38	11.47	2.47
0	2.854486	−4.51	14272	6.15	1.36	11.20	2.49
5	2.285986	−4.38	11430	5.90	1.35	10.94	2.50
10	1.842453	−4.25	9212.3	5.66	1.33	10.70	2.52
15	1.494141	−4.13	7470.7	5.44	1.32	10.46	2.53
20	1.218873	−4.01	6094.4	5.21	1.30	10.22	2.55
25	1.00	−3.90	5000.0	5.00	1.28	10.00	2.56
30	0.824942	−3.80	4124.7	5.21	1.37	10.22	2.69
35	0.68413	−3.69	3420.7	5.41	1.46	10.43	2.82
40	0.570246	−3.59	2851.2	5.60	1.56	10.63	2.96
45	0.47765	−3.50	2388.3	5.79	1.66	10.83	3.10
50	0.401981	−3.40	2009.9	5.97	1.75	11.02	3.24
55	0.339838	−3.31	1699.2	6.15	1.85	11.20	3.38
60	0.288561	−3.23	1442.8	6.32	1.96	11.38	3.52
65	0.246057	−3.15	1230.3	6.48	2.06	11.55	3.67
70	0.210668	−3.07	1053.3	6.64	2.17	11.72	3.82
75	0.181077	−2.99	905.39	6.80	2.28	11.89	3.98
80	0.156233	−2.91	781.16	6.95	2.39	12.05	4.13
85	0.135289	−2.84	676.45	7.10	2.50	12.20	4.29
90	0.117567	−2.77	587.83	7.24	2.61	12.35	4.45
95	0.102513	−2.71	512.57	7.38	2.73	12.50	4.62
100	0.089682	−2.64	448.41	7.52	2.85	12.64	4.78
105	0.078705	−2.58	393.53	7.65	2.97	12.78	4.95
110	0.069284	−2.52	346.42	7.78	3.09	12.91	5.12
115	0.061172	−2.46	305.86	7.91	3.21	13.05	5.30
120	0.054164	−2.41	270.82	8.03	3.34	13.17	5.48
125	0.048092	−2.35	240.46	8.15	3.47	13.30	5.66
130	0.042815	−2.30	214.08	8.27	3.60	13.42	5.84
135	0.038216	−2.25	191.08	8.38	3.73	13.54	6.03
140	0.034197	−2.20	170.99	8.49	3.86	13.66	6.21
145	0.030675	−2.15	153.38	8.60	4.00	13.77	6.40
150	0.027581	−2.10	137.90	8.70	4.14	13.88	6.60

Table 15 Resistance values at intermediate temperatures with R_{25} at 10000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.103						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	23.0973	−5.84	230973	8.50	1.45	13.72	2.34
−35	17.3222	−5.67	173222	8.16	1.44	13.36	2.35
−30	13.1054	−5.49	131054	7.84	1.43	13.02	2.36
−25	9.99934	−5.33	99993	7.53	1.41	12.69	2.38
−20	7.69193	−5.17	76919	7.23	1.40	12.37	2.39
−15	5.96369	−5.01	59637	6.94	1.38	12.07	2.40
−10	4.6589	−4.86	46589	6.67	1.37	11.78	2.42
−5	3.66623	−4.72	36662	6.40	1.36	11.49	2.43
0	2.9054	−4.58	29054	6.15	1.34	11.22	2.44
5	2.31806	−4.45	23181	5.90	1.33	10.96	2.46
10	1.86153	−4.32	18615.3	5.66	1.31	10.71	2.47
15	1.50429	−4.20	15042.9	5.44	1.29	10.46	2.49
20	1.22295	−4.08	12229.5	5.21	1.28	10.23	2.50
25	1.00	−3.97	10000.0	5.00	1.26	10.00	2.52
30	0.82227	−3.86	8222.7	5.21	1.35	10.22	2.65
35	0.67977	−3.75	6797.7	5.41	1.44	10.43	2.78
40	0.56487	−3.65	5648.7	5.60	1.53	10.64	2.91
45	0.47174	−3.55	4717.4	5.79	1.63	10.84	3.05
50	0.39585	−3.46	3958.5	5.97	1.72	11.03	3.19
55	0.33371	−3.37	3337.1	6.15	1.82	11.22	3.33
60	0.28258	−3.28	2825.8	6.32	1.92	11.40	3.47
65	0.24031	−3.20	2403.1	6.48	2.03	11.58	3.62
70	0.20521	−3.12	2052.1	6.64	2.13	11.75	3.77
75	0.17594	−3.04	1759.37	6.80	2.24	11.92	3.92
80	0.15142	−2.96	1514.20	6.95	2.35	12.08	4.08
85	0.1308	−2.89	1308.04	7.10	2.46	12.24	4.24
90	0.1134	−2.82	1134.00	7.24	2.57	12.39	4.40
95	0.09865	−2.75	986.53	7.38	2.68	12.54	4.56
100	0.08611	−2.69	861.10	7.52	2.80	12.68	4.72
105	0.0754	−2.62	754.04	7.65	2.92	12.83	4.89
110	0.06624	−2.56	662.36	7.78	3.04	12.96	5.06
115	0.05836	−2.50	583.58	7.91	3.16	13.10	5.24
120	0.05157	−2.45	515.67	8.03	3.28	13.23	5.41
125	0.4569	−2.39	456.94	8.15	3.41	13.35	5.59
130	0.0406	−2.34	406.01	8.27	3.54	13.48	5.77
135	0.03617	−2.29	361.71	8.38	3.67	13.60	5.96
140	0.03231	−2.23	323.06	8.49	3.80	13.72	6.15
145	0.02893	−2.19	289.26	8.60	3.93	13.83	6.34
150	0.02596	−2.14	259.61	8.70	4.07	13.95	6.53

Table 16 Resistance values at intermediate temperatures with R_{25} at 15000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.153						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	23.3421	−6.06	350131	8.46	1.40	13.63	2.25
−35	17.336	−5.84	260040	8.13	1.39	13.28	2.27
−30	13.0176	−5.62	195263	7.81	1.39	12.94	2.30
−25	9.87717	−5.42	148158	7.50	1.38	12.62	2.33
−20	7.56881	−5.23	113532	7.21	1.38	12.31	2.36
−15	5.8546	−5.05	87819	6.93	1.37	12.02	2.38
−10	4.56918	−4.87	68538	6.65	1.37	11.73	2.41
−5	3.59635	−4.71	53945	6.39	1.36	11.46	2.43
0	2.85356	−4.55	42803	6.14	1.35	11.19	2.46
5	2.28163	−4.40	34224	5.89	1.34	10.94	2.49
10	1.83772	−4.26	27566	5.66	1.33	10.69	2.51
15	1.49054	−4.12	22358	5.43	1.32	10.45	2.54
20	1.21701	−3.99	18255	5.21	1.31	10.22	2.56
25	1.00	−3.87	15000	5.00	1.29	10.00	2.59
30	0.83154	−3.75	12473	5.20	1.39	10.21	2.73
35	0.69408	−3.63	10411	5.40	1.49	10.42	2.87
40	0.58149	−3.53	8722.3	5.60	1.59	10.62	3.01
45	0.48893	−3.42	7334.0	5.78	1.69	10.82	3.16
50	0.41256	−3.32	6188.5	5.96	1.79	11.01	3.31
55	0.34933	−3.23	5240.0	6.14	1.90	11.19	3.47
60	0.2968	−3.14	4451.9	6.31	2.01	11.37	3.62
65	0.253	−3.05	3794.9	6.47	2.12	11.54	3.78
70	0.21635	−2.97	3245.3	6.63	2.24	11.71	3.95
75	0.1856	−2.89	2784.0	6.78	2.35	11.87	4.11
80	0.15971	−2.81	2395.7	6.94	2.47	12.03	4.28
85	0.13785	−2.73	2067.7	7.08	2.59	12.18	4.46
90	0.11932	−2.66	1789.8	7.22	2.71	12.33	4.63
95	0.10358	−2.59	1553.7	7.36	2.84	12.47	4.81
100	0.09016	−2.53	1352.4	7.50	2.97	12.62	4.99
105	0.0787	−2.46	1180.5	7.63	3.10	12.75	5.18
110	0.06887	−2.40	1033.1	7.76	3.23	12.89	5.36
115	0.06043	−2.34	906.41	7.88	3.36	13.02	5.56
120	0.05315	−2.29	797.27	8.00	3.50	13.15	5.75
125	0.04687	−2.23	702.99	8.12	3.64	13.27	5.95
130	0.04142	−2.18	621.33	8.24	3.78	13.39	6.15
135	0.03669	−2.13	550.42	8.35	3.92	13.51	6.35
140	0.03258	−2.08	488.72	8.46	4.07	13.62	6.56
145	0.02899	−2.03	434.88	8.57	4.22	13.74	6.77
150	0.02585	−1.98	387.81	8.67	4.37	13.85	6.98

Table 17 Resistance values at intermediate temperatures with R_{25} at 22000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.223						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	30.7958	−6.42	677507.99	16.71	2.60	22.27	3.47
−35	22.4562	−6.21	494036.94	15.59	2.51	21.09	3.39
−30	16.5404	−6.02	363888.31	14.50	2.41	19.96	3.32
−25	12.3010	−5.83	270622.69	13.47	2.31	18.87	3.24
−20	9.2333	−5.65	203131.71	12.47	2.21	17.82	3.16
−15	6.9923	−5.47	153831.44	11.51	2.10	16.82	3.07
−10	5.3406	−5.31	117492.27	10.59	2.00	15.85	2.99
−5	4.1124	−5.15	90473.18	9.70	1.88	14.92	2.90
0	3.1916	−4.99	70215.46	8.85	1.77	14.03	2.81
5	2.4957	−4.85	54904.79	8.02	1.66	13.17	2.72
10	1.9656	−4.70	43243.49	7.23	1.54	12.33	2.62
15	1.5589	−4.57	34295.62	6.46	1.41	11.53	2.52
20	1.2446	−4.44	27380.67	5.72	1.29	10.75	2.42
25	1.0000	−4.31	22000.00	5.00	1.16	10.00	2.32
30	0.8084	−4.19	17785.47	5.69	1.36	10.73	2.56
35	0.6574	−4.08	14463.33	6.36	1.56	11.43	2.80
40	0.5377	−3.97	11828.57	7.01	1.77	12.11	3.05
45	0.4421	−3.86	9726.63	7.64	1.98	12.77	3.31
50	0.3655	−3.76	8040.24	8.25	2.20	13.41	3.57
55	0.3036	−3.66	6679.83	8.84	2.42	14.02	3.83
60	0.2535	−3.56	5576.61	9.41	2.64	14.62	4.10
65	0.2126	−3.47	4677.41	9.97	2.87	15.21	4.38
70	0.1791	−3.38	3940.90	10.51	3.11	15.77	4.66
75	0.1516	−3.30	3334.80	11.03	3.35	16.32	4.95
80	0.1288	−3.22	2833.74	11.54	3.59	16.86	5.24
85	0.1099	−3.14	2417.69	12.04	3.84	17.37	5.54
90	0.0941	−3.06	2070.77	12.52	4.09	17.88	5.84
95	0.0809	−2.99	1780.29	12.99	4.35	18.37	6.15
100	0.0698	−2.92	1536.11	13.45	4.61	18.85	6.47
105	0.0605	−2.85	1330.07	13.89	4.88	19.31	6.79
110	0.0525	−2.78	1155.56	14.32	5.15	19.77	7.11
115	0.0458	−2.72	1007.23	14.74	5.43	20.21	7.44
120	0.0400	−2.65	880.71	15.15	5.71	20.64	7.78
125	0.0351	−2.59	772.44	15.55	6.00	21.06	8.12
130	0.0309	−2.54	679.48	15.94	6.29	21.46	8.46
135	0.0272	−2.48	599.41	16.32	6.58	21.86	8.82
140	0.0241	−2.43	530.24	16.70	6.88	22.25	9.18
145	0.0214	−2.37	470.31	17.06	7.19	22.63	9.54
150	0.0190	−2.32	418.23	17.41	7.50	23.00	9.91

Table 18 Resistance values at intermediate temperatures with R_{25} at 33000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.333						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	32.68563	−6.59	1078626	16.66	2.53	22.22	3.37
−35	23.6478	−6.36	780377	15.54	2.44	21.04	3.31
−30	17.29545	−6.15	570750	14.46	2.35	19.91	3.24
−25	12.78101	−5.95	421773	13.43	2.26	18.83	3.17
−20	9.538645	−5.76	314775	12.44	2.16	17.79	3.09
−15	7.186265	−5.57	237147	11.48	2.06	16.79	3.01
−10	5.463007	−5.40	180279	10.56	1.96	15.83	2.93
−5	4.18889	−5.23	138233	9.68	1.85	14.90	2.85
0	3.238476	−5.07	106870	8.83	1.74	14.01	2.77
5	2.523488	−4.91	83275	8.01	1.63	13.15	2.68
10	1.9812223	−4.77	65380.4	7.22	1.51	12.32	2.59
15	1.566743	−4.62	51702.5	6.45	1.40	11.52	2.49
20	1.247561	−4.49	41169.5	5.71	1.27	10.75	2.39
25	1.00	−4.36	33000.0	5.00	1.15	10.00	2.29
30	0.806666	−4.24	26620.0	5.69	1.34	10.72	2.53
35	0.654682	−4.12	21604.5	6.36	1.54	11.42	2.78
40	0.534445	−4.00	17636.7	7.00	1.75	12.10	3.02
45	0.438742	−3.89	14478.5	7.63	1.96	12.76	3.28
50	0.362121	−3.79	11950.0	8.24	2.18	13.39	3.54
55	0.30043	−3.68	9914.2	8.82	2.39	14.01	3.80
60	0.250491	−3.59	8266.2	9.40	2.62	14.60	4.07
65	0.209854	−3.49	6925.2	9.95	2.85	15.18	4.35
70	0.17662	−3.40	5828.5	10.49	3.08	15.75	4.63
75	0.149308	−3.32	4927.18	11.01	3.32	16.29	4.91
80	0.126759	−3.23	4183.06	11.52	3.56	16.83	5.20
85	0.108058	−3.15	3565.93	12.01	3.81	17.34	5.50
90	0.092482	−3.07	3051.89	12.49	4.06	17.85	5.80
95	0.079453	−3.00	2621.93	12.96	4.32	18.33	6.11
100	0.068511	−2.93	2260.85	13.41	4.58	18.81	6.43
105	0.059286	−2.86	1956.42	13.85	4.85	19.27	6.74
110	0.051479	−2.79	1698.80	14.28	5.12	19.72	7.07
115	0.044848	−2.73	1479.98	14.70	5.39	20.16	7.40
120	0.039196	−2.66	1293.47	15.11	5.67	20.59	7.73
125	0.034363	−2.60	1133.96	15.51	5.96	21.01	8.07
130	0.030215	−2.54	997.09	15.90	6.25	21.42	8.42
135	0.026645	−2.49	879.28	16.28	6.55	21.81	8.77
140	0.023562	−2.43	777.55	16.65	6.84	22.20	9.13
145	0.020892	−2.38	689.45	17.01	7.15	22.58	9.49
150	0.018573	−2.33	612.93	17.36	7.46	22.95	9.86

Table 19 Resistance values at intermediate temperatures with R_{25} at 47000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.473						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	37.156	−6.82	1746331	11.02	1.62	16.31	2.39
−35	26.5657	−6.60	1248589	10.44	1.58	15.70	2.38
−30	19.2065	−6.38	902705	9.89	1.55	15.12	2.37
−25	14.0347	−6.17	659632	9.35	1.52	14.56	2.36
−20	10.3608	−5.97	486956	8.84	1.48	14.02	2.35
−15	7.72365	−5.78	363012	8.35	1.44	13.51	2.34
−10	5.81188	−5.60	273158	7.87	1.41	13.01	2.32
−5	4.41266	−5.42	207395	7.42	1.37	12.53	2.31
0	3.37917	−5.25	158821	6.98	1.33	12.07	2.30
5	2.60609	−5.09	122627	6.55	1.29	11.63	2.28
10	2.03042	−4.94	95430	6.14	1.24	11.20	2.27
15	1.59206	−4.79	74827	5.75	1.20	10.79	2.25
20	1.2574	−4.65	59098	5.37	1.15	10.39	2.23
25	1.00	−4.51	47000	5.00	1.11	10.00	2.22
30	0.8006	−4.38	37628	5.36	1.22	10.37	2.37
35	0.64506	−4.26	30318	5.70	1.34	10.73	2.52
40	0.52294	−4.14	24578	6.04	1.46	11.08	2.68
45	0.42644	−4.02	20043	6.36	1.58	11.42	2.84
50	0.34971	−3.91	16437	6.67	1.71	11.75	3.00
55	0.28836	−3.81	13553	6.98	1.83	12.07	3.17
60	0.23901	−3.70	11233	7.27	1.96	12.38	3.34
65	0.1991	−3.60	9358	7.56	2.10	12.68	3.52
70	0.16666	−3.51	7833	7.83	2.23	12.97	3.69
75	0.14016	−3.42	6587	8.10	2.37	13.25	3.88
80	0.1184	−3.33	5565	8.37	2.51	13.53	4.06
85	0.10045	−3.25	4721	8.62	2.66	13.79	4.25
90	0.08557	−3.16	4022	8.87	2.80	14.05	4.44
95	0.07319	−3.09	3440	9.11	2.95	14.30	4.64
100	0.06285	−3.01	2954	9.34	3.10	14.55	4.83
105	0.05416	−2.94	2546	9.57	3.26	14.79	5.04
110	0.04685	−2.87	2202	9.79	3.42	15.02	5.24
115	0.04066	−2.80	1911	10.01	3.58	15.25	5.45
120	0.03541	−2.73	1664	10.22	3.74	15.47	5.66
125	0.03094	−2.67	1454	10.43	3.91	15.69	5.88
130	0.02711	−2.61	1274	10.63	4.08	15.90	6.10
135	0.02383	−2.55	1120	10.82	4.25	16.10	6.32
140	0.02101	−2.49	987.6	11.02	4.42	16.30	6.54
145	0.01858	−2.44	873.2	11.20	4.60	16.50	6.77
150	0.01647	−2.38	774.1	11.38	4.78	16.69	7.01

Table 20 Resistance values at intermediate temperatures with R_{25} at 68000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.683						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	25.783	−6.07	1753245	16.02	2.64	21.54	3.55
−35	19.1253	−5.88	1300524	14.96	2.54	20.43	3.47
−30	14.32	−5.70	973759.8	13.94	2.45	19.36	3.40
−25	10.8187	−5.52	735674.7	12.96	2.35	18.34	3.32
−20	8.24438	−5.35	560618	12.02	2.25	17.36	3.24
−15	6.33489	−5.19	430772.3	11.12	2.14	16.41	3.16
−10	4.90655	−5.03	333645.6	10.26	2.04	15.51	3.08
−5	3.82943	−4.88	260401.1	9.42	1.93	14.63	3.00
0	3.01078	−4.74	204733.3	8.62	1.82	13.79	2.91
5	2.3839	−4.60	162105	7.84	1.70	12.98	2.82
10	1.90036	−4.47	129224.7	7.09	1.59	12.19	2.73
15	1.52479	−4.34	103686	6.37	1.47	11.44	2.63
20	1.23112	−4.22	83716.26	5.67	1.35	10.71	2.54
25	1.00	−4.10	68000	5.00	1.22	10.00	2.44
30	0.81697	−3.99	55554.14	5.65	1.42	10.68	2.68
35	0.67116	−3.88	45638.98	6.28	1.62	11.34	2.93
40	0.55433	−3.77	37694.27	6.89	1.83	11.98	3.18
45	0.46019	−3.67	31292.96	7.48	2.04	12.60	3.43
50	0.38393	−3.58	26107.56	8.06	2.25	13.20	3.69
55	0.32184	−3.48	21885.36	8.61	2.47	13.78	3.96
60	0.27103	−3.39	18430.3	9.15	2.70	14.35	4.23
65	0.22926	−3.30	15589.41	9.67	2.93	14.90	4.51
70	0.19475	−3.22	13242.67	10.18	3.16	15.43	4.79
75	0.16611	−3.14	11295.44	10.67	3.40	15.95	5.08
80	0.14225	−3.06	9672.73	11.15	3.64	16.45	5.37
85	0.12228	−2.99	8314.81	11.62	3.89	16.93	5.67
90	0.1055	−2.92	7173.88	12.07	4.14	17.41	5.97
95	0.09135	−2.85	6211.55	12.51	4.40	17.87	6.28
100	0.07936	−2.78	5396.80	12.94	4.66	18.32	6.59
105	0.06918	−2.71	4704.48	13.36	4.92	18.76	6.91
110	0.0605	−2.65	4114.12	13.77	5.19	19.18	7.24
115	0.05307	−2.59	3609	14.16	5.47	19.60	7.57
120	0.0467	−2.53	3175.38	14.55	5.75	20.00	7.90
125	0.04121	−2.47	2801.96	14.92	6.03	20.40	8.24
130	0.03646	−2.42	2479.38	15.29	6.32	20.78	8.59
135	0.03235	−2.37	2199.88	15.65	6.62	21.16	8.94
140	0.02878	−2.31	1957.02	16.00	6.91	21.52	9.30
145	0.02567	−2.26	1745.39	16.34	7.22	21.88	9.66
150	0.02295	−2.22	1560.48	16.67	7.52	22.23	10.03

Table 21 Resistance values at intermediate temperatures with R_{25} at 100000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.104						
	R_T/R_{25}	TC (%/K)	R_T (Ω)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	23.8997	−5.92	2389969	8.58	1.45	13.72	2.32
−35	17.8586	−5.74	1785861	8.24	1.44	13.36	2.33
−30	13.465	−5.56	1346502	7.91	1.42	13.02	2.34
−25	10.2407	−5.39	1024071	7.59	1.41	12.69	2.35
−20	7.85378	−5.23	785378.1	7.28	1.39	12.37	2.37
−15	6.07181	−5.07	607181.2	6.99	1.38	12.07	2.38
−10	4.73061	−4.92	473061.1	6.71	1.36	11.78	2.40
−5	3.7132	−4.77	371319.7	6.44	1.35	11.49	2.41
0	2.93554	−4.63	293553.6	6.18	1.33	11.22	2.42
5	2.33677	−4.50	233677.1	5.92	1.32	10.96	2.44
10	1.87249	−4.37	187249.2	5.68	1.30	10.71	2.45
15	1.51004	−4.24	151003.9	5.45	1.28	10.46	2.47
20	1.22522	−4.12	122522.4	5.22	1.27	13.23	2.48
25	1.00	−4.01	100000	5.00	1.25	10.00	2.50
30	0.82081	−3.89	82081.36	5.21	1.34	10.22	2.62
35	0.67742	−3.79	67741.67	5.42	1.43	10.43	2.76
40	0.56201	−3.68	56201.1	5.62	1.52	10.64	2.89
45	0.46863	−3.59	46862.56	5.81	1.62	10.84	3.02
50	0.39266	−3.49	39266.09	5.99	1.72	11.03	3.16
55	0.33055	−3.40	33055.34	6.18	1.82	11.22	3.30
60	0.27953	−3.31	27952.66	6.35	1.92	11.40	3.45
65	0.23741	−3.22	23740.56	6.52	2.02	11.58	3.59
70	0.20248	−3.14	20247.74	6.69	2.13	11.75	3.74
75	0.17339	−3.06	17338.63	6.85	2.24	11.92	3.89
80	0.14905	−2.99	14905.37	7.00	2.34	12.08	4.05
85	0.12862	−2.91	12861.77	7.15	2.46	12.24	4.20
90	0.11139	−2.84	11138.64	7.30	2.57	12.39	4.36
95	0.0968	−2.77	9680.13	7.44	2.68	12.54	4.52
100	0.08441	−2.71	8441.05	7.58	2.80	12.68	4.69
105	0.07385	−2.64	7384.60	7.72	2.92	12.83	4.85
110	0.06481	−2.58	6480.76	7.85	3.04	12.96	5.02
115	0.05705	−2.52	5704.87	7.98	3.17	13.10	5.20
120	0.05037	−2.46	5036.67	8.11	3.29	13.23	5.37
125	0.04459	−2.41	4459.40	8.23	3.42	13.35	5.55
130	0.03959	−2.35	3959.18	8.35	3.55	13.48	5.73
135	0.03524	−2.30	3524.43	8.46	3.68	13.60	5.91
140	0.03146	−2.25	3145.52	8.58	3.81	13.72	6.10
145	0.02814	−2.20	2814.35	8.69	3.95	13.83	6.29
150	0.02524	−2.15	2524.15	8.80	4.09	13.95	6.48

Table 22 Resistance values at intermediate temperatures with R_{25} at 150000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.154						
	R_T/R_{25}	TC (%/K)	R_T (kΩ)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	27.4500	−6.19	4117.5	16.21	2.62	21.75	3.51
−35	20.2394	−6.00	3035.9	15.13	2.52	20.62	3.44
−30	15.0667	−5.81	2260.0	14.10	2.43	19.53	3.36
−25	11.3199	−5.63	1698.0	13.10	2.33	18.49	3.28
−20	8.5804	−5.46	1287.1	12.15	2.23	17.49	3.21
−15	6.5594	−5.29	983.9	11.23	2.12	16.53	3.13
−10	5.0554	−5.13	758.3	10.35	2.02	15.60	3.04
−5	3.9269	−4.98	589.0	9.50	1.91	14.71	2.96
0	3.0733	−4.83	461.0	8.68	1.80	13.86	2.87
5	2.4227	−4.69	363.41	7.89	1.68	13.03	2.78
10	1.9231	−4.55	288.47	7.13	1.57	12.23	2.69
15	1.5367	−4.42	230.51	6.40	1.45	11.46	2.59
20	1.2358	−4.30	185.38	5.69	1.32	10.72	2.50
25	1.0000	−4.18	150.00	5.00	1.20	10.00	2.39
30	0.8140	−4.06	122.09	5.66	1.40	10.69	2.63
35	0.6663	−3.95	99.94	6.31	1.60	11.37	2.88
40	0.5484	−3.84	82.26	6.93	1.80	12.02	3.13
45	0.4537	−3.74	68.06	7.53	2.01	12.65	3.38
50	0.3773	−3.64	56.60	8.11	2.23	13.26	3.64
55	0.3153	−3.54	47.29	8.68	2.45	13.85	3.91
60	0.2647	−3.45	39.71	9.23	2.67	14.43	4.18
65	0.2232	−3.36	33.49	9.76	2.90	14.98	4.45
70	0.1891	−3.28	28.36	10.27	3.13	15.53	4.74
75	0.1608	−3.20	24.13	10.78	3.37	16.05	5.02
80	0.1374	−3.12	20.60	11.26	3.61	16.56	5.31
85	0.1178	−3.04	17.66	11.74	3.86	17.06	5.61
90	0.1013	−2.97	15.20	12.20	4.11	17.54	5.91
95	0.0875	−2.90	13.13	12.65	4.37	18.01	6.22
100	0.0759	−2.83	11.38	13.08	4.63	18.47	6.53
105	0.0660	−2.76	9.90	13.51	4.89	18.91	6.85
110	0.0576	−2.70	8.63	13.92	5.16	19.35	7.18
115	0.0504	−2.63	7.56	14.33	5.44	19.77	7.51
120	0.0442	−2.57	6.63	14.72	5.72	20.18	7.84
125	0.0389	−2.52	5.84	15.10	6.00	20.58	8.18
130	0.0344	−2.46	5.158	15.48	6.29	20.97	8.53
135	0.0305	−2.41	4.568	15.84	6.58	21.36	8.88
140	0.0270	−2.35	4.055	16.20	6.88	21.73	9.23
145	0.0241	−2.30	3.610	16.54	7.19	22.09	9.60
150	0.0215	−2.25	3.221	16.88	7.49	22.45	9.96

Table 23 Resistance values at intermediate temperatures with R_{25} at 330000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.334						
	R_T/R_{25}	TC (%/K)	R_T (kΩ)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	33.3434	−6.58	11003.3	16.83	2.56	22.39	3.40
−35	24.1285	−6.36	7962.4	15.69	2.46	21.20	3.33
−30	17.6422	−6.16	5821.9	14.60	2.37	21.05	3.25
−25	13.0283	−5.97	4299.4	13.55	2.27	18.95	3.18
−20	9.7132	−5.78	3205.4	12.54	2.17	17.90	3.10
−15	7.3081	−5.60	2411.7	11.57	2.07	16.89	3.01
−10	5.5470	−5.43	1830.5	10.64	1.96	15.91	2.93
−5	4.2457	−5.27	1401.1	9.75	1.85	14.97	2.84
0	3.2760	−5.11	1081.1	8.88	1.74	14.07	2.75
5	2.5474	−4.96	840.63	8.05	1.62	13.20	2.66
10	1.9955	−4.81	658.52	7.25	1.51	12.35	2.57
15	1.5744	−4.67	519.55	6.47	1.39	11.54	2.47
20	1.2506	−4.54	412.71	5.72	1.26	10.76	2.37
25	1.0000	−4.41	330.00	5.00	1.13	10.00	2.27
30	0.8046	−4.29	265.53	5.70	1.33	10.73	2.50
35	0.6514	−4.17	214.95	6.38	1.53	11.44	2.75
40	0.5304	−4.05	175.02	7.03	1.73	12.13	2.99
45	0.4343	−3.94	143.31	7.67	1.94	12.79	3.24
50	0.3575	−3.84	117.97	8.28	2.16	13.44	3.50
55	0.2958	−3.74	97.62	8.88	2.36	14.06	3.76
60	0.2460	−3.64	81.18	9.46	2.60	14.67	4.03
65	0.2056	−3.55	67.83	10.02	2.83	15.26	4.30
70	0.1726	−3.45	56.94	10.56	3.06	15.83	4.58
75	0.1455	−3.37	48.02	11.09	3.29	16.38	4.86
80	0.1232	−3.28	40.66	11.61	3.53	16.92	5.15
85	0.1048	−3.20	34.57	12.11	3.78	17.44	5.45
90	0.0894	−3.12	29.52	12.59	4.03	17.95	5.75
95	0.0767	−3.05	25.30	13.07	4.29	18.45	6.05
100	0.0659	−2.98	21.76	13.53	4.54	18.93	6.36
105	0.0569	−2.91	18.78	13.97	4.81	19.40	6.68
110	0.0493	−2.84	16.27	14.41	5.08	19.86	7.00
115	0.0429	−2.77	14.14	14.84	5.35	20.30	7.32
120	0.0374	−2.71	12.33	15.25	5.63	20.74	7.66
125	0.0327	−2.65	10.79	15.65	5.91	21.16	7.99
130	0.0287	−2.59	9.463	16.05	6.20	21.57	8.34
135	0.0252	−2.53	8.326	16.43	6.49	21.98	8.68
140	0.0223	−2.48	7.347	16.81	6.79	22.37	9.04
145	0.0197	−2.42	6.500	17.17	7.09	22.75	9.40
150	0.0175	−2.37	5.767	17.53	7.40	22.13	9.76

Table 24 Resistance values at intermediate temperatures with R_{25} at 470000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.474						
	R_T/R_{25}	TC (%/K)	R_T (kΩ)	5%TOL. ΔR/R (%)	5%TOL. ΔT (K)	10%TOL. ΔR/R (%)	10%TOL. ΔT (K)
−40	37.1288	−6.79	17450.5	17.16	2.53	22.74	3.35
−35	26.5910	−6.57	12497.8	15.99	2.44	21.52	3.28
−30	19.2505	−6.36	9047.8	14.87	2.34	20.34	3.20
−25	14.0812	−6.15	6618.2	13.79	2.24	19.21	3.12
−20	10.4026	−5.96	4889.2	12.76	2.14	18.13	3.04
−15	7.7582	−5.77	3646.4	11.76	2.04	17.08	2.96
−10	5.8389	−5.60	2744.3	10.80	1.93	16.08	2.87
−5	4.4329	−5.43	2083.5	9.88	1.82	15.11	2.79
0	3.3937	−5.26	1595.0	8.99	1.71	14.18	2.70
5	2.6190	−5.10	1230.93	8.14	1.59	13.29	2.60
10	2.0367	−4.95	957.26	7.31	1.48	12.42	2.51
15	1.5956	−4.81	749.94	6.51	1.35	11.59	2.41
20	1.2589	−4.67	591.68	5.74	1.23	10.78	2.31
25	1.0000	−4.54	470.00	5.00	1.10	10.00	2.20
30	0.7995	−4.41	375.78	5.72	1.30	10.75	2.44
35	0.6433	−4.29	302.34	6.42	1.50	11.48	2.68
40	0.5207	−4.17	244.71	7.09	1.70	12.19	2.92
45	0.4239	−4.06	199.22	7.74	1.91	12.87	3.17
50	0.3470	−3.95	163.08	8.38	2.12	13.54	3.43
55	0.2856	−3.84	134.22	8.99	2.34	14.18	3.69
60	0.2362	−3.74	111.03	9.58	2.56	14.80	3.95
65	0.1964	−3.65	92.30	10.16	2.79	15.41	4.23
70	0.1640	−3.55	77.10	10.72	3.02	15.99	4.50
75	0.1377	−3.46	64.70	11.27	3.25	16.56	4.78
80	0.1160	−3.38	54.53	11.80	3.49	17.12	5.07
85	0.0982	−3.29	46.16	12.31	3.74	17.66	5.36
90	0.0835	−3.21	39.23	12.81	3.99	18.18	5.66
95	0.0712	−3.13	33.48	13.30	4.24	18.69	5.96
100	0.0610	−3.06	28.68	13.77	4.50	19.19	6.27
105	0.0525	−2.99	24.66	14.23	4.77	19.67	6.59
110	0.0453	−2.92	21.27	14.68	5.03	24.14	6.91
115	0.0392	−2.85	18.42	15.12	5.31	20.60	7.23
120	0.0340	−2.78	16.00	15.54	5.58	21.05	7.56
125	0.0297	−2.72	13.94	15.96	5.87	21.48	7.90
130	0.0259	−2.66	12.189	16.36	6.15	21.91	8.24
135	0.0227	−2.60	10.688	16.76	6.45	22.32	8.59
140	0.0200	−2.54	9.398	17.15	6.74	22.72	8.94
145	0.0176	−2.49	8.288	17.52	7.05	23.12	9.30
150	0.0156	−2.43	7.329	17.89	7.35	23.50	9.66

Surface mount NTC thermistors 2322 615 2....

FEATURES

- High sensitivity
- High accuracy over a wide temperature range
- Taped on reel
- Suitable for wave or reflow soldering.

APPLICATION

- Temperature compensation, sensing and protection in, for example:
  - Battery chargers
  - Consumer equipment
  - Office equipment.

DESCRIPTION

Size 0603 chip thermistors with a negative temperature coefficient and silver palladium contacts. The device has no marking.

PACKAGING

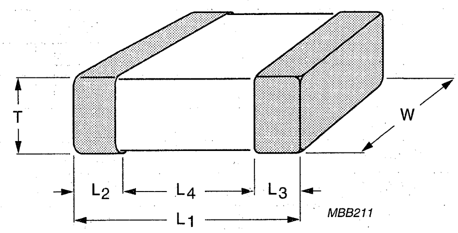
Available in 8 mm punched paper tape on reel packaging of 4000 units.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	4.7 kΩ to 100 kΩ
Tolerance on R_{25}-value	±3%; ±5%; ±10%
Tolerance on $B_{25/85}$-value	see Table 2
Maximum dissipation at 25 °C	125 mW
Operating temperature range	–55 to +150 °C
Climatic category	40/125/56
Mass	≈0.0075 g

MECHANICAL DATA

Outline



For dimensions see Table 1.

Fig.1 Component outline.

Table 1 Component dimensions; see Fig.1

L_1 (mm)	W (mm)	T		L_2 and L_3 (mm)	L_4 MIN. (mm)
		MIN. (mm)	MAX. (mm)		
1.6 ±0.1	0.8 ±0.15	0.5	1.0	0.45 ±0.2	0.2

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 2.

PARAMETER	VALUE
Tolerance on R_{25}	±3%;±5%; ±10%
Tolerance on $B_{25/85}$-value	see Table 2
Climatic category	40/125/56
Maximum dissipation at 25 °C	125 mW
Thermal time constant τ	≈8 s
Operating temperature range	–55 to +150 °C
R/T values	see Tables 4 to 8

Table 2 R_{25}-values, $B_{25/85}$-values and catalogue numbers; see Tables 4 to 8

R_{25} (Ω)	$B_{25/85}$-VALUE (K)	TOLERANCE ON $B_{25/85}$ (%)	CATALOGUE NUMBER 2322 615 2....		
			±3% TOL. ON R_{25}	±5% TOL. ON R_{25}	±10% TOL. ON R_{25}
4700	3560	±3	6472	3472	2472
10000	3620	±3	6103	3103	2103
47000	3977	±3	6473	3473	2473
68000	3740	±3	6683	3683	2683
100000	3650	±3	6104	3104	2104

Table 3 Solderability and resistance to soldering heat

IEC 60068-2-20	TEST METHOD	TEST	PROCEDURE	REQUIREMENTS
6	Tc	solderability	3 s at 215 °C; 2 s at 235 °C	ΔR/R < 5%
		resistance to soldering heat	10 s at 260 °C	ΔR/R < 5%

Table 4 Resistance values at intermediate temperatures with R_{25} at 4700 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.472					
	R_T/R_{25}	TC (%/K)	R_T (Ω)	3% TOL. ΔR/R (%)	5% TOL. ΔR/R (%)	10% TOL. ΔR/R (%)
−40	21.9261	−5.75	103053	9.02	16.71	22.27
−35	16.5224	−5.57	77655	8.44	15.59	21.09
−30	12.5583	−5.40	59024	7.89	14.50	19.96
−25	9.6249	−5.24	45237	7.35	13.47	18.87
−20	7.4362	−5.08	34950	6.84	12.47	17.82
−15	5.7898	−4.93	27212	6.35	11.51	16.82
−10	4.5416	−4.78	21345	5.87	10.59	15.85
−5	3.5881	−4.64	16864	5.42	9.70	14.92
0	2.8545	−4.51	13416	4.98	8.85	14.03
5	2.2860	−4.38	10744	4.55	8.02	13.17
10	1.8425	−4.25	8659.5	4.14	7.23	12.33
15	1.4941	−4.13	7022.5	3.75	6.46	11.53
20	1.2189	−4.01	5728.7	3.37	5.72	10.75
25	1.0000	−3.90	4700.0	3.00	5.00	10.00
30	0.8249	−3.80	3877.2	3.36	5.69	10.73
35	0.6841	−3.69	3215.4	3.70	6.36	11.43
40	0.57025	−3.59	2680.2	4.04	7.01	12.11
45	0.47765	−3.50	2245.0	4.36	7.64	12.77
50	0.40198	−3.40	1889.3	4.67	8.25	13.41
55	0.33984	−3.31	1597.2	4.98	8.84	14.02
60	0.28856	−3.23	1356.2	5.26	9.41	14.62
65	0.24606	−3.15	1156.5	5.56	9.97	15.21
70	0.21067	−3.07	990.1	5.83	10.51	15.77
75	0.18108	−2.99	851.06	6.10	11.03	16.32
80	0.15623	−2.91	734.29	6.37	11.54	16.86
85	0.13529	−2.84	635.86	6.62	12.04	17.37
90	0.11757	−2.77	552.56	6.87	12.52	17.88
95	0.10251	−2.71	481.81	7.11	12.99	18.37
100	0.08968	−2.64	421.50	7.34	13.45	18.85
105	0.07871	−2.58	369.91	7.57	13.89	19.31
110	0.06928	−2.52	325.64	7.79	14.32	19.77
115	0.06117	−2.46	287.51	8.01	14.74	20.21
120	0.05416	−2.41	254.57	8.22	15.15	20.64
125	0.04809	−2.35	226.03	8.43	15.55	21.06
130	0.04282	−2.30	201.23	8.63	15.94	21.46
135	0.03822	−2.25	179.62	8.82	16.32	21.86
140	0.0342	−2.20	160.73	9.02	16.70	22.25
145	0.03068	−2.15	144.17	9.20	17.06	22.63
150	0.02758	−2.10	129.63	9.38	17.41	23.00

Table 5 Resistance values at intermediate temperatures with R_{25} at 10000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.103					
	R_T/R_{25}	TC (%/K)	R_T (Ω)	3% TOL. ΔR/R (%)	5% TOL. ΔR/R (%)	10% TOL. ΔR/R (%)
−40	23.0973	−5.84	230973	9.02	16.71	22.27
−35	17.3222	−5.67	173222	8.44	15.59	21.09
−30	13.1054	−5.49	131054	7.89	14.50	19.96
−25	9.99934	−5.33	99993	7.35	13.47	18.87
−20	7.69193	−5.17	76919	6.84	12.47	17.82
−15	5.96369	−5.01	59637	6.35	11.51	16.82
−10	4.6589	−4.86	46589	5.87	10.59	15.85
−5	3.66623	−4.72	36662	5.42	9.70	14.92
0	2.9054	−4.58	29054	4.98	8.85	14.03
5	2.31806	−4.45	23181	4.55	8.02	13.17
10	1.86153	−4.32	18615.3	4.14	7.23	12.33
15	1.50429	−4.20	15042.9	3.75	6.46	11.53
20	1.22295	−4.08	12229.5	3.37	5.72	10.75
25	1.00	−3.97	10000.0	3.00	5.00	10.00
30	0.82227	−3.86	8222.7	3.36	5.69	10.73
35	0.67977	−3.75	6797.7	3.70	6.36	11.43
40	0.56487	−3.65	5648.7	4.04	7.01	12.11
45	0.47174	−3.55	4717.4	4.36	7.64	12.77
50	0.39585	−3.46	3958.5	4.67	8.25	13.41
55	0.33371	−3.37	3337.1	4.98	8.84	14.02
60	0.28258	−3.28	2825.8	5.27	9.41	14.62
65	0.24031	−3.20	2403.1	5.56	9.97	15.21
70	0.20521	−3.12	2052.1	5.83	10.51	15.77
75	0.17594	−3.04	1759.37	6.10	11.03	16.32
80	0.15142	−2.96	1514.20	6.37	11.54	16.86
85	0.1308	−2.89	1308.04	6.62	12.04	17.37
90	0.1134	−2.82	1134.00	6.87	12.52	17.88
95	0.09865	−2.75	986.53	7.11	12.99	18.37
100	0.08611	−2.69	861.10	7.34	13.45	18.85
105	0.0754	−2.62	754.04	7.57	13.89	19.31
110	0.06624	−2.56	662.36	7.79	14.32	19.77
115	0.05836	−2.50	583.58	8.01	14.74	20.21
120	0.05157	−2.45	515.67	8.22	15.15	20.64
125	0.4569	−2.39	456.94	8.43	15.55	21.06
130	0.0406	−2.34	406.01	8.63	15.94	21.46
135	0.03617	−2.29	361.71	8.82	16.32	21.86
140	0.03231	−2.23	323.06	9.02	16.70	22.25
145	0.02893	−2.19	289.26	9.20	17.06	22.63
150	0.02596	−2.14	259.61	8.38	17.41	23.00

Surface mount NTC thermistors 2322 615 2....

Table 6 Resistance values at intermediate temperatures with R_{25} at 47000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.473					
	R_T/R_{25}	TC (%/K)	R_T (Ω)	3% TOL. ΔR/R (%)	5% TOL. ΔR/R (%)	10% TOL. ΔR/R (%)
−40	33.21001	−6.62	1560870	9.02	16.71	22.27
−35	23.99043	−6.39	1127550	8.44	15.59	21.09
−30	17.52031	−6.18	823454	7.89	14.50	19.96
−25	12.92895	−5.98	607660	7.35	13.47	18.87
−20	9.63600	−5.78	452892	6.84	12.47	17.82
−15	7.25018	−5.60	340758	6.35	11.51	16.82
−10	5.50470	−5.42	258721	5.87	10.59	15.85
−5	4.21578	−5.25	198142	5.42	9.70	14.92
0	3.25548	−5.09	153008	4.98	8.85	14.03
5	2.53391	−4.93	119094	4.55	8.02	13.17
10	1.98726	−4.79	93401	4.14	7.23	12.33
15	1.56988	−4.64	73784	3.75	6.46	11.53
20	1.24880	−4.51	58694	3.37	5.72	10.75
25	1.00000	−4.38	47000	3.00	5.00	10.00
30	0.80592	−4.25	37878	3.36	5.69	10.73
35	0.65349	−4.13	30714	3.70	6.36	11.43
40	0.53300	−4.02	25051	4.04	7.01	12.11
45	0.43718	−3.91	20547	4.36	7.64	12.77
50	0.36053	−3.80	16945	4.67	8.25	13.41
55	0.29887	−3.70	14047	4.98	8.84	14.02
60	0.24900	−3.60	11703	5.27	9.41	14.62
65	0.20845	−3.51	9797.0	5.56	9.97	15.21
70	0.17531	−3.42	8239.5	5.83	10.51	15.77
75	0.14809	−3.33	6960.4	6.10	11.03	16.32
80	0.12564	−3.26	5905.1	6.37	11.54	16.86
85	0.10703	−3.17	5030.6	6.62	12.04	17.37
90	0.09154	−3.09	4203.6	6.87	12.52	17.88
95	0.09865	−3.01	3694.1	7.11	12.99	18.37
100	0.08611	−2.94	3183.4	7.34	13.45	18.85
105	0.0754	−2.87	2753.1	7.57	13.89	19.31
110	0.06624	−2.80	2389.1	7.79	14.32	19.77
115	0.05836	−2.74	2080.2	8.01	14.74	20.21
120	0.05157	−2.67	1817.0	8.22	15.15	20.64
125	0.4569	−2.61	1592.1	8.43	15.55	21.06
130	0.0406	−2.55	1399.2	8.63	15.94	21.46
135	0.03617	−2.50	1233.2	8.82	16.32	21.86
140	0.03231	−2.44	1090.0	9.02	16.70	22.25
145	0.02893	−2.39	966.0	9.20	17.06	22.63
150	0.02596	−2.34	858.4	8.38	17.41	23.00

Table 7 Resistance values at intermediate temperatures with R_{25} at 68000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.683					
	R_T/R_{25}	TC (%/K)	R_T (Ω)	3% TOL. ΔR/R (%)	5% TOL. ΔR/R (%)	10% TOL. ΔR/R (%)
−40	25.783	−6.07	1753245	9.02	16.71	22.27
−35	19.1253	−5.88	1300524	8.44	15.59	21.09
−30	14.32	−5.70	973760	7.89	14.50	19.96
−25	10.8187	−5.52	735675	7.35	13.47	18.87
−20	8.24438	−5.35	560618	6.84	12.47	17.82
−15	6.33489	−5.19	430772	6.35	11.51	16.82
−10	4.90655	−5.03	333646	5.87	10.59	15.85
−5	3.82943	−4.88	260401	5.42	9.70	14.92
0	3.01078	−4.74	204733	4.98	8.85	14.03
5	2.3839	−4.60	162105	4.55	8.02	13.17
10	1.90036	−4.47	129225	4.14	7.23	12.33
15	1.52479	−4.34	103686	3.75	6.46	11.53
20	1.23112	−4.22	83716	3.37	5.72	10.75
25	1.00	−4.10	68000	3.00	5.00	10.00
30	0.81697	−3.99	55554.1	3.36	5.69	10.73
35	0.67116	−3.88	45639.0	3.70	6.36	11.43
40	0.55433	−3.77	37694.3	4.04	7.01	12.11
45	0.46019	−3.67	31293.0	4.36	7.64	12.77
50	0.38393	−3.58	26107.6	4.67	8.25	13.41
55	0.32184	−3.48	21885.4	4.98	8.84	14.02
60	0.27103	−3.39	18430.3	5.27	9.41	14.62
65	0.22926	−3.30	15589.4	5.56	9.97	15.21
70	0.19475	−3.22	13242.7	5.83	10.51	15.77
75	0.16611	−3.14	11295.4	6.10	11.03	16.32
80	0.14225	−3.06	9672.7	6.37	11.54	16.86
85	0.12228	−2.99	8314.8	6.62	12.04	17.37
90	0.1055	−2.92	7173.9	6.87	12.52	17.88
95	0.09135	−2.85	6211.6	7.11	12.99	18.37
100	0.07936	−2.78	5396.8	7.34	13.45	18.85
105	0.06918	−2.71	4704.5	7.57	13.89	19.31
110	0.0605	−2.65	4114.1	7.79	14.32	19.77
115	0.05307	−2.59	3609.0	8.01	14.74	20.21
120	0.0467	−2.53	3175.4	8.22	15.15	20.64
125	0.04121	−2.47	2802.0	8.43	15.55	21.06
130	0.03646	−2.42	2479.4	8.63	15.94	21.46
135	0.03235	−2.37	2199.9	8.82	16.32	21.86
140	0.02878	−2.31	1957.0	9.02	16.70	22.25
145	0.02567	−2.26	1745.4	9.20	17.06	22.63
150	0.02295	−2.22	1560.5	9.38	17.41	23.00

Table 8 Resistance values at intermediate temperatures with R_{25} at 100000 Ω; see also Table 2

T_{oper} (°C)	CATALOGUE NUMBER 2322 615 1.104					
	R_T/R_{25}	TC (%/K)	R_T (Ω)	3% TOL. ΔR/R (%)	5% TOL. ΔR/R (%)	10% TOL. ΔR/R (%)
−40	23.8997	−5.92	2389969	9.02	16.71	22.27
−35	17.8586	−5.74	1785861	8.44	15.59	21.09
−30	13.465	−5.56	1346502	7.89	14.50	19.96
−25	10.2407	−5.39	1024071	7.35	13.47	18.87
−20	7.85378	−5.23	785378	6.84	12.47	17.82
−15	6.07181	−5.07	607181	6.35	11.51	16.82
−10	4.73061	−4.92	473061	5.87	10.59	15.85
−5	3.7132	−4.77	371320	5.42	9.70	14.92
0	2.93554	−4.63	293554	4.98	8.85	14.03
5	2.33677	−4.50	233677	4.55	8.02	13.17
10	1.87249	−4.37	187249	4.14	7.23	12.33
15	1.51004	−4.24	151004	3.75	6.46	11.53
20	1.22522	−4.12	122522	3.37	5.72	10.75
25	1.00	−4.01	100000	3.00	5.00	10.00
30	0.82081	−3.89	82081.4	3.36	5.69	10.73
35	0.67742	−3.79	67741.7	3.70	6.36	11.43
40	0.56201	−3.68	56201.1	4.04	7.01	12.11
45	0.46863	−3.59	46862.6	4.36	7.64	12.77
50	0.39266	−3.49	39266.1	4.67	8.25	13.41
55	0.33055	−3.40	33055.3	4.98	8.84	14.02
60	0.27953	−3.31	27952.7	5.27	9.41	14.62
65	0.23741	−3.22	23740.6	5.56	9.97	15.21
70	0.20248	−3.14	20247.7	5.83	10.51	15.77
75	0.17339	−3.06	17338.6	6.10	11.03	16.32
80	0.14905	−2.99	14905.4	6.37	11.54	16.86
85	0.12862	−2.91	12861.8	6.62	12.04	17.37
90	0.11139	−2.84	11138.6	6.87	12.52	17.88
95	0.0968	−2.77	9680.1	7.11	12.99	18.37
100	0.08441	−2.71	8441.1	7.34	13.45	18.85
105	0.07385	−2.64	7384.6	7.57	13.89	19.31
110	0.06481	−2.58	6480.8	7.79	14.32	19.77
115	0.05705	−2.52	5704.9	8.01	14.74	20.21
120	0.05037	−2.46	5036.7	8.22	15.15	20.64
125	0.04459	−2.41	4459.4	8.43	15.55	21.06
130	0.03959	−2.35	3959.2	8.63	15.94	21.46
135	0.03524	−2.30	3524.4	8.82	16.32	21.86
140	0.03146	−2.25	3145.5	9.02	16.70	22.25
145	0.02814	−2.20	2814.4	9.20	17.06	22.63
150	0.02524	−2.15	2524.2	9.38	17.41	23.00

NTC thermistors, long non-insulated leads 2322 645 90028

FEATURES

- Long and flexible leads for special mounting or assembly requirements
- Small diameter
- Electrical features of the *"2322 645 0...."* accuracy line sensors.

APPLICATION

Temperature sensing and control.

DESCRIPTION

This thermistor has a negative temperature coefficient. The device consists of a chip with two tinned nickel leads.

PACKAGING

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

MECHANICAL DATA

Marking

The body of the device is coated with a black coloured EPQ lacquer.

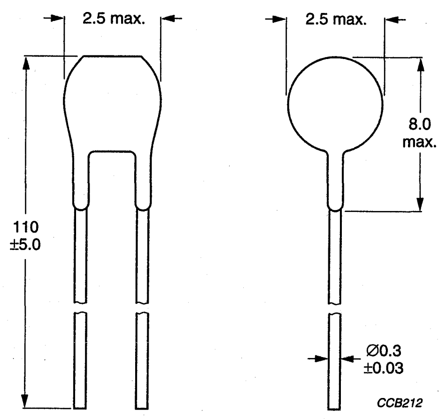
Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	10 kΩ
Tolerance on R_{25}-value	±5%
$B_{25/100}$-value	3993 K
Tolerance on $B_{25/100}$-value	±1.2%
Rated dissipation	100 mW
Dissipation factor τ	1.35 mW/K
Operating temperature range:	
at zero dissipation	−40 to +125 °C
at maximum dissipation	0 to +55 °C
Mass	≈0.21 g

Outline



Dimensions in mm.

Fig.1 Component outline.

NTC thermistors, long non-insulated leads 2322 645 90028

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.

PARAMETER	VALUE
Resistance value at 25 °C	10 kΩ
Tolerance on R_{25}-value	±5%
$B_{25/100}$-value	3993 K
Tolerance on $B_{25/100}$-value	±1.2%
Rated dissipation	100 mW
Dissipation factor τ	1.35 mW/K
Operating temperature range at: zero dissipation maximum dissipation	 −40 to +125 °C 0 to +55 °C
Mass	≈0.21 g

Derating

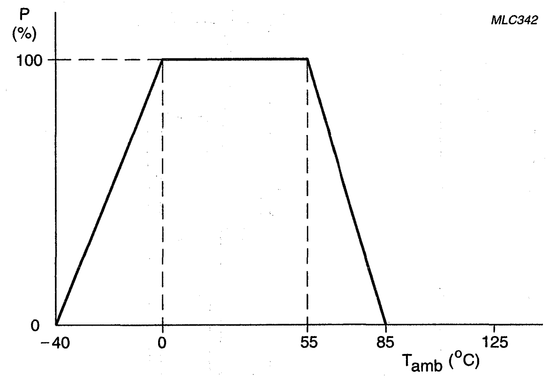


Fig.2 Power derating curve.

NTC thermistors, long non-insulated leads 2322 645 90028

Stability data

Table 1 Test procedures and requirements

CECC	IEC TEST METHOD	TEST	PROCEDURE	DRIFT	
				REQUIREMENT	TYPICAL(1)
Tests in accordance with the schedule of IEC publication 60068 (unless otherwise stated)					
15	U	robustness of terminations:			
	Ua	tensile strength	load 10 N		
		bending	load 5 N		
		impact, free fall	1 m		
16	T	solderability	max. 4 s; max. 240 °C		
		resistance to soldering heat	max. 11 s; max. 265 °C		
		climatic sequence:			
	Ba	dry heat (steady state)	1000 hours; 125 °C	ΔR/R < 3%	ΔR/R = 0.1%
D1 4.19	Db	damp heat (steady state)	56 days; 40 °C; 90 to 95% RH	ΔR/R < 3%	ΔR/R = −0.2%
C2 4.14	Aa	rapid change of temperature	−40 °C to 125 °C; 50 cycles	ΔR/R < 2%	ΔR/R = 0.1%
D3 4.20.1		endurance	1000 hours; 25 °C	ΔR/R < 1%	ΔR/R = 0.1%
		endurance	1000 hours; −40 °C	ΔR/R < 1%	ΔR/R = 0.15%
	539-gen.	endurance	1000 hours; 100 mW; 55 °C	ΔR/R < 3%	ΔR/R = 0.5%

Note

1. Typical drift based on sample products with $B_{25/75}$-value of 3977 K.

NTC thermistor, long insulated leads 2322 640 90059

FEATURES

- Long and flexible leads for special mounting or assembly requirements
- Insulated leads for prevention of short circuits
- Electrical features of 'accuracy line' sensors
- Small diameter.

APPLICATIONS

- Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two insulated nickel leads.

PACKAGING

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

MECHANICAL DATA

Marking

The body is coated with ochre-coloured epoxy lacquer and is not marked.

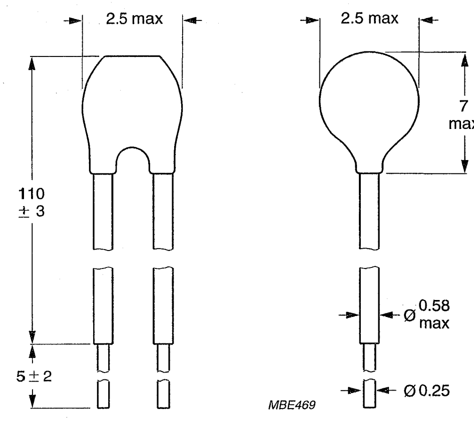
Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at:	
0 °C	9000 Ω
25 °C	2769 Ω
Tolerance on R_{25}-value:	
0 °C	±2%
25 °C	±3.82%
$B_{25/85}$-value	3977 K
Maximum dissipation	100 mW
Dissipation factor δ	1.35 mW/K
Minimum dielectric withstanding voltage (RMS) between leads and coating	500 V
Response time	1.25 s
Operating temperature range:	
at zero power	−40 to +125 °C
at maximum power	0 to +55 °C
Climatic category	40/125/56
Mass	≈0.16 g

Outline



Dimensions in mm.

Fig.1 Component outline for 2322 640 90059 series.

NTC thermistor, long insulated leads 2322 640 90059

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.
Stability is in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Resistance value at:	
0 °C	9000 Ω
25 °C	2769 Ω
Tolerance on R_{25}-value:	
0 °C	±2%
25 °C	±3.82%
Minimum dielectric withstanding voltage (RMS) between leads and coating	500 V
Response time	1.25 s
Operating temperature range:	
at zero power	−40 to +125 °C
at maximum power	0 to +55 °C
Climatic category	40/125/56
Mass	≈0.16 g

NTC thermistor, long insulated leads 2322 640 90059

Table 1 Resistance values at intermediate temperatures

T_{oper} (°C)	RESISTANCE (Ω)	TC (%/K)	RESISTANCE TOLERANCE (%)
−40	90923	6.57	±5.60
−35	65808	6.35	±5.09
−30	48141	6.15	±4.60
−25	35578	5.95	±4.13
−20	26550	5.76	±3.67
−15	19998	5.58	±3.23
−10	15197	5.40	±2.81
−5	11648	5.24	±2.40
0	9000	5.08	±2.00
5	7008.6	4.92	±2.38
10	5498.8	4.78	±2.76
15	4345.1	4.64	±3.12
20	3457.2	4.50	±3.47
25	2769.0	4.37	±3.82
30	2231.7	4.25	±4.16
35	1809.6	4.13	±4.48
40	1476.0	4.02	±4.80
45	1210.6	3.91	±5.12
50	998.37	3.80	±5.42
55	827.59	3.70	±5.72
60	689.46	3.60	±6.01
65	577.15	3.51	±6.29
70	485.38	3.42	±6.57
75	410.02	3.33	±6.84
80	347.86	3.25	±7.10
85	296.35	3.16	±7.36
90	253.47	3.09	±7.61
95	217.64	3.01	±7.86
100	187.57	2.94	±8.10
105	162.24	2.87	±8.33
110	140.81	2.80	±8.56
115	122.63	2.73	±8.79
120	107.14	2.67	±9.01
125	93.90	2.61	±9.22

NTC thermistors, long lead sensors 2322 645 10/20...

FEATURES

- Accuracy of 0.5 °C between 0 °C and 50 °C
- Small diameter
- High stability over a long life
- Long and flexible leads for special mounting or assembly requirements.

APPLICATIONS

- Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a chip with two insulated or non-insulated nickel leads.

MOUNTING

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at:	
0 °C	see Table 2
50 °C	see Table 2
$B_{25/85}$-value	3977 K
ΔT ensured between 0 °C and 50 °C	±0.5 °C
Temperature coefficient	see Table 2
Maximum dissipation	100 mW
Minimum dielectric withstanding voltage (RMS) between leads and coating	500 V
Operating temperature range	–40 to +125 °C
Climatic category	40/125/56
Mass	≈0.2 g

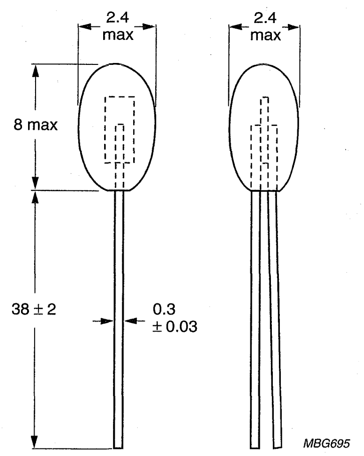
PACKAGING

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

MARKING

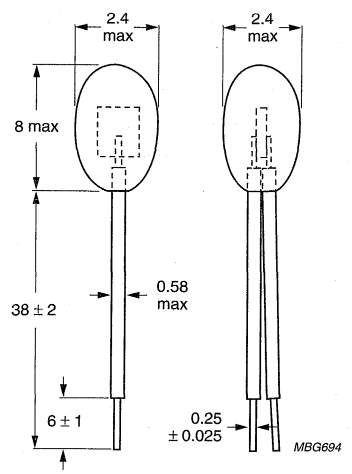
The body is coloured with ochre lacquer and not marked.

MECHANICAL DATA



Dimensions in mm.

Fig.1 Component outline for 2322 645 10... series.



Dimensions in mm.

Fig.2 Component outline for 2322 645 20... series.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*. Stability is in accordance with *"CECC 43000"* and *"IEC 60068-2"*. For parameters and values see Chapter "Quick reference data".

Derating

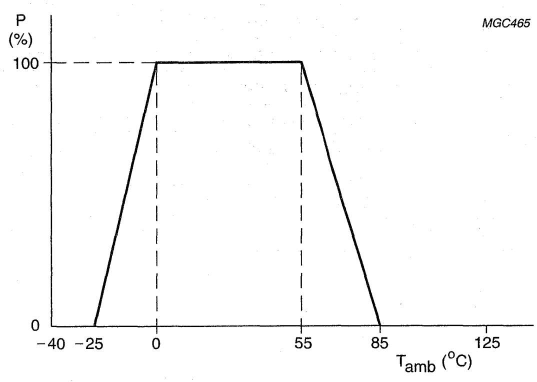


Fig.3 Power derating curve.

ORDERING INFORMATION

Table 1 R_{25}-values, $B_{25/85}$-values and catalogue numbers

R_{25}-VALUE (kΩ)	**$B_{25/85}$-VALUE (K)**	**CATALOGUE NUMBER 2322 645 .....(1)**
3	3977	.0302
5	3977	.0502
10	3977	.0103

Note

1. Replace dot in last 5 digits of catalogue number by 1 for non-insulated or 2 for insulated leads.

NTC thermistors, long lead sensors 2322 645 10/20...

Table 2 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔT (K)	TC (%/K)	R_{25} (kΩ)		
				2322 645 .....; see note 1		
				.0302	**.0502**	**.0103**
−40	33.21	0.68	6.57	99.63	166.1	332.1
−35	23.99	0.66	6.36	71.97	120.0	239.9
−30	17.52	0.64	6.15	52.56	87.60	175.2
−25	12.93	0.62	5.95	38.79	64.65	129.3
−20	9.636	0.59	5.76	28.91	48.18	96.36
−15	7.250	0.57	5.58	21.75	36.25	72.50
−10	5.505	0.55	5.40	16.51	27.52	55.05
−5	4.216	0.52	5.24	12.65	21.08	42.16
0	3.255	0.50	5.08	9.766	16.28	32.56
5	2.534	0.50	4.92	7.602	12.67	25.34
10	1.987	0.50	4.78	5.962	9.936	19.87
15	1.570	0.50	4.64	4.710	7.849	15.70
20	1.249	0.50	4.50	3.746	6.244	12.49
25	1.000	0.50	4.37	3.000	5.000	10.00
30	0.8059	0.50	4.25	2.418	4.030	8.059
35	0.6535	0.50	4.13	1.960	3.267	6.535
40	0.5330	0.50	4.02	1.599	2.665	5.330
45	0.4372	0.50	3.91	1.312	2.186	4.372
50	0.3605	0.50	3.80	1.082	1.803	3.606
55	0.2989	0.55	3.70	0.8966	1.494	2.989
60	0.2490	0.61	3.60	0.7470	1.245	2.490
65	0.2084	0.66	3.51	0.6253	1.042	2.084
70	0.1753	0.72	3.42	0.5259	0.8765	1.753
75	0.1481	0.77	3.33	0.4443	0.7405	1.481
80	0.1256	0.83	3.25	0.3769	0.6282	1.256
85	0.1070	0.89	3.16	0.3211	0.5352	1.070
90	0.09154	0.95	3.09	0.2746	0.4577	0.9154
95	0.07860	1.02	3.01	0.2358	0.3930	0.7860
100	0.06773	1.08	2.94	0.2032	0.3387	0.6773
105	0.05858	1.14	2.87	0.1757	0.2929	0.5858
110	0.05083	1.21	2.80	0.1525	0.2542	0.5083
115	0.04426	1.27	2.73	0.1328	0.2213	0.4426
120	0.03866	1.34	2.67	0.1160	0.1933	0.3866
125	0.03387	1.41	2.61	0.1016	0.1694	0.3387

Note

1. Replace dot in last 5 digits of catalogue number by 1 for non-insulated or 2 for insulated leads.

NTC thermistors, high-temperature sensors 2322 633 5/7/8....

FEATURES

- Small diameter
- Quick response to temperature change
- High stability over a long life
- Wide temperature range from –40 to +300 °C
- Resistant to corrosive atmospheres and harsh environments.

APPLICATION

- High temperature measurement control:
  - Domestic appliances
  - Automotive systems
  - Industrial process control.

DESCRIPTION

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

2322 633 5.... (SOD80) without leads and suitable for surface mounting

2322 633 7.... (SOD27) with nickel-plated copper-clad iron leads

2322 633 8.... (SOD27) with tinned copper-clad iron leads.

MECHANICAL DATA

Marking

None.

Mounting

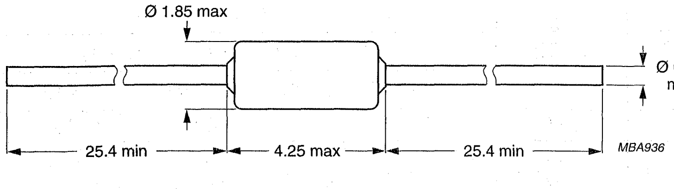
By soldering (633 5...., 633 8....).

By clamping (633 7....).

QUICK REFERENCE DATA

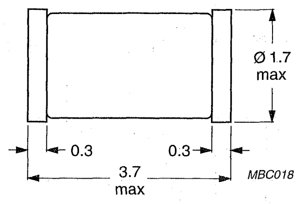
PARAMETER	VALUE
Temperature range:	
2322 633 5....	–40 to +200 °C
2322 633 7....	–40 to +300 °C
2322 633 8....	–40 to +200 °C
Resistance value at 25 °C (R_{25})	10 to 100 kΩ
Tolerance on R_{25}-value	±5% and ±10%
$B_{25/85}$-value	3977 K
Tolerance on $B_{25/85}$-value	±1.3%
Rated dissipation	100 mW
Dissipation factor	2.5 mW/K
Response time	0.9 s
Thermal time constant τ	6 s
Temperature coefficient at 25 °C	–4.38%/K
Climatic category:	
2322 633 5....	40/155/56
2322 633 7....	40/300/56
2322 633 8....	40/200/56
Mass:	
2322 633 5....	≈0.03 g
2322 633 7....	≈0.14 g
2322 633 8....	≈0.14 g

Outlines



Dimensions in mm.

Fig.1 Component outline for 2322 633 7/8.... (SOD27).



Dimensions in mm.

Fig.2 Component outline for 2322 633 5.... (SOD80).

ORDERING INFORMATION

Table 1 Catalogue numbers and packaging quantities

CATALOGUE NUMBER	BULK	BLISTER	TAPE
2322 633 3....; note 1	–	–	10000
2322 633 4....; note 2	–	–	10000
2322 633 5....	–	2500	–
2322 633 7....	1000	–	–
2322 633 8....	1000	–	–

Notes

1. Catalogue number 2322 633 3.... is the series 2322 633 8.... on tape.
2. Catalogue number 2322 633 4.... is the series 2322 633 7.... on tape.

Table 2 R_{25}-values, $B_{25/85}$-values and catalogue numbers

The thermistors have a 12-digit catalogue number starting with 2322 633 5..../7..../8....; the subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	CATALOGUE NUMBER 2322 633					
		SOD27 (leaded)				SOD80 (SMD)(2) 5....	
		8.... tinned-copper		7....(1) nickel-plated			
		R_{25} ±10%	R_{25} ±5%	R_{25} ±10%	R_{25} ±5%	R_{25} ±10%	R_{25} ±5%
10	3977 K ±1.3%	2103	3103	–	–	2103	3103
20	3977 K ±1.3%	2203	3203	–	–	2203	3203
30	3977 K ±1.3%	2303	3303	–	–	2303	3303
100	3977 K ±1.3%	2104	3104	2104	3104	2104	3104

Notes

1. 2322 633 7.... only available at 100 kΩ.
2. Only available in blister tape.

Table 3 Resistance values at intermediate temperatures for 2322 633 5.... series

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 633 ..... (see Table 5, note 1)			
				5.103	**5.203**	**5.303**	**5.104**
−40	33.06	4.65	6.59	330.6	661.2	991.8	3306
−35	23.90	4.21	6.37	239.0	478.1	717.1	2390
−30	17.47	3.79	6.16	174.7	349.4	524.1	1747
−25	12.90	3.38	5.96	129.0	258.0	387.0	1290
−20	9.621	2.99	5.77	96.21	192.4	288.6	962.1
−15	7.242	2.61	5.59	72.42	144.8	217.3	724.2
−10	5.501	2.24	5.41	55.01	110.0	165.0	550.1
−5	4.214	1.89	5.24	42.14	84.28	126.4	421.4
0	3.255	1.55	5.08	32.55	65.09	97.64	325.5
5	2.534	1.22	4.93	25.34	50.67	76.01	253.4
10	1.987	0.90	4.78	19.87	39.74	59.62	198.7
15	1.570	0.59	4.64	15.70	31.40	47.10	157.0
20	1.249	0.29	4.51	12.49	24.98	37.46	124.9
25	1.000	0.00	4.38	10.00	20.00	30.00	100.0
30	0.8059	0.28	4.25	8.059	16.12	24.18	80.59
35	0.6534	0.55	4.13	6.534	13.07	19.60	65.34
40	0.5329	0.82	4.02	5.329	10.66	15.99	53.29
45	0.4371	1.08	3.91	4.371	8.742	13.11	43.71
50	0.3604	1.34	3.80	3.604	7.209	10.81	36.04
55	0.2988	1.58	3.70	2.988	5.976	8.963	29.88
60	0.2489	1.82	3.60	2.489	4.978	7.467	24.89
65	0.2084	2.06	3.51	2.084	4.168	6.251	20.84
70	0.1753	2.29	3.42	1.753	3.505	5.258	17.53
75	0.1481	2.51	3.33	1.481	2.961	4.442	14.81
80	0.1256	2.73	3.24	1.256	2.512	3.769	12.56
85	0.1070	2.95	3.16	1.070	2.141	3.211	10.70
90	0.09156	3.16	3.08	0.9156	1.831	2.747	9.156
95	0.07862	3.36	3.01	0.7862	1.572	2.359	7.862
100	0.06777	3.56	2.93	0.6777	1.355	2.033	6.777
105	0.05863	3.76	2.86	0.5863	1.173	1.759	5.863
110	0.05089	3.95	2.79	0.5089	1.018	1.527	5.089
115	0.04433	4.13	2.73	0.4433	0.8865	1.330	4.433
120	0.03873	4.32	2.66	0.3873	0.7747	1.162	3.873
125	0.03395	4.50	2.60	0.3395	0.6791	1.019	3.395
130	0.02985	4.67	2.54	0.2985	0.5971	0.8956	2.985
135	0.02633	4.84	2.49	0.2633	0.5265	0.7898	2.633
140	0.02328	5.01	2.43	0.2328	0.4656	0.6984	2.328
145	0.02065	5.17	2.38	0.2065	0.4129	0.6194	2.065
150	0.01836	5.33	2.32	0.1836	0.3671	0.5507	1.836

Table 4 Resistance values at intermediate temperatures for 2322 633 7.... series

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 633 ..... (see Table 5, note 1) 7.104
0	3.255	1.55	5.08	325.5
5	2.534	1.22	4.93	253.4
10	1.987	0.90	4.78	198.7
15	1.570	0.59	4.64	157.0
20	1.249	0.29	4.51	124.9
25	1.000	0.00	4.38	100.0
30	0.8059	0.28	4.25	80.59
35	0.6534	0.55	4.13	65.34
40	0.5329	0.82	4.02	53.29
45	0.4371	1.08	3.91	43.71
50	0.3604	1.34	3.80	36.04
55	0.2988	1.58	3.70	29.88
60	0.2489	1.82	3.60	24.89
65	0.2084	2.06	3.51	20.84
70	0.1753	2.29	3.42	17.53
75	0.1481	2.51	3.33	14.81
80	0.1256	2.73	3.24	12.56
85	0.1070	2.95	3.16	10.70
90	0.09156	3.16	3.08	9.156
95	0.07862	3.36	3.01	7.862
100	0.06777	3.56	2.93	6.777
105	0.05863	3.76	2.86	5.863
110	0.05089	3.95	2.79	5.089
115	0.04433	4.13	2.73	4.433
120	0.03873	4.32	2.66	3.873
125	0.03395	4.50	2.60	3.395
130	0.02985	4.67	2.54	2.985
135	0.02633	4.83	2.49	2.633
140	0.02328	4.98	2.43	2.328
145	0.02065	5.12	2.38	2.065
150	0.01836	5.27	2.32	1.836
155	0.01636	5.40	2.27	1.636
160	0.01455	5.54	2.23	1.455
165	0.01303	5.67	2.18	1.303
170	0.01169	5.80	2.14	1.169
175	0.01052	5.93	2.09	1.052

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)
				2322 633 ..... (see Table 5, note 1)
				7.104
180	0.00948	6.06	2.05	0.948
185	0.00857	6.18	2.01	0.857
190	0.00776	6.30	1.97	0.776
195	0.00704	6.41	1.93	0.704
200	0.00640	6.53	1.89	0.640
205	0.00575	6.64	1.87	0.575
210	0.00524	6.75	1.83	0.524
215	0.00479	6.86	1.80	0.479
220	0.00438	6.96	1.76	0.438
225	0.00402	7.07	1.73	0.402
230	0.00369	7.17	1.70	0.369
235	0.00339	7.27	1.66	0.339
240	0.00312	7.36	1.63	0.312
245	0.00288	7.46	1.60	0.288
250	0.00266	7.55	1.57	0.266
255	0.00246	7.64	1.55	0.246
260	0.00228	7.73	1.52	0.228
265	0.00211	7.82	1.49	0.211
270	0.00196	7.91	1.47	0.196
275	0.00182	7.99	1.44	0.182
280	0.00170	8.08	1.42	0.170
285	0.00158	8.16	1.39	0.158
290	0.00148	8.24	1.37	0.148
295	0.00138	8.32	1.35	0.138
300	0.00129	8.40	1.32	0.129

Table 5 Resistance values at intermediate temperatures for 2322 633 8.... series

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)			
				2322 633 ..... (see note 1)			
				8.103	**8.203**	**8.303**	**8.104**
−40	33.06	4.65	6.59	330.6	661.2	991.8	3306
−35	23.90	4.21	6.37	239.0	478.1	717.1	2390
−30	17.47	3.79	6.16	174.7	349.4	524.1	1747
−25	12.90	3.38	5.96	129.0	258.0	387.0	1290
−20	9.621	2.99	5.77	96.21	192.4	288.6	962.1
−15	7.242	2.61	5.59	72.42	144.8	217.3	724.2
−10	5.501	2.24	5.41	55.01	110.0	165.0	550.1
−5	4.214	1.89	5.24	42.14	84.28	126.4	421.4
0	3.255	1.55	5.08	32.55	65.09	97.64	325.5
5	2.534	1.22	4.93	25.34	50.67	76.01	253.4
10	1.987	0.90	4.78	19.87	39.74	59.62	198.7
15	1.570	0.59	4.64	15.70	31.40	47.10	157.0
20	1.249	0.29	4.51	12.49	24.98	37.46	124.9
25	1.000	0.00	4.38	10.00	20.00	30.00	100.0
30	0.8059	0.28	4.25	8.059	16.12	24.18	80.59
35	0.6534	0.55	4.13	6.534	13.07	19.60	65.34
40	0.5329	0.82	4.02	5.329	10.66	15.99	53.29
45	0.4371	1.08	3.91	4.371	8.742	13.11	43.71
50	0.3604	1.34	3.80	3.604	7.209	10.81	36.04
55	0.2988	1.58	3.70	2.988	5.976	8.963	29.88
60	0.2489	1.82	3.60	2.489	4.978	7.467	24.89
65	0.2084	2.06	3.51	2.084	4.168	6.251	20.84
70	0.1753	2.29	3.42	1.753	3.505	5.258	17.53
75	0.1481	2.51	3.33	1.481	2.961	4.442	14.81
80	0.1256	2.73	3.24	1.256	2.512	3.769	12.56
85	0.1070	2.95	3.16	1.070	2.141	3.211	10.70
90	0.09156	3.16	3.08	0.9156	1.831	2.747	9.156
95	0.07862	3.36	3.01	0.7862	1.572	2.359	7.862
100	0.06777	3.56	2.93	0.6777	1.355	2.033	6.777
105	0.05863	3.76	2.86	0.5863	1.173	1.759	5.863
110	0.05089	3.95	2.79	0.5089	1.018	1.527	5.089
115	0.04433	4.13	2.73	0.4433	0.8865	1.330	4.433
120	0.03873	4.32	2.66	0.3873	0.7747	1.162	3.873
125	0.03395	4.50	2.60	0.3395	0.6791	1.019	3.395
130	0.02985	4.67	2.54	0.2985	0.5971	0.8956	2.985
135	0.02633	4.84	2.49	0.2633	0.5265	0.7898	2.633

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 633 ..... (see note 1)			
				8.103	**8.203**	**8.303**	**8.104**
140	0.02328	5.01	2.43	0.2328	0.4656	0.6984	2.328
145	0.02065	5.17	2.38	0.2065	0.4129	0.6194	2.065
150	0.01836	5.33	2.32	0.1836	0.3671	0.5507	1.836
155	0.01636	5.49	2.27	0.1636	0.3273	0.4909	1.636
160	0.01455	5.65	2.23	0.1455	0.2910	0.4365	1.455
165	0.01303	5.80	2.18	0.1303	0.2606	0.3909	1.303
170	0.01169	5.95	2.14	0.1169	0.2339	0.3508	1.169
175	0.01052	6.10	2.09	0.1052	0.2104	0.3156	1.052
180	0.00948	6.24	2.05	0.09484	0.1897	0.2845	0.9484
185	0.00857	6.38	2.01	0.08569	0.1714	0.2571	0.8569
190	0.00776	6.52	1.97	0.07757	0.1551	0.2327	0.7757
195	0.00704	6.66	1.93	0.07037	0.1407	0.2111	0.7037
200	0.00640	6.79	1.89	0.06396	0.1279	0.1919	0.6396

Note

1. Replace dot in last 5-digits of catalogue number by a number according to the following list and depending on tolerance on required R_{25}-value:
   a) 3 for a tolerance of ±5%.
   b) 2 for a tolerance of ±10%.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 2.

PARAMETER	VALUE		
	2322 633 5....	**2322 633 7....**	**2322 633 8....**
$B_{25/85}$-values	3977 K		
Tolerance on B-value	±1.3%		
Ratio R_T/R_{25}	refer to Table 3	refer to Table 4	refer to Table 5
Rated dissipation	100 mW		
Deviation in resistance value due to B-tolerance	refer to Table 3	refer to Table 4	refer to Table 5
Temperature coefficient	refer to Table 3	refer to Table 4	refer to Table 5

Derating

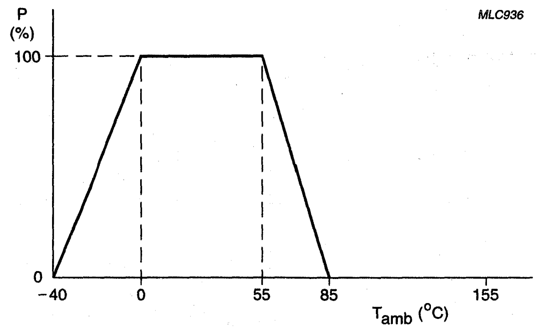


Fig.3 Derating curve for 2322 633 5.... series.

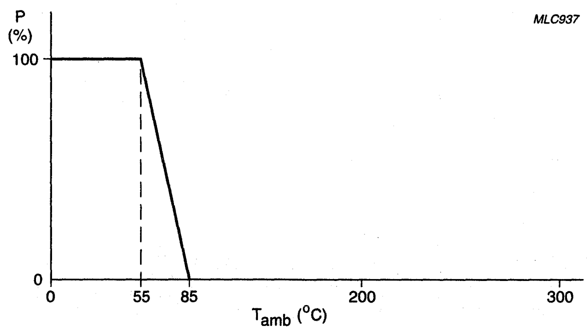


Fig.4 Derating curve for 2322 633 7.... series.

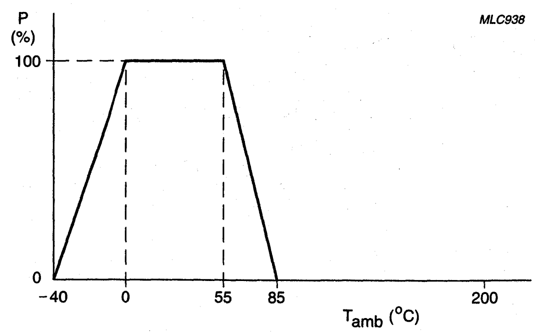


Fig.5 Derating curve for 2322 633 8.... series.

Stability and R-T characteristics

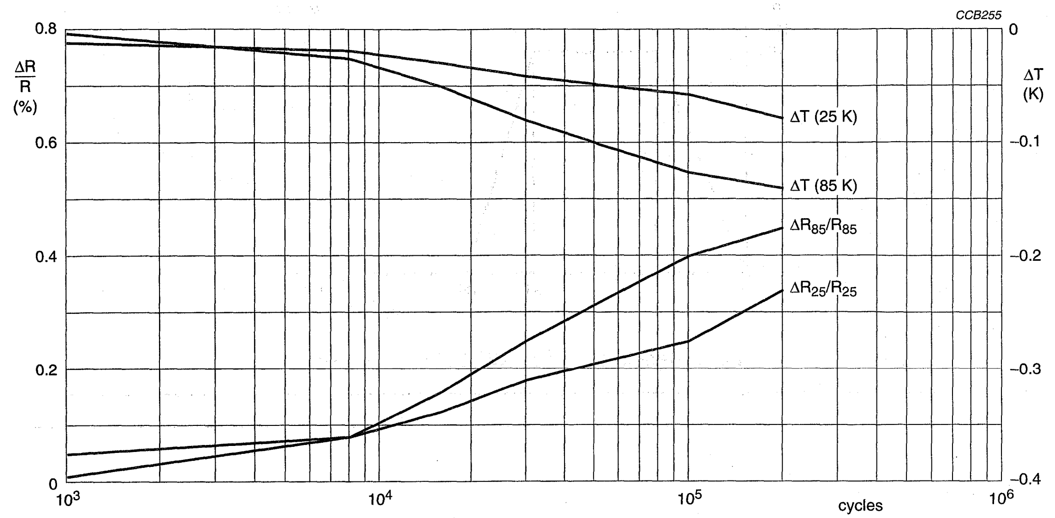


Fig.6 Stability of glass encapsulated NTCs after thermal shock test.

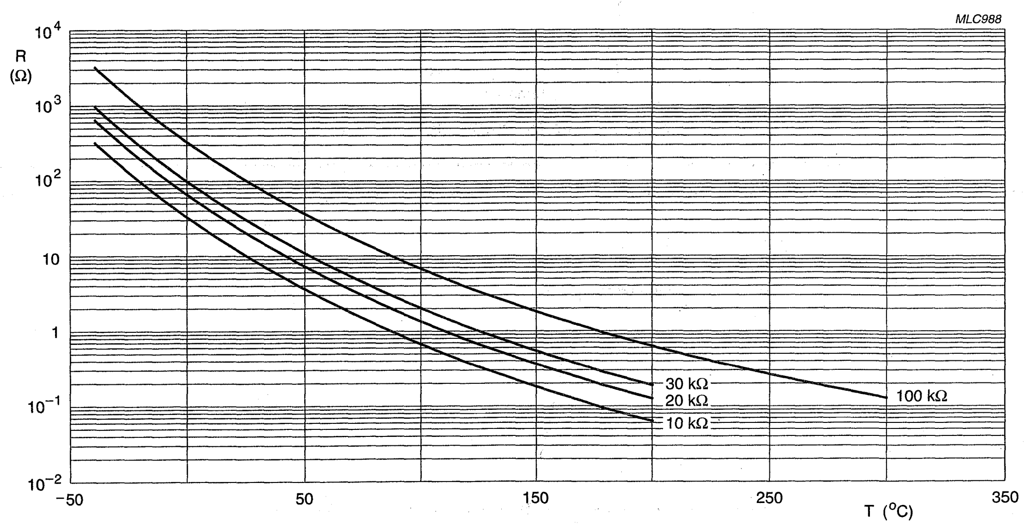
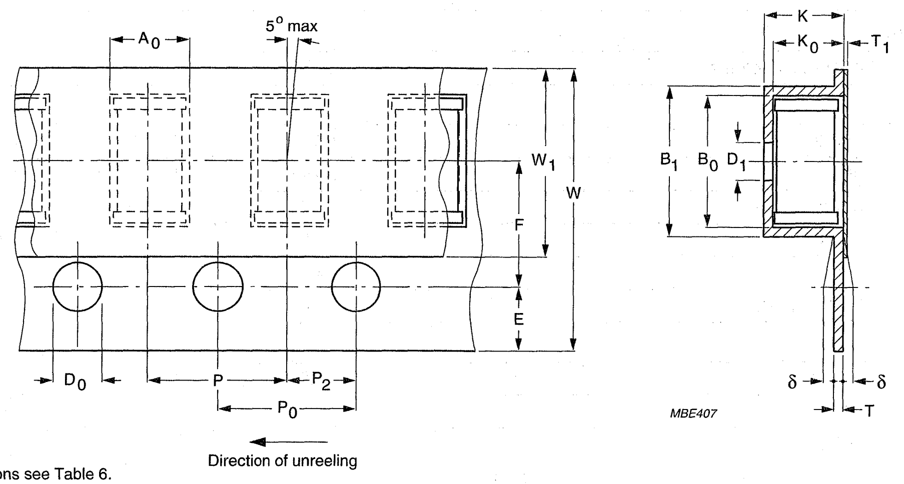


Fig.7 Typical R-T characteristics for the 2322 633 5/7/8.... series.

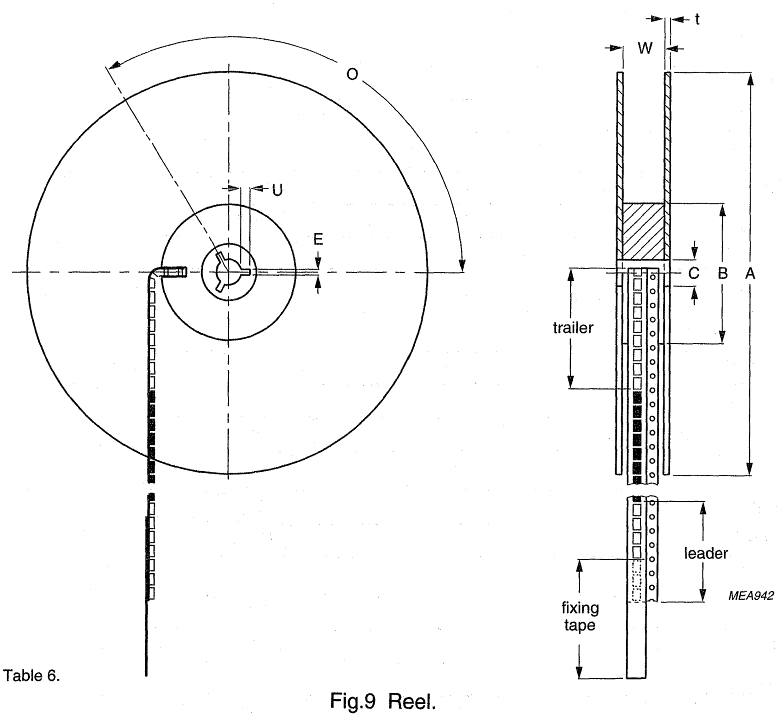
PACKAGING

Blister tape, reel and bandolier data



For dimensions see Table 6.

Fig.8 Blister tape.

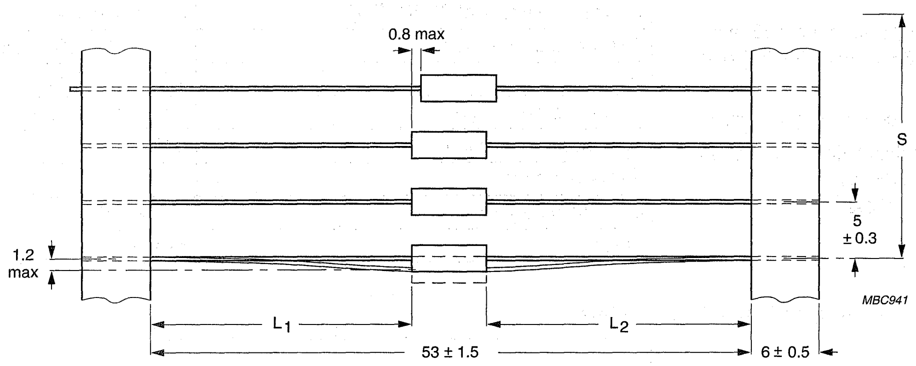


For dimensions see Table 6.

Fig.9 Reel.

Table 6 Blister tape and reel dimensions; see Figs 8 and 9

SYMBOL	PARAMETER	NOMINAL DIMENSIONS	TOLERANCE	UNIT
Blister tape				
K	overall thickness	<2.5	–	mm
POCKET				
A_0	length	2.1	+0.3	mm
B_0	width	>3.8	–	mm
K_0	depth	2.1	+0.3	mm
B_1	outside width	<4.5	–	mm
P	pitch	4.0	±0.1	mm
D_1	hole diameter	1.0	±0.1	mm
FEED-HOLE				
D_0	diameter	1.5	±0.1	mm
P_0	pitch	4.0	±0.1	mm
E	distance	1.75	±0.1	mm
	cumulative pitch error over 10 positions	0	±0.1	mm
CENTRE LINE				
P_2	length	2.0	±0.05	mm
F	width	3.5	±0.1	mm
FIXING TAPE				
W_1	width	<5.5	–	mm
T_1	thickness	<0.1	–	mm
CARRIER TAPE				mm
W	thickness	8.0	±0.2	mm
δ	bending	<0.3	–	mm
T	thickness	<0.4	–	mm
Reel				
FLANGE				
A	diameter	180	+0	mm
t	thickness	1.5	+0.5	mm
W	space between flanges	9.5	±0.5	mm
HUB				
B	diameter	62.0	±1.5	mm
C	spindle hole	12.75	+0.15/–0	mm
KEY SLIT				
E	width	2.0	±0.5	mm
U	depth	4.0	±0.5	mm
O	location	120	–	°



A black marker is printed on the tape of the bandolier after every 50 units.
The components are centred so that $|L_1 - L_2|$ = 1.2 mm max.
The cumulative space (S) measured over 10 spacings = 50 ±2 mm.

Fig.10 Thermistors on bandolier.

Note to Table 6 and Fig.10

The bandolier of a 180 mm reel contains at least 2500 devices with no more than 0.5% empty positions.
Three consecutive empty places may be found provided this gap is followed by 6 consecutive devices.
The carrier tape starts (leader) and ends (trailer) with at least 75 empty positions (equivalent to 300 mm); the covering foil is at least 300 mm. In order to fix the carrier tape a self-adhesive tape of 20 to 50 mm width is applied.

NTC thermistors, naked chips — 2322 640 0....

FEATURES

- Accurate over a wide temperature range
- High stability (tolerance on B-value between ±2.5% and ±0.75%) over a long life
- Excellent price/performance ratio
- For mechanical fixing in a housing or soldering directly to 'non-standard' leads.

APPLICATION

- Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a metallized square chip.

PACKAGING

The naked chips are placed in sealed polythene bags and packed in cardboard boxes. The smallest packaging quantity is 5000 units.

MECHANICAL DATA

Marking

None.

Mounting

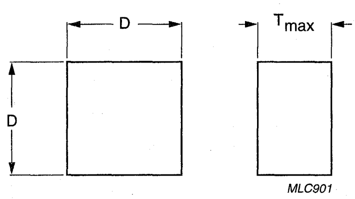
By reflow or wave soldering in any position or mechanical fixing.

The use of ultrasonic soldering is **not** recommended.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	2.2 to 470 kΩ
Tolerance on R_{25}-value	±1%; ±2%; ±3%; ±5%
$B_{25/85}$-value	3740 to 4570 K
Tolerance on $B_{25/85}$-value	±2.5% to ±0.75%
Maximum dissipation	500 mW
Response time	<1.2 s
Climatic category	40/125/56
Mass	see Table 1

Outline



For dimensions see Table 1.

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, TC, mass, dimensions and catalogue numbers

R_{25} (Ω)	TC (%/K)	MASS (g)	D (mm)	T_{max} (mm)	$B_{25/85}$ K	$B_{25/85}$ TOL. (%)	CATALOGUE NUMBER 2322 640 .....(1)
2200	4.37	0.016	2.3 ±0.4	1.3	3977	±0.75	0.222
2700	4.37	0.014	2.3 ±0.4		3977	±0.75	0.272
3300	4.37	0.011	2.0 ±0.4		3977	±0.75	0.332
4700	4.37	0.008	2.0 ±0.4		3977	±0.75	0.472
5000	4.37	0.008	2.0 ±0.4		3977	±0.75	0.502
6000	4.37	0.008	2.0 ±0.4		3977	±0.75	0.602
6800	4.37	0.011	2.0 ±0.4		3977	±0.75	0.682
8000	4.37	0.011	2.0 ±0.4		3977	±0.75	0.802
10000	4.37	0.016	2.0 ±0.4		3977	±0.75	0.103
12000	4.10	0.014	2.0 ±0.4		3740	±2.0	0.123
15000	4.10	0.011	2.0 ±0.4		3740	±2.0	0.153
22000	4.10	0.008	2.0 ±0.4		3740	±2.0	0.223
33000	4.46	0.011	2.0 ±0.4		4090	±1.5	0.333
47000	4.46	0.016	2.0 ±0.4		4090	±1.5	0.473
68000	4.57	0.012	2.0 ±0.4		4190	±1.5	0.683
100000	4.57	0.008	2.0 ±0.4		4190	±1.5	0.104
150000	4.75	0.011	2.0 ±0.4		4370	±2.5	0.154
220000	4.75	0.008	2.0 ±0.4		4370	±2.5	0.224
330000	4.95	0.014	2.0 ±0.4		4570	±1.5	0.334
470000	4.95	0.014	2.0 ±0.4		4570	±1.5	0.474

Note

1. Replace dot in last 5 digits of catalogue number, by a number according to the following list and depending on tolerance on required R_{25}-value:
   a) 5 for a tolerance of ±1%.
   b) 4 for a tolerance of ±2%.
   c) 6 for a tolerance of ±3%.
   d) 3 for a tolerance of ±5%.

NTC thermistors, naked chips 2322 640 0....

Table 2 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1)			
				0.222	**0.272**	**0.332**	**0.472**
−40	33.21	2.66	6.57	73.06	89.67	109.6	156.1
−35	23.99	2.41	6.36	52.78	64.77	79.17	112.8
−30	17.52	2.17	6.15	38.55	47.31	57.82	82.35
−25	12.93	1.94	5.95	28.44	34.91	42.67	60.77
−20	9.636	1.71	5.76	21.20	26.02	31.80	45.30
−15	7.250	1.50	5.58	15.95	19.58	23.93	34.08
−10	5.505	1.29	5.40	12.11	14.86	18.16	25.87
−5	4.216	1.08	5.24	9.275	11.38	13.91	19.81
0	3.255	0.89	5.08	7.162	8.790	10.74	15.30
5	2.534	0.70	4.92	5.575	6.842	8.362	11.91
10	1.987	0.52	4.78	4.372	5.366	6.558	9.340
15	1.570	0.34	4.64	3.454	4.239	5.181	7.378
20	1.249	0.17	4.50	2.747	3.372	4.121	5.869
25	1.000	0.00	4.37	2.200	2.700	3.300	4.700
30	0.8059	0.16	4.25	1.773	2.176	2.660	3.788
35	0.6535	0.32	4.13	1.438	1.764	2.156	3.072
40	0.5330	0.47	4.02	1.173	1.439	1.759	2.505
45	0.4372	0.62	3.91	0.9618	1.180	1.443	2.055
50	0.3605	0.77	3.80	0.7932	0.973	1.190	1.694
55	0.2989	0.91	3.70	0.6575	0.807	0.9863	1.405
60	0.2490	1.05	3.60	0.5478	0.672	0.8217	1.170
65	0.2084	1.18	3.51	0.4586	0.562	0.6879	0.9797
70	0.1753	1.31	3.42	0.3857	0.473	0.5785	0.8239
75	0.1481	1.44	3.33	0.3258	0.399	0.4887	0.6960
80	0.1256	1.57	3.25	0.2764	0.339	0.4146	0.5905
85	0.1070	1.69	3.16	0.2355	0.289	0.3532	0.5031
90	0.09154	1.81	3.09	0.2014	0.247	0.3021	0.4303
95	0.07860	1.93	3.01	0.1729	0.212	0.2594	0.3694
100	0.06773	2.04	2.94	0.1490	0.182	0.2235	0.3183
105	0.05858	2.15	2.87	0.1289	0.158	0.1933	0.2753
110	0.05083	2.26	2.80	0.1118	0.137	0.1677	0.2389
115	0.04426	2.37	2.73	0.0974	0.1195	0.1461	0.2080
120	0.03866	2.47	2.67	0.0851	0.1044	0.1276	0.1817
125	0.03387	2.57	2.61	0.0745	0.0915	0.1118	0.1592
130	0.02977	2.67	2.55	0.0655	0.0804	0.0982	0.1399
135	0.02624	2.77	2.49	0.0577	0.0709	0.0866	0.1233
140	0.02319	2.86	2.43	0.0510	0.0626	0.0765	0.1090
145	0.02055	2.96	2.38	0.0452	0.0555	0.0678	0.0966
150	0.01826	3.05	2.33	0.0402	0.0493	0.0603	0.0858

NTC thermistors, naked chips — 2322 640 0....

Table 3 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1) 0.502	0.602	0.682	0.802	0.103
−40	33.21	2.66	6.57	166.1	199.3	225.8	265.7	332.1
−35	23.99	2.41	6.36	120.0	143.9	163.1	191.9	240.0
−30	17.52	2.17	6.15	87.60	105.1	119.1	140.2	175.2
−25	12.93	1.94	5.95	64.65	77.57	87.92	103.4	129.3
−20	9.636	1.71	5.76	48.18	57.82	65.53	77.09	96.36
−15	7.250	1.50	5.58	36.25	43.50	49.30	58.00	72.50
−10	5.505	1.29	5.40	27.52	33.03	37.43	44.04	55.05
−5	4.216	1.08	5.24	21.08	25.30	28.67	33.73	42.16
0	3.255	0.89	5.08	16.28	19.53	22.14	26.04	32.56
5	2.534	0.70	4.92	12.67	15.20	17.23	20.27	25.34
10	1.987	0.52	4.78	9.936	11.92	13.51	15.90	19.87
15	1.570	0.34	4.64	7.849	9.419	10.67	12.56	15.70
20	1.249	0.17	4.50	6.244	7.493	8.492	9.990	12.49
25	1.000	0.00	4.37	5.000	6.000	6.800	8.000	10.00
30	0.8059	0.16	4.25	4.030	4.836	5.480	6.447	8.059
35	0.6535	0.32	4.13	3.267	3.921	4.444	5.228	6.535
40	0.5330	0.47	4.02	2.665	3.198	3.624	4.264	5.330
45	0.4372	0.62	3.91	2.186	2.623	2.972	3.497	4.372
50	0.3605	0.77	3.80	1.803	2.163	2.451	2.884	3.606
55	0.2989	0.91	3.70	1.494	1.793	2.032	2.391	2.989
60	0.2490	1.05	3.60	1.245	1.494	1.693	1.992	2.490
65	0.2084	1.18	3.51	1.042	1.251	1.417	1.668	2.084
70	0.1753	1.31	3.42	0.8765	1.052	1.192	1.402	1.753
75	0.1481	1.44	3.33	0.7405	0.8886	1.007	1.185	1.481
80	0.1256	1.57	3.25	0.6282	0.7538	0.8544	1.005	1.256
85	0.1070	1.69	3.16	0.5352	0.6422	0.7278	0.8563	1.070
90	0.09154	1.81	3.09	0.4577	0.5493	0.6225	0.7324	0.9154
95	0.07860	1.93	3.01	0.3930	0.4716	0.5345	0.6288	0.7860
100	0.06773	2.04	2.94	0.3387	0.4064	0.4607	0.5419	0.6773
105	0.05858	2.15	2.87	0.2929	0.3515	0.3983	0.4686	0.5858
110	0.05083	2.26	2.80	0.2542	0.3050	0.3457	0.4067	0.5083
115	0.04426	2.37	2.73	0.2213	0.2656	0.3010	0.3541	0.4426
120	0.03866	2.47	2.67	0.1933	0.2320	0.2629	0.3093	0.3866
125	0.03387	2.57	2.61	0.1694	0.2032	0.2303	0.2710	0.3387
130	0.02977	2.67	2.55	0.1488	0.1786	0.2024	0.2382	0.2977
135	0.02624	2.77	2.49	0.1312	0.1574	0.1784	0.2099	0.2624
140	0.02319	2.86	2.43	0.1160	0.1391	0.1577	0.1855	0.2319
145	0.02055	2.96	2.38	0.1028	0.1233	0.1398	0.1644	0.2055
150	0.01826	3.05	2.33	0.0913	0.1096	0.1242	0.1461	0.1826

Table 4 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1)		
				0.123	**0.153**	**0.223**
−40	25.78	6.81	6.09	309.4	386.8	567.2
−35	19.13	6.16	5.89	229.5	286.9	420.8
−30	14.32	5.53	5.70	171.8	214.8	315.0
−25	10.82	4.93	5.52	129.8	162.3	238.0
−20	8.245	4.35	5.35	98.93	123.7	181.4
−15	6.335	3.80	5.19	76.02	95.03	139.4
−10	4.907	3.26	5.03	58.88	73.60	107.9
−5	3.830	2.74	4.88	45.95	57.44	84.25
0	3.011	2.24	4.73	36.13	45.16	66.24
5	2.384	1.76	4.60	28.60	35.76	52.45
10	1.900	1.30	4.46	22.80	28.50	41.81
15	1.525	0.85	4.34	18.30	22.87	33.55
20	1.231	0.42	4.21	14.77	18.47	27.09
25	1.000	0.00	4.10	12.00	15.00	22.00
30	0.8170	0.41	3.98	9.804	12.26	17.97
35	0.6712	0.80	3.88	8.054	10.07	14.77
40	0.5543	1.19	3.77	6.652	8.315	12.20
45	0.4602	1.57	3.67	5.522	6.903	10.12
50	0.3839	1.94	3.57	4.607	5.759	8.447
55	0.3219	2.30	3.48	3.862	4.828	7.081
60	0.2710	2.65	3.39	3.252	4.067	5.963
65	0.2293	2.99	3.30	2.751	3.439	5.044
70	0.1947	3.33	3.22	2.337	2.921	4.284
75	0.1661	3.66	3.14	1.993	2.492	3.654
80	0.1422	3.98	3.06	1.707	2.134	3.129
85	0.1223	4.29	2.99	1.467	1.834	2.690
90	0.1055	4.60	2.92	1.266	1.583	2.321
95	0.09135	4.90	2.85	1.096	1.370	2.010
100	0.07937	5.19	2.78	0.9524	1.190	1.746
105	0.06919	5.48	2.71	0.8302	1.038	1.522
110	0.06050	5.76	2.65	0.7260	0.9075	1.331
115	0.05307	6.04	2.59	0.6369	0.7961	1.168
120	0.04670	6.31	2.53	0.5604	0.7005	1.027
125	0.04121	6.57	2.47	0.4945	0.6181	0.9065

Table 5 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1)	
				0.333	**0.473**
−40	33.81	5.55	6.55	1116	1589
−35	24.50	5.02	6.34	808.6	1151
−30	17.93	4.52	6.15	591.7	842.8
−25	13.25	4.03	5.96	437.1	622.6
−20	9.875	3.56	5.78	325.9	464.1
−15	7.425	3.10	5.61	245.0	349.0
−10	5.630	2.67	5.45	185.8	264.6
−5	4.304	2.24	5.29	142.0	202.3
0	3.315	1.84	5.14	109.4	155.8
5	2.573	1.44	4.99	84.91	120.9
10	2.011	1.07	4.85	66.37	94.53
15	1.583	0.70	4.72	52.24	74.40
20	1.254	0.34	4.59	41.39	58.95
25	1.000	0.00	4.46	33.00	47.00
30	0.8024	0.33	4.34	26.47	37.71
35	0.6474	0.66	4.23	21.37	30.43
40	0.5255	0.98	4.12	17.34	24.70
45	0.4288	1.28	4.01	14.15	20.15
50	0.3518	1.59	3.91	11.61	16.53
55	0.2901	1.88	3.81	9.572	13.63
60	0.2403	2.17	3.71	7.931	11.30
65	0.2001	2.45	3.62	6.603	9.404
70	0.1674	2.72	3.53	5.522	7.865
75	0.1406	2.99	3.44	4.639	6.607
80	0.1186	3.25	3.36	3.913	5.573
85	0.1004	3.51	3.28	3.315	4.721
90	0.08542	3.76	3.20	2.819	4.015
95	0.07292	4.00	3.13	2.406	3.427
100	0.06248	4.24	3.06	2.062	2.936
105	0.05372	4.47	2.98	1.773	2.525
110	0.04635	4.70	2.92	1.530	2.179
115	0.04013	4.93	2.85	1.342	1.886
120	0.03485	5.15	2.79	1.150	1.638
125	0.03037	5.36	2.73	1.002	1.427
130	0.02654	5.57	2.67	0.8757	1.247
135	0.02326	5.78	2.61	0.7675	1.093
140	0.02044	5.98	2.55	0.6746	0.9608
145	0.01802	6.18	2.50	0.5945	0.8468
150	0.01592	6.37	2.44	0.5254	0.7483

NTC thermistors, naked chips 2322 640 0....

Table 6 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1) 0.683	0.104
−40	36.66	5.69	6.70	2493	3666
−35	26.38	5.15	6.49	1794	2638
−30	19.17	4.63	6.29	1303	1917
−25	14.06	4.13	6.10	956.2	1406
−20	10.41	3.65	5.92	708.0	1041
−15	7.779	3.18	5.74	528.9	777.9
−10	5.861	2.73	5.57	398.5	586.1
−5	4.453	2.30	5.41	302.8	445.3
0	3.409	1.88	5.26	231.8	340.9
5	2.631	1.48	5.11	178.9	263.1
10	2.044	1.09	4.97	139.0	204.4
15	1.600	0.72	4.83	108.8	160.0
20	1.261	0.35	4.70	85.74	126.1
25	1.000	0.00	4.57	68.00	100.0
30	0.7981	0.34	4.45	54.27	79.81
35	0.6408	0.67	4.35	43.57	64.08
40	0.5175	1.00	4.22	35.19	51.74
45	0.4202	1.32	4.11	28.57	42.02
50	0.3431	1.63	4.00	23.33	34.31
55	0.2816	1.93	3.90	19.15	28.16
60	0.2322	2.22	3.80	15.79	23.22
65	0.1925	2.51	3.71	13.09	19.25
70	0.1602	2.79	3.62	10.90	16.03
75	0.1340	3.06	3.53	9.114	13.40
80	0.1126	3.33	3.45	7.655	11.26
85	0.09496	3.59	3.36	6.457	9.496
90	0.08042	3.85	3.28	5.469	8.042
95	0.06837	4.10	3.21	4.649	6.837
100	0.05835	4.35	3.13	3.968	5.835
105	0.04998	4.59	3.06	3.399	4.998
110	0.04296	4.82	2.99	2.921	4.296
115	0.03705	5.05	2.92	2.519	3.705
120	0.03206	5.28	2.86	2.180	3.206
125	0.02783	5.50	2.80	1.892	2.783

Table 7 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1)	
				0.154	**0.224**
−40	41.02	10.10	6.89	6153	9024
−35	29.29	9.12	6.68	4394	6444
−30	21.12	8.18	6.48	3168	4646
−25	15.37	7.28	6.29	2305	3381
−20	11.28	6.42	6.11	1693	2483
−15	8.358	5.59	5.93	1254	1839
−10	6.242	4.80	5.76	936.4	1373
−5	4.700	4.03	5.60	705.0	1034
0	3.567	3.30	5.44	535.0	784.7
5	2.727	2.59	5.29	409.1	600.0
10	2.101	1.90	5.15	315.1	462.1
15	1.629	1.25	5.01	244.4	358.4
20	1.272	0.61	4.88	190.8	279.9
25	1.000	0.00	4.75	150.0	220.0
30	0.7910	0.59	4.62	118.6	174.0
35	0.6295	1.18	4.51	94.42	138.5
40	0.5039	1.74	4.39	75.58	110.9
45	0.4056	2.30	4.28	60.85	89.24
50	0.3283	2.84	4.17	49.25	72.24
55	0.2672	3.37	4.07	40.08	58.78
60	0.2185	3.89	3.97	32.78	48.08
65	0.1796	4.40	3.87	26.94	39.51
70	0.1483	4.90	3.78	22.25	32.63
75	0.1231	5.39	3.69	18.46	27.07
80	0.1025	5.86	3.60	15.38	22.56
85	0.08582	6.33	3.52	12.87	18.88
90	0.07213	6.79	3.44	10.82	15.87
95	0.06086	7.24	3.36	9.129	13.39
100	0.05155	7.68	3.28	7.732	11.34
105	0.04383	8.11	3.21	6.574	9.642
110	0.03740	8.53	3.14	5.610	8.228
115	0.03203	8.94	3.07	4.804	7.046
120	0.02752	9.35	3.00	4.128	6.054
125	0.02372	9.75	2.94	3.559	5.219

NTC thermistors, naked chips 2322 640 0....

Table 8 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2322 640 ..... (see Table 1, note 1)	
				0.334	**0.474**
−40	48.62	6.22	7.13	16044	22850
−35	34.19	5.63	6.91	11282	16068
−30	24.28	5.06	6.71	8013	11413
−25	17.42	4.51	6.52	5747	8185
−20	12.61	3.98	6.33	4161	5926
−15	9.211	3.47	6.15	3040	4329
−10	6.788	2.98	5.98	2240	3190
−5	5.045	2.51	5.82	1665	2371
0	3.781	2.06	5.66	1248	1776
5	2.855	1.62	5.50	942.3	1342
10	2.173	1.19	5.36	717.1	1021
15	1.666	0.78	5.22	549.8	783.0
20	1.286	0.38	5.08	424.5	604.6
25	1.000	0.00	4.95	330.0	470.0
30	0.7825	0.37	4.82	258.2	367.8
35	0.6163	0.74	4.70	203.4	289.6
40	0.4883	1.09	4.59	161.1	229.5
45	0.3892	1.44	4.47	128.4	182.9
50	0.3120	1.77	4.36	103.0	146.7
55	0.2515	2.10	4.26	83.00	118.2
60	0.2038	2.43	4.15	67.26	95.80
65	0.1660	2.74	4.06	54.79	78.03
70	0.1359	3.05	3.96	44.86	63.88
75	0.1118	3.35	3.87	36.90	52.55
80	0.09240	3.64	3.78	30.49	43.43
85	0.07670	3.93	3.69	25.31	36.05
90	0.06395	4.21	3.61	21.10	30.06
95	0.05354	4.48	3.53	17.67	25.16
100	0.04501	4.75	3.45	14.85	21.15
105	0.03798	5.01	3.37	12.53	17.85
110	0.03218	5.27	3.30	10.70	15.12
115	0.02736	5.52	3.23	9.029	12.86
120	0.02335	5.77	3.16	7.704	10.97
125	0.01999	6.01	3.09	6.597	9.396

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1.

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	2.2 to 470 kΩ
Standard selection tolerances	±1%; ±2%; ±3%; ±5%
Climatic category	40/125/56
Maximum dissipation	500 mW
Operating temperature range:	
at zero dissipation (continuously)	−40 to +125 °C
for short periods	≤150 °C
at maximum dissipation	0 to +55 °C

Derating

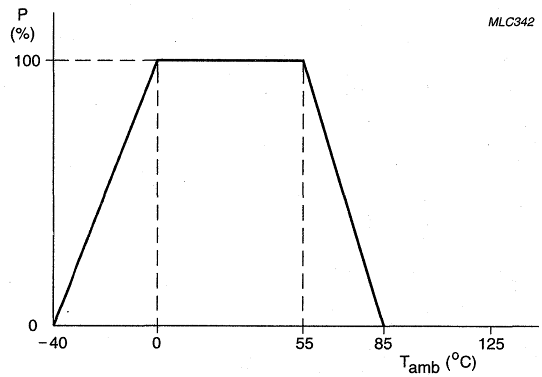


Fig.2 Power derating curve.

NTC thermistors, moulded range 2322 641 6....

FEATURES

- Excellent for surface measurement
- Designed for harsh environments
- Based on the *"2322 640 0...."* naked thermistor chips.

APPLICATION

- Temperature control.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a moulded chip with two tin-plated solid copper leads.

PACKAGING

The smallest packing quantity is 500 units.

MECHANICAL DATA

Marking

White coloured body.

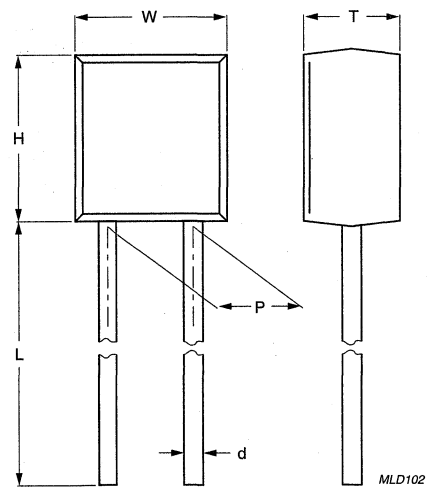
Mounting

By soldering in any position or mechanical fixing.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	2.2 to 470 kΩ
Tolerance on R_{25}-value	±3%
$B_{25/85}$-values	3740 to 4570 K
Maximum dissipation	250 mW
Response time	≈2.7 s
Operating temperature range:	
at zero dissipation	−40 to +125 °C
at maximum dissipation	0 to 55 °C
Climatic category	40/125/56
Mass	≈0.3 g

Outline



For dimensions see Table 1.

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, TC, mass, dimensions and catalogue numbers; see note 1

R_{25} (kΩ)	TC (%/K)	MASS (g)	W (mm)	H (mm)	L (mm)	P (mm)	T (mm)	d (mm)	$B_{25/85}$		CATALOGUE NUMBER 2322 641 .....
									K	TOL. (%)	
2.2	4.37	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	3977	±0.75	66222
2.7	4.37	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	3977	±0.75	66272
12	4.10	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	3740	±2.0	66123
15	4.10	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	3740	±2.0	66153
100	4.57	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	4190	±1.5	66104
470	4.95	≈0.3	4 ±0.2	4.4 ±0.2	21 ±1	2.54 ±0.3	2.5 ±0.2	0.6 ±0.06	4570	±1.5	66474

Note

1. Other R_{25}-values between 2.2 kΩ to 470 kΩ are available on request.

NTC thermistors, moulded range 2322 641 6....

Table 2 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 641 66222	R_{25} (Ω) 2322 641 66272
−40	33.21	2.66	6.57	73062	89667
−35	23.99	2.41	6.36	52779	64774
−30	17.52	2.17	6.15	38545	47305
−25	12.93	1.94	5.95	28444	34908
−20	9.636	1.71	5.76	21199	26017
−15	7.250	1.50	5.58	15950	19575
−10	5.505	1.29	5.40	12110	14863
−5	4.216	1.08	5.24	9275	11383
0	3.255	0.89	5.08	7162	8790
5	2.534	0.70	4.92	5575	6842
10	1.987	0.52	4.78	4372	5366
15	1.570	0.34	4.64	3454	4239
20	1.249	0.17	4.50	2747	3372
25	1.000	0.00	4.37	2200	2700
30	0.8059	0.16	4.25	1773	2176
35	0.6535	0.32	4.13	1438	1764
40	0.5330	0.47	4.02	1173	1439
45	0.4372	0.62	3.91	961.8	1180
50	0.3605	0.77	3.80	793.2	973.4
55	0.2989	0.91	3.70	657.5	807.0
60	0.2490	1.05	3.60	547.8	672.3
65	0.2084	1.18	3.51	458.6	562.8
70	0.1753	1.31	3.42	385.7	473.3
75	0.1481	1.44	3.33	325.8	399.9
80	0.1256	1.57	3.25	276.4	339.2
85	0.1070	1.69	3.16	235.5	289.0
90	0.09154	1.81	3.09	201.4	247.2
95	0.07860	1.93	3.01	172.9	212.2
100	0.06773	2.04	2.94	149.0	182.9
105	0.05858	2.15	2.87	128.9	158.2
110	0.05083	2.26	2.80	111.8	137.2
115	0.04426	2.37	2.73	97.37	119.5
120	0.03866	2.47	2.67	85.05	104.4
125	0.03387	2.57	2.61	74.52	91.46
130	0.02977	2.67	2.55	65.49	80.38
135	0.02624	2.77	2.49	57.73	70.85
140	0.02319	2.86	2.43	51.02	62.62
145	0.02055	2.96	2.38	45.22	55.49
150	0.01826	3.05	2.33	40.18	49.31

NTC thermistors, moulded range 2322 641 6....

Table 3 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 641 66123	66153
−40	25.78	6.81	6.09	309403	386754
−35	19.13	6.16	5.89	229509	286887
−30	14.32	5.53	5.70	171844	214805
−25	10.82	4.93	5.52	129828	162285
−20	8.245	4.35	5.35	98935	123669
−15	6.335	3.80	5.19	76020	95025
−10	4.907	3.26	5.03	58880	73600
−5	3.830	2.74	4.88	45954	57443
0	3.011	2.24	4.73	36130	45163
5	2.384	1.76	4.60	28607	35759
10	1.900	1.30	4.46	22805	28506
15	1.525	0.85	4.34	18298	22872
20	1.231	0.42	4.21	14774	18467
25	1.000	0.00	4.10	12000	15000
30	0.8171	0.41	3.98	9804	12255
35	0.6712	0.80	3.88	8054	10068
40	0.5543	1.19	3.77	6652	8315
45	0.4602	1.57	3.67	5522	6903
50	0.3839	1.94	3.57	4607	5759
55	0.3219	2.30	3.48	3862	4828
60	0.2710	2.65	3.39	3252	4066
65	0.2293	2.99	3.30	2751	3439
70	0.1947	3.33	3.22	2337	2921
75	0.1661	3.66	3.14	1993	2492
80	0.1422	3.98	3.06	1707	2134
85	0.1223	4.29	2.99	1467	1834
90	0.1055	4.60	2.92	1266	1583
95	0.09135	4.90	2.85	1096	1370
100	0.07937	5.19	2.78	952.2	1190
105	0.06919	5.48	2.71	830.2	1038
110	0.06050	5.76	2.65	726.0	907.5
115	0.05307	6.04	2.59	636.9	796.1
120	0.04670	6.31	2.53	560.4	700.5
125	0.04121	6.57	2.47	494.5	618.1

NTC thermistors, moulded range 2322 641 6....

Table 4 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 641 66104
−40	36.66	5.69	6.70	3666321
−35	26.38	5.15	6.49	2637604
−30	19.17	4.63	6.29	1916588
−25	14.06	4.13	6.10	1406120
−20	10.41	3.65	5.92	1041190
−15	7.779	3.18	5.74	777851
−10	5.861	2.73	5.57	586100
−5	4.453	2.30	5.41	445260
0	3.409	1.88	5.26	340944
5	2.631	1.48	5.11	263055
10	2.044	1.09	4.97	204447
15	1.600	0.72	4.83	160015
20	1.261	0.35	4.70	126087
25	1.000	0.00	4.57	100000
30	0.7981	0.34	4.45	79808
35	0.6408	0.67	4.35	64077
40	0.5175	1.00	4.22	51746
45	0.4202	1.32	4.11	42021
50	0.3431	1.63	4.00	34308
55	0.2816	1.93	3.90	28156
60	0.2322	2.22	3.80	23223
65	0.1925	2.51	3.71	19246
70	0.1602	2.79	3.62	16025
75	0.1340	3.06	3.53	13402
80	0.1126	3.33	3.45	11258
85	0.09496	3.59	3.36	9496
90	0.08042	3.85	3.28	8042
95	0.06837	4.10	3.21	6837
100	0.05835	4.35	3.13	5835
105	0.04998	4.59	3.06	4998
110	0.04296	4.82	2.99	4296
115	0.03705	5.05	2.92	3705
120	0.03206	5.28	2.86	3206
125	0.02783	5.50	2.80	2783

Table 5 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (Ω) 2322 641 66474
−40	48.62	6.22	7.13	22849885
−35	34.19	5.63	6.91	16068156
−30	24.28	5.06	6.71	11412861
−25	17.42	4.51	6.52	8185271
−20	12.61	3.98	6.33	5925780
−15	9.211	3.47	6.15	4329092
−10	6.788	2.98	5.98	3190465
−5	5.045	2.51	5.82	2371302
0	3.781	2.06	5.66	1776920
5	2.855	1.62	5.50	1342065
10	2.173	1.19	5.36	1021372
15	1.666	0.78	5.22	783037
20	1.286	0.38	5.08	604583
25	1.000	0.00	4.95	470000
30	0.7825	0.37	4.82	367792
35	0.6163	0.74	4.70	289646
40	0.4883	1.09	4.59	229509
45	0.3892	1.44	4.47	182938
50	0.3120	1.77	4.36	146652
55	0.2515	2.10	4.26	118215
60	0.2038	2.43	4.15	95801
65	0.1660	2.74	4.06	78037
70	0.1359	3.05	3.96	63884
75	0.1118	3.35	3.87	52549
80	0.09240	3.64	3.78	43427
85	0.07670	3.93	3.69	30055
90	0.06395	4.21	3.61	25163
95	0.05354	4.48	3.53	21153
100	0.04501	4.75	3.45	17852
105	0.03798	5.01	3.37	15123
110	0.03218	5.27	3.30	12859
115	0.02736	5.52	3.23	10973
120	0.02335	5.77	3.16	9396
125	0.01999	6.01	3.09	9325

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	see Table 1
Standard selection tolerances	±3%
$B_{25/85}$-values	see Table 1
Temperature coefficient at 25 °C	see Table 1
Climatic category	40/125/56
Maximum dissipation	250 mW
Response time (for information only)	≈2.7 s
Minimum dielectric withstanding voltage (RMS) between leads and lead insulation	350 V
Minimum insulation resistance between leads and lead insulation at 100 V (DC)	100 MΩ
Operating temperature range:	
at zero dissipation	−40 to +125 °C
at maximum dissipation	0 to 55 °C

Derating

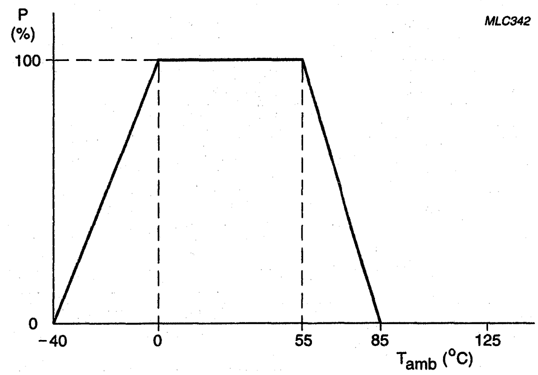


Fig.2 Power derating curve.

NTC thermistors, special long lead sensors 2338 640 7/8/9....

FEATURES

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

APPLICATION

Temperature sensing and control.

DESCRIPTION

These thermistors have a negative temperature coefficient.

The water-resistant type (2338 640 7....) and the brass pipe type (2338 640 8....) are suitable for application in various environmental conditions.

The epoxy-coated type (2338 640 9....) consists of a chip with UL wire and is lacquered and insulated with black epoxy.

MARKING

UL mark on wire, no mark on body.

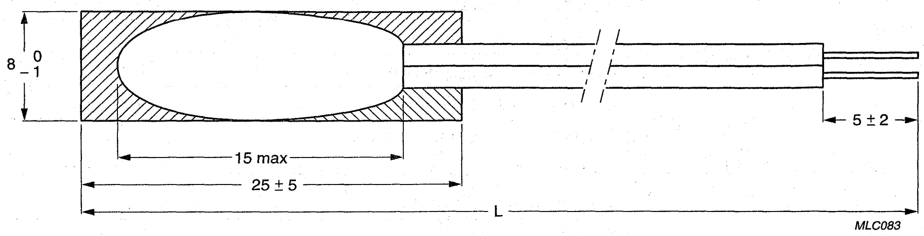
QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	2.2 to 470 kΩ
Tolerance on R_{25}-value	±3%
Tolerance on $B_{25/85}$-value	±1.5% or ±0.75%
Maximum dissipation	250 mW
Operating temperature range:	
at zero dissipation (continuously)	−40 to +85 °C
at maximum dissipation	0 to +50 °C
Climatic category	40/085/56
Total length (L); note 1 and Figs 1 to 3	400 ±10 mm
Lead wire; note 1	UL-2468.AWG24 wire
Mass:	
2338 640 7....	≈6 g
2338 640 8....	≈6 g
2338 640 9....	≈4 g

Note

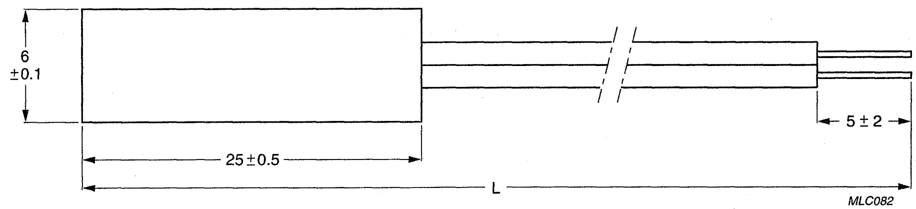
1. Wire length and wire type are optional on request. The products can be provided with a connector on request.

MECHANICAL DATA



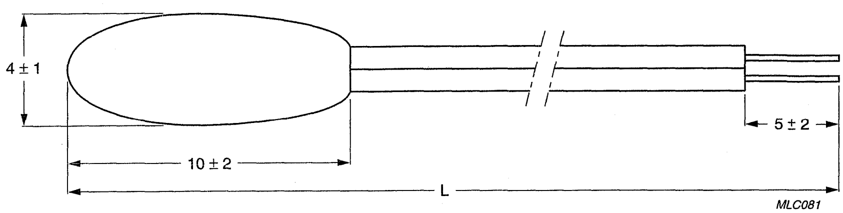
Dimensions in mm.
L = 400 ±10 mm. Other wire lengths available on request.

Fig.1 Water-resistant type 2338 640 7....



Dimensions in mm.
L = 400 ±10 mm. Other wire lengths available on request.

Fig.2 Brass pipe type 2338 640 8....



Dimensions in mm.
L = 400 ±10 mm. Other wire lengths available on request.

Fig.3 Epoxy-coated type 2338 640 9....

ORDERING INFORMATION

Table 1 R_{25}-values and catalogue numbers; note 1

R_{25} (kΩ)	$B_{25/85}$-VALUE	CATALOGUE NUMBER 2338 640 .....(2)		
		WATER-RESISTANT TYPE	BRASS PIPE TYPE	EPOXY-COATED TYPE
2.2	3977 K ±0.75%	70106	80102	90102
5	3977 K ±0.75%	70105	–	90104
10	3977 K ±0.75%	70104	80106	90106
47	4090 K ±1.5%	70452	–	90452
100	4190 K ±1.5%	70504	80504	90504

Notes

1. Other values based on the *"2322 640 0...."* series, are available on request.
2. The specified catalogue numbers refer to products with L = 400 mm, without connector and adopt UL-2468.AWG24 wire.

NTC thermistors, special long lead sensors 2338 640 7/8/9....

Table 2 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)		
				2338 640 7/8/9.... (see Table 4, note 1)		
				.6222	.6502	.6103
−40	33.21	2.66	6.57	73.06	166.1	332.1
−35	23.99	2.41	6.36	52.78	120.0	240.0
−30	17.52	2.17	6.15	38.55	87.60	175.2
−25	12.93	1.94	5.95	28.44	64.65	129.3
−20	9.636	1.71	5.76	21.20	48.18	96.36
−15	7.250	1.50	5.58	15.95	36.25	72.50
−10	5.505	1.29	5.40	12.11	27.52	55.05
−5	4.216	1.08	5.24	9.275	21.08	42.16
0	3.255	0.89	5.08	7.162	16.28	32.56
5	2.534	0.70	4.92	5.575	12.67	25.34
10	1.987	0.52	4.78	4.372	9.936	19.87
15	1.570	0.34	4.64	3.454	7.849	15.70
20	1.249	0.17	4.50	2.747	6.244	12.49
25	1.000	0.00	4.37	2.200	5.000	10.00
30	0.8059	0.16	4.25	1.773	4.030	8.059
35	0.6535	0.32	4.13	1.438	3.267	6.535
40	0.5330	0.47	4.02	1.173	2.665	5.330
45	0.4372	0.62	3.91	0.9618	2.186	4.372
50	0.3605	0.77	3.80	0.7932	1.803	3.606
55	0.2989	0.91	3.70	0.6575	1.494	2.989
60	0.2490	1.05	3.60	0.5478	1.245	2.490
65	0.2084	1.18	3.51	0.4586	1.042	2.084
70	0.1753	1.31	3.42	0.3857	0.8765	1.753
75	0.1481	1.44	3.33	0.3258	0.7405	1.481
80	0.1256	1.57	3.25	0.2764	0.6282	1.256
85	0.1070	1.69	3.16	0.2355	0.5352	1.070

NTC thermistors, special long lead sensors 2338 640 7/8/9....

Table 3 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ) 2338 640 7/8/9.... (see Table 4, note 1) .6473
−40	33.81	5.55	6.55	1589
−35	24.50	5.02	6.34	1151
−30	17.93	4.52	6.15	842.8
−25	13.25	4.03	5.96	622.6
−20	9.875	3.56	5.78	464.1
−15	7.425	3.10	5.61	349.0
−10	5.630	2.67	5.45	264.6
−5	4.304	2.24	5.29	202.3
0	3.315	1.84	5.14	155.8
5	2.573	1.44	4.99	120.9
10	2.011	1.07	4.85	94.53
15	1.583	0.70	4.72	74.40
20	1.254	0.34	4.59	58.95
25	1.000	0.00	4.46	47.00
30	0.8024	0.33	4.34	37.71
35	0.6474	0.66	4.23	30.43
40	0.5255	0.98	4.12	24.70
45	0.4288	1.28	4.01	20.15
50	0.3518	1.59	3.91	16.53
55	0.2901	1.88	3.81	13.63
60	0.2403	2.17	3.71	11.30
65	0.2001	2.45	3.62	9.404
70	0.1674	2.72	3.53	7.865
75	0.1406	2.99	3.44	6.607
80	0.1186	3.25	3.36	5.573
85	0.1004	3.51	3.28	4.721

Table 4 Resistance values at intermediate temperatures

T_{oper} (°C)	R_T/R_{25}	ΔR DUE TO B-TOLERANCE (%)	TC (%/K)	R_{25} (kΩ)
				2338 640 7/8/9.... (see note 1)
				.6104
−40	36.66	5.69	6.70	3666
−35	26.38	5.15	6.49	2638
−30	19.17	4.63	6.29	1917
−25	14.06	4.13	6.10	1406
−20	10.41	3.65	5.92	1041
−15	7.779	3.18	5.74	777.9
−10	5.861	2.73	5.57	586.1
−5	4.453	2.30	5.41	445.3
0	3.409	1.88	5.26	340.9
5	2.631	1.48	5.11	263.1
10	2.044	1.09	4.97	204.4
15	1.600	0.72	4.83	160.0
20	1.261	0.35	4.70	126.1
25	1.000	0.00	4.57	100.0
30	0.7981	0.34	4.45	79.81
35	0.6408	0.67	4.35	64.08
40	0.5175	1.00	4.22	51.74
45	0.4202	1.32	4.11	42.02
50	0.3431	1.63	4.00	34.31
55	0.2816	1.93	3.90	28.16
60	0.2322	2.22	3.80	23.22
65	0.1925	2.51	3.71	19.25
70	0.1602	2.79	3.62	16.03
75	0.1340	3.06	3.53	13.40
80	0.1126	3.33	3.45	11.26
85	0.09496	3.59	3.36	9.496

Note to Tables 2, 3 and 4

1. Replace dot in last 5 digits of catalogue number by a number according to the following details:
   a) 2 for epoxy-coated type.
   b) 3 for water-resistant type.
   c) 4 for brass-pipe type.

ELECTRICAL CHARACTERISTICS

PARAMETER	VALUE
Resistance value at 25 °C (R_{25})	2.2 to 470 kΩ
Tolerance on R_{25}-value	±3%
Tolerance on $B_{25/85}$-value	±1.5% or ±0.75%
Maximum dissipation	250 mW
Dissipation factor:	
2338 640 7....	8.0 mW/K
2338 640 8....	6.0 mW/K
2338 640 9....	6.0 mW/K
Response time; note 1:	
2338 640 7....	≈15 s
2338 640 8....	≈10 s
2338 640 9....	≈7 s

Note

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

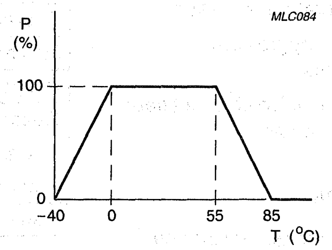


Fig.4 Power derating curve.

STABILITY TESTS

Essentially all tests are carried out in accordance with *"IEC publication 60068-2; Environmental testing"*, except where indicated.

Table 5 Test procedures and requirements

IEC	CECC	TEST	PROCEDURE	DRIFT REQUIREMENT
	D3; 4.20.1	endurance	85 °C; 1000 hours	ΔR/R < 5%
68-2-1		endurance	−40 °C; 1000 hours	ΔR/R < 5%
539		endurance	250 mW; 55 °C; 1000 hours	ΔR/R < 5%
68-2-3	D1; 4.19	damp heat, steady state	56 days at 40 °C; 90 to 95% RH	ΔR/R < 7%
68-2-14	C2; 4.14	rapid change of temperature	−40 to +85 °C; 50 cycles	ΔR/R < 5%

NTC thermistors, glass encapsulated miniature bead

2322 626 1....

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.

APPLICATION

Temperature measurement and control.

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned durnet (CuNiFe) leads. The device is non-flammable.

QUICK REFERENCE DATA

PARAMETER	VALUE
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%
Maximum dissipation at 55 °C	100 mW
Response time	≈1 s
Operating temperature range:	
at zero dissipation	−55 to +200 °C or −55 to +300 °C
at maximum dissipation	0 to 55 °C
Mass	≈0.27 g

MECHANICAL DATA

Marking

The thermistors are marked with four coloured dots on the glass envelope; see Fig.1 and Table 1.

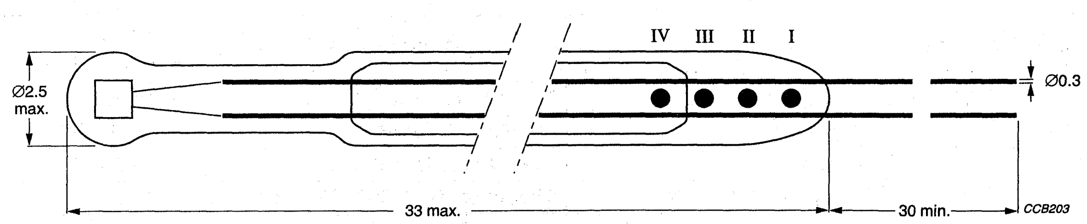
Mounting

By soldering in any position.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 100 units.

Outline



Dimensions in mm.

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

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, temperature coefficients, catalogue numbers and coding

The thermistors have a 12-digit catalogue number starting with 2322 626 1. The subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	TC (%/K)	CATALOGUE NUMBER 2322 626 1....		COLOUR CODE (see Fig.1 and note 1)		
			R_{25} ±5%	R_{25} ±10%	I	II	III
1	2075 K ±5%	−2.3	3102	2102	brown	black	red
2.2	2285 K ±5%	−2.6	3222	2222	red	red	red
4.7	2485 K ±5%	−2.8	3472	2472	yellow	violet	red
10	3750 K ±5%	−4.2	3103	2103	brown	black	orange
22	3560 K ±5%	−4.0	3223	2223	red	red	orange
47	3750 K ±5%	−4.2	3473	2473	yellow	violet	orange
100	3900 K ±5%	−4.4	3104	2104	brown	black	yellow
220	3860 K ±5%	−4.3	3224	2224	red	red	yellow
470	3950 K ±5%	−4.5	3474	2474	yellow	violet	yellow
1000	4100 K ±5%	−4.6	3105	2105	brown	black	green

Note

1. Dependent upon R_{25}-tolerance, the dot IV is coloured as follows:
   a) for R_{25} ±5%, dot IV is coloured gold;
   b) for R_{25} ±10%, dot IV is coloured silver.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1. Stability in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%; ±10%
Maximum dissipation at +55 °C	100 mW
Dissipation factor	≈1.2 mW/K
Response time; note 1	≈1 s
Thermal time constant	≈10 s
Operating temperature range (see Fig.2):	
at zero dissipation	−55 to +200 °C or −55 to +300 °C
at maximum dissipation	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 MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

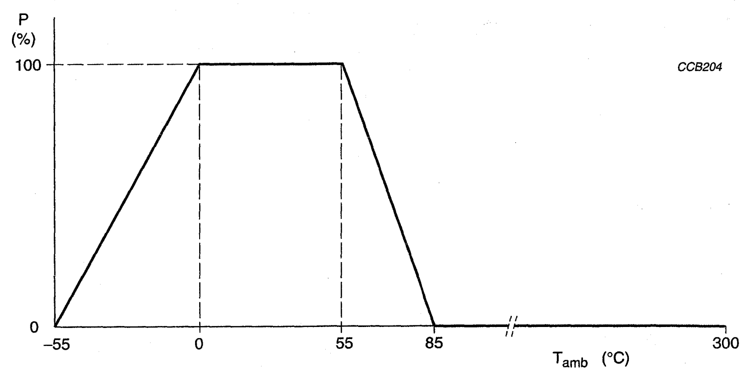


Fig.2 Power derating curve.

NTC thermistors, glass encapsulated miniature bead

2322 626 2....

FEATURES

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

APPLICATION

Temperature measurement and control up to 300 °C.

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned durnet (CuNiFe) leads. The device is non-flammable.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 100 units.

MECHANICAL DATA

Marking

None.

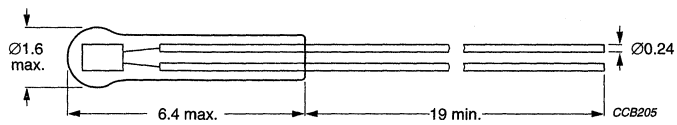
Mounting

By soldering in any position.

QUICK REFERENCE DATA

PARAMETER	VALUE
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%
Maximum dissipation at 55 °C	100 mW
Response time	≈0.85 s
Operating temperature range:	
at zero dissipation	−55 to +200 °C or −55 to +300 °C
at maximum dissipation	0 to 55 °C
Mass	≈33 mg

Outline



Dimensions in mm.

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, temperature coefficients and catalogue numbers

The thermistors have a 12-digit catalogue number starting with 2322 626 2. The subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	T_{max} (°C)	TC (%/K)	CATALOGUE NUMBER 2322 626 2....	
				R_{25} ±5%	R_{25} ±10%
1	2075 K ±5%	200	−2.3	3102	2102
2.2	2285 K ±5%	200	−2.6	3222	2222
4.7	2485 K ±5%	200	−2.8	3472	2472
10	3750 K ±5%	200	−4.2	3103	2103
22	3560 K ±5%	200	−4.0	3223	2223
47	3750 K ±5%	200	−4.2	3473	2473
100	3900 K ±5%	300	−4.4	3104	2104
220	3860 K ±5%	300	−4.3	3224	2224
470	3950 K ±5%	300	−4.5	3474	2474
1000	4100 K ±5%	300	−4.6	3105	2105

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1. Stability in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%; ±10%
Maximum dissipation at +55 °C	100 mW
Dissipation factor	≈0.8 mW/K
Response time; note 1	≈1 s
Thermal time constant	≈7.5 s
Operating temperature range (see Fig.2):	
at zero dissipation	−55 to +200 °C or −55 to +300 °C
at maximum dissipation	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

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

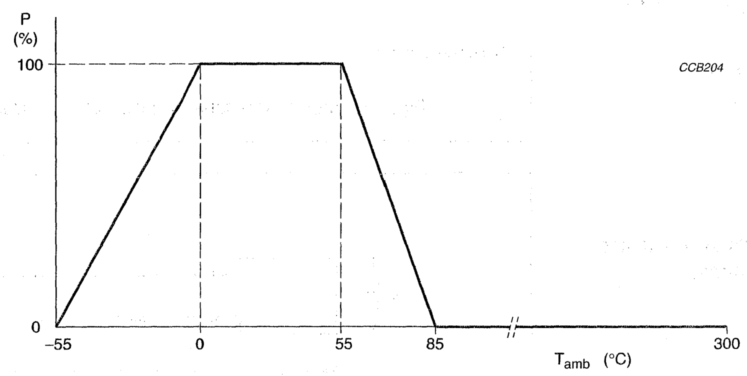


Fig.2 Power derating curve.

NTC thermistors, miniature beads

2322 633 0.... 2322 633 1....

FEATURES

- Small diameter
- Quick response to changes in temperature
- Very high long term stability
- High temperature operation.

APPLICATION

Temperature measurement, level and flow sensing.

DESCRIPTION

Bead thermistor with negative temperature coefficient, having two solid platinum-iridium leads in axial or radial configuration. The device is non-flammable.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 100 units.

MECHANICAL DATA

Marking

None.

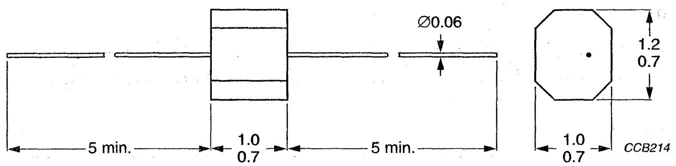
Mounting

Spot weld the leads to conducting wires or other supports.

QUICK REFERENCE DATA

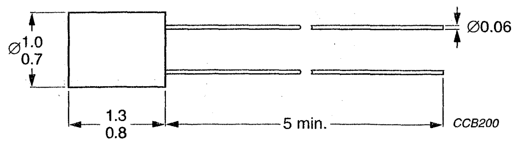
PARAMETER	VALUE
Resistance value at 25 °C	1 kΩ to 1 MΩ
Tolerance on R_{25}-value	±5%; ±10%
$B_{25/85}$-value	2075 to 4100 K
Tolerance on $B_{25/85}$-value	±5%
Response time	≈0.5 s
Operating temperature range: at zero dissipation	−55 to +200 °C
Mass	≈5 mg

Outlines



Dimensions in mm.

Fig.1 Component outline of 2322 633 0.... (axial leads).



Dimensions in mm.

Fig.2 Component outline of 2322 633 1.... (radial leads).

ORDERING INFORMATION

Table 1 R_{25}-values, temperature coefficients and catalogue numbers

The thermistors have a 12-digit catalogue number starting with 2322 633. The subsequent 5 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	TC (%/K)	CATALOGUE NUMBER 2322 633			
			AXIAL LEADS		RADIAL LEADS	
			R_{25} ±5%	R_{25} ±10%	R_{25} ±5%	R_{25} ±10%
1	2075 K ±5%	−2.3	03102	02102	13102	12102
2.2	2285 K ±5%	−2.6	03222	02222	13222	12222
4.7	2485 K ±5%	−2.8	03472	02472	13472	12472
10	3750 K ±5%	−4.2	03103	02103	13103	12103
22	3560 K ±5%	−4.0	03223	02223	13223	12223
47	3750 K ±5%	−4.2	03473	02473	13473	12473
100	3900 K ±5%	−4.4	03104	02104	13104	12104
220	3860 K ±5%	−4.3	03224	02224	13224	12224
470	3950 K ±5%	−4.5	03474	02474	13474	12474
1000	4100 K ±5%	−4.6	03105	02105	13105	12105

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1.
Stability in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%; ±10%
Maximum dissipation at +55 °C	100 mW
Response time; note 1	≈0.5 s
Operating temperature range (see Fig.3):	
at zero dissipation	−55 to +200 °C

Note

1. Response time in silicone oil MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

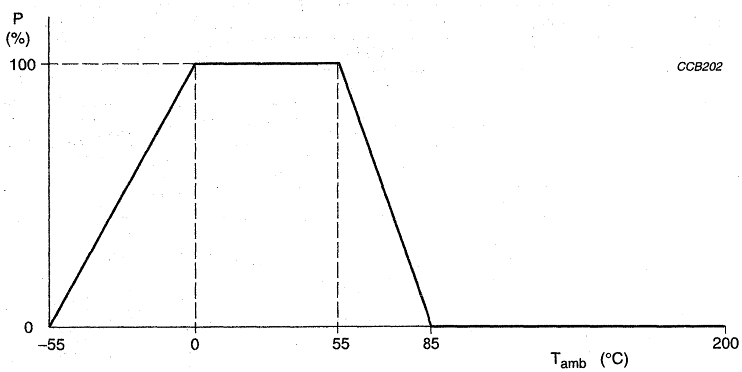


Fig.3 Power derating curve.

NTC thermistors, glass encapsulated miniature bead

2322 633 2....

FEATURES

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

APPLICATION

Temperature measurement.

DESCRIPTION

Bead thermistor with negative temperature coefficient, in a glass envelope with two tinned durnet (CuNiFe) wires. The device is non-flammable.

QUICK REFERENCE DATA

PARAMETER	VALUE
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%
Maximum dissipation at 55 °C	60 mW
Response time	≈6 s
Operating temperature range:	
at zero dissipation	−55 to +200 °C
at maximum dissipation	0 to 55 °C
Mass	≈0.1 g

MECHANICAL DATA

Marking

The thermistors are marked with four coloured dots on the glass envelope; see Fig.1 and Table 1.

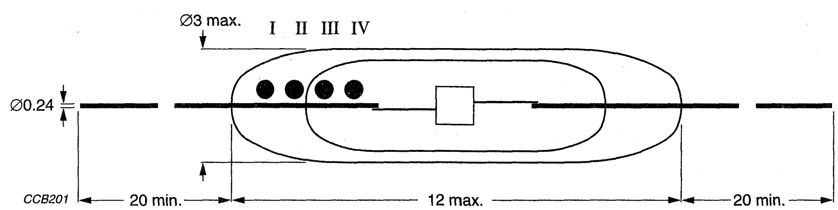
Mounting

By soldering in any position.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 100 units.

Outline



Dimensions in mm.

Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, temperature coefficients, catalogue numbers and coding

The thermistors have a 12-digit catalogue number starting with 2322 633 2. The subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	TC (%/K)	CATALOGUE NUMBER 2322 633 2....		COLOUR CODE (see Fig.1 and note 1)		
			R_{25} ±5%	R_{25} ±10%	I	II	III
1	2075 K ±5%	−2.3	3102	2102	brown	black	red
2.2	2285 K ±5%	−2.6	3222	2222	red	red	red
4.7	2485 K ±5%	−2.8	3472	2472	yellow	violet	red
10	3750 K ±5%	−4.2	3103	2103	brown	black	orange
22	3560 K ±5%	−4.0	3223	2223	red	red	orange
47	3750 K ±5%	−4.2	3473	2473	yellow	violet	orange
100	3900 K ±5%	−4.4	3104	2104	brown	black	yellow
220	3860 K ±5%	−4.3	3224	2224	red	red	yellow
470	3950 K ±5%	−4.5	3474	2474	yellow	violet	yellow
1000	4100 K ±5%	−4.6	3105	2105	brown	black	green

Note

1. Dependent upon R_{25}-tolerance, the dot IV is coloured as follows:
   a) for R_{25} ±5%, dot IV is coloured gold;
   b) for R_{25} ±10%, dot IV is coloured silver.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1. Stability in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%; ±10%
Maximum dissipation at +55 °C	60 mW
Dissipation factor	≈0.5 mW/K
Response time; note 1	≈6 s
Thermal time constant	≈5.5 s
Operating temperature range (see Fig.2):	
at zero dissipation	−55 to +200 °C
at maximum dissipation	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 MS200/50. This is the time needed for the sensor to reach 63.2% of the total temperature difference when subjected to a temperature change from 25 °C in air to 85 °C in oil.

Derating

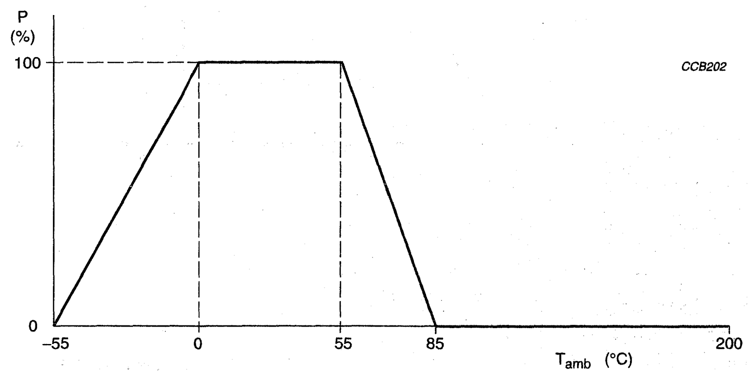


Fig.2 Power derating curve.

NTC thermistors, screw threaded sensors 2322 640 7....

FEATURES

- Easy mounting
- Rugged construction.

APPLICATION

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

DESCRIPTION

Disc thermistor with negative temperature coefficient and two solid tinned copper leads.

The device is mounted in the head of aluminium screws size M4.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 100 units.

MECHANICAL DATA

Marking

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

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.

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at 25 °C	2.2 kΩ to 470 kΩ
Tolerance on R_{25}-value	±5%
$B_{25/85}$-value	3740 to 4570 K
Dissipation factor; note 1	≈23 mW/K
Thermal time constant; note 1	≈7.5 s
Operating temperature range at:	
zero dissipation	−25 to +100 °C
maximum dissipation	0 to +55 °C
Mass	≈1.5 g

Note

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

Outline

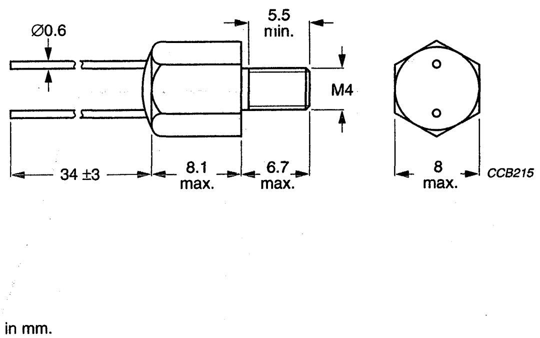


Fig.1 Component outline.

ORDERING INFORMATION

Table 1 R_{25}-values, temperature coefficients and catalogue numbers

The thermistors have a 12-digit catalogue number starting with 2322 640 7. The subsequent 4 digits indicate the resistance value and tolerance.

R_{25} (kΩ)	$B_{25/85}$-VALUE	TC (%/K)	CATALOGUE NUMBER 2322 640 7....
			R_{25} ±5%
4.7	3977 K ±0.75%	−4.37	3472
10	3977 K ±0.75%	−4.37	3103
12	3740 K ±1.5%	−4.10	3123
15	3740 K ±1.5%	−4.10	3153
47	4090 K ±1.5%	−4.46	3473
100	4190 K ±1.5%	−4.57	3104
150	4370 K ±2.5%	−4.75	3154
470	4570 K ±2%	−4.95	3474

NTC thermistors, screw threaded sensors 2322 640 7....

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*; see also Table 1. Stability in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Standard selection tolerance on R_{25}	±5%
Maximum dissipation	0.5 W
Heat capacity	≈0.5 J/K
Operating temperature range:	
at zero dissipation	−25 to +100 °C
at maximum dissipation	0 to +55 °C
Dielectric withstanding voltage (RMS) between terminals and screw	min. 100 V
Insulation resistance between terminals and screw at 100 V (DC)	min. 100 MΩ

NTC thermistors, steel capped sensors 2322 640 90042

FEATURES

- Excellent performance in humid environments
- High mechanical strength
- AMP connectors for easy connection
- Excellent accuracy over a wide temperature range.

APPLICATIONS

- Sensors for water temperature control in, for example:
  - washing machines
  - dish washers
  - heat pumps
  - electric boilers.

DESCRIPTION

These thermistors have a negative temperature coefficient. The device consists of a ceramic material which is mounted in a capsule of stainless steel and provided with two 6.3 mm tinned bronze spade connectors.

The device is non-flammable and the housing is stainless steel in accordance with *"DIN 1.4301"* (× 5 CrNi 18 9).

QUICK REFERENCE DATA

PARAMETER	VALUE
Resistance value at:	
0 °C	35875 Ω ±7%
25 °C	12000 Ω ±4%
85 °C	1475 Ω ±3%
100 °C	963 Ω ±4.2%
Maximum dissipation	250 mW
Operating temperature range:	
at zero power; continuously	−25 to +110 °C
at zero power; peak	130 °C
at maximum power	0 to +55 °C
Mass	≈8 g

MARKING

Green marking between the connectors.

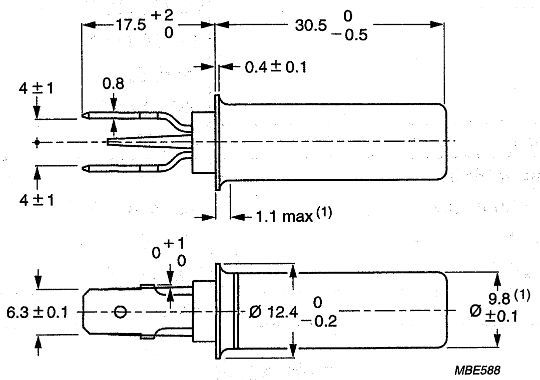
MOUNTING

Electrical mounting with AMP connectors in any position.

PACKAGING

The thermistors are packed in cardboard boxes; the smallest packaging quantity is 50 units.

MECHANICAL DATA



Dimensions in mm.

(1) To be controlled by gauging.

Fig.1 Component outline.

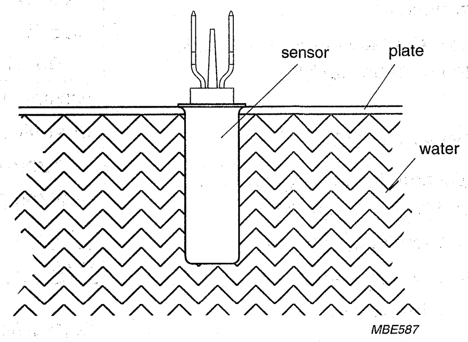


Fig.2 Method of application.

ELECTRICAL DATA

Derating

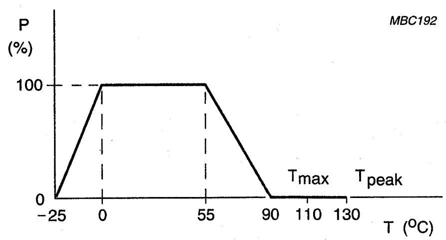


Fig.3 Power derating curve.

NTC thermistors, steel capped sensors 2322 640 90042

Electrical characteristics

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"* and *"CECC 43000"*. Stability is in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE
Resistance value at:	
0 °C	35875 Ω ±7%
25 °C	12000 Ω ±4%
85 °C	1475 Ω ±3%
100 °C	963 Ω ±4.2%
$B_{25/85}$-value	3730 K
Temperature coefficient	−4.2%/K
Dissipation	≤250 mW
Dissipation factor:	
in still air (for information only); note 1	7.5 mW/K
in still water (for information only); note 1	18 mW/K
Thermal time constant (τ) in still air; note 1	285 s
Response time; note 2	13 to 16 s
Temperature gradient; note 3	≤0.02 K/K
Operating temperature range:	
at zero power; continuously	−25 to +110 °C
at zero power; peak during 24 hours	130 °C
at maximum power	0 to +55 °C
Minimum dielectric withstanding voltage (RMS) between terminals and capsule during:	
1 minute	1500 V
10 seconds	1650 V
Minimum insulation resistance between terminals and capsule at 100 V (DC)	100 MΩ

Notes

1. Measured with AMP connectors in still air with solid copper wires of 1 mm diameter.
2. The response time is the time necessary to change 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:
   a) initial temperature: air at 25 °C
   b) final temperature: water at 100 °C.
3. The temperature gradient is the difference per degree Celsius between the true temperature of the liquid (water) and the temperature measured by the sensor.

NTC thermistors, moulded range

2322 640 90004
2322 640 98004

FEATURES

- Designed for harsh environments
- Excellent for surface temperature measurement
- Metal strip for heat conduction and easy mounting (2322 640 98004)
- High accuracy at 100 °C
- Minimum 350 V dielectric withstanding voltage.

APPLICATION

For temperature control.

DESCRIPTION

Moulded disc thermistor with negative temperature control and two solid tinned copper leads. The body colour is white and the device is non-flammable.

The thermistor 2322 640 98004 is provided with a metal strip for mounting.

PACKAGING

The thermistors are packed in cardboard boxes:

2322 640 90004: 500 units

2322 640 98004: 400 units.

MECHANICAL DATA

Marking

The thermistors are marked with a grey dot.

Mounting

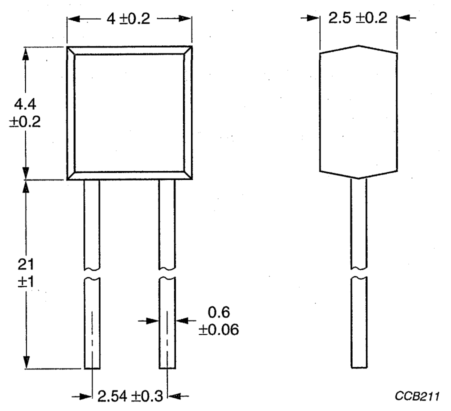
2322 640 90004: by soldering in any position

2322 640 98004: by means of the mounting strip.

QUICK REFERENCE DATA

PARAMETER	VALUE 2322 640 90004	VALUE 2322 640 98004
Resistance value at:		
+25 °C	12 kΩ	
+100 °C	950 Ω	
Tolerance on R_{25}-value:		
+25 °C	±7%	
+100 °C	±5%	
$B_{25/85}$-value	3750 K	
Maximum dissipation	0.25 W	
Dissipation factor	7 mW/K	9.5 mW/K
when mounted on a heatsink	19 mW/K	27 mW/K
Thermal time constant	19 s	33 s
when mounted on a heatsink	10 s	5 s
Operating temperature range:		
at zero dissipation	−10 to +125 °C	
at maximum dissipation	0 to +55 °C	
Mass	≈0.3 g	≈0.5 g

Outline



Dimensions in mm.

Fig.1 Component outline 2322 640 90004.

NTC thermistors, moulded range

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.

PARAMETER	VALUE	
	2322 640 90004	**2322 640 98004**
Resistance value at:		
+25 °C	12 ±7% kΩ	
+100 °C	950 ±5% Ω	
$B_{25/85}$-value	3750 K	
Temperature coefficient	−4.2%/K	
Maximum dissipation	0.25 W	
Dissipation factor	7 mW/K	9.5 mW/K
when mounted on a heatsink; note 1	19 mW/K	27 mW/K
Thermal time constant	19 s	33 s
when mounted on a heatsink; note 1	10 s	5 s
Heat capacity of ceramic (in air)	0.028 J/K	0.028 J/K
when mounted on a heatsink	0.13 J/K	0.3 J/K
Response time; note 2	3 s	
Operating temperature range:		
at zero dissipation	−10 to +125 °C	
at maximum dissipation	0 to +55 °C	
Dielectric withstanding voltage (RMS) between terminals and coating	min. 350 V	
Insulation resistance between terminals and coating at 100 V (DC)	min. 100 MΩ	
Mass	≈0.3 g	≈0.5 g

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 (∅1.3 mm).
2. The thermistor being transferred from ambient air of +25 °C to a silicone oil (MS200/50) bath of 85 °C.

NTC thermistors, moulded range

2322 640 90005
2322 640 98005

FEATURES

- Designed for harsh environments
- Excellent for surface temperature measurement
- Metal strip for heat conduction and easy mounting (2322 640 98005)
- Will withstand temperatures up to 200 °C
- High accuracy at 200 °C
- Minimum 300 V dielectric withstanding voltage.

APPLICATION

For high temperature control.

DESCRIPTION

Moulded disc thermistor with negative temperature control and two solid tinned copper leads. The device is non-flammable.

The thermistor 2322 640 98005 is provided with a metal strip for mounting.

PACKAGING

The thermistors are packed in cardboard boxes:

2322 640 90005: 500 units

2322 640 98005: 400 units

MECHANICAL DATA

Marking

The thermistors are marked with a blue dot.

Mounting

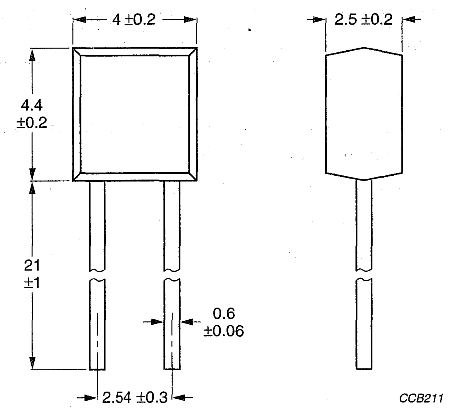
2322 640 90005: by soldering in any position

2322 640 98005: by means of the mounting strip.

QUICK REFERENCE DATA

PARAMETER	VALUE	
	2322 640 90005	2322 640 98005
Resistance value at:		
+100 °C	16.7 kΩ	
+200 °C	1120 Ω	
Tolerance on R_{25}-value	±7%	
$B_{25/85}$-value	4300 K	
Maximum dissipation	0.25 W	
Dissipation factor	7 mW/K	9.5 mW/K
when mounted on a heatsink	17.5 mW/K	20.5 mW/K
Thermal time constant	19 s	33 s
when mounted on a heatsink	12 s	8.5 s
Operating temperature range:		
at zero dissipation	−25 to +200 °C	
at maximum dissipation	0 to +55 °C	
Mass	≈0.3 g	≈0.5 g

Outline



Dimensions in mm.

Fig.1 Component outline 2322 640 90005.

NTC thermistors, moulded range

2322 640 90005
2322 640 98005

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.

PARAMETER	VALUE	
	2322 640 90005	**2322 640 98005**
Resistance value at:		
+100 °C	16.7 kΩ	
+200 °C	1 120 Ω	
+25 °C	310 kΩ	
Tolerance on R_{25}-value	±7%	
$B_{25/85}$-value	4300 K	
Temperature coefficient	−4.85%/K	
Maximum dissipation	0.25 W	
Dissipation factor	7 mW/K	9.5 mW/K
when mounted on a heatsink; note 1	17.5 mW/K	20.5 mW/K
Thermal time constant	19 s	33 s
when mounted on a heatsink; note 1	12 s	8.5 s
Heat capacity of ceramic (in air)	0.028 J/K	0.028 J/K
when mounted on a heatsink	0.13 J/K	0.3 J/K
Response time; note 2	3 s	
Operating temperature range:		
at zero dissipation	−25 to +200 °C	
at maximum dissipation	0 to +55 °C	
Dielectric withstanding voltage (RMS) between terminals and coating	min. 350 V	
Insulation resistance between terminals and coating at 100 V (DC)	min. 100 MΩ	
Mass	≈0.3 g	≈0.5 g

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 (∅1.3 mm).
2. The thermistor being transferred from ambient air of +25 °C to a silicone oil (MS200/50) bath of 85 °C.

POSITIVE TEMPERATURE COEFFICIENT (PTC) THERMISTORS

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 thermistor 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 chapter "Applications".

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+}
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:

$$R_b \cong \frac{1}{a} \times e^{eV_b/kT} \quad (\cong = \text{directly proportional to})$$

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 in the formula:

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

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 polarization 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 thermistor with respect to its switching temperature, causing the potential barriers to decrease in strength. This means that the PTC thermistor 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 thermistor are, therefore, restricted by a certain temperature limit.

Since the PTC thermistor 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 chapter "Electrical properties" are thus restricted to this frequency range.

ELECTRICAL PROPERTIES

Resistance/temperature characteristics

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

Current/voltage characteristics

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

As can be seen in 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.

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

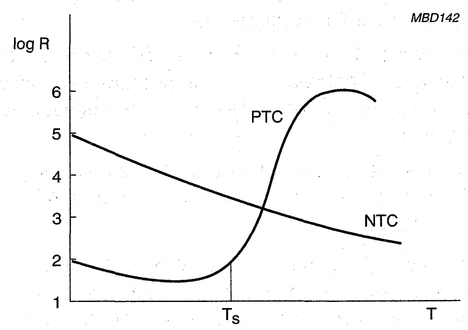


Fig.1 Typical resistance/temperature characteristic curves for PTC and NTC thermistors.

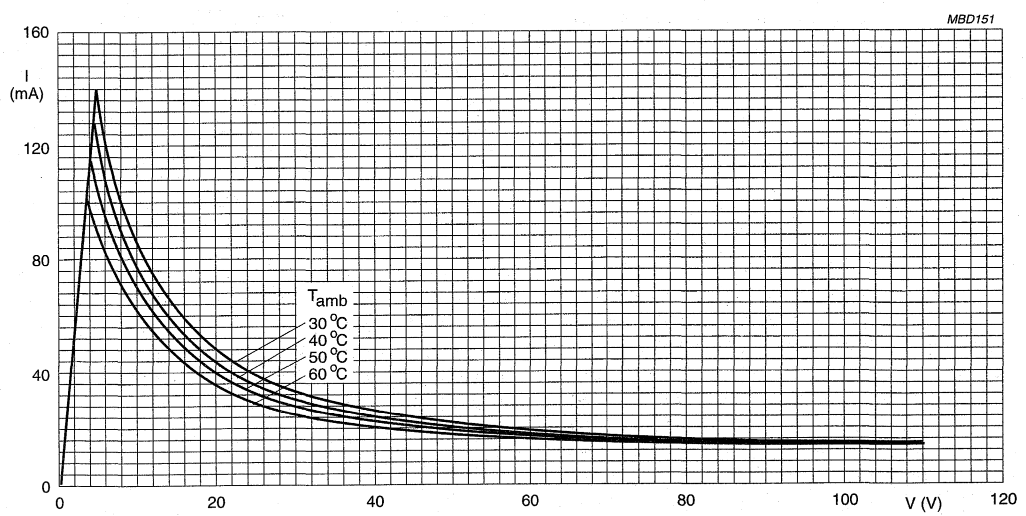


Fig.2 Current/voltage characteristics of a PTC thermistor plotted on a linear scale and using ambient temperature as the parameter.

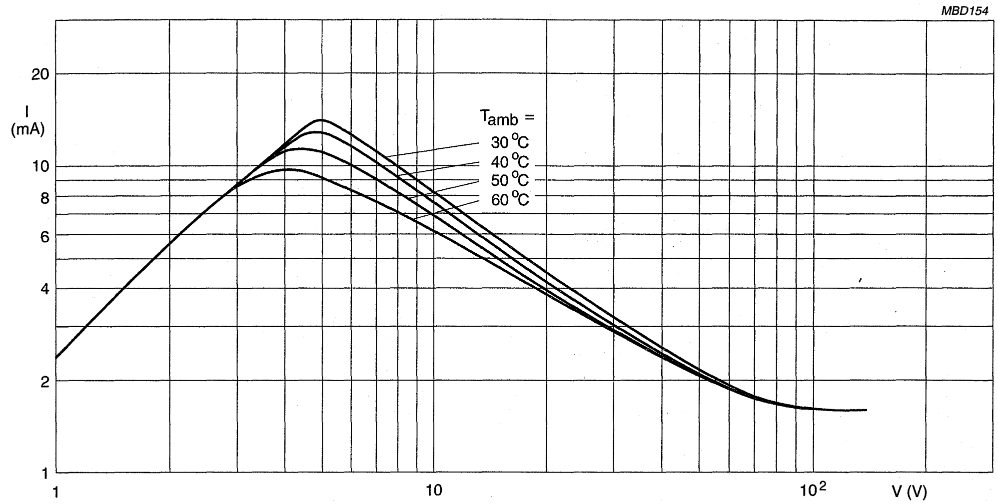


Fig.3 Current/voltage characteristics of a PTC thermistor plotted on a logarithmic scale, using ambient temperature as the parameter.

The dissipation factor (measured in mW/K) 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 I/V curve, also making use of the corresponding point on the R/T characteristic.

By definition:

The electrical power injected in the PTC thermistor is:

$$P = I^2R$$

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:

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

Remark: This equation is only valid for temperatures lower 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:

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

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

where R is the PTC thermistor 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}.

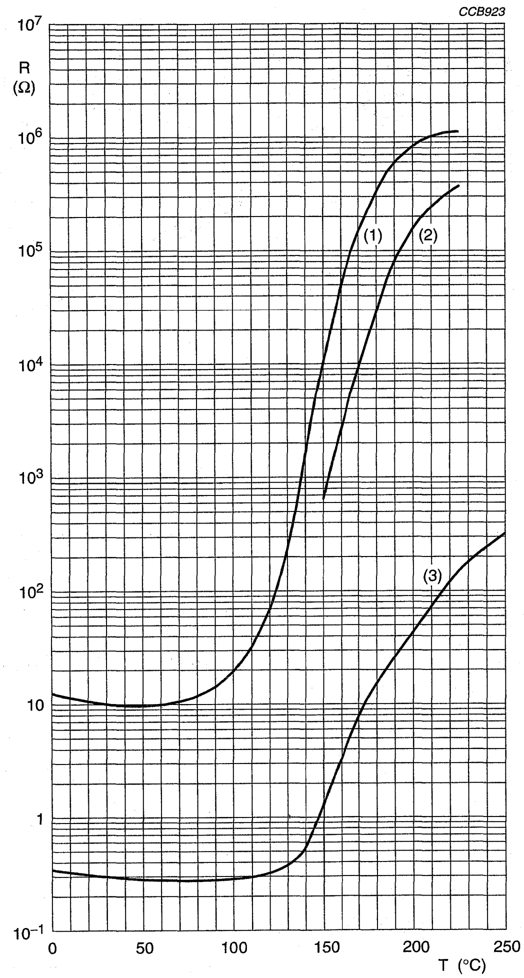
The non-trip current (I_{nt}) is defined as the guaranteed maximum current at which the thermistor will not switch, and is given by:

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

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

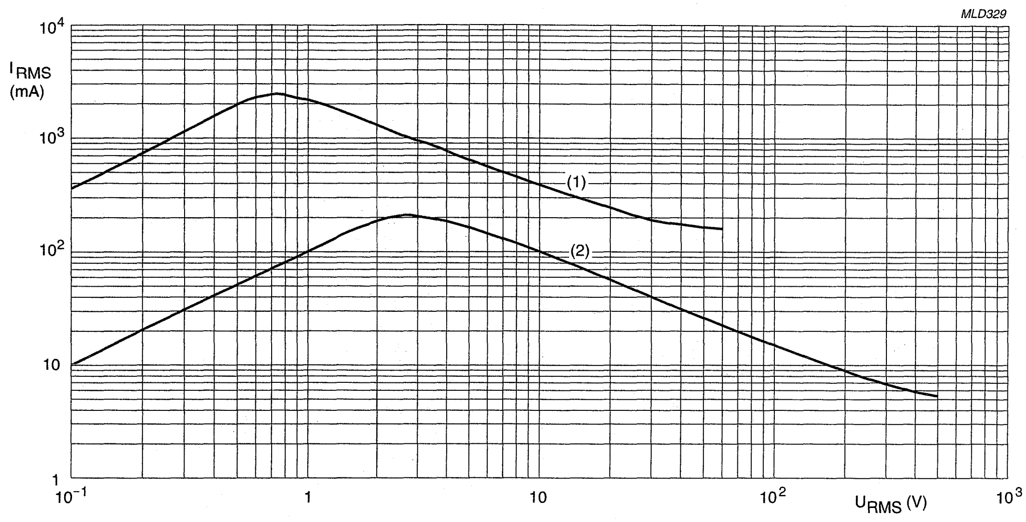
A security margin of $-\omega$ °C is maintained to ensure that the thermistor will not switch.

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



Curve 1: For 2322 662 93074 (≤5 V (DC)).
Curve 2: For 2322 662 93074; 345 V_{pulse}.
Curve 3: For 2322 664 52021 (≤5 V (DC)).

Fig.4 R/T characteristics of thermistor types 2322 662 93074 and 2322 664 52051.



Curve 1: For 2322 662 93074.
Curve 2: For 2322 664 52021.

Fig.5 Typical I/V characteristics of thermistor types 2322 662 93074 and 2322 664 52051, measured in still air at 25 °C.

PTC thermistors in series with a load

It can be shown from the I/V characteristics that, because of the non-linearity of the PTC thermistors curve, three working points are possible when a load R_L is connected in series with a PTC thermistor (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 I/V 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.

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 I/V 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.

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

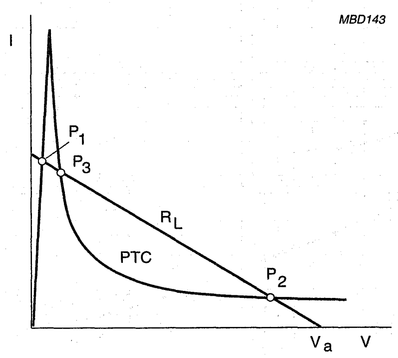


Fig.6 PTC thermistor in series with a load showing the possible working points.

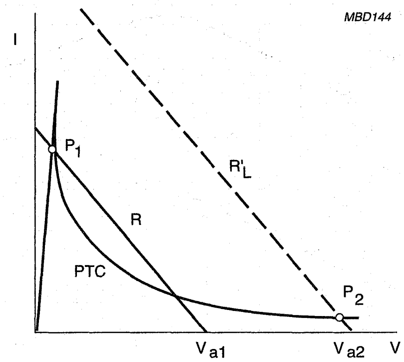


Fig.7 PTC thermistor in series with a load showing the influence of the supply voltage V_a.

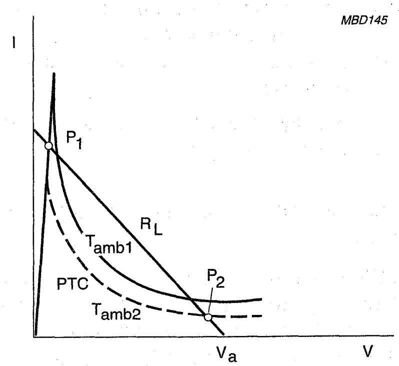


Fig.8 PTC thermistor in series with a load showing the influence of the ambient temperature.

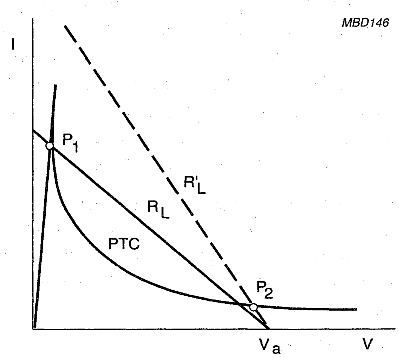


Fig.9 PTC thermistor in series with a load showing the influence of the load resistance.

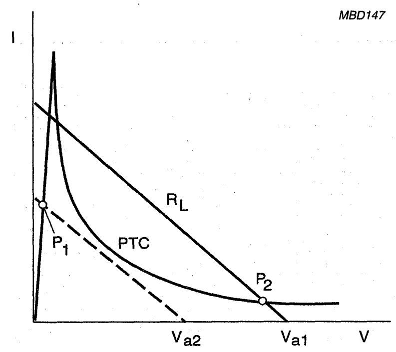


Fig.10 PTC thermistor in series with a load showing the influence of a decrease in supply voltage V_a.

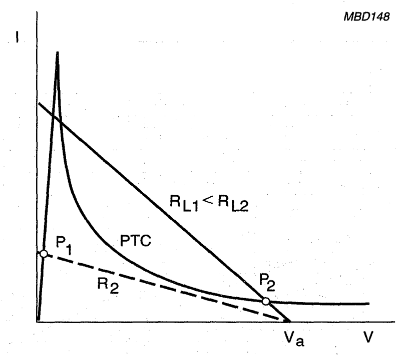


Fig.11 PTC thermistor in series with a load showing the influence of an increase in load resistance.

Current/time characteristic

If a PTC thermistor is connected in series with a resistance of such a value that the peak of the I/V curve lies under the load line, the PTC thermistor 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_L (see Fig.13) and the ambient temperature.

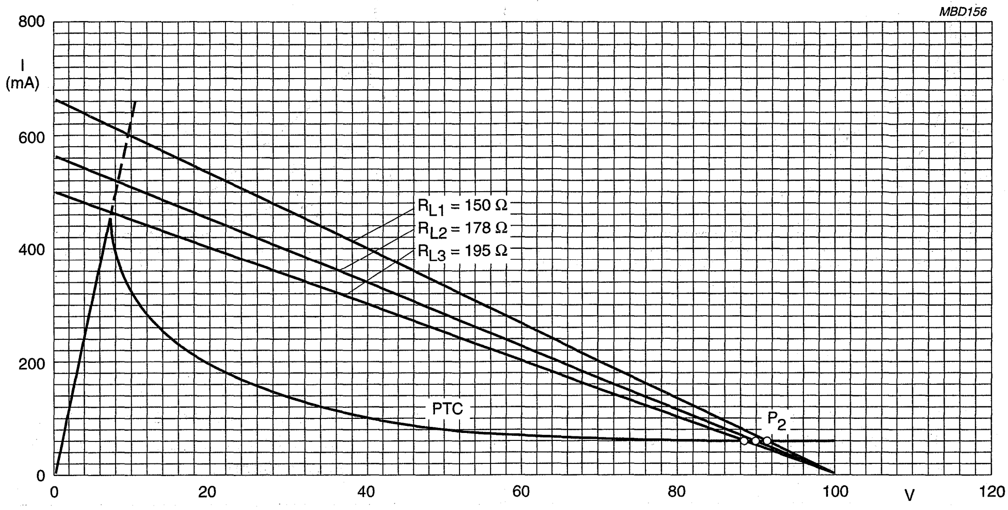


Fig.12 PTC thermistor in series with different load resistors.

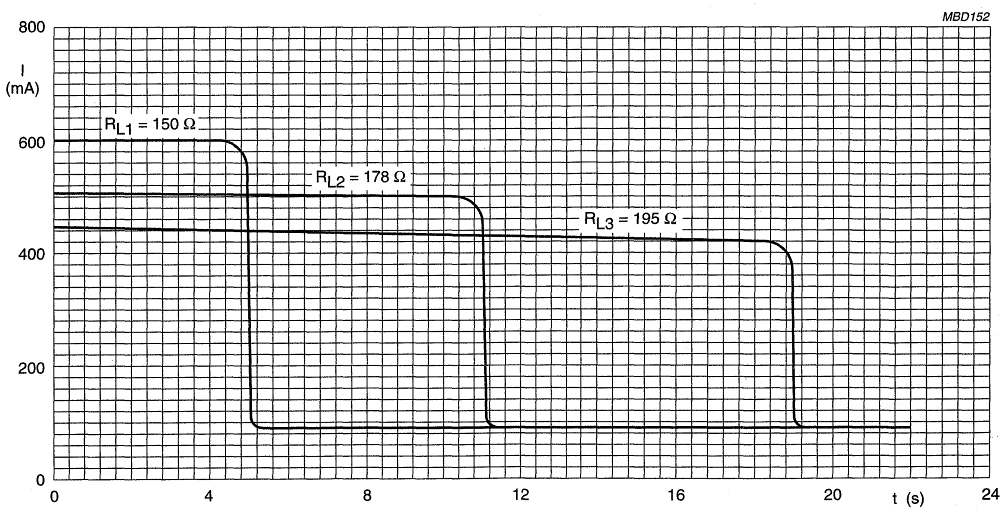


Fig.13 Current/time characteristics showing the influence of the load resistance.

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 $T_s > T_{Rmin}$ and $R_s = 2\ R_{min}$.

Temperature coefficient (α)

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

For R/T curves plotted on a logarithmic R/T scale:

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

In the product data, 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).

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 approximate trip time (t_s) can be calculated using the formula:

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

where:

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

The above formula is only valid for relatively short trip times (<1 minute). For longer trip times, R should be adapted to:

$$R = \frac{3}{2} \times R_{min}$$

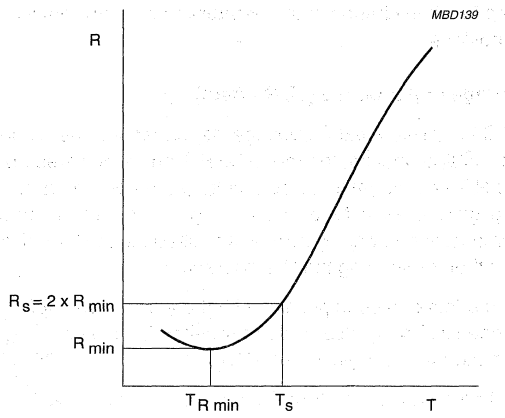


Fig.14 Switch temperature.

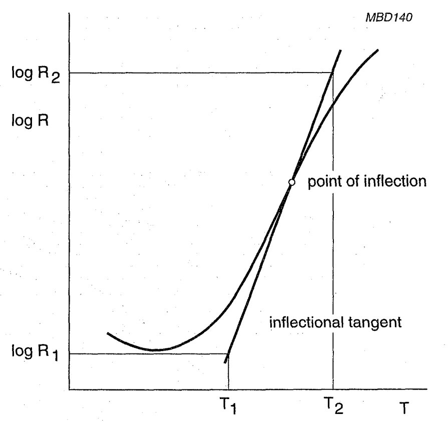


Fig.15 Temperature coefficient.

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.

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 dependency can be demonstrated by applying a pulse 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 thermistor, having no voltage dependence, and an 'ideal' VDR.

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).

These lines coincide with the PTC thermistors 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.

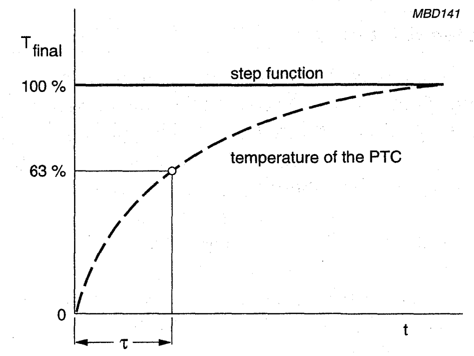


Fig.16 Thermal time constant.

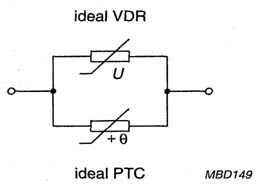


Fig.17 VDR effect.

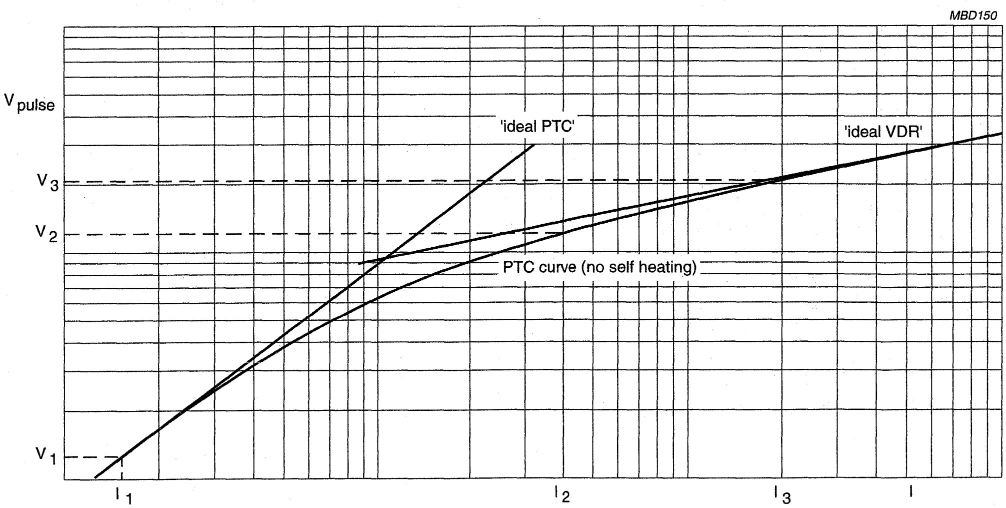


Fig.18 Relationship between an 'ideal' PTC and an 'ideal' VDR.

FAILURE MECHANISMS OF CERAMIC PTCs

CAUSE	FAILURE PHENOMENA	CONSEQUENCE	REMARKS
Overvoltage			
Exceeding the maximum rated voltage or the minimum hold voltage by at least 25%.	Heat generated by Joule effect is greater than the heat which can be dissipated. The temperature of the PTC rises above the temperature corresponding to the resistance maximum. The material enters an NTC zone with a thermal runway.	Short flame (self-extinguished), a burn hole, melted soldered joint, detached leads falling out of the ceramic. Depending on available power a **short circuit** is also possible.	A voltage spike (e.g. lightning pulses) ranging from microseconds to milliseconds will not provoke any failure of this type as the energy is too low to heat the PTC above its maximum resistance. Depending on the thermal capacity of the ceramic, overvoltage of short durations (<1 s to 10 s) will not provoke failure.
Overcurrent density			
Exceeding the maximum current of the metallization layer.	Current density is above that which the contact can withstand. The contact can be a combination of lead-solder metallization layer or clamping contact and metallization layer.	Burned electrode, small sparks, eventual flashover, positive resistance shift. **Fails open**.	In practice, this current is hardly ever reached, as the ceramic bulk resistance is sufficient to restrict unacceptable increases. Only in special cases, such as voltage spikes with high energy (>100 A) can this current be exceeded.
Overpower			
Exceeding the maximum overload current at a specified voltage or a combination of current and voltage which are not guaranteed by the manufacturer.	PTC ceramics are poor thermal conductors. High power can introduce thermal gradients as high as 1 500 °C/cm. this gradient will provoke mechanical strain due to thermal expansion mismatches. Two different phenomena can occur: Overpower in the low-ohmic region (below the switch temperature) due to very high inrush currents, when the power per mm^3 is exceeded. Overpower above the switch temperature occurs when a combination of final voltage and maximum current during switching is exceeded.	In both cases, there will be ceramic rupture (fragmentation) on the hot-spots in the ceramic and/or thermal stress points. **Fails open**. For high voltage types (>400 V) a possible local hot-spot can drive the ceramic into thermal runway. This special condition can generate the same consequences as described in 'Overvoltage'.	The maximum power that a ceramic PTC can have is also influenced by the way he is attached to the electrical contacts. Large thermal masses on the electrodes reduce the maximum power a ceramic can sustain.

CAUSE	FAILURE PHENOMENA	CONSEQUENCE	REMARKS
Thermal shock			
Caused by an uneven power distribution within the ceramic during switching from the low-ohmic to the high-ohmic region.	The heat generated in the ceramic is not evenly divided over the ceramic body. This means that some parts will heat up faster than others (the centre heating up the fastest). These temperature gradients will provoke expansion mismatch.	Ceramic breaks into two parts. this breaking up of the ceramic can be a slow process induced by micro-cracks every time they are tripped in certain conditions. **Fails open**.	When thermal shock is caused by micro-cracks, the cracking-up or breaking of the ceramic is not always visible on the surface.
Reduction effect			
Caused by any unstable material (such as: wax, potting material, glue, lacquer, thermal sleeves, aggressive (washing) fluids and reducing gases being in close contact with the PTC.	An unstable material surrounding or even touching the ceramic will typically disintegrate or burn at high temperatures. This is an oxygen consuming phenomenon. When in close contact with the PTC, the material may react with oxygen of the grain boundaries, thus reducing the PTC ceramic and in turn its maximum rated voltage or hold voltage.	See 'Overvoltage'.	
Number of cycles			
Repetitive tripping of ceramic PTC (even within specified power handling capabilities).	Repetitive cycling introduces micro-cracks at the solder joints. This phenomenon is based on re-crystallization of the solder when thermal stress is applied. The number of cycles a normal PTC ceramic can have is dependent on the final temperature reached every cycle. A normal range of cycles can range from 100 to 5000.	Leads become detached and small sparks can occur between the detached lead and the ceramic. **Fails open**.	When micro-cracks are present due to power handling **inside** the ceramic bulk, the number of cycles can also be limited. Short term peak-temperatures, as in an electronic lamp ballast application, can handle a higher number of cycles (usually >20000). A clamped PTC ceramic can handle a much higher number of cycles due to a free contact movement during heating up (number of cycles > 300000). Cycling at low ambient temperature is more severe because of the large difference between initial and final temperatures.

HOW TO MEASURE PTC THERMISTORS

Since PTC thermistors often exhibit a very high temperature coefficient, especially at high temperatures, measurement at high temperatures 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.

To prevent self-heating of the PTC thermistor the measuring current should be adapted to a low value (for example ≤1 mA).

When measuring high resistance values (for example above T_S), voltage should be limited to a maximum of 5 V.

Pulsed voltages should be used for measuring the voltage dependence of PTC thermistors, with a maximum pulse time of 20 ms to prevent self-heating.

Tolerances

The resistances of standard PTC thermistors are generally specified at:

1. 25 °C
2. 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 thermistors 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 NOTICE

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.

The manufacturer should be consulted if special PTC thermistor characteristics are required which cannot be found in this data handbook, as the 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) protection.

These applications are based on two principles:

1. Applications where the temperature (hence the resistance) is primarily determined by the current flowing through the thermistor.
2. 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 THERMISTOR FOR A PROLONGED PERIOD OF TIME SINCE THIS MAY DESTROY THE DEVICE.
DO NOT CONNECT PTC THERMISTORS IN SERIES TO OBTAIN HIGHER VOLTAGES OR WATTAGES, SINCE THIS MAY CAUSE AN INDIVIDUAL PTC THERMISTOR TO HEAT UP FASTER THAN THE OTHER(S), RESULTING IN TOO HIGH A VOLTAGE ACROSS THE PTC THERMISTOR IN QUESTION.

PTC overload protection

Introduction

FEATURES

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

APPLICATIONS

Applications are wide, varied and include the following:

General industries

- Transformers
- Battery chargers
- Delay lines
- Rechargeable batteries
- Switched-mode power supplies
- Measuring equipment.

Automotive systems

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

Consumer electronics

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

Domestic appliances

- Boilers
- Shaver socket transformers
- Coffee grinders
- Hobby tools
- Ice makers
- Washing machines.

Telecommunications

- Line protection
- Main Distribution Frame (MDF)
- Set-top boxes
- Base stations for cordless telephones
- Regulation of telephones, facsimiles and modems
- Integrated Services Data Network (ISDN).

DESCRIPTION

As one of the market leaders in non-linear ceramic technology, BC 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 Positive Temperature Coefficient (PTC) thermistors. They provide reliable protection time and time again, opposed to a normal fuse, which is usually slower and only gives one-shot protection.

Compared to conductive-polymer technology, ceramic PTCs give a more reliable protection in time with regard to the number of trip cycles, stability and operation at mains voltages.

For specific areas like telecommunication they offer very good resetability with low drift, which guarantees a high performance connection over the whole lifetime.

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.

MECHANICAL OPTIONS

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)
- SMD devices, taped on reel.

HOW PTC THERMISTORS PROTECT AGAINST OVERLOADS

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

Normally the thermistor resistance is low (see 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.

Figure 3 shows the PTC thermistor I/V 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 thermistor I/V characteristic. Under this condition the PTC thermistor 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 (see Fig.3), where the load current increases due to a decrease in load resistance, for example when a motor winding short-circuits.
2. Overvoltage (see Fig.4), caused for example, when the 220 V mains is accidentally applied to a 115 V mains appliance.
3. Overtemperature (see 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.

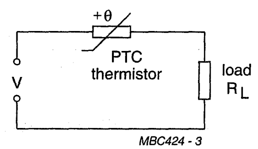


Fig.1 Typical circuit.

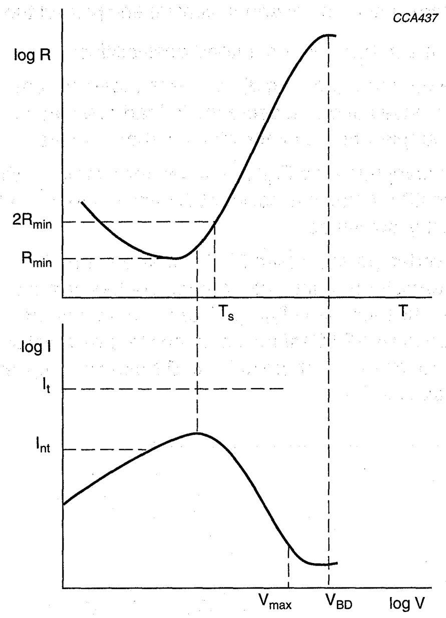
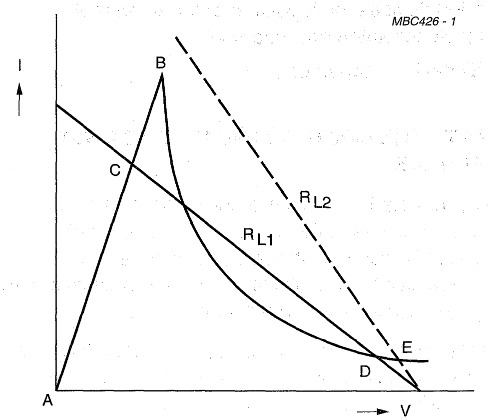
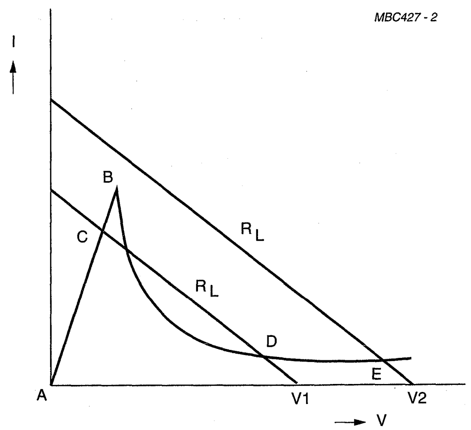


Fig.2 PTC thermistor characteristics.



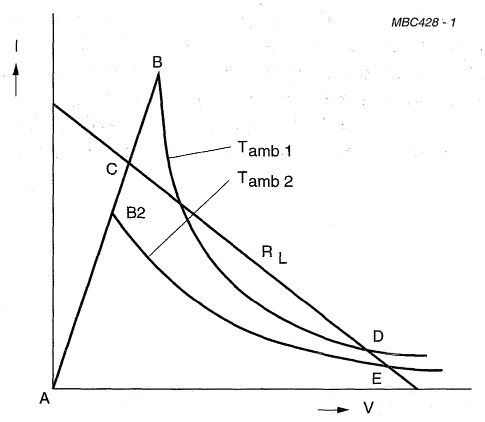
$R_{L2} < R_{L1}$.

Fig.3 Overcurrent protection.



V2 > V1.

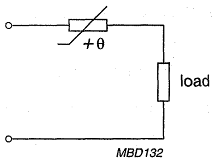
Fig.4 Overvoltage protection.



$T_{amb\ 2} > T_{amb\ 1}$.

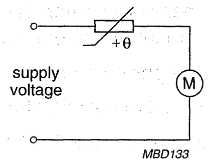
Fig.5 Overtemperature protection.

APPLICATION EXAMPLES



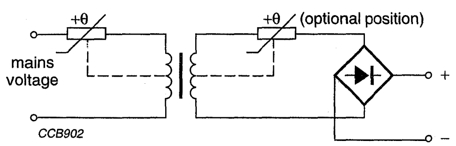
As soon as the current increases, the PTC limits it to a safe value.

Fig.6 Current limiting.



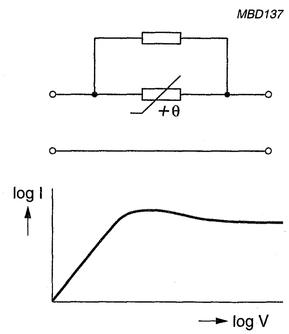
The increased current heats the PTC to its switch temperature. As a result, the total dissipated power is reduced to a safe value. The example shown could also be used as protection against overheating in transformers, lamps, printed-circuit boards, rechargeable batteries, power supplies, etc.

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



The PTC may be thermally coupled to the transformer to increase thermal electricity.

Fig.8 Protection of transformers, power-supplies and charging equipment.



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

Fig.9 Current stabilization.

HOW TO SELECT THE CORRECT PTC OVERLOAD DEVICE

1. Check the operational parameters of the application:
   a) What is the **maximum voltage (V_{max})** that the PTC has to handle after an overload has occurred?
   b) What is the **maximum normal operating current (I_{hold} or $I_{non\text{-}trip}$)** at **maximum ambient temperature ($T_{amb\ max}$)** that the PTC has to handle without switching to the high ohmic state?
   c) What is the **maximum overload current (I_{max})** that the PTC has to handle?
2. On the basis of these parameters a first selection can be made; choose a standard or application specific PTC which has the values (or higher values) of the selected parameter.
3. Check if the device parameters correspond to the application requirements, with regard to trip-time or response time.
4. Check if the outline dimensions of the selected PTC are within the available space considerations.
5. Verify the performance of the PTC in the application to make sure that all aspects of the design (electrical and thermal) have been taken into account. Also check the failure modes on ceramic PTCs to ensure that no unwanted operation can occur.

PTCs designed for mains voltage operation, can also operate at lower voltages with maximum overload currents which are significantly higher than those indicated in the data Tables.

If a specific PTC cannot be found in the range of available products, a custom made PTC can be the solution for the protection of your application. In such cases, please contact your local BC Components sales organization.

PTC thermistors for overload protection

56 V and 265 V (T_s = 120 °C)

FEATURES

- Different voltages to be chosen in function of the application
- Available in three mechanical versions:
  - 2322 66. 0.... naked discs
  - 2322 66. 1.... leaded
  - 2322 66. 3.... taped, on reel (to diameter 12.5 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 1.6 Ω up to 1.9 kΩ
- Small ratio between trip and non-trip currents: ($I_t/I_{nt} \leq$ 1.5 at 25 °C)
  $$\left(\frac{I_t \text{ (at 10 °C)}}{I_{nt} \text{ (at 55 °C)}} = 2\right)$$
- Leaded parts withstand mechanical stresses and vibration.

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.

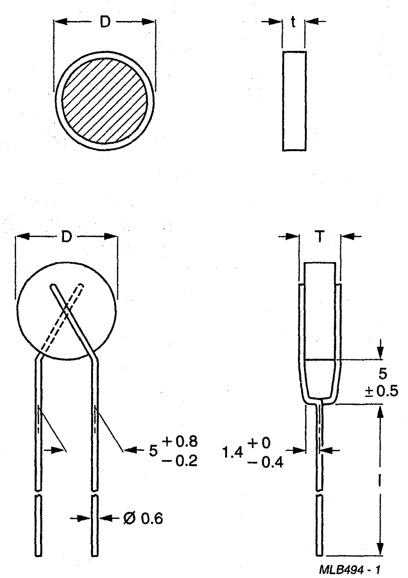
QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Switch temperature; note 1	120	°C
Maximum voltage:		
2322 66. 0/1/3...1	56	V (DC)
2322 66. 0/1/3...3	265	V (RMS)
Temperature range:		
2322 66. 0/1/3...1/3 at zero dissipation	–25 to 125	°C
2322 66. 0/1/3...1/3 at V_{max}	0 to +70	°C
Climatic category	25/125/56	

Note

1. For information only.

MECHANICAL DATA



Dimensions in mm.
For D, T and t see Table 1.

Fig.1 Component outline for 2322 66. 0/1...1

Table 1 Device dimensions, packaging and catalogue numbers

D MAX. (mm)	t ±10% (mm)	T MAX. (mm)	PACKAGING AND CATALOGUE NUMBERS 2322		
			NAKED (Fig.1)	**LEADED BULK** (Fig.1)	**LEADED TAPED** (Fig.5)
5	1.6	4.0	660 05691; 660 06891; 660 08291	660 15691; 660 16891; 660 18291	660 35691; 660 36891; 660 38291
	2.6	5.0	660 01293; 660 01593; 660 01893; 660 02293; 660 02793	660 11293; 660 11593; 660 11893; 660 12293; 660 12793	660 31293; 660 31593; 660 31893; 660 32293; 660 32793
7	1.6	4.0	661 01011; 661 01211	661 11011; 661 11211	661 31011; 661 31211
	2.6	5.0	661 03393; 661 03993; 661 04793; 661 05693	661 13393; 661 13993; 661 14793; 661 15693	661 33393; 661 33993; 661 34793; 661 35693
8.5	1.6	4.0	661 01511	661 11511	661 31511
	2.6	5.0	661 06893; 661 08293; 661 01013	661 16893; 661 18293; 661 11013	661 36893; 661 38293; 661 31013
10.5	2.0	4.5	662 01811	662 11811	662 31811
	2.6	5.0	662 01213	662 11213	662 31213
12.5	2.0	4.5	662 02211; 662 02711	662 12211; 662 12711	662 32211; 662 32711
	2.6	5.0	662 01513; 662 01813	662 11513; 662 11813	662 31513; 662 31813
13.5	2.6	5.0	663 03311; 663 02213	663 13311; 663 12213	663 33311; 663 32213
16.5	2.6	5.0	663 03911; 663 04711; 663 02713	663 13911; 663 14711; 663 12713	–
20.5	3.2	6.0	664 05611; 664 06811; 664 03313; 664 03913; 664 04713	664 15611; 664 16811; 664 13313; 664 13913; 664 14713	–

PTC thermistors for overload protection

56 V (T_S = 120 °C)

ELECTRICAL DATA AND ORDERING INFORMATION

Table 2 Electrical data for **2322 66. 0/1/3...1;** max. voltage = 56 V (AC or DC); see note 1

I_{nt}(2) MAX. at 25 °C (mA)	I_t(2) MIN. at 25 °C (mA)	I_{nt}(2) at 55 °C (mA)	I_t(2) at 10 °C (mA)	R_{25} ±30% (Ω)	I MAX. at 25 °C (mA)	I_{res} MAX. at V_{max} and 25 °C (mA)	DISSIP. FACTOR (mW/K)	TYPICAL ∅D (mm)	CATALOGUE NUMBERS(3) BULK	TAPE ON REEL
70	100	56	112	70	460	30	6.1	4.5	2322 660 15691	2322 660 35691
90	125	68	136	48	600	30	6.1	4.5	2322 660 16891	2322 660 36891
105	150	82	164	33	750	30	6.1	4.5	2322 660 18291	2322 660 38291
130	180	100	200	26	950	35	7.1	6.5	2322 661 11011	2322 661 31011
155	220	120	240	18	1300	35	7.1	6.5	2322 661 11211	2322 661 31211
195	275	150	300	12	1600	40	7.8	8	2322 661 11511	2322 661 31511
230	330	180	360	9.5	2200	45	8.5	10	2322 662 11811	2322 662 31811
285	400	220	440	7.3	2900	50	9.4	12	2322 662 12211	2322 662 32211
350	495	270	540	4.8	4000	50	9.4	12	2322 662 12711	2322 662 32711
425	600	330	660	3.8	6300	60	10	13	2322 663 13311	2322 663 33311
505	710	390	780	3.1	7300	70	12	16	2322 663 13911	–
605	808	470	940	2.2	12000	70	12	16	2322 663 14711	–
725	1020	560	1120	2.1	14000	100	16	20	2322 664 15611	–
878	1240	680	1360	1.4	18000	100	16	20	2322 664 16811	–

Notes

1. The thermistors are clamped at the seating plane.
2. For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted in accordance with *"IEC 60738"*. Thermistor dissipation depends on mounting and can slightly affect the typical values.
3. For leadless types replace the 8^{th} digit in the catalogue numbers by 0.

PTC thermistors for overload protection

265 V (T_S = 120 °C)

Table 3 Electrical data for **2322 66. 0/1/3...3**; max. voltage = 265 V (AC or DC); see note 1

I_{nt}(2) MAX. at 25 °C (mA)	I_t(2) MIN. at 25 °C (mA)	I_{nt}(2) at 55 °C (mA)	I_t(2) at 10 °C (mA)	R_{25} ±30% (Ω)	I MAX. at 25 °C (mA)	I_{res} MAX. at V_{max} and 25 °C (mA)	DISSIP. FACTOR (mW/K)	TYPICAL ∅D (mm)	CATALOGUE NUMBERS(3)	
									BULK	TAPE ON REEL
15	22	12	24	1500	110	5	6.1	4.5	2322 660 11293	2322 660 31293
20	27	15	30	1000	135	5	6.1	4.5	2322 660 11593	2322 660 31593
25	33	18	36	700	165	5	6.1	4.5	2322 660 11893	2322 660 31893
30	40	22	44	460	200	6	6.1	4.5	2322 660 12293	2322 660 32293
35	50	27	54	300	250	6	6.1	4.5	2322 660 12793	2322 660 32793
45	60	33	66	240	290	7	7.0	6.5	2322 661 13393	2322 661 33393
50	70	39	78	170	350	7	7.0	6.5	2322 661 13993	2322 661 33993
60	85	47	94	120	420	7	7.0	6.5	2322 661 14793	2322 661 34793
70	100	56	112	80	500	8	7.0	6.5	2322 661 15693	2322 661 35693
90	125	68	136	60	600	8	7.6	8	2322 661 16893	2322 661 36893
105	150	82	164	45	730	9	7.6	8	2322 661 18293	2322 661 38293
130	185	100	200	30	900	9	7.6	8	2322 661 11013	2322 661 31013
155	220	120	240	23	1100	12	8.2	10	2322 662 11213	2322 662 31213
195	275	150	300	17	1300	12	9.2	12	2322 662 11513	2322 662 31513
230	325	180	360	12	1700	14	9.2	12	2322 662 11813	2322 662 31813
285	400	220	440	8.5	2100	16	10	13	2322 663 12213	2322 663 32213
350	495	270	540	6.5	2500	19	12	16	2322 663 12713	–
425	600	330	660	6.0	3000	25	16	20	2322 664 13313	–
505	715	390	780	4.3	3600	25	16	20	2322 664 13913	–
605	860	470	940	3.0	4300	25	16	20	2322 664 14713	–

Notes

1. The thermistors are clamped at the seating plane.
2. For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted in accordance with *"IEC 60738"*. Thermistor dissipation depends on mounting and can slightly affect the typical values.
3. For leadless types replace the 8^{th} digit in the catalogue numbers by 0.

PTC thermistors for overload protection

56 V and 265 V (T_s = 120 °C)

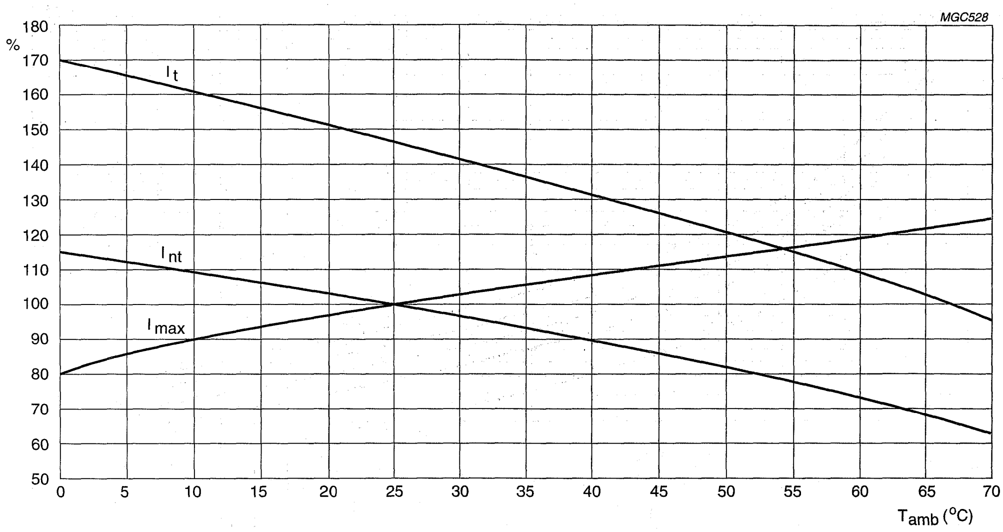
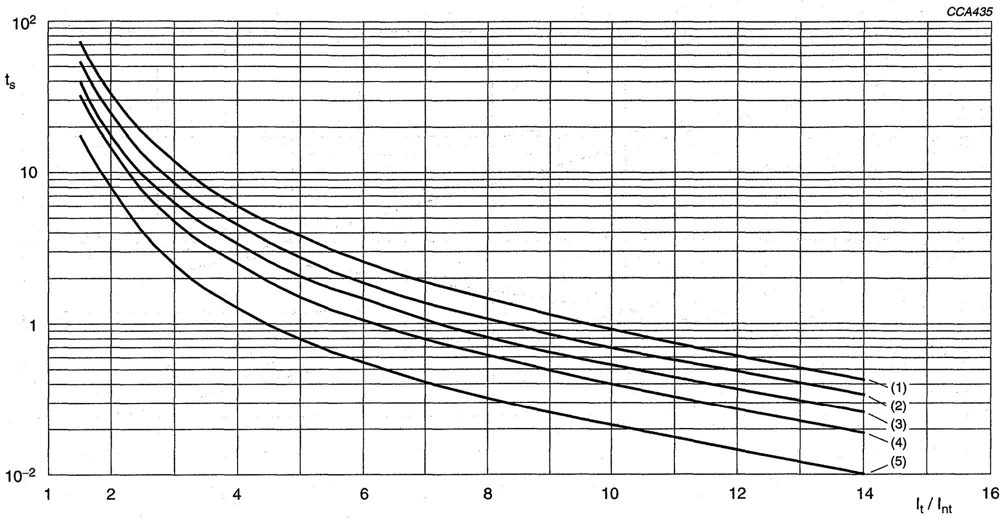
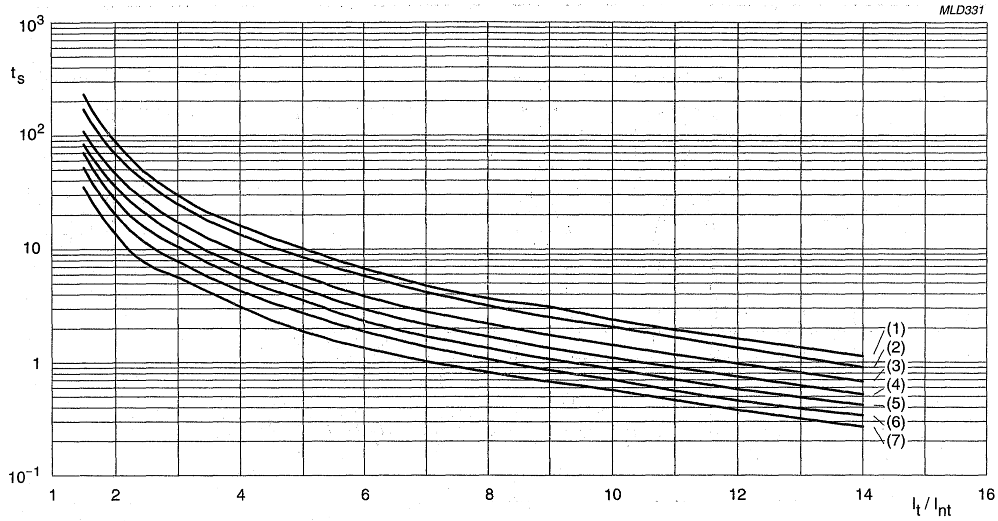


Fig.2 Current deviation as a function of the ambient temperature.



Curve 1: typical ∅D = 12.0 mm.
Curve 2: typical ∅D = 10.0 mm.
Curve 3: typical ∅D = 8.0 mm.
Curve 4: typical ∅D = 6.5 mm.
Curve 5: typical ∅D = 4.5 mm.
Measured in accordance with *"IEC 60738"*.
For an example, see "Trip-time or switching time (ts)".

Fig.3 Typical trip-time as a function of trip current ratio for 56 volt types.



Curve 1: typical ∅D = 20.0 mm.
Curve 2: typical ∅D = 16.0 mm.
Curve 3: typical ∅D = 12.0 and 13.0 mm.
Curve 4: typical ∅D = 10.0 mm.
Curve 5: typical ∅D = 8.0 mm.
Curve 6: typical ∅D = 6.5 mm.
Curve 7: typical ∅D = 4.5 mm.
Measured in accordance with *"IEC 60738"*.
For an example, see "Trip-time or switching time (ts)".

Fig.4 Typical trip-time as a function of trip current ratio for 56 volt and 265 volt (∅D > 12 mm) types.

Trip-time or switching time (t_s)

To check the trip-time for a specific PTC, refer to Tables 2 or 3 for the value I_{nt}. Divide the overload or trip current by this I_{nt} and you realize the factor I_t/I_{nt}. This rule is valid for any ambient temperature between 0 and 70 °C. Adapt the correct non-trip current with the appropriate curve in Fig.2. The relationship between the I_t/I_{nt} factor and the switching time as a function of the PTC diameter; see Fig.3.

EXAMPLE

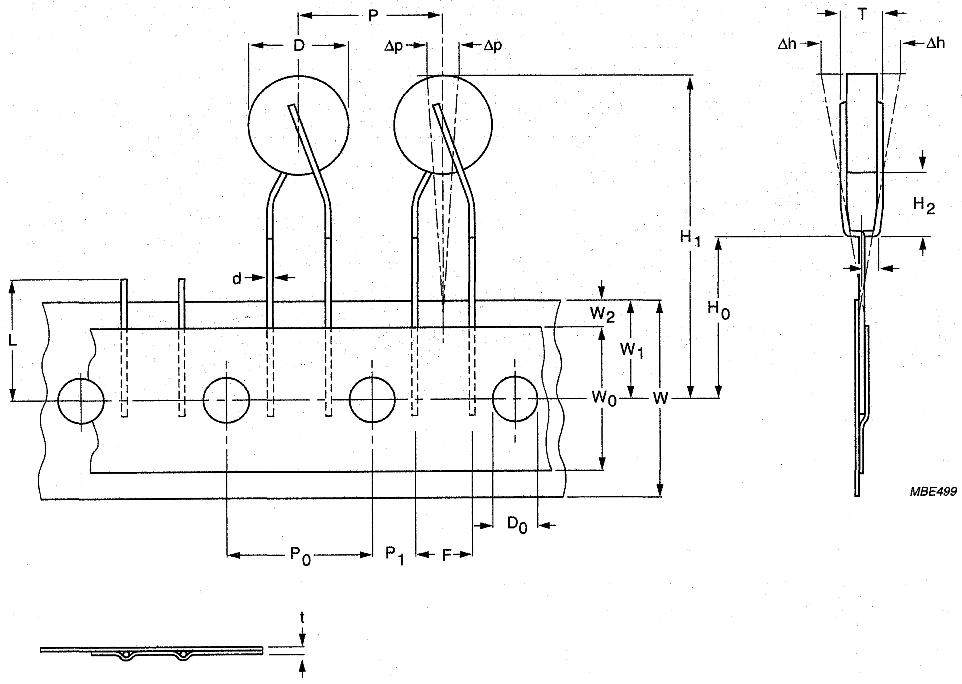
What will be the trip-time at I_{ol} = 3 A and T_{amb} = 10 °C of a thermistor type 2322 662 12711; 6.5 Ω; ∅D = 12 mm:

I_{nt} from Table 2: 350 mA at 25 °C

I_{nt}: 350 × 1.08 = 378 mA (10 °C).

Overload current = 3 A; factor: $3/_{0.378}$ = 7.94. In Fig.3 at the 12 mm line and I_t/I_{nt} = 7.94, the typical trip-time is 1.6 s.

TAPE AND REEL DATA



Taped in accordance with *"IEC 60286-2"*.

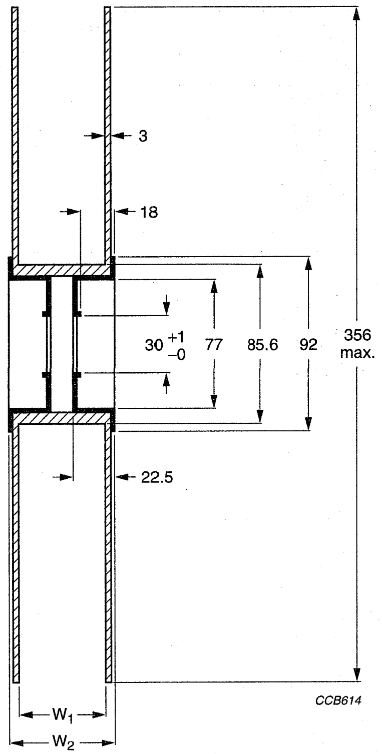
Fig.5 Thermistors on tape for 2322 66. 3...1/3.

Table 4 Tape and other device dimensions; see Figs 1 and 5. Taped in accordance with *"IEC 60286-2"*.

SYMBOL	PARAMETER	DIMENSIONS (mm)	TOLERANCE	REMARKS
D	body diameter	see Table 1	±0.5	
T	total maximum thickness	see Table 1		
d	lead diameter	0.6	±10%	
P	pitch between thermistors:			
	∅ < 12 mm	12.7	±1	
	∅ ≥ 12 mm	25.4	±2	
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
Δp	component alignment	0	±1.3	
F	lead to lead distance	5	+0.6 to –0.1	guaranteed between component and tape
Δh	component alignment	0	±2	
W	tape width	18	+1 to –0.5	
W_0	hold down tape width	≥12.5	–	
W_1	hole position	9	±0.5	
W_2	hold down tape position	≤3.0	–	
H_1	component height	≤37	–	
H_O	lead-wire clinch height	16	±0.5	
D_0	feed hole diameter	4	±0.2	
t	total tape thickness	≤0.9	–	with cardboard tape 0.5 ±0.1 mm
L	length of snipped lead	≤11	–	

Characteristics concerning taped thermistors

PARAMETER	VALUE
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%



Dimensions in mm.
For W_1 and W_2, see Table 5.

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

Table 5 Reel dimensions; see Fig.6

DIAMETER ∅ (mm)	**W_1 (mm)**	**W_2 MAX. (mm)**
<12	42 ±1	56
12	46 ±1	60

PACKAGING INFORMATION

PACKAGING		CATALOGUE NUMBERS	
SPQ	PQ	FIRST 7 DIGITS	LAST 5 DIGITS
5000	20000	2322 660	0...1
500	10000		1...1
3000	3000		3...1
3000	12000		0...3
500	10000		1...3
3000	3000		3...3
5000	5000	2322 661	0...1
250	5000		1...1
3000	3000		3...1
3000	3000		0...3
250	5000		1...3
3000	3000		3...3
4000	4000	2322 662	0...1
200	4000		11811
100	2000		12211; 12711
3000	3000		31811
1500	1500		32211; 32711
3000	3000		0...3
200	4000		11213
100	2000		11513; 11813
3000	3000		31213
1500	1500		31513; 31813
3000	3000	2322 663	03311; 02213
100	2000		1...1
550	2750		03911; 04711; 02713
100	2000		1...3
1500	1500		32213
100	2000	2322 664	0...1
100	2000		1...1
250	1250		0...3
50	1000		1...3

PTC thermistors for overload protection

56 V and 265 V (T_S = 120 °C)

TESTS AND REQUIREMENTS

Clause numbers of tests and performance requirements refer to the CECC 44000 standard.
Inspection levels are selected from *"IEC 60410"*. Tables with requirements for lot-by-lot and periodic tests.
In these tables:
D = Destructive
ND = Non-destructive.

Acceptable quality level

CLAUSE NUMBER	TEST	D OR ND	CONDITIONS	PERFORMANCE
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
Group B inspection (lot-by-lot)				
SUB-GROUP B1		D		
4.13.1	soldering, solderability		solder bath method: 235 ±5 °C	the leads shall be evenly tinned
Group C inspection (periodic)				
SUB-GROUP C1		D		
4.20.1	endurance (cycling)		duration: 10 cycles temperature: 25 °C voltage: as specified I_{max}: see Tables 2, 3 and Fig.2 cycle: 1 minute on and 9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8 ΔR/R: ≤±10%
			duration: 10 cycles temperature: 0 °C voltage: as specified I_{max}: see Tables 2, 3 and Fig.2 cycle: 1 minute on and 9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8 ΔR/R: ≤±10%

PTC thermistors for overload protection

56 V and 265 V (T_S = 120 °C)

CLAUSE NUMBER	TEST	D OR ND	CONDITIONS	PERFORMANCE
SUB-GROUP C2		D		
4.12	robustness of terminations		visual examination zero power resistance at 25 °C	as in 4.12.4; note 1 ΔR/R: ≤±10%
4.13.2	resistance to soldering heat		test Tb of *"IEC 60068-2-20A"* visual examination zero power resistance at 25 °C	 as in 4.13.2.3 ΔR/R: ≤±10%
4.14	rapid change of temperature		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%
SUB-GROUP C3		D		
4.20.3	endurance at maximum rated temperature		duration: for 2322 66. 0/1/3....1 series, 24 hours at 70 °C and 56 V for 2322 66. 0/1/3....3 series, 24 hours at 70 °C and 265 V examination at 24 hours visual examination zero power resistance at 25 °C	 as in 4.20.3.10 ΔR/R: ≤±10%
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%

Note

1. Leads should neither come loose or break.

PTC thermistors for overload protection

30 to 60 V, 145 V and 265 V (T_s = 140 °C)

FEATURES

- Different voltages to be chosen in function of the application
- Available in three mechanical versions:F
  - 2322 66. 4.... naked discs
  - 2322 66. 5.... leaded and coated
  - 2322 66. 6.... taped, on reel (to diameter 12.5 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 (I_t/I_{nt} = 1.5 at 25 °C)
- High maximum inrush current
- Excellent long term behaviour, also in humidity
- Leaded parts withstand mechanical stresses and vibration
- UL approved PTCs are guaranteed to withstand severe test programmes including:
  - long-life cycle tests (over 5000 trip cycles)
  - long-life storage tests (3000 hours at 250 °C)
  - cycle tests at low ambient temperatures (–40 °C or 0 °C)
  - damp-heat and water immersion tests
  - overvoltage tests at up to 200% of rated voltage.
- UL file E148885 according to XGPU2 standard UL1434.

MARKING

- Clear marking: the grey lacquered thermistors with a diameter of 8.5 to 20 mm are marked with PH, R_{25} value (example 4R6) on one side and I_{nt}, V_{max} on the other.

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 and coated.

QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Switch temperature; note 1	140	°C
Maximum voltage; note 2:		
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)
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:		
66. 4/5/6...1	40/125/56	
66. 4/5/6...2/3	25/125/56	

Notes

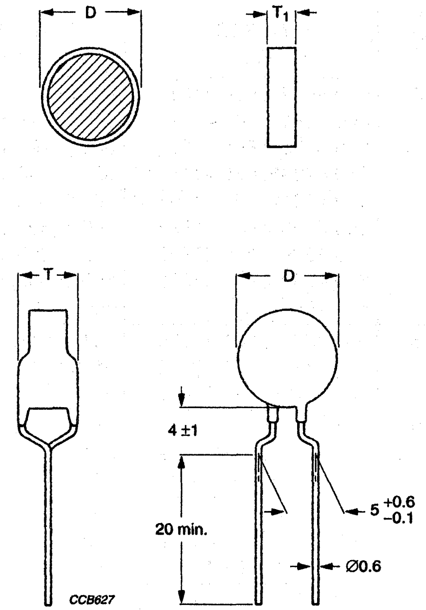
1. 2322 660 4/5/6 ...3 types, have a 120 °C switch temperature.
2. Rated voltages are respectively:

   24 to 48 V (AC or DC)

   120 V (AC or DC)

   230 V (AC or DC).

MECHANICAL DATA



Dimensions in mm.
For D see Table 1; for T_1 and T see Table 2.

Fig.1 Component outline for 2322 66. 4/5...1/2/3.

Table 1 Device and tape dimensions, packaging and catalogue numbers

D MAX. (mm)	H_1 MAX. (mm)	H_3 MAX. (mm)	PACKAGING AND CATALOGUE NUMBERS 2322		
			NAKED (Fig.1)	LEADED BULK (Fig.1)	LEADED TAPED (Fig.25)
5	26	9.5	660 49491; 660 41311; 660 41811; 660 42711; 660 44792; 660 46592; 660 49392; 660 41112; 660 41312; 660 41193; 660 41593; 660 41993; 660 42893; 660 43993; 660 46393; 660 47693; 660 49593	660 59491; 660 51311; 660 51811; 660 52711; 660 54792; 660 56592; 660 59392; 660 51112; 660 51312; 660 51193; 660 51593; 660 51993; 660 52893; 660 53993; 660 56393; 660 57693; 660 59593	660 69491; 660 61311; 660 61811; 660 62711; 660 64792; 660 66592; 660 69392; 660 61112; 660 61312; 660 61193; 660 61593; 660 61993; 660 62893; 660 63993; 660 66393; 660 67693; 660 69593
7	28	11.5	661 43211; 661 44111; 661 41712; 661 42112; 661 41113; 661 41413	661 53211; 661 54111; 661 51712; 661 52112; 661 51113; 661 51413	661 63211; 661 64111; 661 61712; 661 62112; 661 61113; 661 61413
8.5	29.5	13.0	661 44711; 661 45411; 661 42512; 661 42712; 661 41713; 661 41913	661 54711; 661 55411; 661 52512; 661 52712; 661 51713; 661 51913	661 64711; 661 65411; 661 62512; 661 62712; 661 61713; 661 61913
10.5	31.5	15.0	662 46111; 662 47011; 662 43212; 662 43612; 662 42113; 662 42513	662 56111; 662 57011; 662 53212; 662 53612; 662 52113; 662 52513	662 66111; 662 67011; 662 63212; 662 63612; 662 62113; 662 62513
12.5	32.5	17.0	662 48311; 662 49211; 662 44112; 662 44512; 662 42813; 662 43213	662 58311; 662 59211; 662 54112; 662 54512; 662 52813; 662 53213	662 68311; 662 69211; 662 64112; 662 64512; 662 62813; 662 63213
16.5	–	–	663 41121; 663 41321; 663 46012; 663 47112; 663 44013; 663 44913	663 51121; 663 51321; 663 56012; 663 57112; 663 54013; 663 54913	–
20.5	–	–	664 41721; 664 42021; 664 48812; 664 41022; 664 45913; 664 47013	664 51721; 664 52021; 664 58812; 664 51022; 664 55913; 664 57013	–

Table 2 Thickness dimensions and catalogue numbers

T_1 MAX. (mm)	T MAX. (mm)	CATALOGUE NUMBERS 2322 ... .
1.7	4.0	66. 4/5...1
2.8	5.0	66. 4/5...2
3.2	5.5	66. 4/5...3

ELECTRICAL DATA AND ORDERING INFORMATION

Table 3 Electrical data and ordering information for **2322 66. 4/5/6...1**; max. voltage = 30 to 60 V (AC or DC); see note 1. Preferred types in shaded cells.

I_{nt}(2) MAX. at 25 °C (mA)	I_t(2) MIN. at 25 °C (mA)	R_{25} ±20% (Ω)	V MAX. (V)	I(4) MAX. at 25 °C (mA)	I_{res} MAX. at V_{max} and 25 °C (mA)	DISSIP. FACTOR (mW/K)	TYPICAL ∅D (mm)	CATALOGUE NUMBERS(3)	
								BULK	TAPE ON REEL
94	145	50	60	800	22	6.9	4.5	2322 660 59491	2322 660 69491
130	195	25	60	1200	25	6.9	4.5	2322 660 51311	2322 660 61311
180	270	13	30	1700	45	6.9	4.5	2322 660 51811	2322 660 61811
270	405	6	30	2500	60	6.9	4.5	2322 660 52711	2322 660 62711
320	480	5	30	3500	62	7.8	6.5	2322 661 53211	2322 661 63211
410	615	3	30	4500	65	7.8	6.5	2322 661 54111	2322 661 64111
470	705	2.5	30	5000	70	8.8	8.0	2322 661 54711	2322 661 64711
540	810	1.9	30	6000	75	8.8	8.0	2322 661 55411	2322 661 65411
610	915	1.7	30	7000	80	9.9	10	2322 662 56111	2322 662 66111
700	1050	1.3	30	8000	90	9.9	10	2322 662 57011	2322 662 67011
830	1245	1.1	30	10000	100	11.5	12	2322 662 58311	2322 662 68311
920	1380	0.9	30	11000	105	11.5	12	2322 662 59211	2322 662 69211
1 170	1755	0.7	30	13500	140	14.5	16	2322 663 51121	–
1390	2085	0.5	30	16000	170	14.5	16	2322 663 51321	–
1770	2655	0.4	30	20000	200	18.7	20	2322 664 51721	–
2050	3075	0.3	30	23000	220	18.7	20	2322 664 52021	–

Notes

1. The thermistors are clamped at the seating plane.
2. For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted in accordance with *"IEC 60738"*. Thermistor dissipation depends on mounting and can slightly affect the typical values.
3. For leadless types replace the 8th digit in the catalogue numbers by 4.
4. I_{max} is the maximum overload current that may flow through the PTC when it passes from the low ohmic to the high ohmic state; see Figs 2 and 3.

Table 4 Electrical data and ordering information for **2322 66. 4/5/6...2**; max. voltage = 145 V (AC or DC); see note 1

I_{nt}(2) MAX. at 25 °C (mA)	I_t(2) MIN. at 25 °C (mA)	R_{25} ±25% (Ω)	I(4) MAX. at 25 °C (mA)	I_{res} MAX. at V_{max} and 25 °C (mA)	DISSIP. FACTOR (mW/K)	TYPICAL ∅D (mm)	CATALOGUE NUMBERS(3)	
							BULK	TAPE ON REEL
47	70	240	200	9	7.3	4.5	2322 660 54792	2322 660 64792
65	100	115	300	11	7.3	4.5	2322 660 56592	2322 660 66592
93	140	55	450	13	7.3	4.5	2322 660 59392	2322 660 69392
110	165	40	500	13	7.3	4.5	2322 660 51112	2322 660 61112
130	195	28	600	13	7.3	4.5	2322 660 51312	2322 660 61312
170	255	19	1000	15	8.3	6.5	2322 661 51712	2322 661 61712
210	315	12	1400	15	8.3	6.5	2322 661 52112	2322 661 62112
250	375	9.4	2000	16.5	9	8.0	2322 661 52512	2322 661 62512
270	405	8	2200	16.5	9	8.0	2322 661 52712	2322 661 62712
320	480	6.7	3000	19	10.5	10	2322 662 53212	2322 662 63212
360	540	5.3	3500	19	10.5	10	2322 662 53612	2322 662 63612
410	615	4.6	4500	22.5	11.7	12	2322 662 54112	2322 662 64112
450	675	3.8	5000	22.5	11.7	12	2322 662 54512	2322 662 64512
600	900	2.9	7200	28.5	15.5	16	2322 663 56012	–
710	1065	2.1	8500	28.5	15.5	16	2322 663 57112	–
880	1320	1.7	11000	37.5	19.8	20	2322 664 58812	–
1000	1500	1.3	13000	37.5	19.8	20	2322 664 51022	–

Notes

1. The thermistors are clamped at the seating plane.
2. For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted in accordance with *"IEC 60738"*. Thermistor dissipation depends on mounting and can slightly affect the typical values.
3. For leadless types replace the 8th digit in the catalogue numbers by 4.
4. I_{max} is the maximum overload current that may flow through the PTC when it passes from the low ohmic to the high ohmic state; see Figs 2 and 3.

Table 5 Electrical data and ordering information for **2322 66. 4/5/6...3**; max. voltage = 265 V (AC or DC); see note 1. Preferred types in shaded cells.

I_{nt}(2) MAX. at 25 °C (mA)	I_t(2) MIN. at 25 °C (mA)	R_{25} ±25% (Ω)	I(4) MAX. at 25 °C (mA)	I_{res} MAX. at V_{max} and 25 °C (mA)	DISSIP. FACTOR (mW/K)	TYPICAL ∅D (mm)	CATALOGUE NUMBERS(3) BULK	TAPE ON REEL
11	17	3000	80	6.5	7.3	4.5	2322 660 51193	2322 660 61193
15	23	1900	110	6.5	7.3	4.5	2322 660 51593	2322 660 61593
19	29	1200	140	6.5	7.3	4.5	2322 660 51993	2322 660 61993
28	42	500	200	6.8	7.3	4.5	2322 660 52893	2322 660 62893
39	59	260	300	6.8	7.3	4.5	2322 660 53993	2322 660 63993
63	95	120	450	7	7.3	4.5	2322 660 56393	2322 660 66393
76	115	85	550	7	7.3	4.5	2322 660 57693	2322 660 67693
95	143	56	600	7	7.3	4.5	2322 660 59593	2322 660 69593
110	165	48	650	7.5	8.3	6.5	2322 661 51113	2322 661 61113
140	210	29	800	8	8.3	6.5	2322 661 51413	2322 661 61413
170	255	22	900	9	9	8.0	2322 661 51713	2322 661 61713
190	285	18	1000	9.5	9	8.0	2322 661 51913	2322 661 61913
210	315	17	1300	10	10.5	10	2322 662 52113	2322 662 62113
250	375	12	1500	11	10.5	10	2322 662 52513	2322 662 62513
280	420	11	1800	12	11.7	12	2322 662 52813	2322 662 62813
320	480	8.4	2200	13	11.7	12	2322 662 53213	2322 662 63213
400	600	6.6	3000	15	15.5	16	2322 663 54013	–
490	735	4.4	3500	16	15.5	16	2322 663 54913	–
590	855	4	4500	19.5	19.8	20	2322 664 55913	–
700	1050	2.8	5500	21	19.8	20	2322 664 57013	–

Notes

1. The thermistors are clamped at the seating plane.
2. For leadless types the values given for I_{nt} and I_t are only valid for thermistors mounted in accordance with *"IEC 60738"*. Thermistor dissipation depends on mounting and can slightly affect the typical values.
3. For leadless types replace the 8th digit in the catalogue numbers by 4.
4. I_{max} is the maximum overload current that may flow through the PTC when it passes from the low ohmic to the high ohmic state; see Figs 2 and 3.

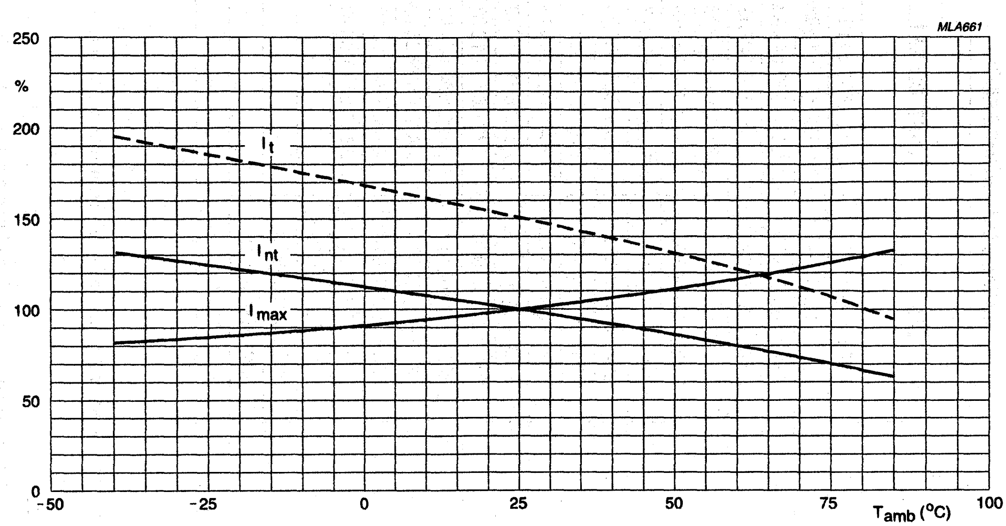


Fig.2 Current deviation as a function of the ambient temperature.

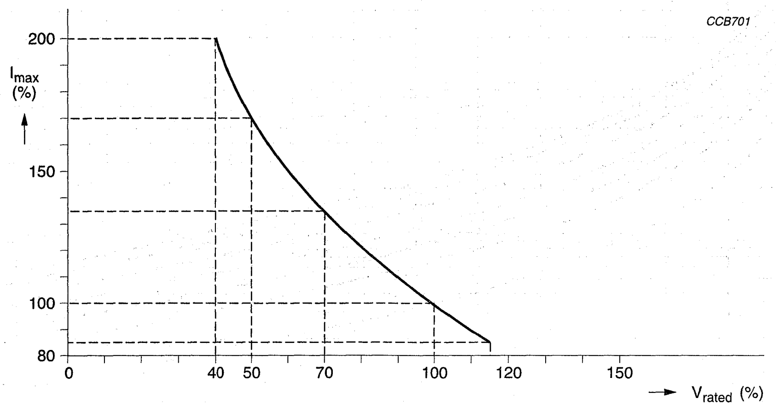


Fig.3 I_{max} as a function of voltage.

I_{max} as stated in Tables 3, 4 and 5 is the maximum overload current that may flow through the PTC when passing from the low ohmic to high ohmic state at rated voltage.

When other voltages are present after tripping, the I_{max} value can be derived from the above Fig.3. Voltages below V_{rated} will allow higher overload currents to pass the PTC.

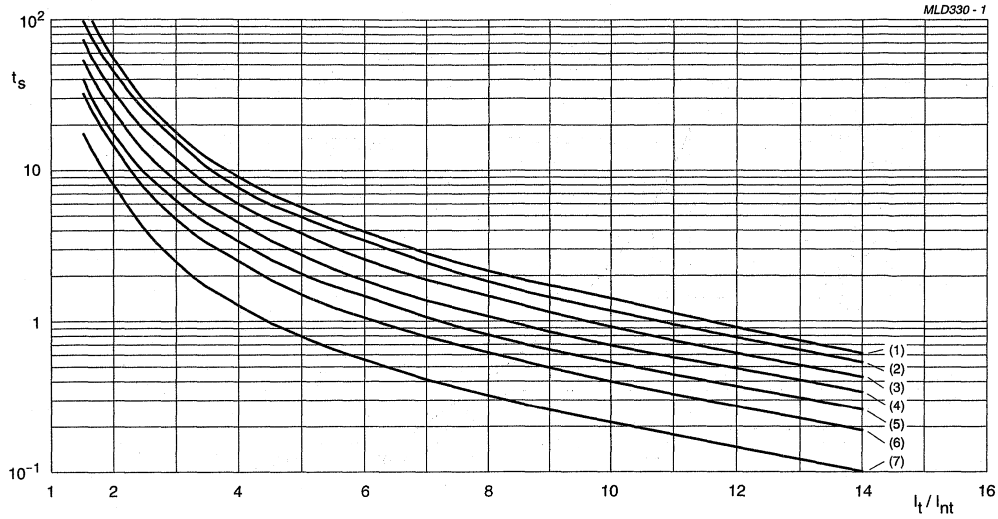
Example

What maximum overload current is allowed for a thermistor type 2322 662 52513 at 0 °C and a maximum voltage after tripping of 180 V_{RMS}:

I_{max} at 230 V and 25 °C = 1.5 A_{RMS}: see Table 5.

I_{max} at 180 V and 25 °C = 1.85 A_{RMS} (180 V_{RMS} = 78% of 230 V_{RMS} gives 123% of I_{max}).

At 0 °C this gives 1.68 A_{RMS} maximum overload current; see Fig.2.



Curve 1: typical ∅D = 20 mm.
Curve 2: typical ∅D = 16 mm.
Curve 3: typical ∅D = 12.0 mm.
Curve 4: typical ∅D = 10.0 mm.
Curve 5: typical ∅D = 8.0 mm.
Curve 6: typical ∅D = 6.5 mm.
Curve 7: typical ∅D = 4.5 mm.
Measured in accordance with *"IEC 60738"*.
For an example, see "Trip-time or switching time (ts)".

Fig.4 Typical trip-time as a function of trip current ratio for 30 to 60 volt types.

Trip-time or switching time (t_s)

To check the trip-time for a specific PTC, refer to Table 3, 4 or 5 for the value I_{nt}. Divide the overload or trip current by this I_{nt} and you realize the factor I_t/I_{nt}. This rule is valid for any ambient temperature between 0 and 70 °C. Adapt the correct non-trip current with the appropriate curve in Fig.2. The relationship between the I_t/I_{nt} factor and the switching time is a function of the PTC diameter; see Figs 4 and 5.

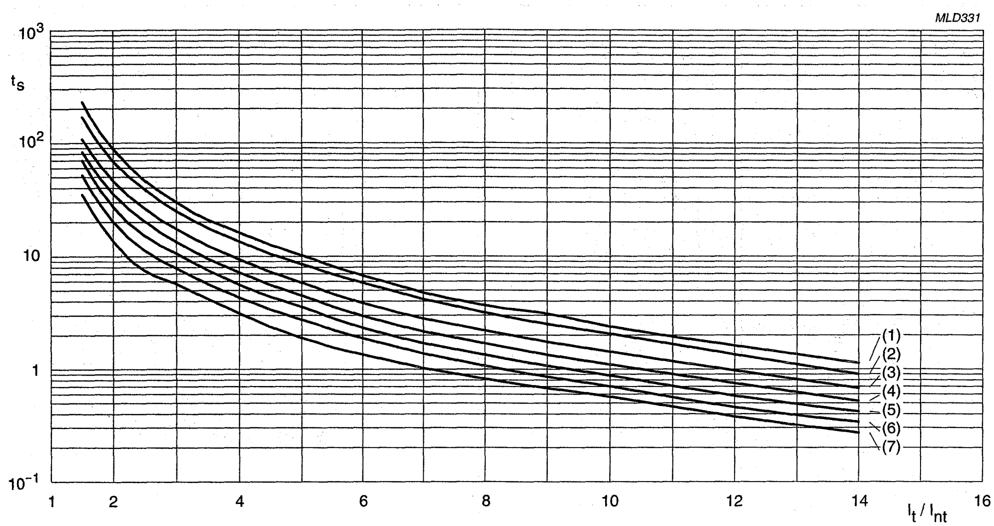
EXAMPLE

What will be the trip-time at I_{ol} = 3 A and T_{amb} = 0 °C of a thermistor type 2322 661 54711; 2.5 Ω; ∅D = 8.0 mm:

I_{nt} from Table 3: 470 mA at 25 °C

I_{nt}: 470 × 1.12 = 526 mA (0 °C).

Overload current = 3 A; factor I_t/I_{nt}: $3/_{0.526}$ = 5.70. In Fig.4 at the 8.0 mm line and I_t/I_{nt} = 5.70, the typical trip-time is 1.7 s.



Curve 1: typical ∅D = 20.0 mm.
Curve 2: typical ∅D = 16.0 mm.
Curve 3: typical ∅D = 12.0 mm.
Curve 4: typical ∅D = 10.0 mm.
Curve 5: typical ∅D = 8.0 mm.
Curve 6: typical ∅D = 6.5 mm.
Curve 7: typical ∅D = 4.5 mm.
Measured in accordance with *"IEC 60738"*.
For an example, see "Trip-time or switching time (ts)".

Fig.5 Typical trip-time as a function of trip current ratio for 145 and 265 volt types.

Typical R/T characteristics

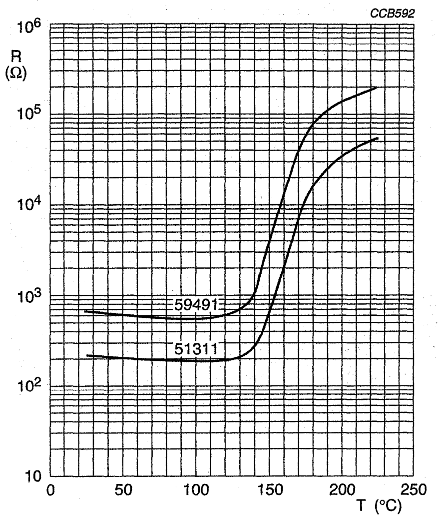


Fig.6 Typical resistance/temperature characteristic for 2322 660 59491/51311.

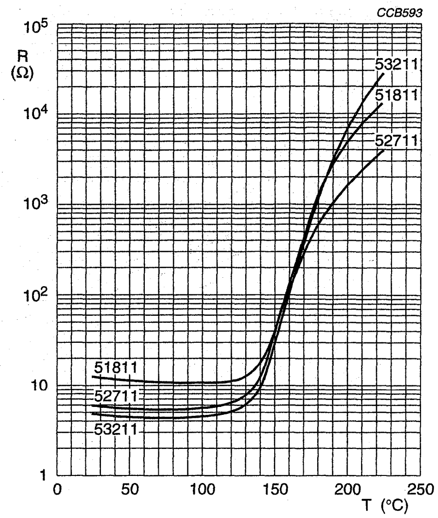


Fig.7 Typical resistance/temperature characteristic for 2322 660 51811/52711 and 661 53211.

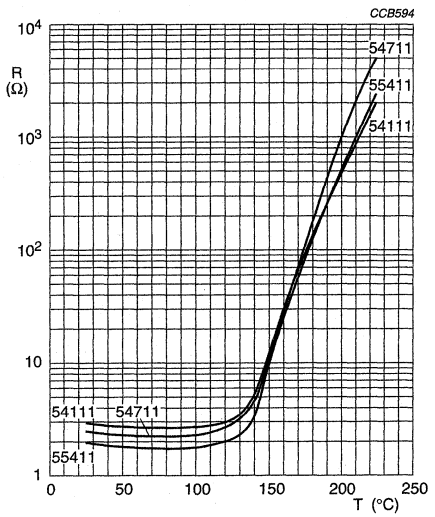


Fig.8 Typical resistance/temperature characteristic for 2322 661 54111/54711/55411.

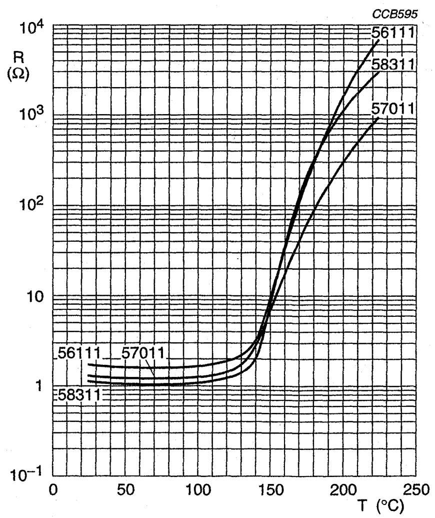


Fig.9 Typical resistance/temperature characteristic for 2322 662 56111/57011/58311.

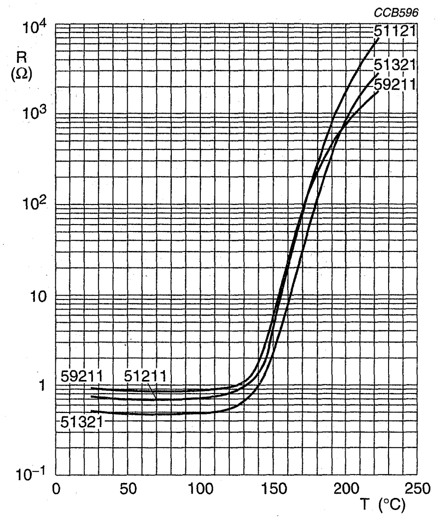


Fig.10 Typical resistance/temperature characteristic for 2322 662 59211 and 663 51121/51321.

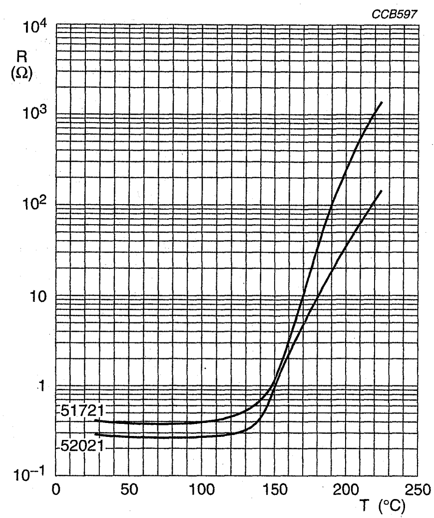


Fig.11 Typical resistance/temperature characteristic for 2322 664 51721/52021.

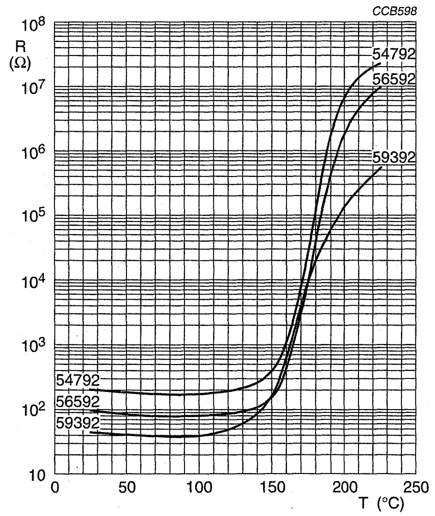


Fig.12 Typical resistance/temperature characteristic for 2322 660 54792/56592/59392.

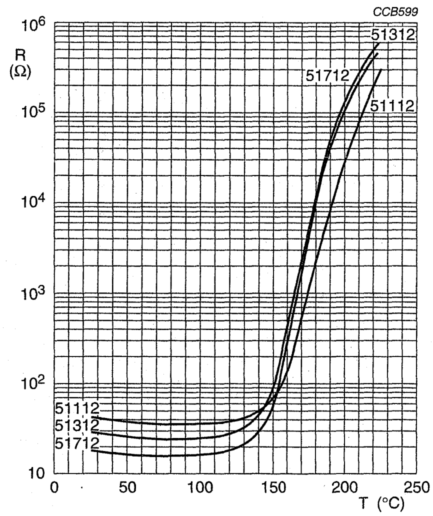


Fig.13 Typical resistance/temperature characteristic for 2322 660 51112/51312 and 661 51712.

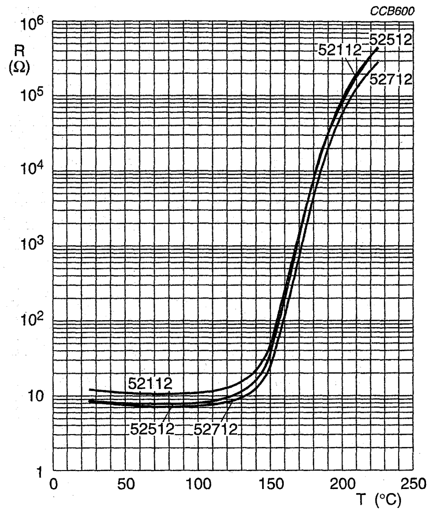


Fig.14 Typical resistance/temperature characteristic for 2322 661 52112/52512/52712.

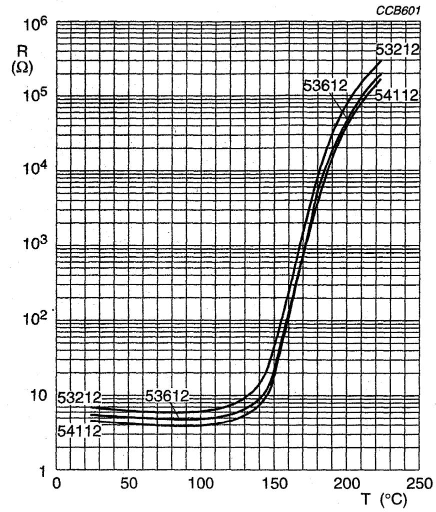


Fig.15 Typical resistance/temperature characteristic for 2322 662 53212/53612/54112.

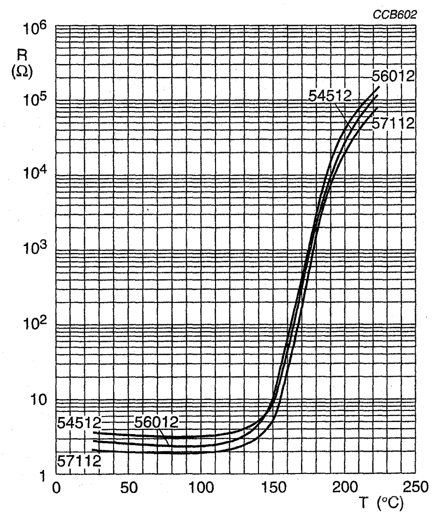


Fig.16 Typical resistance/temperature characteristic for 2322 662 54512 and 663 56012/57112.

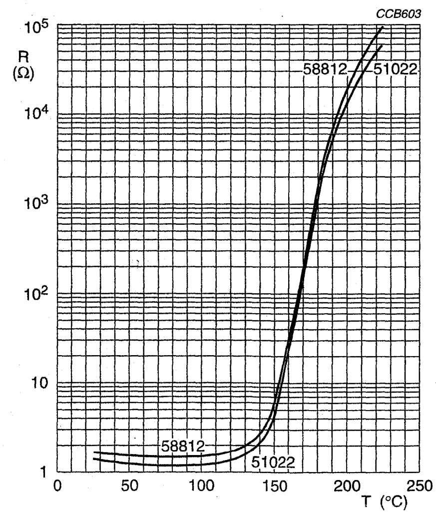


Fig.17 Typical resistance/temperature characteristic for 2322 664 58812/51022.

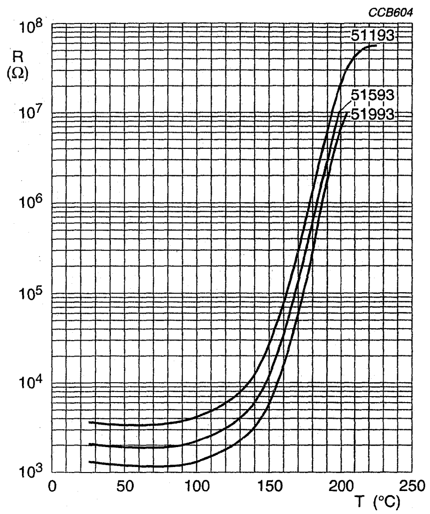


Fig.18 Typical resistance/temperature characteristic for 2322 660 51193/51593/51993.

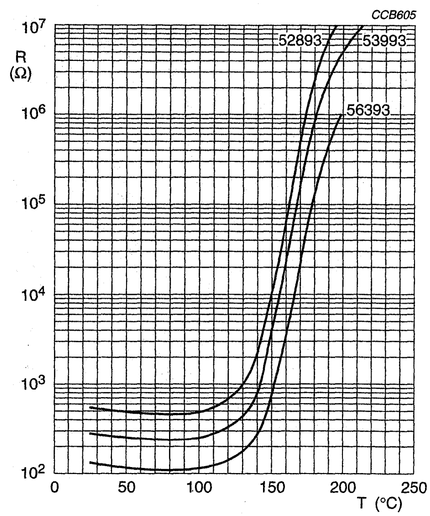


Fig.19 Typical resistance/temperature characteristic for 2322 660 52893/53993/56393.

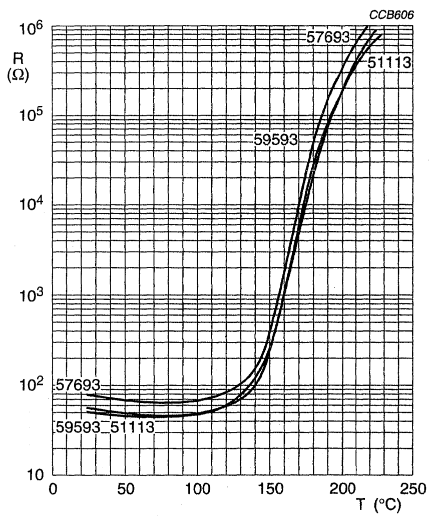


Fig.20 Typical resistance/temperature characteristic for 2322 660 57693/59593 and 661 51113.

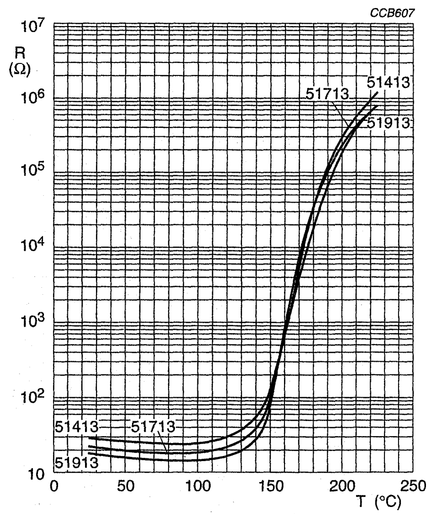


Fig.21 Typical resistance/temperature characteristic for 2322 661 51413/51713/51913.

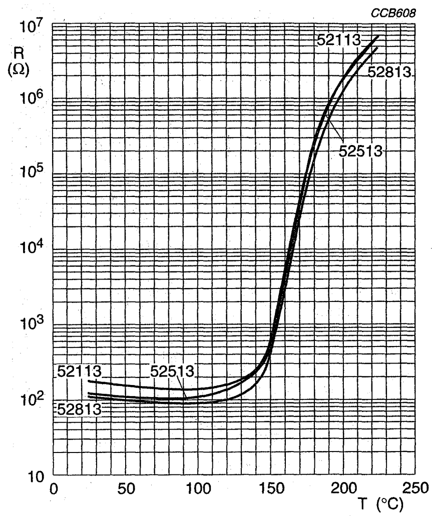


Fig.22 Typical resistance/temperature characteristic for 2322 662 52113/52513/52813.

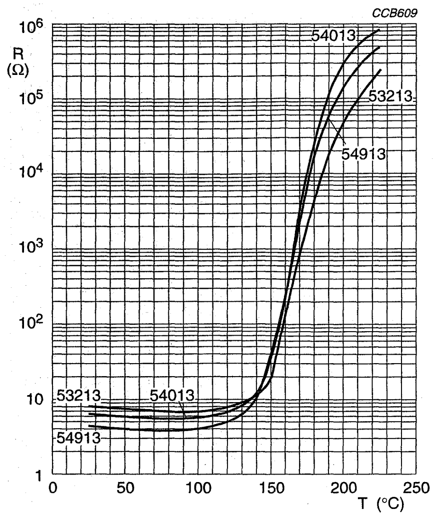


Fig.23 Typical resistance/temperature characteristic for 2322 662 53213 and 663 54013/54913.

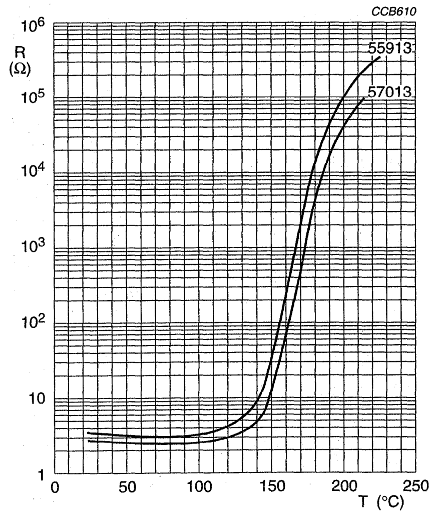
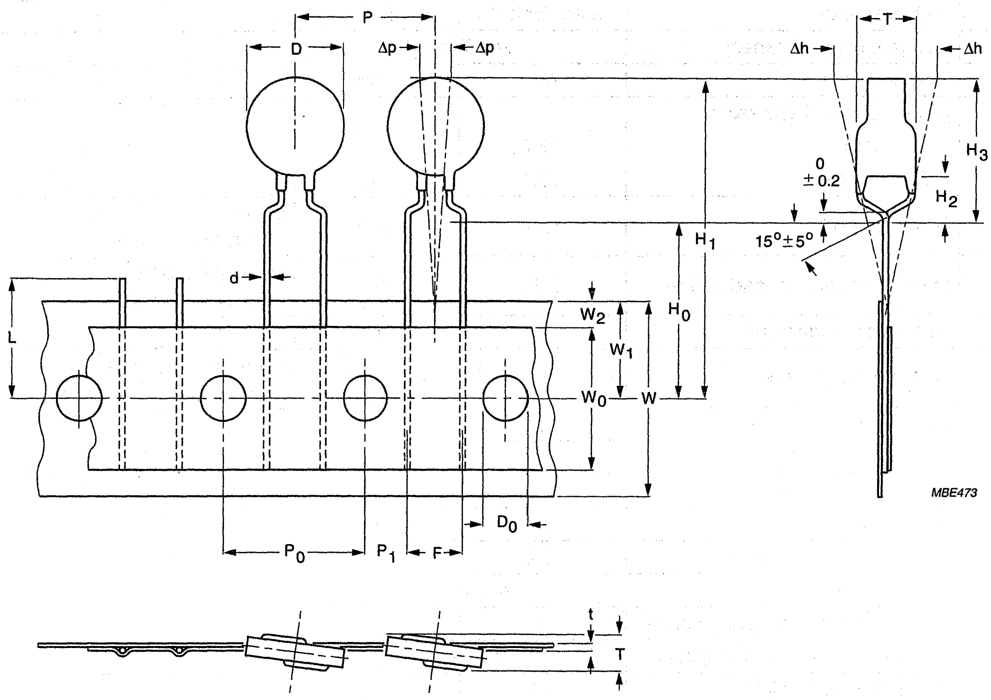


Fig.24 Typical resistance/temperature characteristic for 2322 664 55913/57013.

TAPE AND REEL DATA



Dimensions in mm.
Taped in accordance with *"IEC 60286-2"*.
For dimensions, see Table 6.

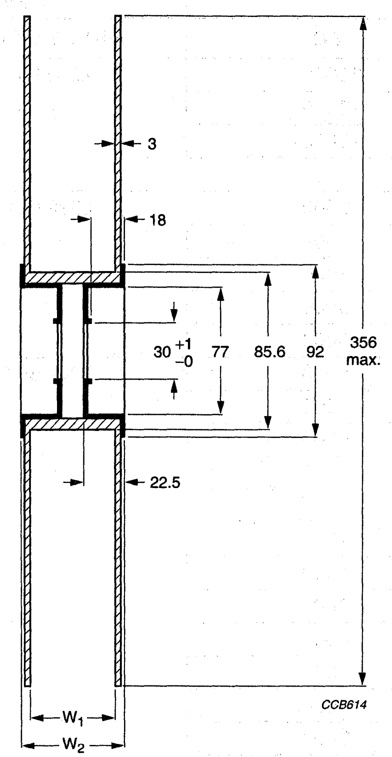
Fig.25 Thermistors with ∅D ≤ 12 mm on tape for 2322 66. 6...1/2/3.

Table 6 Tape and other device dimensions; see Figs 1 and 25

SYMBOL	PARAMETER	DIMENSIONS (mm)	TOLERANCE	REMARKS
D	body diameter	see Table 1	±0.5	
T	total maximum thickness	see Table 2		
d	lead diameter	0.6	±10%	
P	pitch between thermistors: ∅ < 12 mm ∅ ≥ 12 mm	 12.7 25.4	 ±1 ±2	
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
Δh	component alignment	0	±1.3	
F	lead to lead distance	5	+0.6 to −0.1	guaranteed between component and tape
Δh	component alignment	0	±2	
W	tape width	18	+1 to −0.5	
W_0	hold down tape width	≥12.3	–	
W_1	hole position	9	±0.5	
W_2	hold down tape position	≤3.0	–	
H_1	component height	see Table 1		
H_2	component body to seating plane	4	±1	
H_3	component top to seating plane	see Table 1		
H_0	lead-wire clinch height	16	±0.5	
D_0	feed hole diameter	4	±0.2	
t	total tape thickness	≤0.9	–	with cardboard tape 0.5 ±0.1 mm
L	length of snipped lead	≤11	–	

Characteristics concerning taped thermistors

PARAMETER	VALUE
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%



Dimensions in mm.
For W_1 and W_2, see Table 7.

Fig.26 Dimensions of the reel for 2322 66. 6...1/2/3.

Table 7 Reel dimensions; see Fig.26

DIAMETER ∅ (mm)	W_1 (mm)	W_2 MAX. (mm)
<12	42 ±1	56
12	46 ±1	60

PACKAGING INFORMATION

PACKAGING		CATALOGUE NUMBERS	
SPQ	PQ	FIRST 7 DIGITS	LAST 5 DIGITS
5000	20000	2322 660	4...1
3000	12000		4...2 and 3
500	10000		5...1, 2 and 3
3000	3000		6...1, 2 and 3
6000	6000	2322 661	4...1
3000	3000		4...2
3000	3000		4...3
250	5000		5...1, 2 and 3
3000	3000		6...1, 2 and 3
5500	5500	2322 662	4...1
3000	3000		4...2 and 3
250	5000		56111; 57011
3000	3000		66111; 67011
250	5000		58311; 59211
1500	1500		68311; 69211
200	4000		53212; 53612
3000	3000		63212; 63612
200	4000		54112; 54512
1500	1500		64112; 64512
200	4000		52113; 52513
3000	3000		62113; 62513
200	4000		52813; 53213
1500	1500		62813; 63213
400	1600	2322 663	4...1, 2 and 3
200	4000		5...1
100	2000		5...2 and 3
400	1600	2322 664	4...1, 2 and 3
100	2000		5...1 and 2
50	1000		5...3

TESTS AND REQUIREMENTS

Clause numbers of tests and performance requirements refer to the CECC 44000 standard.
Inspection levels are selected from *"IEC 60410"*. Tables with requirements for lot-by-lot and periodic tests.
In these tables:
D = Destructive
ND = Non-destructive.

Acceptable quality level

CLAUSE NUMBER	TEST	D OR ND	CONDITIONS	PERFORMANCE
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
4.23	tripping current		measured at 25 °C	as specified
4.24	non-tripping current		measured at 25 °C	as specified
4.25	residual current at V_{max}		measured at 25 °C	as specified
Group B inspection (lot-by-lot)				
SUB-GROUP B1		D		
4.13.1	soldering, solderability		solder bath method: 235 ±5 °C	the leads shall be evenly tinned
Group C inspection (periodic)				
SUB-GROUP C1		D		
4.22.1	endurance (cycling)		duration: 10 cycles temperature: 25 °C voltage: as specified I_{max}: see Tables 3, 4, 5 and Fig.2 cycle: 1 minute on and 9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8 ΔR/R: ≤±10%
			duration: 10 cycles temperature for: 30 and 60 V; −40 °C 145 and 265 V; 0 °C voltage: as specified I_{max}: see Tables 3, 4, 5 and Fig.2 cycle: 1 minute on and 9 minutes off visual examination zero power resistance at 25 °C	 as in 4.20.1.8 ΔR/R: ≤±10%

CLAUSE NUMBER	TEST	D OR ND	CONDITIONS	PERFORMANCE
SUB-GROUP C2		D		
4.12	robustness of terminations		half of the sample visual examination zero power resistance at 25 °C	 as in 4.12.4; note 1 ΔR/R: ≤±10%
4.13.2	resistance to soldering heat		test Tb of *"IEC 60068-2-20A"* visual examination zero power resistance at 25 °C	 as in 4.13.2.3 ΔR/R: ≤±10%
4.14	rapid change of temperature		other half of the sample 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%
SUB-GROUP C3		D		
4.20.3	endurance at maximum rated temperature and maximum rated voltage		duration: 24 hours examination after 24 hours visual examination zero power resistance at 25 °C	 as in 4.20.3.10 ΔR/R: ≤±10%
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%

Note

1. Leads should neither come loose or break.

GENERAL

Advanced developments in telephony equipment in recent years have radically altered the protection requirements for both exchange and subscriber equipment. The BC Components range of Positive Temperature Coefficient (PTC) thermistors includes devices specially designed to provide overcurrent protection.

OVERCURRENT PROTECTION OF TELECOMMUNICATION LINES

The PTC thermistor must protect the telephone line circuit against overcurrent which may be caused by the following examples:

- Surges due to lightning strikes on or near to the line plant.
- Short-term induction of alternating voltages from adjacent power lines or railway systems, usually caused when these lines or systems develop faults.
- Direct contact between telephone lines and power lines.

To provide good protection under such conditions a PTC thermistor is connected in series with each line, usually as secondary protection; see Fig.1. However, even with primary line protection (usually a gas discharge tube), the PTC thermistor must fulfil severe requirements.

Surge pulses of up to 2 kV can occur and in order to withstand short-term power induction the PTC thermistor must withstand high voltages. If the line has primary protection a 220 V to 300 V PTC thermistor is adequate. Without primary protection, however, a 600 V PTC device is necessary. BC Components manufacturers a range of PTC thermistors (see Table 1) covering both requirements.

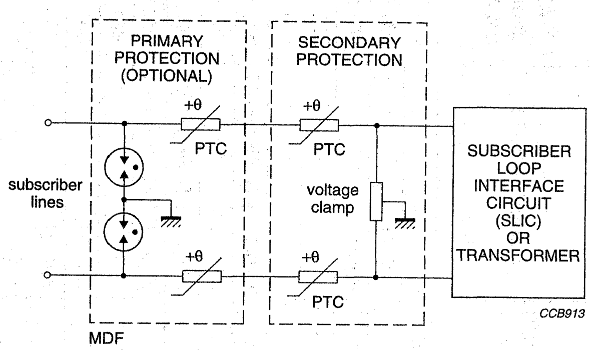


Fig.1 Typical telephone line equipment showing where PTC thermistors can be used for overcurrent protection.

In the case of direct contact between the telephone line and a power line, the PTC thermistor must withstand very high inrush power at normal mains voltage. Under such conditions, overload currents of up to 10 A on a 230 V mains could occur for up to several hours. To handle this power, the resistance/temperature characteristic of the thermistor must have a very steep slope and the ceramic must be extremely homogeneous.

In case of overcurrent due to short-term induction of alternating voltages, currents of several AMPs with voltages as high as 650 V_{RMS} can be present for several seconds

For standard high voltage applications, resistance values from 25 to 50 Ω are available. However, ISDN networks which carry high-frequency sound and vision, need lower line impedance.

Telecommunication designers are therefore demanding high voltage thermistors with much lower R_{25} values, which places even greater demands on the manufacture of PTC thermistors. For these applications PTC thermistors which have a R_{25} value of 10 Ω with voltages in the 300 to 600 V_{RMS} range are available.

In a typical telephone line application, two PTC thermistors are used, one each for the tip and ring (or A and B) wire together with their series resistors. For good line balance it is important that the thermistor and resistor pairs are matched.

On request, BC Components can supply matched or binned PTC thermistors with R_{25} values matched to as close as 0.5 Ω.

ELECTRICAL DATA

Table 1 Electrical data for catalogue numbers as listed

V MAX. (V)	NON-TRIP CURRENT		RESISTANCE		MATCHED PAIRS	TRIP CURRENT		MAX. TRIP TIME at 25 °C		APPLICATION AREA(1)	COMPATIBILITY	CATALOGUE NUMBER 2322 ... .
	I_{nt} (mA)	at T (°C)	R_{25} (Ω)	TOL (%)		I_t (mA)	at T (°C)	t_t (s)	at I_t (mA)			
100	85	65	4	±25	0.5 Ω	280	25	4.0	1000	MDF; ISDN	–	661 91066
220	70	70	25	±20	1 Ω	200	25	2.5	1000	C.S.	K20/21	661 93048
230	100	70	10	±20	1 Ω	250	25	3	1000	MDF; ISDN	K20/21	661 93147
245	60	70	70	+10/−15	no	180	25	60	220	C.S.	–	661 93025
245	75	70	33	±20	±5%	150	10	1.2	1000	C.S.	–	661 93037
245	70	70	25	±15	1 Ω	200	25	20	400	C.S.	K20/21; FTCSE I31-24	661 93043
245	65	85	25	±20	2%	200	25	3.40	650	C.S.	K20/21	661 93142
245	140	55	16	±20	no	270	25	8	1000	T.E.	K20/21; FTCSE I31-21	662 93081
245	140	55	10	±20	no	270	25	8	1000	T.E.	K20/21; FTCSE I31-21	662 93074
250	100	40	20	+10/−20	1 Ω	220	25	1	1000	MDF	–	661 93118
250	70	70	25	±20	1 Ω	175	25	1.3	1000	MDF; C.S.	K20/21	661 93148
250	100	70	10	±20	no	450	0	0.30	8000	T.E.	K20/21	663 93025
285	135	95	8	±25	0.5 Ω	400	25	6	1000	MDF; ISDN	K20/21	661 93078
300	100	70	16	±25	no	250	25	2.0	1000	MDF; T.E.	K20/21	661 93121
350	100	70	10	±20	no	270	25	4.0	1000	T.E.	K20/21	661 93124
350	100	70	10	±20	1 Ω	270	25	4.0	1000	C.S.; S.B.	K20/21	661 93146
600	50	70	50	±20	1 Ω	140	25	1	1000	C.S.	K20/21	661 93135
600	70	70	35	±20	3 Ω	600	0	3	1000	C.S.	K20/21	661 93056
600	70	70	25	±20	2%	170	25	4	700	C.S.	K20/21	661 93139
600	70	70	25	±20	2%	170	25	8	700	C.S.	K20/21	662 93129
600	175	25	10	±20	0.5 Ω	400	25	7	1000	C.S.; S.B.	UL1459/GR1089	662 93114
600	175	25	10	±20	no	400	25	7	1000	T.E.	UL1459/GR1089	662 93131

Note

1. MDF: Main Distribution Frame; C.S.: Central Office Switching; T.E.: Subscriber Terminal Equipment; S.B.: Set-top Box.

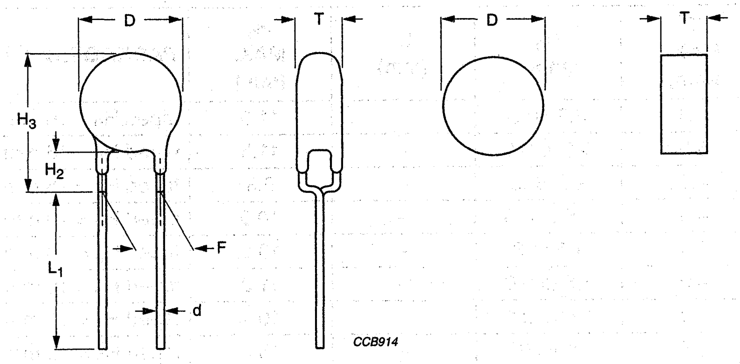
MECHANICAL DATA

Table 2 Specific physical dimensions and packaging for catalogue numbers as listed; see Fig.2

D MAX. (mm)	T MAX. (mm)	H_2 (mm)	L_1 (mm)	H_3 MAX. (mm)	PACKAGING(1)(2)	CATALOGUE NUMBER 2322 ... .
7.0	4.0	3.5 ±0.5	–	11.0	taped H_0 = 16 mm	661 91066
8.5	5.0	1.5 to 3.0	–	11.5	taped H_0 = 16 mm	661 93048
7.0	4.0	2.0 ±0.5	–	9.8	taped H_0 = 18 mm	661 93147
6.7	4.0	1.5 to 3.0	–	10.0	taped H_0 = 18 mm	661 93025
7.0	5.0	1.5 to 3	–	10.0	taped H_0 = 16 mm	661 93037
8.3	4.0	1.5 to 3.0	–	11.0	taped H_0 = 18 mm	661 93043(3)
6.8	4.3	1.5 to 3.0	–	10.1	taped H_0 = 16 mm	661 93142
11	4.5	4 ±1.0	–	15.5	taped H_0 = 16 mm	662 93081
11	4.5	4 ±1.0	–	15.5	taped H_0 = 16 mm	662 93074(3)
6.7	1.8	–	–	–	disc on tray	661 93118
7.0	4.0	2.0 ±0.5	–	9.8	taped H_0 = 18 mm	661 93148
13.6	6.0	4 ±1.0	20 ±4.0	18.6	bulk	663 93025(3)
8.3	5.0	1.5 ±0.5	20 ±3.0	10.3	bulk	661 93078
7.0	4.0	2.5 ±0.5	–	10.0	taped H_0 = 16 mm	661 93121
8.5	4.0	2.5 ±0.5	4.1 ±0.5	11.5	bulk	661 93124
8.5	4.0	2.5 ±0.5	–	11.5	taped H_0 = 16 mm	661 93146
8.5	4.0	2.5 ±0.5	4.1 ±0.5	11.5	bulk	661 93135
8.0	5.0	2.5 ±0.5	–	11.0	taped H_0 = 16 mm	661 93056
8.5	4.0	2 ±0.5	–	11.0	taped H_0 = 16 mm	661 93139
10.5	5.0	2 ±0.5	–	12.6	taped H_0 = 16 mm	662 93129
13	5.5	4 ±1.0	20 min.	18.0	bulk	662 93114
13	5.5	4 ±1.0	20 min.	18.0	bulk	662 93131

Notes

1. Taped in accordance with *"IEC 60286-2"*; standard packaging: 1500 units/reel.
2. Naked disc ceramic for substrate mounting, available on request.
3. Insulated version is also available.



For dimensions see Table 2.
Lead pitch F = 5 mm +0.6/–0.1.
Lead thickness d = 0.0.6 mm ±10%.

Fig.2 Component outline.

Surface mount PTC thermistors for overload protection

2322 661 97...

FEATURES

- Ideal for pick-and-place circuit assembly
- Low mounting height
- Suitable for reflow soldering
- Small ceramic diameter for faster response
- Low heat transfer to substrate
- Flat terminations for stable positioning and good solderability.

CONSTRUCTION

The component consists of a high-performance PTC ceramic disc mounted in a lead-frame for direct soldering onto a printed-circuit board (PCB) or substrate.

The ceramic is soldered to the leadframe by a local reflow process, during which the solder layer is melted to the metallized ceramic surface using a low residue flux.

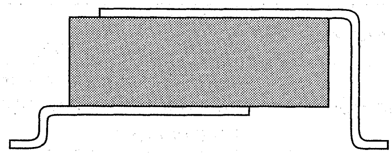


Fig.1 Product outline.

QUICK REFERENCE DATA

DESCRIPTION	VALUE	
	STANDARD TYPES(1)(2)	TELECOM TYPES(1)(2)
Nominal R25	2 to 500 Ω	10 to 70 Ω
Resistance tolerance	±10%; ±15%; ±20%	
Maximum overload current (voltage dependent)	2 to 10 A	
Non-trip current	50 to 500 mA at 25 °C	50 to 100 mA at 70 °C
Maximum voltage	16 to 400 V (RMS)	220 to 600 V (RMS)
Response time at 25 °C and 20 W overload power	<1 s	
Matching	–	down to 0.5 Ω
Maximum continuous power at 25 °C	2 W	

Notes

1. Customized products between the resistance ranges are available on request.
2. Coated and/or reinforced types are available on request.

MECHANICAL DATA

Table 1 Material information; see Fig.2

REF.	DESCRIPTION	MATERIAL AND REMARKS
1	ceramic	$BaTiO_3$ doped
2	metallization	NiCr Ag layer (vacuum deposition)
3	leadframe	Ni plated phosphor bronze material covered by PbSn8 solder layer

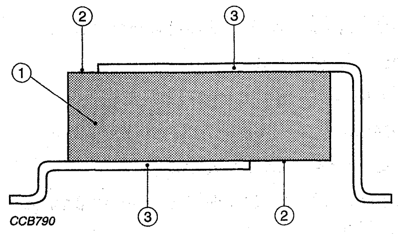


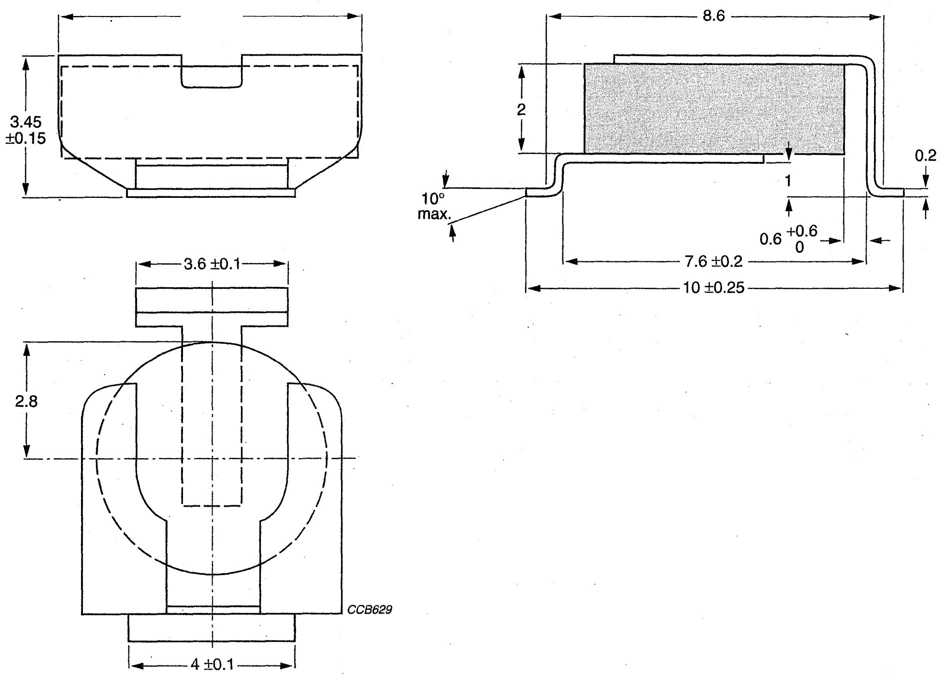
Fig.2 Product outline; see Table 1.

Handling precautions

The special leadframe construction and the applied processes do not allow high handling forces on the component. Because of the nature of PTC ceramic material the component should not be touched with bare hands, as the residue of perspiration can influence component behaviour at high temperatures.

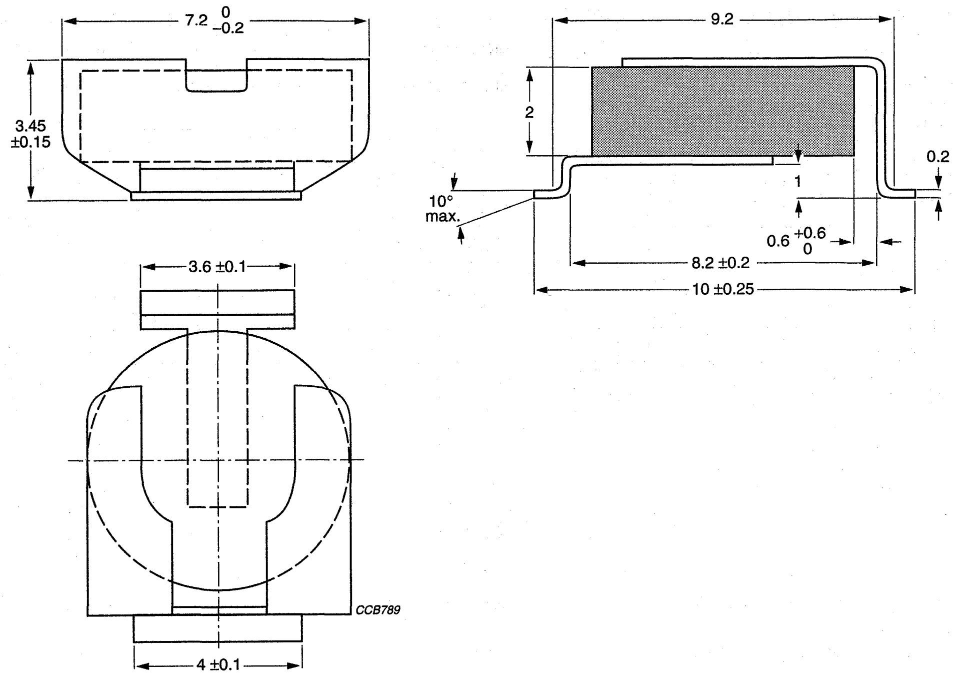
Handling forces vertically applied to the centre of the component should be limited to 5 N in the non-soldered condition and to 10 N in the soldered. These forces should not be exceeded during the handling, transportation and packaging of the soldered product.

PTC outlines



Dimensions in mm.
For electrical data, see Table 2.

Fig.3 PTC SMD ceramic size: 6.5 mm.



Dimensions in mm.
For electrical data, see Table 3.

Fig.4 PTC SMD ceramic size: 7.1 mm.

Table 2 Ceramic size: 6.5 mm; see Fig.3

R_{25} (Ω)	R_{25} (%)	V MAX. (V)	I_{nt} at 25 °C	I_{nt} at 70 °C	I_t at 25 °C	MAX. TRIP-TIME t_t (s)	MAX. TRIP-TIME at I_t (mA)	MATCHED PAIRS AVAILABLE	CATALOGUE NUMBER 2322 661 .....
Telecommunication types; note 1									
40	25	265	80	50	130	2.5	500	no	97002
15 to 20	–	300	150	100	250	1.5	1000	0.5 Ω	97003
15 to 20	–	300	150	100	250	1.5	1000	no	97004
25	20	265	120	70	220	1.3	1000	1 Ω	97005
35	+15/–20	425	110	70	175	1.0	1000	1 Ω	97009
10	20	245	165	100	270	3.0	1000	no	97012
10	20	245	165	100	270	3.0	1000	0.5 Ω	97016
20	20	300	120	70	250	1.4	1000	0.5 Ω	97018
50	20	425	90	60	150	0.8	1000	1 Ω	97019
General industrial types									
9.4	25	60	150	100	300	4.0	600	–	97011
3.3	25	24	400	–	650	6.0	1000	–	97013

Note

1. All types with $R_{25} \leq 35\ \Omega$ pass *"ITU-T K20/21"* telecommunication protection recommendation.

Table 3 Ceramic size: 7.1 mm; see Fig.4

R_{25} (Ω)	R_{25} (%)	V MAX. (V)	I_{nt} at 25 °C	I_{nt} at 70 °C	I_t at 25 °C	MAX. TRIP-TIME t_t (s)	MAX. TRIP-TIME at I_t (mA)	MATCHED PAIRS AVAILABLE	CATALOGUE NUMBER 2322 661 .....
Telecommunication types; note 1									
10	20	300	150	100	250	3.0	1000	0.5 Ω	97203
25	20	400	120	70	220	2.0	1000	1 Ω	97204
50	20	600	70	40	140	0.7	1000	1 Ω	97205

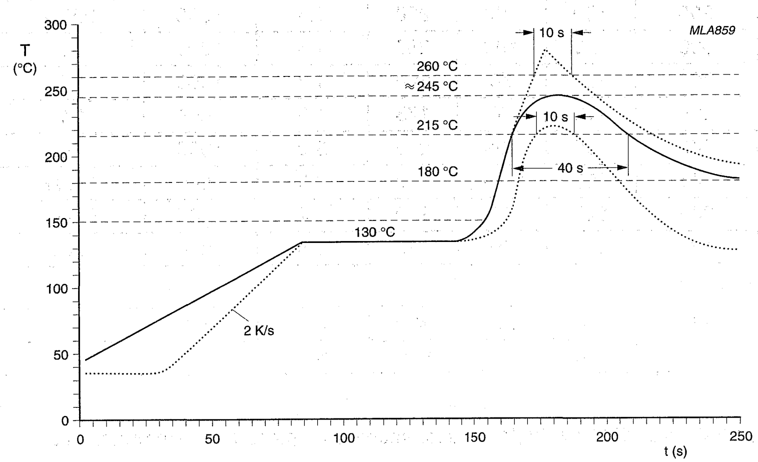
Note

1. All types pass *"ITU-T K20/21"* telecommunication protection recommendation.

SOLDERING CONDITIONS

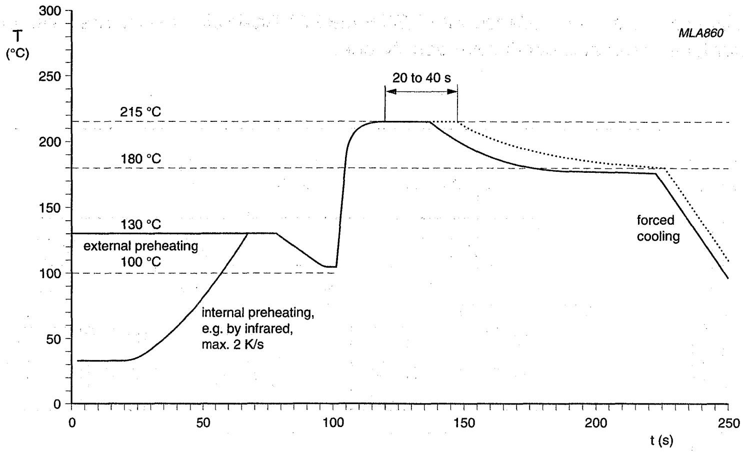
This SMD thermistor is only suitable for reflow soldering, in accordance with *"CECC 00802"*. Soldering processes which can be used are reflow (infrared and convection heating) and vapour phase. The maximum temperature of 260 °C during 10 s should not be exceeded and no liquid flux should be allowed to reach the ceramic body.

Typical examples of a soldering processes that will provide reliable joints without damage, are shown in Figs 5 and 6.



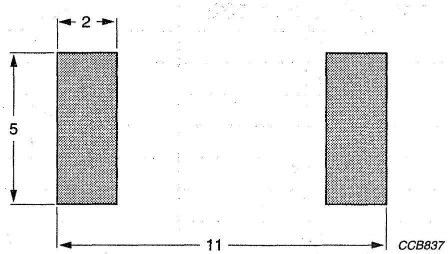
Typical values (solid line).
Process limits (dotted lines).

Fig.5 Reflow soldering.



Typical values (solid line).
Process limits (dotted line).

Fig.6 Vapour phase soldering.



Dimensions in mm.

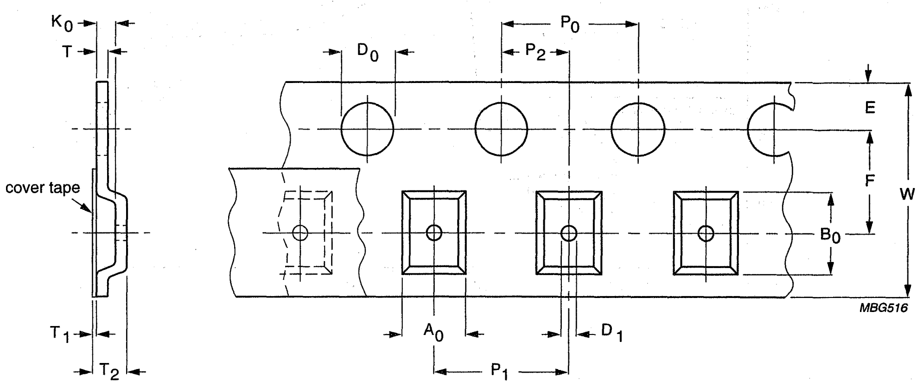
Fig.7 Dimensions of the solder lands.

PACKAGING

Tape and reel specifications

All tape and reel specifications are in accordance with *"IEC 60286-3"*. Basic dimensions are given in Figs 8 and 11, and Tables 4 and 5. Carrier tape material is conductive polystyrene.

Blister tape



Cumulative pitch error: 0.2 mm over 10 pitches.
Cumulative tolerance over 10 holes: ±0.2 mm.
For dimensions see Table 4.

Fig.8 Blister tape.

Table 4 Dimensions of blister tape; see Fig.8

SYMBOL	PRODUCT SIZE CODE	TOL.	UNIT
A_0; note 1	7.5	±0.1	mm
B_0; note 1	10.5	±0.1	mm
K_0	4.1	±0.1	mm
W	16	±0.3	mm
E	1.75	±0.1	mm
F	7.5	±0.1	mm
D_0	1.5	+0.1/–0.0	mm
D_1	1.5	+0.1/–0.0	mm
P_0; note 2	4	±0.1	mm
P_1	12	±0.1	mm
P_2	2	±0.1	mm
T tape thickness	0.3	±0.03	mm
T_1 cover tape	0.05	–	mm
T_2	4.6	max.	mm

Notes

1. Measured 0.3 mm above base pocket.
2. P_0 pitch tolerance over any 10 pitches is ±0.2 mm.

Leader/trailer tape specification

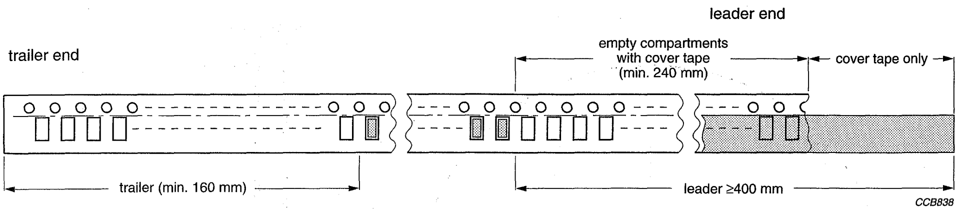


Fig.9 Leader/trailer tape.

Taping package requirements

Component is free and not sticking to top and/or bottom tape.

Component should be easy to remove from carrier tape.

Peel-off force

Peel-off force of blister tape is in accordance with *"IEC 60286-3"*; that is, 0.1 to 1.3 N at a peel-off speed of 300 mm/minute.

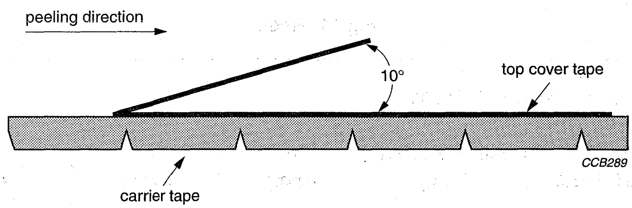
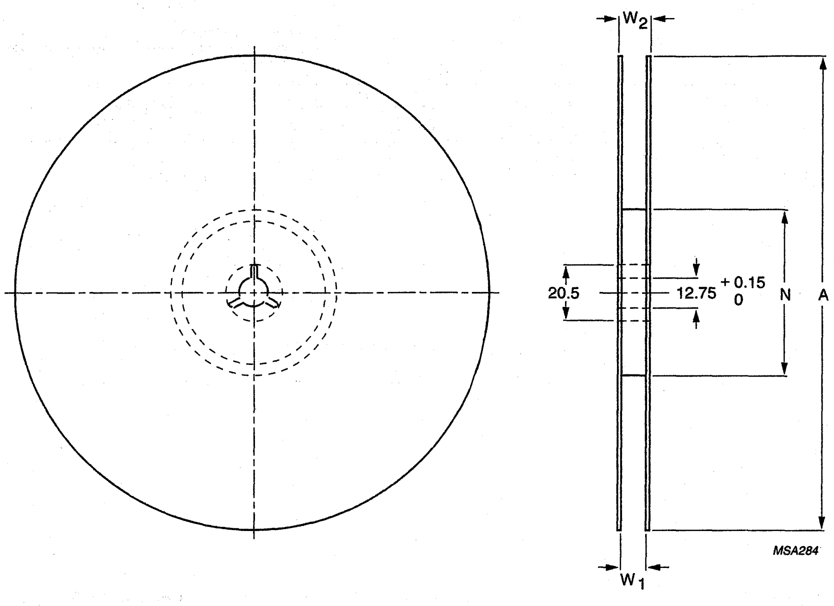


Fig.10 Peel-off force.

REEL SPECIFICATIONS



Dimensions in mm.
For reel dimensions see Table 5.

Fig.11 Reel.

Table 5 Reel dimensions; see note 1 and Fig.11

PRODUCT SIZE CODE	UNITS(2) PER REEL	TAPE WIDTH (mm)	A (mm)	N (mm)	W_1 (mm)	W_2 MAX. (mm)
4028	1500	16	330	62	16.4	20.4

Notes

1. Reels are packed in sealed plastic bags for protection against high humidity and corrosive atmospheres.
2. For matched components it is possible to have a maximum of one incomplete reel per resistance group. The minimum packaging quantity will be 500 units, with an even 100 up to 1400.

FEATURES

- Reliable starting, time and time again
- Accurate resistance for ease of circuit design
- Small size and durable
- Available bulk-packed or taped-on-reel
- Long life: more than 20000 starts for a 20 W lamp
- Low self-inductance for high frequency applications.

APPLICATIONS

- Domestic electronics
- Industrial electronics.

DESCRIPTION

The conventional fluorescent strip lamp is rapidly being superseded by a more compact fluorescent lamp in which the old troublesome starter is replaced by an electronic ballast circuit which pre-heats the cathode to make ignition easy.

Positive Temperature Coefficient (PTC) thermistors for overload protection have proved to be the ideal electronic ballast component for companies worldwide.

When the rectified mains is first applied, the PTC thermistor is cold, so its resistance is low. The lamp voltage will be below the necessary ignition value, so the current will flow through the cathodes, heating them to their emission temperature. At the same time, the PTC thermistor will heat up to its switch temperature, whereupon its resistance will rise rapidly, allowing the lamp voltage to reach its ignition value and light the lamp.

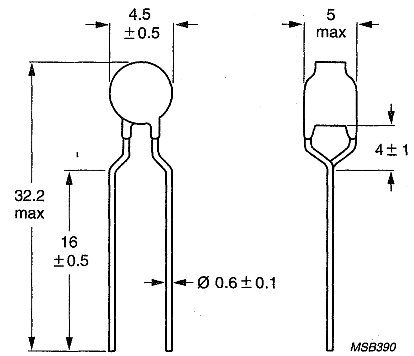
Once the lamp is lit, the cathodes are fed by a high-frequency (36 kHz) lamp supply, to avoid flicker, via two power FET switches; see Fig.4. The PTC thermistor plays no further part until the lamp is switched off, whereupon it is ready to resume its smooth-starting function.

We supply a range of overload PTC thermistors for this application (see Table 2) offering a wide choice of voltage and switch temperatures.

MOUNTING

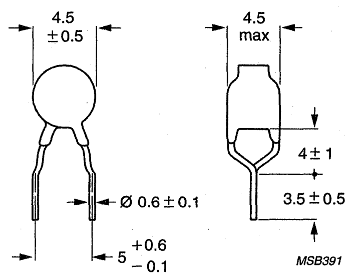
The leads are suitable for soldering in any position. The lacquer may cover the leads up to 1.0 mm from the seating plane.

MECHANICAL DATA



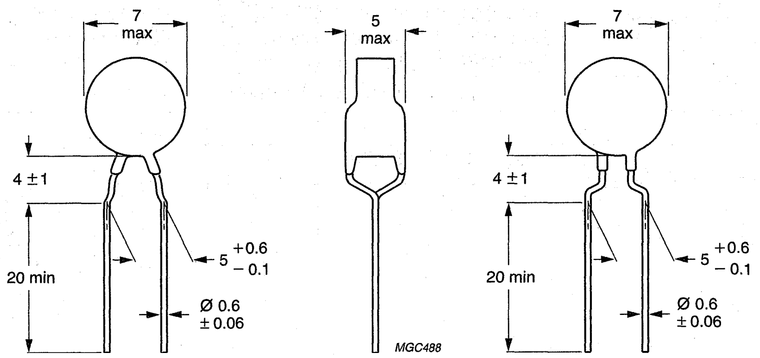
Dimensions in mm.

Fig.1 Component outline for 2322 660 93055 and 2322 660 93066 taped on reel.



Dimensions in mm.

Fig.2 Component outline for 2322 660 93049; packaged in bulk.



Dimensions in mm.

Fig.3 Component outlines for 2322 661 93102; packaged in bulk.

Table 1 Device diameter, mass, packaging quantities and catalogue numbers

DIAMETER (mm)	MASS (g)	PACKAGING	SPQ	PQ	CATALOGUE NUMBER
4.5	≈0.33	bulk	500	10000	2322 660 93049
4.5	≈0.45	on tape	3000	3000	2322 660 93055
4.5	≈0.45	on tape	3000	3000	2322 660 93066
7	≈0.66	bulk	250	5000	2322 661 93102
7	≈0.66	on tape	3000	3000	2322 661 93114

ELECTRICAL DATA

Table 2 PTC for PLC-E lamp electronic starter and HF-TL ballast; see Fig.4

R_{25} (Ω) MIN.	R_{25} (Ω) MAX.	SWITCH TEMPERATURE (°C)	MAXIMUM VOLTAGE (PEAK VALUE) (V)	TYPICAL(3) TRIP TIME at 25 °C t_t (s)	TYPICAL(3) TRIP TIME at 25 °C at I_t (mA)	CATALOGUE NUMBER 2322 66. .....
500	750	≈110	700	0.4	200	0 93049; note 1
185	300	≈120	700	0.5	300	0 93055; note 1
75	125	≈80	700	0.7	300	0 93066; note 1
225	375	≈105	1000	0.75	300	1 93102; note 2
75	125	≈105	650	0.85	500	1 93114; note 2

Notes

1. Specific for PLC-E lamp electronic starter.
2. Specific for HF-TL ballast.
3. Ignition time of the lamp approximately equals the tripping time.

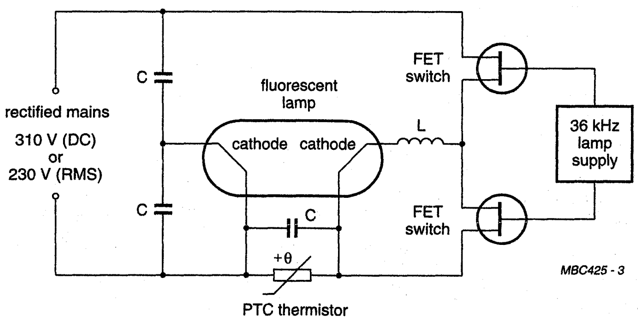


Fig.4 Typical electronic ballast circuit.

FEATURES AND BENEFITS

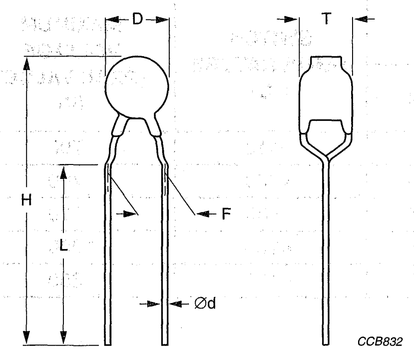
- Fast response time for rapid protection
- Automatic resetting once overload is removed
- No contacts to burn out
- No thermal runaway
- Operates on DC or AC voltage
- Small size and rugged construction; see Fig.1.

DESCRIPTION

Test and measuring instruments, such as oscilloscopes and digital multimeters, can be easily damaged if excessive voltages are applied across their input terminals.

Simple and effective overload protection can be provided by connecting a high-voltage PTC thermistor in series with the instrument; see Fig.2. Under normal conditions, the resistance of the PTC thermistor is low, so the test voltage will be measured by the instrument. Under an overload condition, the PTC thermistor will switch to its high-resistance state, absorbing the overload current and protecting the instrument. When the overload is removed, the PTC thermistor will return to its low-resistance state, ready to resume its protective function.

MECHANICAL DATA



Dimensions in mm.
For dimensions, see Table 1.

Fig.1 Component outline.

Table 1 Physical dimensions; see Fig.1

H (mm)	L (mm)	D MAX. (mm)	T MAX. (mm)	F (mm)	d (mm)	CATALOGUE NUMBER
30 ±3	20 ±3	5	4.5	5.08	0.6	2322 660 93034
15.5 ±1.5	3.1 ±0.5	10	6.5	8.12	0.8	2322 661 93113

Table 2 Mass, packaging quantities and catalogue numbers

MASS (g)	SPQ	PQ	CATALOGUE NUMBER
≈0.47	500	10000	2322 660 93034
≈1.82	500	10000	2322 661 93113

ELECTRICAL DATA

Table 3 Electrical data and catalogue numbers

NON-TRIP CURRENT (RMS VALUE) at 25 °C (mA)	TRIP CURRENT (RMS VALUE) at 25 °C (mA)	NOMINAL RESISTANCE at 25 °C (Ω)	MAXIMUM(1) VOLTAGE (V)	INSULATION VOLTAGE (V)	CATALOGUE NUMBER
10	20	1600 ±300	600	–	2322 660 93034
10	50	400 ±100	600	>1000	2322 661 93113

Note

1. These PTCs can handle maximum voltage without series resistance.

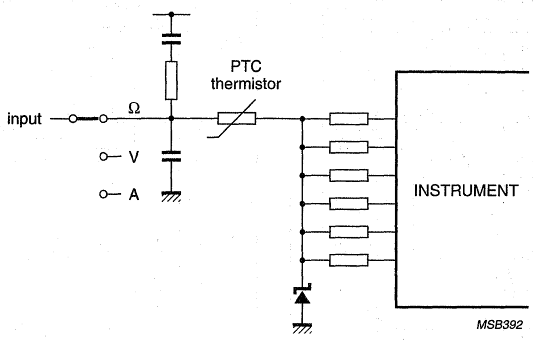


Fig.2 Typical connection of the PTC thermistor for digital multimeter protection.

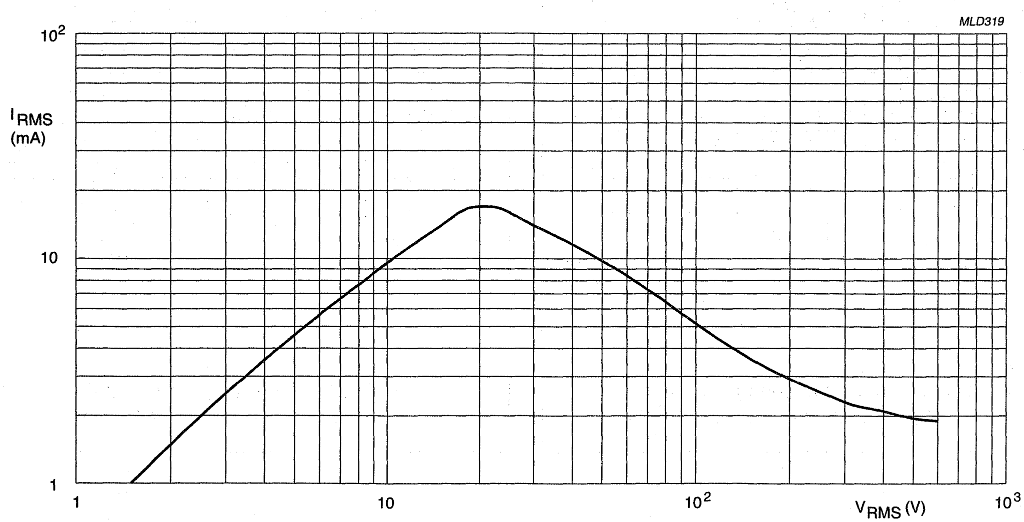


Fig.3 Typical current/voltage characteristic for 2322 660 93034.

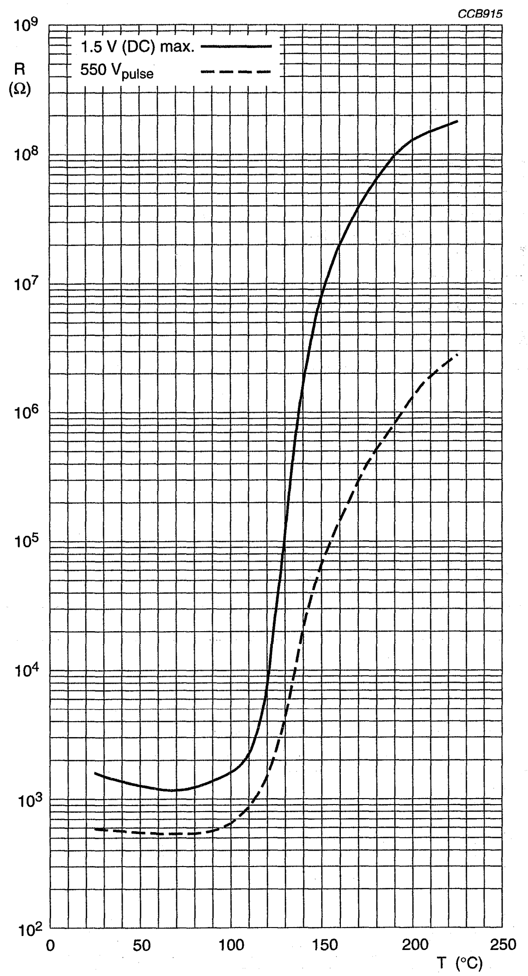


Fig.4 Typical resistance/temperature characteristic for 2322 660 93034.

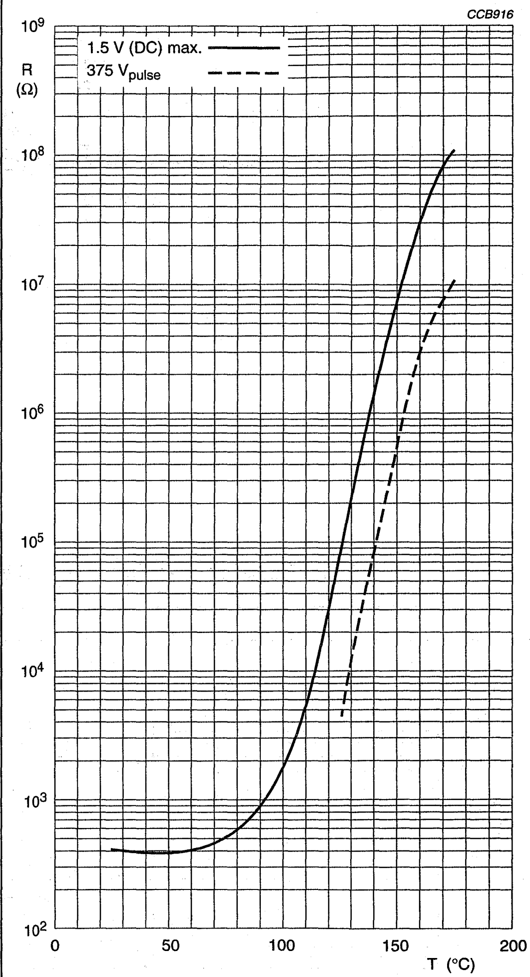


Fig.5 Typical resistance/temperature characteristic for 2322 661 93113.

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 switch
- Small size and rugged
- Naked and leaded devices available.

APPLICATIONS

- Industrial electronics
- Power supplies
- Electronic data processing
- Motor protection.

DESCRIPTION

Negative Temperature Coefficient (NTC) thermistors are well known for temperature sensing. What is not well known, however, is that Positive Temperature Coefficient (PTC) thermistors can be used for thermal 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 switch at one particular temperature. Just like thermostats they protect such equipment and components as motors, transformers, power transistors and thyristors against overtemperature. A PTC thermistor is less expensive than a thermostat, and its switch 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 thermistor resistance (R_p) is lower than R_s (see Fig.2), so the comparator's output voltage V_O will be low. If an equipment overtemperature occurs, the PTC thermistor will quickly heat up to its trigger or nominal reference temperature T_n, whereupon its resistance will increase to a value much higher than R_s, causing V_O to switch to a high level sufficient to activate an alarm, relay or power shutdown circuit.

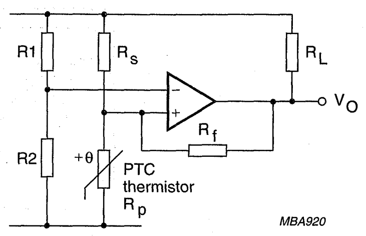


Fig.1 Typical comparator circuit.

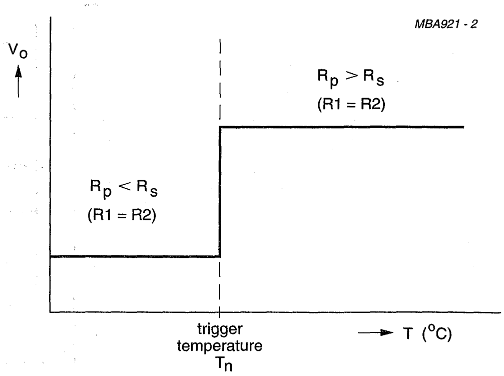
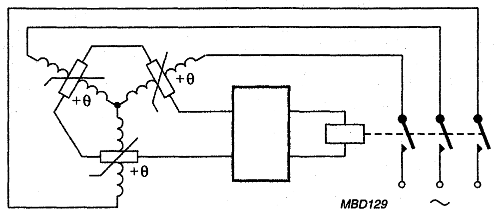


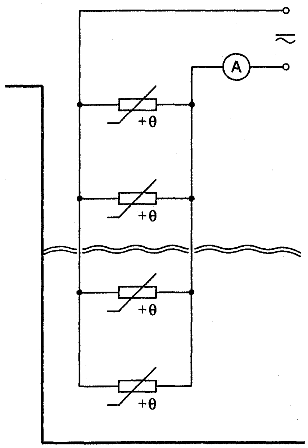
Fig.2 Typical switch characteristic.

APPLICATION EXAMPLES



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

Fig.3 Temperature protection of electric motors.



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

Fig.4 Liquid-level indication.

PTC thermistors for temperature protection T_n = 70 to 170 °C

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.

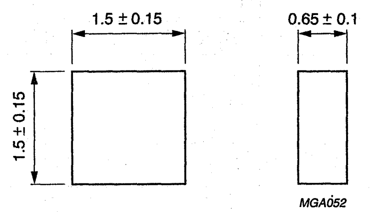
QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Maximum resistance at 25 °C	120	Ω
Minimum resistance at (T_n + 15) °C	4000	Ω
Maximum (DC) voltage	30	V
Temperature range	−20 to (T_n + 15)	°C
Weight:		
91052 to 91067	≈0.008	g
91002 to 91014	≈0.013	g
91102 to 91114	≈0.08	g
Climatic category	25/125/56	

PACKAGING INFORMATION

PACKAGING		CATALOGUE NUMBERS 2322 ... .
SPQ	PQ	
5000	20000	671 91052 to 671 91067
5000	20000	671 91002 to 671 91014
500	6000	671 91102 to 671 91114

MECHANICAL DATA

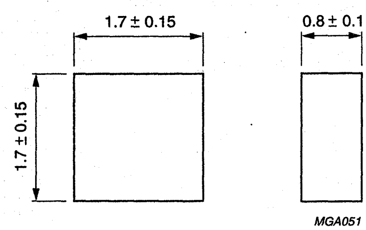


Dimensions in mm.

For clamping, reflow or hand soldering. Not intended for either wave or ultrasonic soldering and not for spot welding.

All standard solder alloys with low activated halogene-free fluxes are acceptable, for example: 62Sn/36Pb/2Ag.

Fig.1 Component outline for 91052 to 91067.

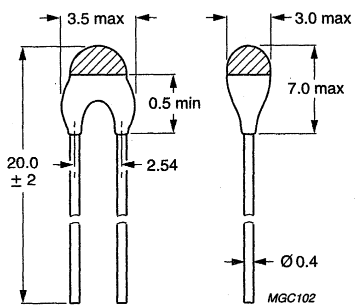


Dimensions in mm.

For clamping, reflow or hand soldering. Not intended for either wave or ultrasonic soldering and not for spot welding.

All standard solder alloys with low activated halogene-free fluxes are acceptable, for example: 62Sn/36Pb/2Ag.

Fig.2 Component outline for 91002 to 91017.



Dimensions in mm.

Fig.3 Component outline for 91102 to 91114.

PTC thermistors for temperature protection T_n = 70 to 170 °C

ELECTRICAL CHARACTERISTICS

PARAMETER	VALUES
Maximum resistance at 25 °C	120 Ω
Maximum resistance at (T_n – 5) °C	see Table 1
Minimum resistance at (T_n + 15) °C	4000 Ω
Minimum resistance at (T_n + 5) °C	see Table 1
Maximum voltage	30 V (AC or DC)

Table 1 Nominal working temperatures and ordering information

NOMINAL WORKING TEMPERATURE				TYPE/CATALOGUE NUMBER 2322			
				NAKED CHIP(1)(2)		LEADED DEVICE(3)	
T_n (°C)	RESISTANCE from –20 °C to T_n –20 °C (Ω)	RESISTANCE at T_n –5 °C (Ω)	RESISTANCE at T_n +5 °C (kΩ)	1.5 × 1.5 mm 671	1.7 × 1.7 mm 671	671	COLOUR CODE
70	30 to 250	50 to 570	0.570 to 50	91052(2)	91002(2)	91102(2)	black
80	30 to 250	50 to 550	1.33 to 50	91053	91003	91103	brown
90	30 to 250	50 to 550	1.33 to 50	91054	91004	91104	red
100	30 to 250	50 to 550	1.33 to 50	91055	91005	91105	orange
110	30 to 250	50 to 550	1.33 to 50	91056	91006	91106	yellow
120	30 to 250	50 to 550	1.33 to 50	91057	91007	91107	green
125	30 to 250	50 to 550	1.33 to 50	91058	–	–	–
130	30 to 250	50 to 550	1.33 to 50	91059	91009	91109	blue
135	30 to 250	50 to 550	1.33 to 50	91061	–	–	–
140	30 to 250	50 to 550	1.33 to 50	91062	91012	91112	violet
145	30 to 250	50 to 550	1.33 to 50	91063	–	–	–
150	30 to 250	50 to 550	1.33 to 50	91064	91014	91114	grey
155	30 to 250	50 to 550	1.33 to 50	91065	–	–	–
160	30 to 250	50 to 550	1.33 to 50	91066	–	–	–
170	30 to 250	50 to 550	1.33 to 50	91067	–	–	–

Notes

1. Naked chips are packed in a hermetically-sealed alu-plastic bag.
2. Smaller chip dimensions down to 1.0 × 1.0 mm are available on request.
3. Lug type devices are available on request.

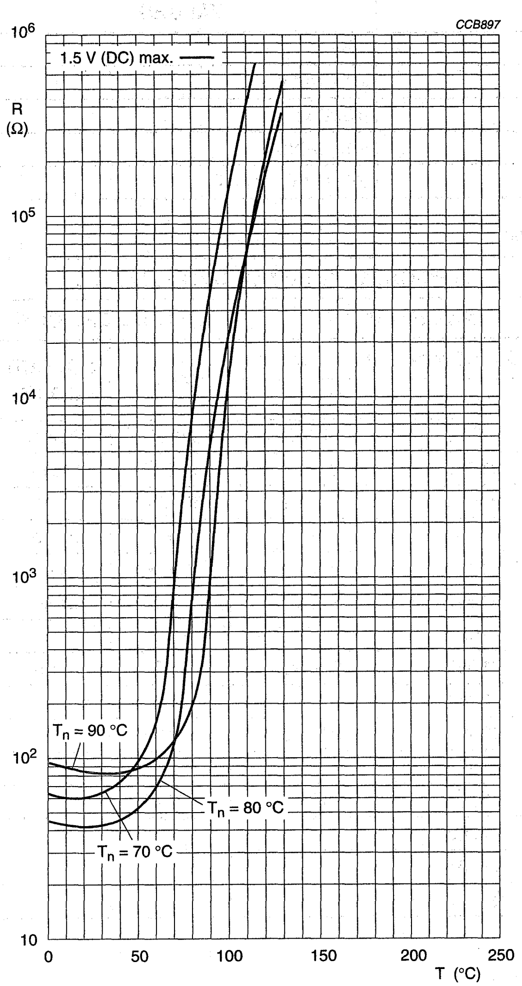


Fig.4 Typical resistance/temperature characteristic for 2322 671 91052/002/102, 91053/003/103 and 91054/004/104.

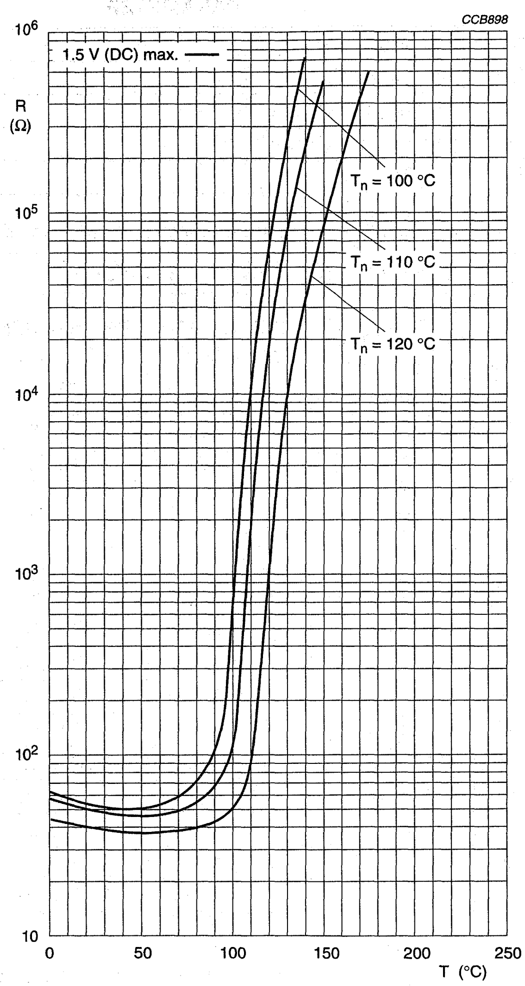


Fig.5 Typical resistance/temperature characteristic for 2322 671 91055/005/105, 91056/006/106 and 91057/007/107.

PTC thermistors for temperature protection T_n = 70 to 170 °C

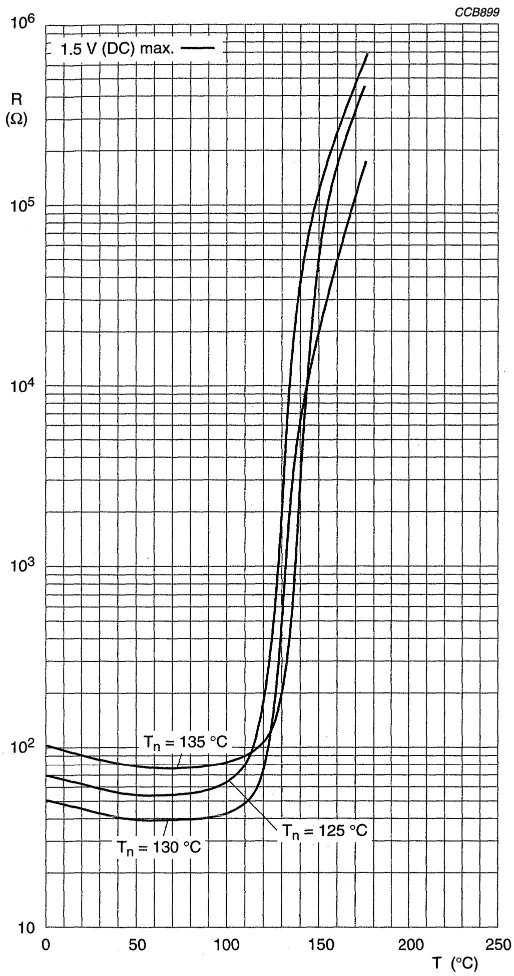


Fig.6 Typical resistance/temperature characteristic for 2322 671 91058, 91059/009/109 and 91061.

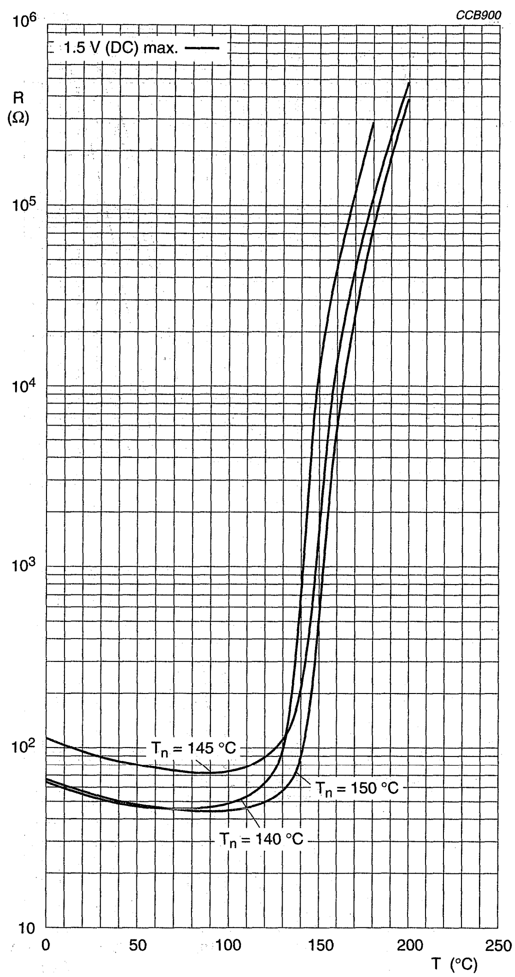


Fig.7 Typical resistance/temperature characteristic for 2322 671 91062/012/112, 91063 and 91064/014/114.

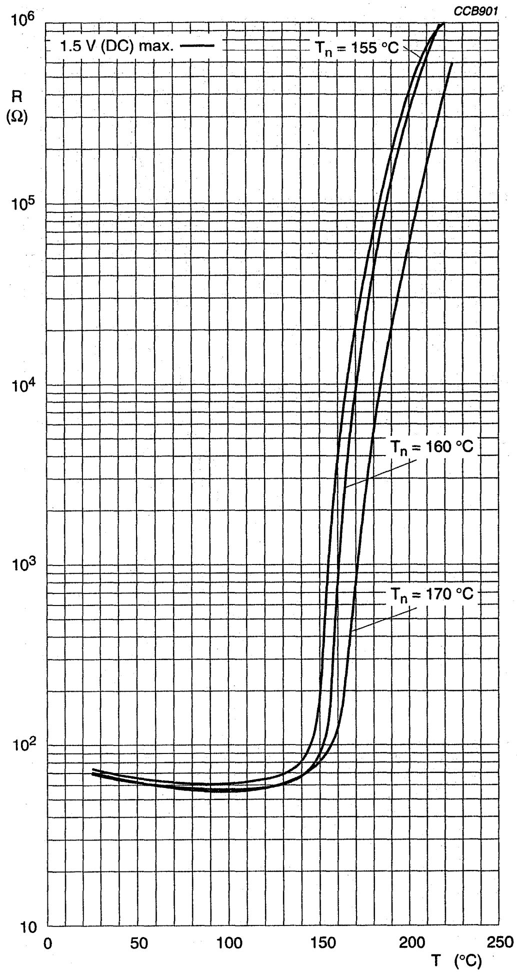


Fig.8 Typical resistance/temperature characteristic for 2322 671 91065, 91066 and 91067.

PTC thermistors for temperature protection T_n = 70 to 170 °C

TEST AND REQUIREMENTS

Clause numbers of tests and performance requirements refer to the *"IEC 60738-1-4"*.
Tables with requirements for lot-by-lot and periodic tests.
In these tables:
D = Destructive
ND = Non-destructive.

Acceptable quality level

IEC CLAUSE	TEST	D or ND	PROCEDURE	REQUIREMENTS
Group A inspection (lot-by-lot)				
SUB-GROUP A0		ND		
4.5	zero power resistance		temperature: 25 °C voltage: ≤1.5 V (T_n – 5) °C (T_n + 5) °C (T_n + 15) °C	30 to 120 Ω as specified as specified ≥4000 Ω
SUB-GROUP A1		ND		
4.4.1	visual examination			no defect likely to impair function
SUB-GROUP A2		ND		
4.4.3	dimensions (gauging)			as specified
Group B inspection (lot-by-lot)				
SUB-GROUP B2		D		
4.16.1	soldering, solderability		for 2322 671 91052 to 91067 and 91002 to 91017: solder bath: 60/40; 260 ±5 °C and RMA flux; duration: 30 s for 2322 671 91102 to 91114 and 91102 to 91114: solder bath method: 235 ±5 °C	75% of surface covered with solder the terminations shall be evenly tinned
Group C inspection (periodic)				
SUB-GROUP C1A		D		
4.15	robustness of terminations		for 2322 671 91102 to 91114: test Ua (10 N) and test Ub (5 N) of *"IEC 60068-2-21"* visual examination zero power resistance at 25 °C	 as in 4.12.4; see note 1 ΔR/R ≤±10%
4.16.2	resistance to soldering heat		for 2322 671 91102 to 91114: test Tb of *"IEC 60068-2-20A"* visual examination zero power resistance at 25 °C	 as in 4.13.2.3 ΔR/R ≤±10%

PTC thermistors for temperature protection T_n = 70 to 170 °C

IEC CLAUSE	TEST	D or ND	PROCEDURE	REQUIREMENTS
SUB-GROUP C1B		D		
4.17	rapid change of temperature, no load		for 2322 671 91052 to 91067, 91002 to 91017 and 91102 to 91114: test Na of *"IEC 60068-2-14"*	
			T_A: lower category temperature = −25 °C	
			T_B: upper category temperature = +125 °C	as in 4.17
			5 cycles	ΔR/R ≤±10%
			visual examination	as in 4.14.4
			zero power resistance at 25 °C	ΔR/R ≤±10%
SUB-GROUP C4		D		
4.23.2	endurance at upper category temperatures		for 2322 671 91002 to 91017 and 91052 to 91067: duration 168 hours at 200 °C	
			for 2322 671 91102 to 91114: duration 168 hours at 150 °C	
			for 2322 671 91002 to 91017, 91052 to 91067 and 91102 to 91114: duration 1000 hours at 125 °C	
			examination: at 168, 500 and 1000 hours	
			visual examination	as in 4.23.2
			zero power resistance at 25 °C	ΔR/R ≤±5%
SUB-GROUP D2		D		
4.23.3	endurance at maximum rated temperature		duration: 24 hours at (T_n + 15) °C and 30 V (DC)	
			examination: at 24 hours	
			visual examination	as in 4.23.3
			zero power resistance at 25 °C	ΔR/R ≤±10%
SUB-GROUP D3		D		
4.22	damp heat, steady state, no load		visual examination	as in 4.22
			zero power resistance at 25 °C	ΔR/R ≤±10%

Note

1. No loose or broken leads.

PTC thermistors for degaussing

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 improvement is in degaussing the tube. By using our dual Positive Temperature Coefficient (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 three main requirements for degaussing colour televisions and monitors are:

- High inrush current, into the degaussing coil
- Slow current decrease per half wave (long decay)
- Low residual current, after degaussing.

The larger the ratio of inrush current to residual current (degaussing ratio) the better the degaussing. These basic features, together with a long smooth decay can demagnetize even the largest picture tubes. As inventors and leaders in dual PTC thermistors, we have perfected their manufacture and acquired a comprehensive knowledge of optimizing degaussing circuits.

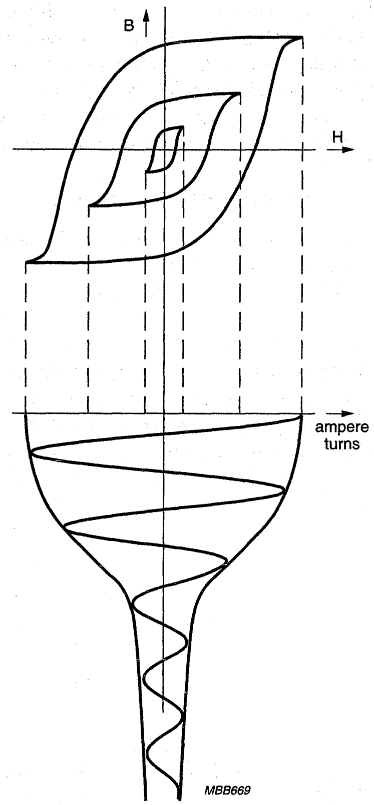


Fig.1 Typical BH curve of shadow mask and corresponding ampere-turns in the degaussing coil.

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; see Fig.5.

Degaussing with mono PTC thermistors

Connecting a PTC thermistor (mono PTC) in series with the AC mains and degaussing coil (see Fig.2) 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; see Fig.5. 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; see Fig.5.

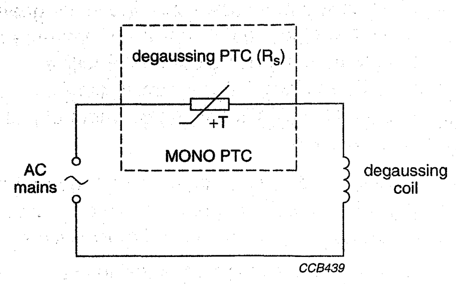


Fig.2 Mono PTC arrangement.

Degaussing with 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 connected in series with the degaussing coil; see Fig.3. 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, the two thermistors are carefully matched and clamped in close thermal contact inside a PBTP (polybutyleneteraphthalate) case.

The plastic composition of the case is self-extinguishing in accordance with *"UL 94.V.O"*.

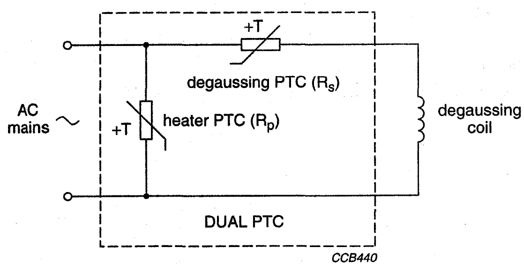


Fig.3 Dual PTC arrangement.

Degaussing with double mono PTC thermistors

A double mono PTC thermistor consists of a parallel combination of two degaussing PTC thermistors in one standard Philips 3-pin housing. This component offers substantial benefits compared to a single PTC degaussing thermistor. Inrush currents can be higher than with normal dual or mono degaussing PTC thermistors and by doubling the normal ceramic volume, a smoother decay is obtained. Decay times of up to 200 ms or maximum current decrease of 20% are possible.

Using a double mono PTC thermistor makes extra cost reductions possible. Due to a higher inrush current capability, the weight of the coil can be reduced by lowering the numbers of windings or reducing the guage of the degaussing coil wire.

Combining single PTC thermistors of low value (<8 Ω) with low coil impedances can lead to very short decay times, which give a bad degaussing performance and unreliable operation. The double mono principle will give you good decay time, even with the highest inrush currents. The two PTCs together have the equivalent ceramic volume of a 17 to 19 mm diameter single disc.

For degaussing large-screen or high resolution picture tubes, sometimes two dual or mono cased PTC thermistors are needed for a good decay performance. By using the double mono PTC thermistor, less board space is needed and the mounting costs can be reduced. The use of double mono PTCs is usually combined with a switch-off circuit for the degaussing function.

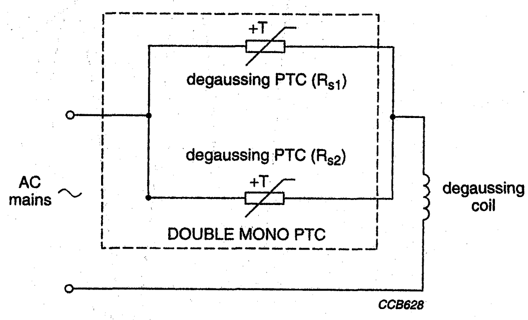
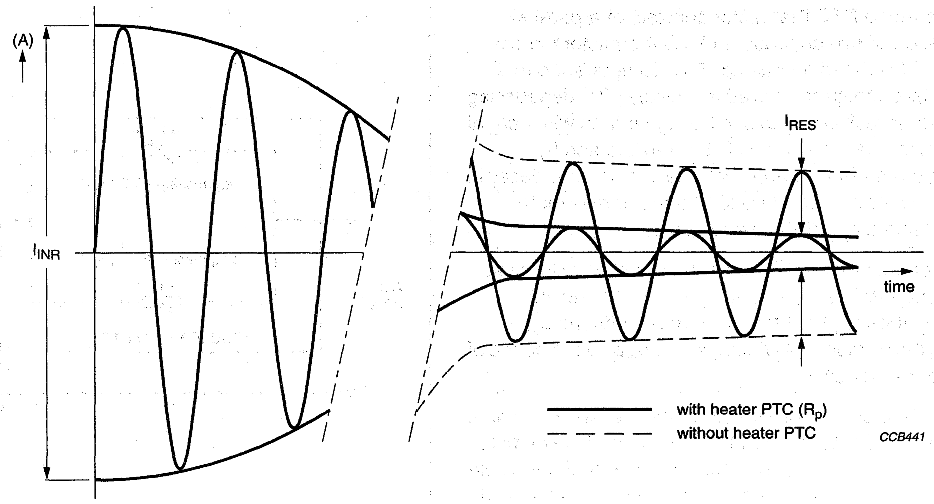
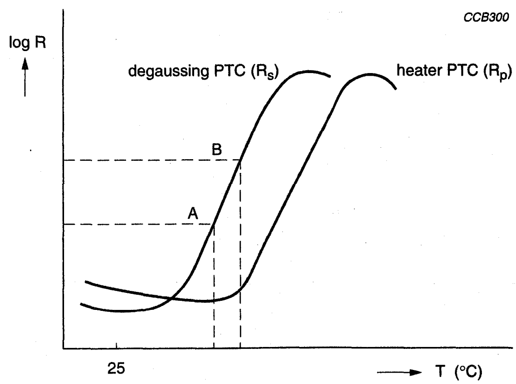


Fig.4 Double mono PTC arrangement.



I_{INR} = inrush current [A_{p-p}].
I_{RES} = residual current [mA_{p-p}].

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



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

Fig.6 Typical R/T characteristics for a dual PTC.

Derating

Figures 7 to 13 show typical degaussing data at other parameters than those indicated in the *"Product data"*.

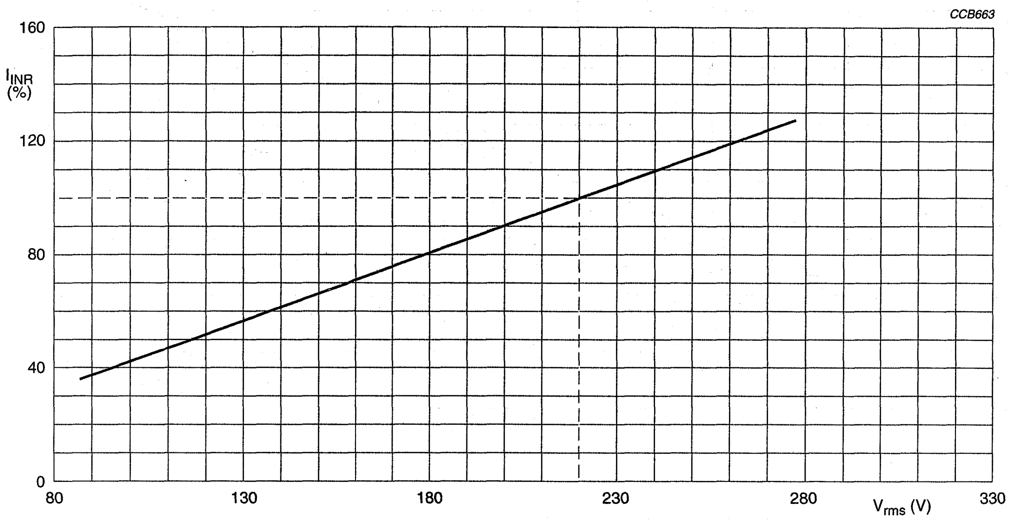


Fig.7 Typical inrush current as a function of mains voltage.

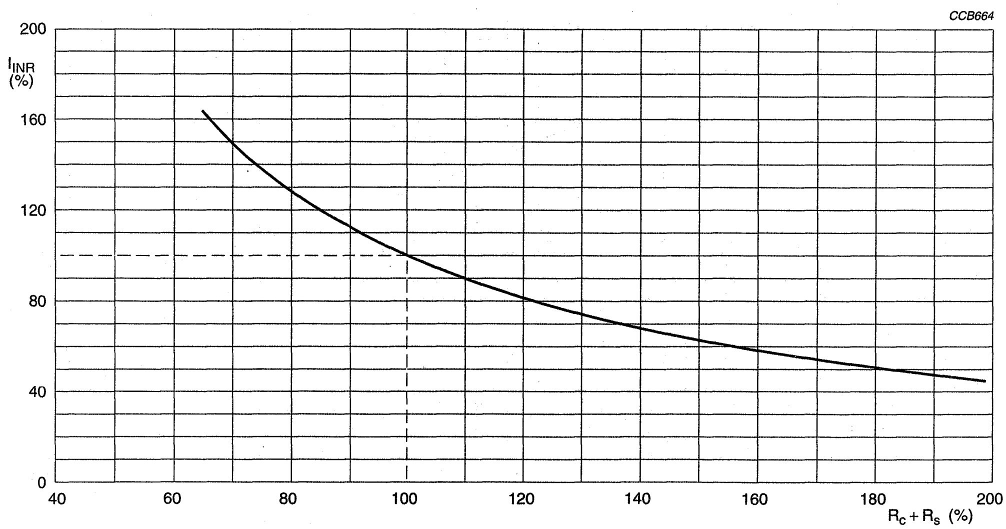


Fig.8 Typical inrush current as a function of $R_c + R_s$ variation.

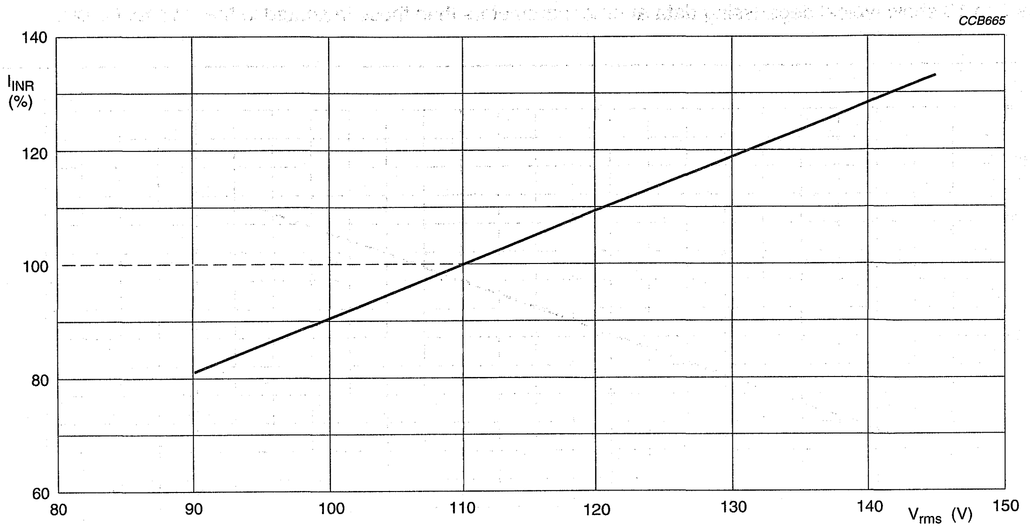


Fig.9 Typical inrush current as a function of mains voltage.

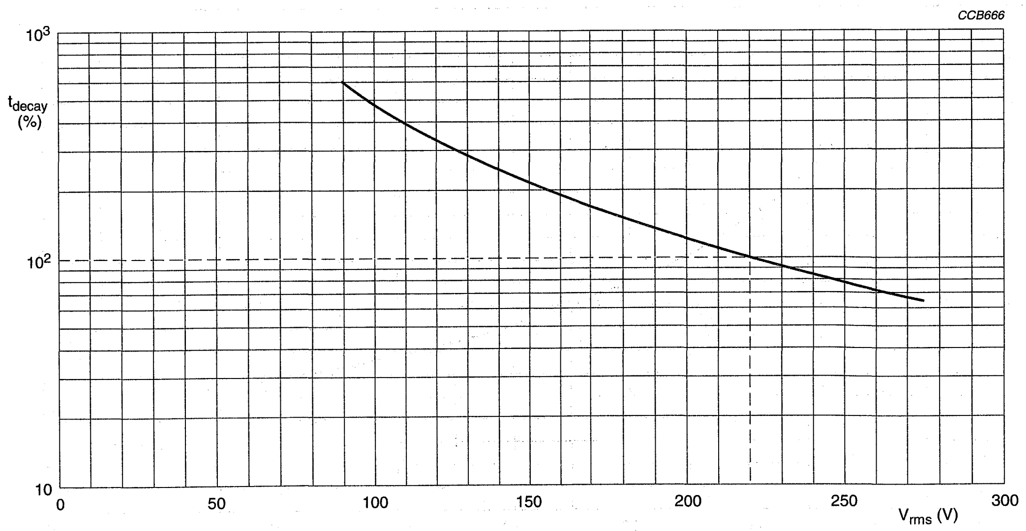


Fig.10 Typical decay time as a function of mains voltage.

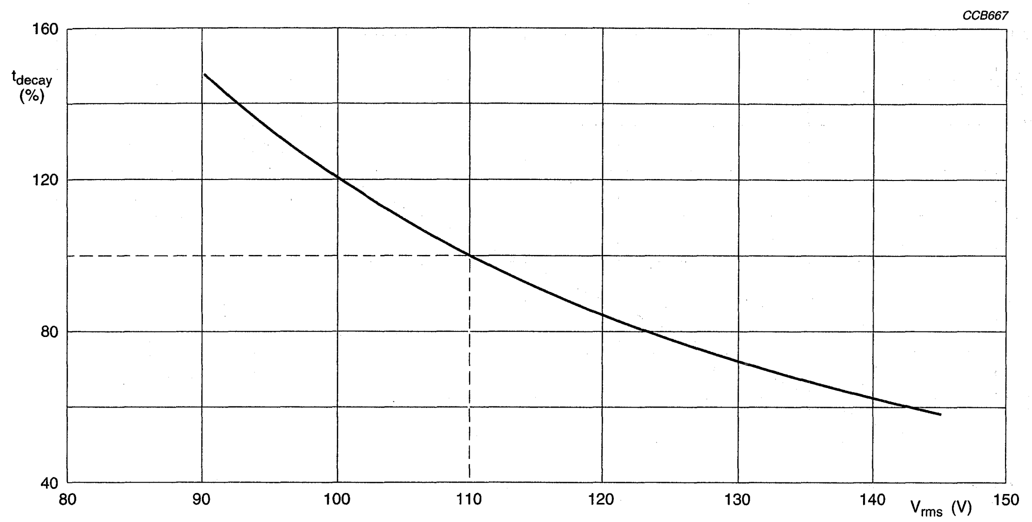


Fig.11 Typical decay time as a function of mains voltage.

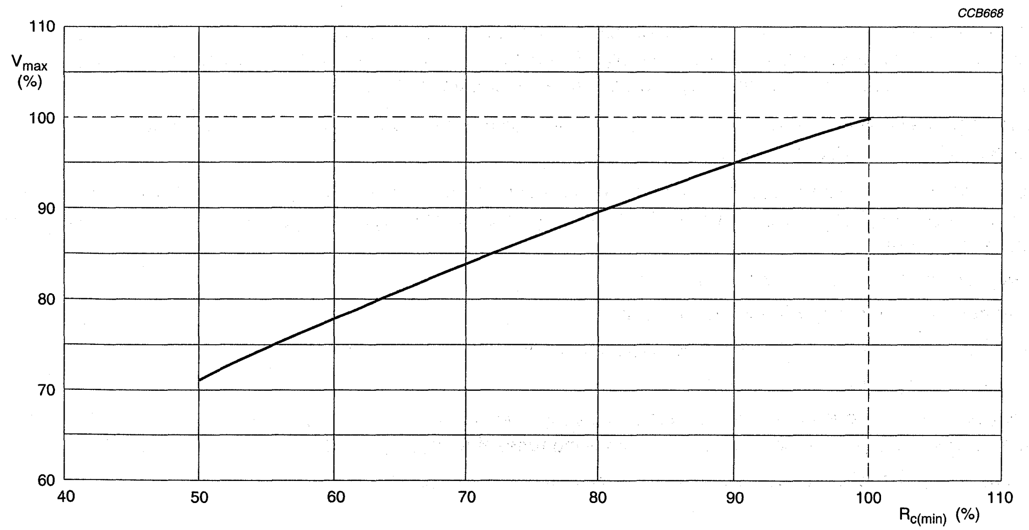


Fig.12 Variation of V_{max} as a function of R_c minimum.

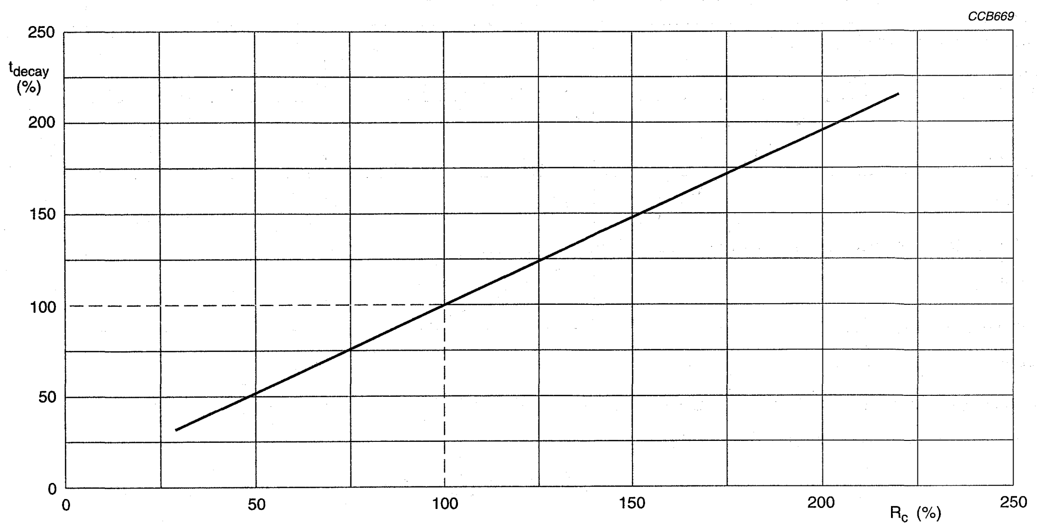


Fig.13 Typical decay time as a function of R_c.

OPTIMUM SOLUTIONS IN DEGAUSSING

As a major manufacturer of PTC thermistors for degaussing, BC Components has a wealth of experience in the degaussing of picture tubes and monitor tubes. Experience that we readily share with our customers to help them arrive at optimum cost-effective degaussing solutions and speed their time to market.

Optimum degaussing solutions are a compromise between picture tube requirements and a cost-effective combination of degaussing PTC and degaussing coil.

Optimum solutions can be calculated by using a specific software tool. By completing the questionnaire on the following page we can make an optimal selection of a PTC and/or coil for a specific degaussing circuit. The minimum requirements for a proposal include:

- Screen size and format (4 : 3 or 16 : 9).
- Mains voltage and maximum operating voltage.
- Initial magnetomotive force (MMF) required to saturate the tube and final MMF.
- Final MMF required for optimum resolution.
- Current decay characteristics expressed either as decay time or as decrease of current per half wave (the default value is 30% for general-purpose picture tubes; for high-end tubes the default is 20%).
- Coil details (number of coils, dimensions, wire material and thickness, number of turns, coil resistance).

QUESTIONNAIRE DEGAUSSING CIRCUIT DESIGN

Please mark the appropriate boxes and/or fill in the numbers and values.

Application design environment

Application	❑ colour television		❑ colour monitor
Screen ratio	❑ 4 : 3		❑ 16 : 9
Main voltage	❑ 120 V_{RMS} ±10%		❑ 230 V_{RMS} ±10%
Maximum voltage	❑ 145 V_{RMS}		❑ 276 V_{RMS}

Picture tube degaussing requirements

Picture tube (type)			
Dimensions (screen diagonal)		inches	cm
Degaussing quick reference:			
initial magnetomotive force MMF (ampere peak-peak turns)		$A_{p\text{-}p}W$	
final magnetomotive force MMF (ampere peak-peak turns)		$A_{p\text{-}p}W$	
degaussing	❑ decrease of current	% (default 30%)	
	❑ decay time	ms or	cycles

Degaussing coil(s) currently used on picture tube

Degaussing coil parameters:			
material	❑ copper (default)		❑ aluminium
number of degaussing coil(s)			
length		cm	
diameter (winding wheel)		cm	
resistance		Ω	
number of turns			
wire diameter		mm	

Special attention points/remarks

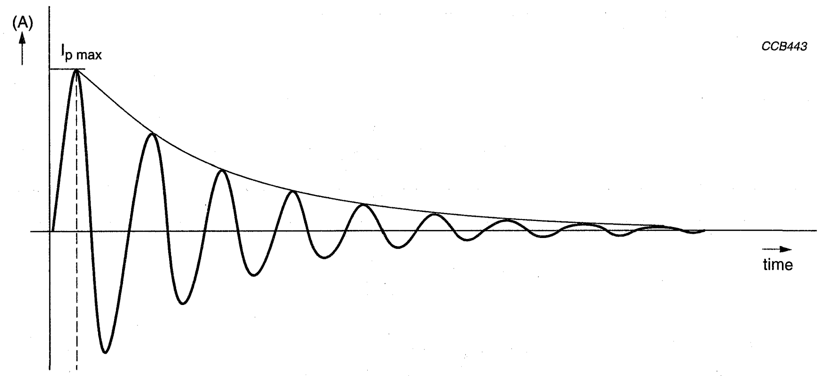
Power management	❑ green design; degaussing circuit switches off:		
	❑ after	seconds	❑ in standby mode
	❑ no switch-off		
Global colour television/colour monitor (90 to 276 V_{RMS})	❑ yes		❑ no

CAPABILITY AND SELECTION

VOLTAGE RANGE(1) (V)	MONO/DUAL RANGE			DOUBLE MONO RANGE		
	R_s (Ω)	MINIMUM PEAK-TO-PEAK INRUSH CURRENT(1) (A)	DECAY(1)(2) TIME (ms)	$R_{s1}//R_{s2}$ (Ω)	MINIMUM PEAK-TO-PEAK INRUSH CURRENT(1) (A)	DECAY(1)(2) TIME (ms)
100 to 120	7 to 3	19 to 30	80 to 115	3.5 to 1.5	27 to 39	>100
220 to 240	30 to 7	10 to 25	40 to 115	9.0 to 3.5	33 to 36	80 to 135

Notes

1. Measurements are done at 50 Hz which guarantees a performance of 60 Hz.
2. Decay time is the time from the moment of maximum peak current until half of the maximum peak inrush current.



I_p = peak current [A].
$I_{p\,max}$ = maximum peak current [A].

Fig.14 Typical inrush current.

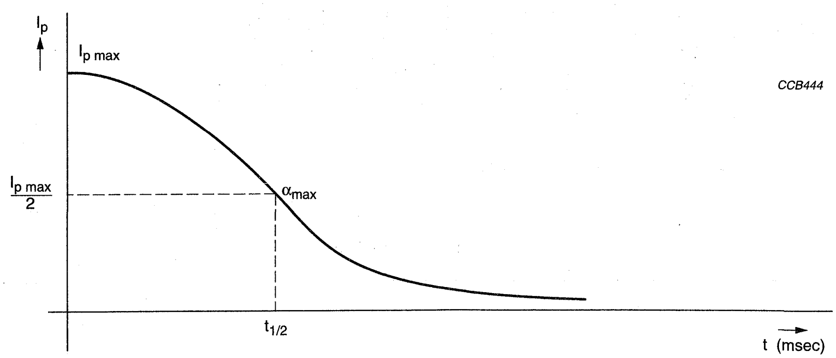
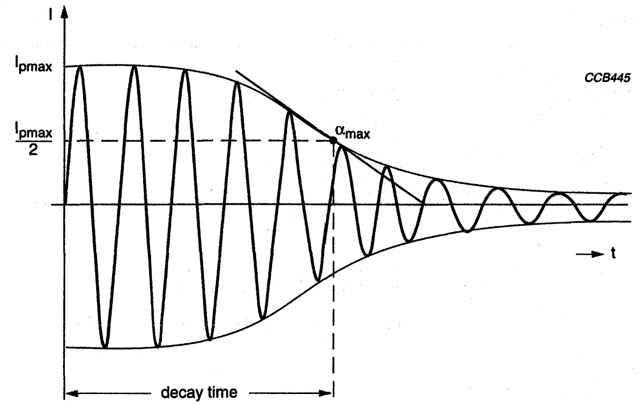


Fig.15 Decay time.

Decay examples



I_p = peak current [A].
$I_{p\,max}$ = maximum peak current [A].

Fig.16 Normal decay.

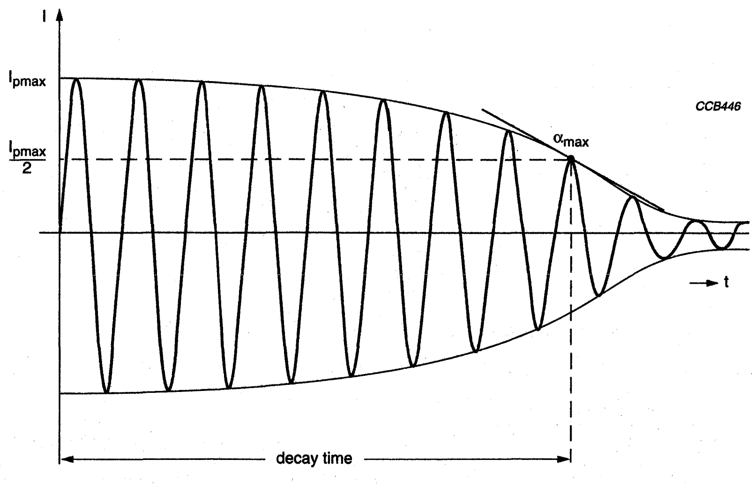


Fig.17 Long decay.

CONSTRUCTION

The dimensions of the ceramic are just for reference and might vary according to the PTC degaussing type.

Mono cased PTC degaussing

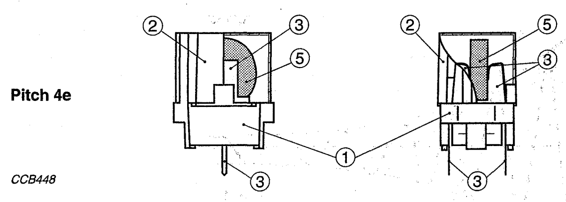


Fig.1 Mono cased PTC degaussing.

Dual cased PTC degaussing

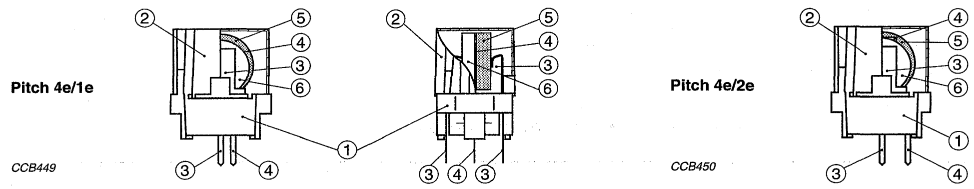


Fig.2 Dual cased PTC degaussing.

Double mono cased PTC degaussing

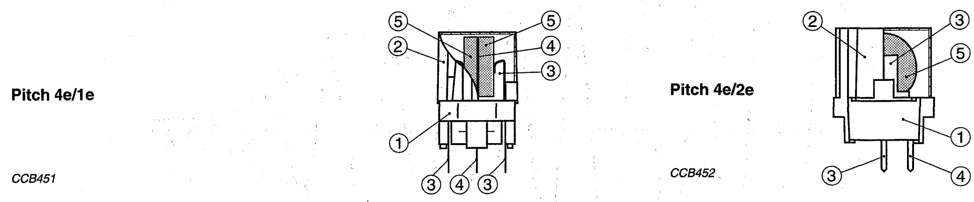


Fig.3 Double mono cased PTC degaussing.

Table 1 Material information; see Figs 1, 2 and 3

NUMBER	DESCRIPTION	MATERIAL AND REMARKS
1	base	glass fibre reinforced polybutyleneteraphtalate (PBTP); self-extinguishing according to *"UL 94 V-0"*, UL number E69578(M) or equivalent
2	cap	
3	spring contact (outer)	corrosion resisting steel with nickel/silver flash; pin termination in Sn60Pb40 coated
4	central contact	
5	degaussing PTC thermistor (R_S)	$BaTiO_3$ doped
6	heater PTC thermistor (R_P)	

MONO, DUAL AND DOUBLE MONO RANGE

Table 2 Dimensions and pin configuration; see Figs 4, 5 and 6

CAP	H (mm)	PRODUCT TYPE			
		MONO	DUAL		DOUBLE MONO
		4e	4e/1e	4e/2e	4e/2e
Low cap	18.4 ±0.4	2322 662 9628.	2322 662 962..	2322 662 963..	–
High cap	20.5 ±0.4	2322 662 9668. 2322 662 9669.	2322 662 966..	2322 662 967..	2322 662 9675.

Pin configuration

Table 3 Mounting on metallized side of the PCB

CONNECTION	PRODUCT TYPE		
	MONO	DUAL	DOUBLE MONO
Mains	point A	points A and B	point B
Coil(s)	point B	points A and B	points A and C

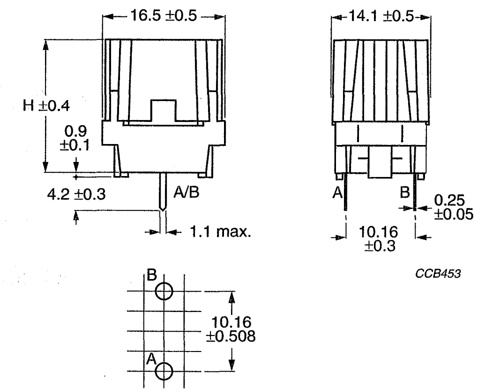


Fig.4 Mono; 4e pitch.

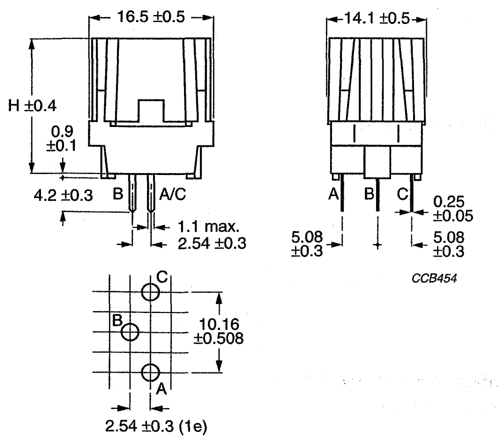


Fig.5 Dual;4e/1e pitch.

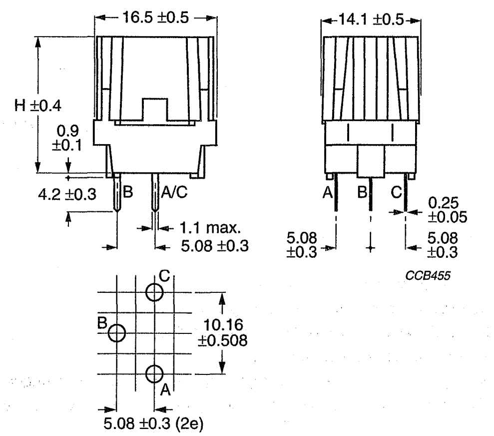
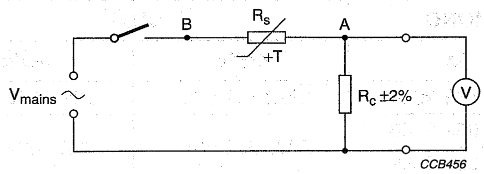


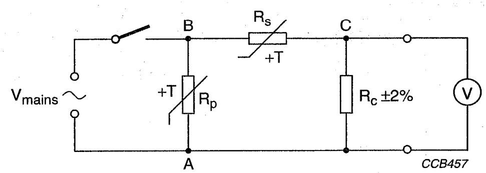
Fig.6 Dual and double mono; 4e/2e pitch.

ELECTRICAL DATA

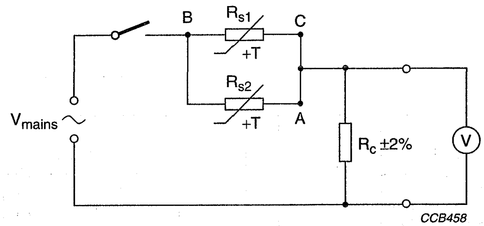
Measuring circuits



a. Mono cased PTC degaussing.



b. Dual cased PTC degaussing.



c. Double mono cased PTC degaussing.

V = A/D converter or oscilloscope.
R_s = resistance of series PTC or degaussing PTC.
R_p = resistance of parallel PTC or heater PTC.
R_c = replaces the degaussing coil.
V_{mains} = AC power source with high output current capability; frequency = 50 Hz ±1%; total harmonic distortion < 2%.
For residual current measurement the R_c resistor can be increased to 100 Ω 1%, 30 s after inrush.

Fig.7 Measuring circuits.

MASS

PTC DEGAUSSING	MASS	
	PER UNIT (g)	PER BOX OF 600 units (kg)
Dual or double mono	≈5.0	≈3.6
Mono cased	≈4.2	≈3.0

MARKING

Product marking

The thermistors are manufactured in Belgium and assembly is either in Belgium or Indonesia (Batam).

The products are marked on the top with the last five digits of the catalogue number, code of manufacturer and the date code (year, week and day of manufacture).

Assembled in Belgium

MARKING	DESCRIPTION
96724	last 5-digits of code number
PH	code of manufacturer
98141	manufacturing date (YYWWD)

MARKING EXAMPLE

96724

PH98141

Assembled in Indonesia (Batam)

MARKING	DESCRIPTION
PH	code of manufacturer
96724	last 5-digits of code number
SP	code of assembler
98141	manufacturing date (YYWWD)

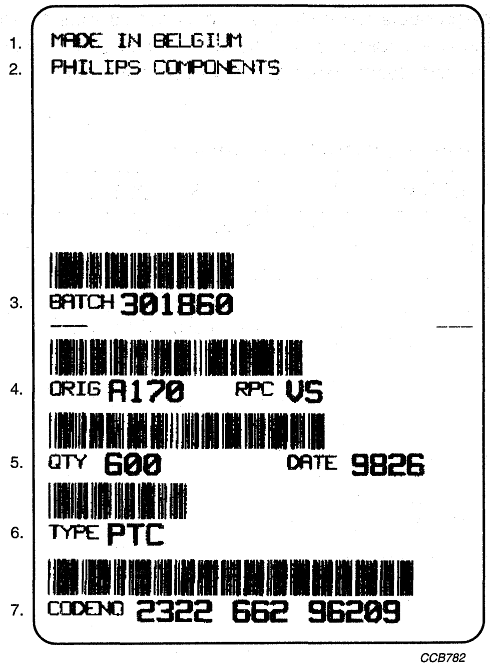
MARKING EXAMPLE

PH96724

SP98141

Package marking

The package containing the thermistors marked as shown in Fig.10.



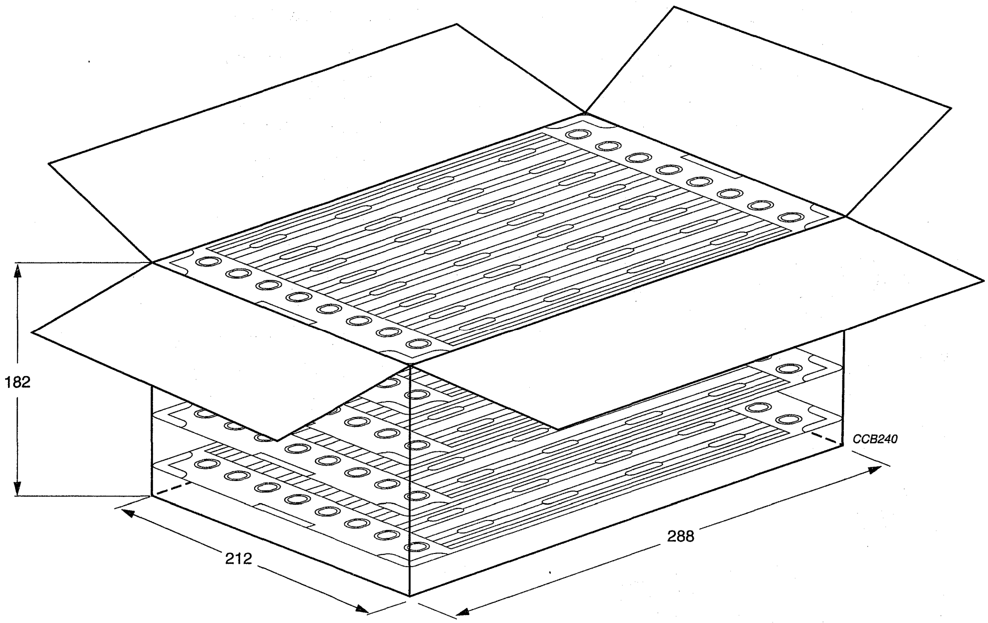
Barcode label marking

LINE	MARKING EXPLANATION
1	Country of origin
2	Name of manufacturer
3	Batch number
4	Preference origin code: A Country of origin in code: 170 (Belgium) Responsible production centre: VS
5	Quantity and production period, year and week code
6	Product type description
7	Product code (12NC)

Fig.10 Barcode label.

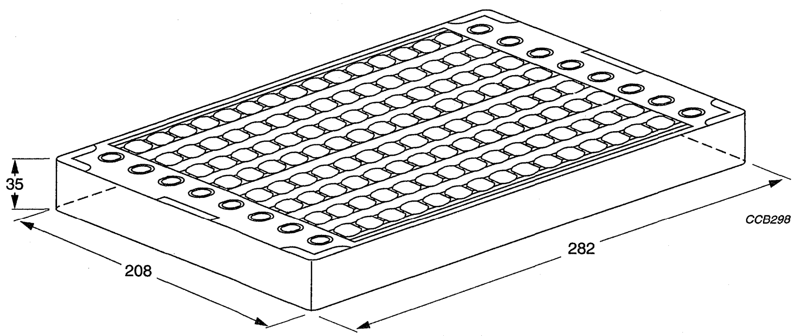
PACKAGING

The thermistors are supplied in cardboard boxes containing 5 trays of 120 items per tray; each box containing 600 units.



Dimensions in mm.

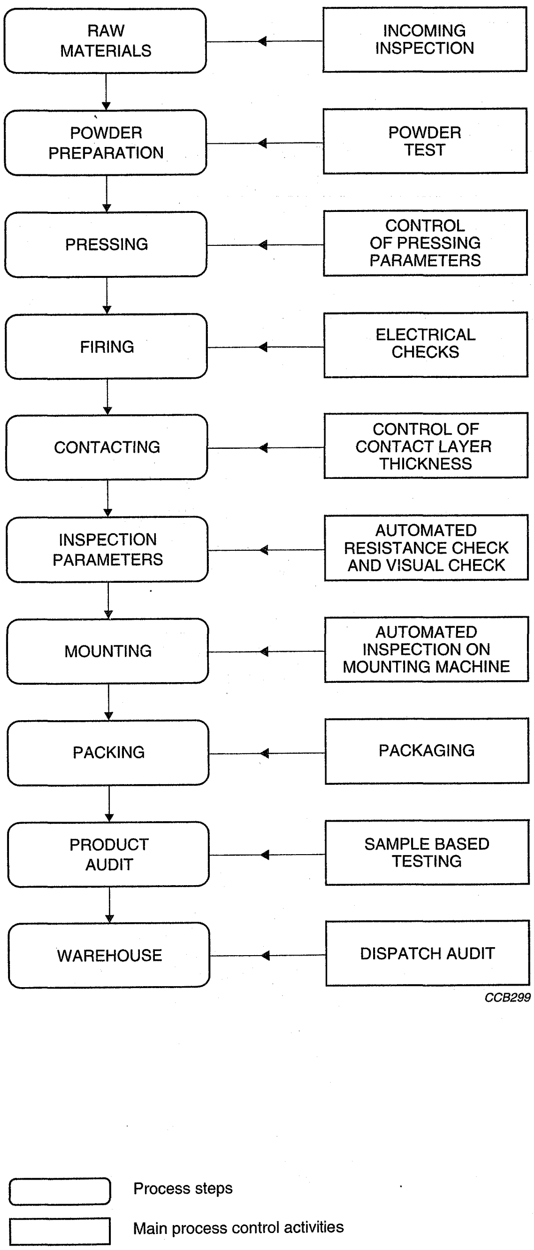
Fig.11 Outer box dimensions.



Dimensions in mm.

Fig.12 Tray dimensions.

GENERAL OVERVIEW OF PRODUCTION AND QUALITY CONTROL FLOWCHART



TEST AND REQUIREMENTS

In Table 4 the tests can either be:
D = Destructive
ND = Non-destructive.

Table 4 Standard test schedule

CECC 44003 CLAUSE	TEST	D or ND	CONDITIONS	PERFORMANCE REQUIREMENTS
Outgoing inspection (lot-by-lot)				
4.3.1 4.3.2 4.3.3	visual examination marking dimensions (gauging)	ND		no visible damage legible as detailed specifications
4.4	zero power resistance: degaussing PTC (R_s) heater PTC (R_p)	ND	at 25 °C	as specified
4.27	minimum peak to peak inrush current	ND	at 220/110 V_{RMS} and reference coil	as specified
	maximum peak to peak current after: 5 s 30 s 180 s	ND	at 220/110 V_{RMS} and reference coil	
4.13.1	solderability	D	solder bath method: 235 ±5 °C	the terminations shall be evenly tinned; 95% covered

Table 5 Life tests

<table>
<tr><th>IEC 60738 TEST METHOD</th><th>TEST</th><th>PROCEDURE</th><th>REQUIREMENTS</th></tr>
<tr><td></td><td>endurance cycling: maximum voltage at low temperature</td><td>maximum voltage with minimum coil: see detailed specifications;
temperature: 0 ±5 °C;
duration, 100 cycles</td><td rowspan="9">no visible damage
ΔR_s/R_s (25 °C) max.: ±20%
ΔR_p/R_p (25 °C) max.: ±50%
inrush current at 25 °C:
I_{inrush} > 95%; I_{inrush} specified
final current at 25 °C:
I_{final} < 105%; I_{final} specified
I_{final} = I after 3 minutes</td></tr>
<tr><td></td><td>endurance cycling: maximum voltage at 25 °C</td><td>maximum voltage with minimum coil: see detailed specifications;
temperature: 25 ±5 °C;
duration, 40000 cycles</td></tr>
<tr><td></td><td>endurance at maximum rated temperature and maximum voltage</td><td>maximum voltage: see detailed specifications;
temperature: 60 ±5 °C;
duration, 2000 hours</td></tr>
<tr><td></td><td>endurance cycling at maximum voltage in humidity</td><td>maximum voltage with minimum coil: see detailed specifications;
conditions: 40 °C, 95% RH;
cycle; 30 on 60 off;
duration, 56 days (900 cycles)</td></tr>
<tr><td colspan="3">Other tests in accordance with IEC 60068-2</td></tr>
<tr><td>3 (Ca)</td><td>damp heat (steady state)</td><td>56 days; 40 °C; 95% RH</td></tr>
<tr><td>2 (Ba)</td><td>dry heat</td><td>1000 hours; 125 °C</td></tr>
<tr><td>6 (Fc)</td><td>vibration (mounted state)</td><td>frequency: 10 to 55 Hz;
displacement 0.75 mm or acceleration 10 g; 3 directions; total 6 hours</td></tr>
<tr><td>20 (Tb)</td><td>resistance to soldering heat</td><td>10 s; 260 ±5 °C</td></tr>
<tr><td colspan="4">Other test in accordance with IEC 60695.2</td></tr>
<tr><td>2</td><td>flammability needle flame test</td><td>vertical severity; duration 10 s</td><td>flammability: flame 5 s max.</td></tr>
</table>

FEATURES

- Residual currents as low as 2 mA (p-p), ideal for high-resolution displays
- Long decay time
- Stable performance over a long time (>20000 operations)
- Self-extinguishing white plastic case (*"UL 94.V.0"*)
- Design-in support available.

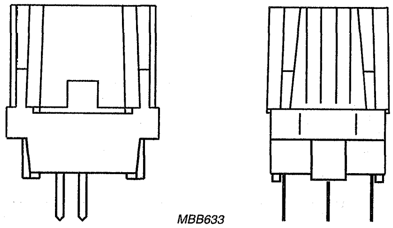
APPLICATIONS

- Colour televisions
- Colour monitors.

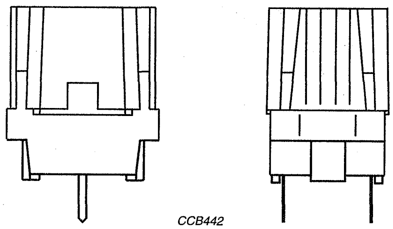
DESCRIPTION

For good picture definition, colour televisions and 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 colour televisions and 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.



a. Dual or double mono PTC degaussing.



b. Mono PTC degaussing.

Fig.1 Component outlines.

QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Resistance of degaussing PTC (R_s) at 25 °C	3 to 30	Ω
Standard tolerance on resistance of degaussing PTC (R_s) at 25 °C	20 and 25	%
Resistance of heater PTC (R_p) at 25 °C	3000	Ω
Standard tolerance on resistance of heater PTC (R_p) at 25 °C	75	%
Maximum AC voltage (RMS value)	145 to 276	V
Minimum inrush current (peak-to-peak value)	10 to 30	A
Temperature range (at maximum voltage)	0 to 60	°C
Available pitch:		
4e/1e	10.16 to 2.54	mm
4e/2e	10.16 to 5.08	mm
Standard pin length	4.2	mm
Detailed specifications based on	CECC 44000/IEC 60738	

INRUSH CURRENT

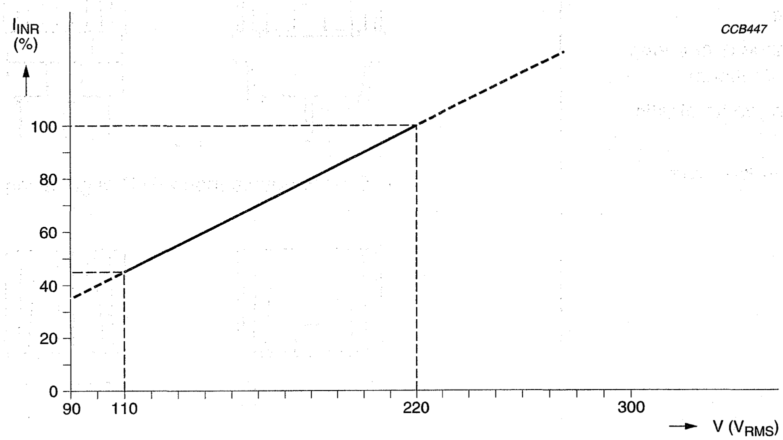
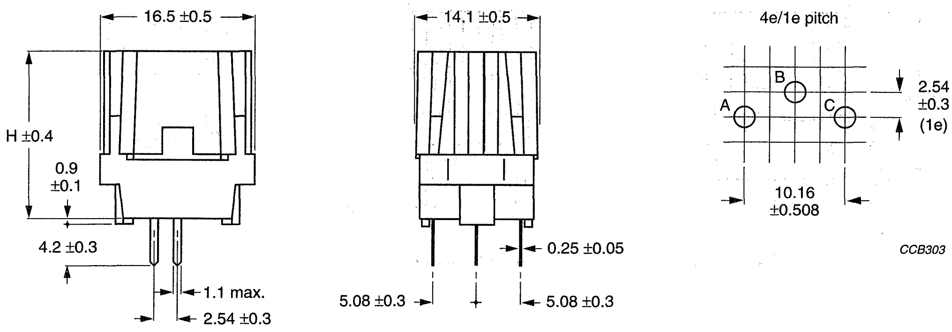


Fig.2 Minimum inrush current as a percentage of mains voltage.

Application specific data

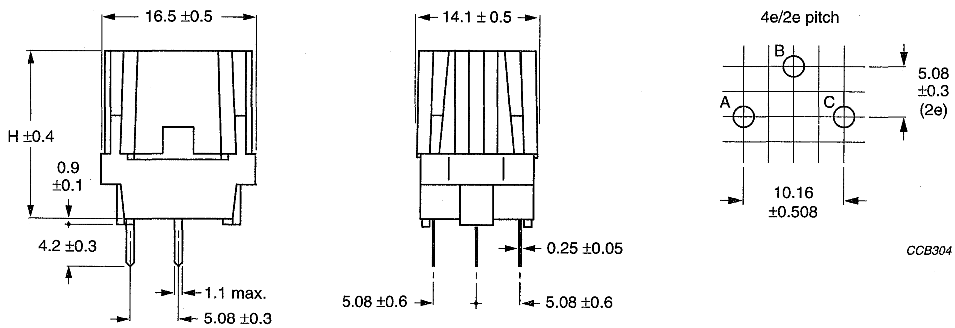
The data shown in Tables 1 to 4 is obtained from measurements at reference parameters. If these parameters do not correspond to the application parameters required, refer to Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.

MECHANICAL DATA



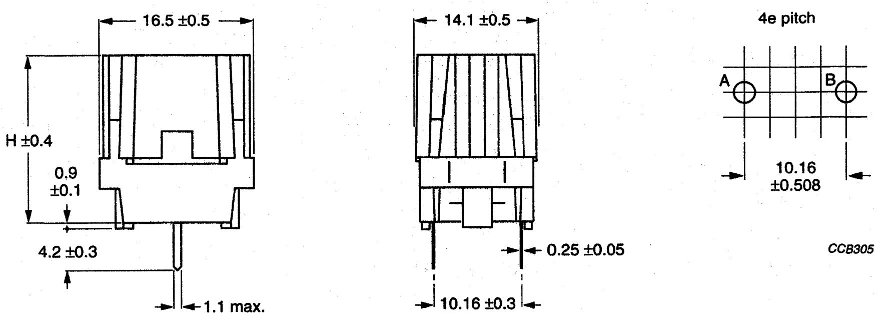
Dimensions in mm.
Low cap (H = 18.4 mm).
High cap (H = 20.5 mm).
For electrical data and ordering information, see Tables 1 and 2.

Fig.3 Dual PTC pin configuration 4e/1e pitch.



Dimensions in mm.
Low cap (H = 18.4 mm).
High cap (H = 20.5 mm).
For electrical data and ordering information, see Tables 1 and 2.

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



Dimensions in mm.
Low cap (H = 18.4 mm).
High cap (H = 20.5 mm).
For electrical data and ordering information, see Tables 3 and 4.

Fig.5 Mono PTC pin configuration 4e pitch.

ELECTRICAL DATA AND ORDERING INFORMATION

Dual range

Table 1 Electrical data and catalogue numbers; **U_R = 220 to 240 V (RMS)**. The shading indicates preferred types.

MINIMUM PEAK-TO-PEAK(1)(6) INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK(1) RESIDUAL CURRENT (mA)			R_{25}(2) (Ω)		R_{coil}(3)(6) (Ω)		TYPICAL DECAY PERFORMANCE		CAP(7)	CATALOGUE NUMBER(8) 2322 662	
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME(4)(6) (ms)	ALPHA MAX.(5) (%)		4e/1e pitch	4e/2e pitch
11	50	5	2	30	25	17	25	60	36	low	2322 662 96209	2322 662 96309
14	50	5	2	26	25	14	17	40	43	low	2322 662 96211	2322 662 96311
16	80	8	4	22	25	14	17	40	44	low	2322 662 96216	2322 662 96316
16	80	8	2	22	25	10	17	65	33	high	2322 662 96616	2322 662 96716
20	80	8	2	18	25	10	13	50	38	high	2322 662 96624	2322 662 96724
18	80	15	2	18	25	10	17	75	29	high	2322 662 96626	2322 662 96726
25	80	10	4	14	25	10	10	40	45	high	2322 662 96602	2322 662 96702
25	80	10	4	14	25	10	10	45	40	high	2322 662 96642	2322 662 96742
21	80	10	5	12	20	10	17	70	36	high	2322 662 96606	2322 662 96706
21	100	20	5	12	20	10	17	80	30	high	2322 662 96646	2322 662 96746
20	100	40	10	9	20	13	20	95	33	high	2322 662 96608	2322 662 96708
20	100	25	10	9	20	13	20	115	26	high	2322 662 96648	2322 662 96748
21	100	25	10	7	20	20	20	100	33	high	–	2322 662 96709

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 220 V, 50 Hz (AC) and at 25 °C.
2. Lower tolerances on resistance of degaussing PTC are available on request.
3. Lower minimum coil resistance is available on request.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Low cap: H = 18.4 mm; High cap: H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

Table 2 Electrical data and catalogue numbers; U_R **= 100 to 120 V (RMS)**. The shading indicates preferred types.

MINIMUM PEAK-TO-PEAK(1) INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK(1) RESIDUAL CURRENT (mA)			R_{25}(2)(6) (Ω)		R_{coil}(3)(6) (Ω)		TYPICAL DECAY PERFORMANCE		CAP(7)	CATALOGUE NUMBER(8) 2322 662	
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME(4)(6) (ms)	ALPHA MAX.(5) (%)		4e/1e pitch	4e/2e pitch
19	200	20	10	7	20	5	7	80	31	low	2322 662 96213	2322 662 96313
27	200	50	14	5	20	5	6	85	30	high	2322 662 96605	2322 662 96705
30	200	20	10	5	20	4	5	85	31	high	2322 662 96645	2322 662 96745
30	200	20	10	3	30/15	4	6	115	29	high	2322 662 96643	2322 662 96743

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 110 V 50 Hz (AC) and at 25 °C.
2. Lower tolerances on resistance of degaussing PTC are available on request.
3. Lower minimum coil resistance is available on request.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Low cap: H = 18.4 mm; High cap: H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

Mono cased range

Table 3 Electrical data and catalogue numbers; $\mathbf{U_R}$ **= 220 to 240 V (RMS)**; note 1. The shading indicates preferred types.

MINIMUM PEAK-TO-PEAK[(1)] INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK[(1)] RESIDUAL CURRENT (mA)			R_{25}[(2)] (Ω)		R_{coil}[(3)(6)] (Ω)		TYPICAL DECAY PERFORMANCE		CAP[(7)]	CATALOGUE NUMBER[(8)] 2322 662 .....
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME[(4)(6)] (ms)	ALPHA MAX.[(5)] (%)		4e pitch
11	100	40	20	30	25	17	25	75	30	low	2322 662 96281
12	50	30	20	26	25	14	25	90	30	high	2322 662 96688
16	80	40	20	22	25	14	17	40	44	low	2322 662 96286
20	100	50	25	18	25	10	13	50	38	high	2322 662 96682
25	200	50	30	14	25	10	10	40	45	high	2322 662 96683
25	200	80	30	14	25	10	10	45	40	high	2322 6 62 96692
21	200	80	30	12	25	10	17	70	36	high	2322 662 96684
21	200	80	30	12	25	10	17	80	30	high	2322 662 96696
20	100	50	30	9	20	13	20	95	33	high	2322 662 96687
20	200	50	25	9	20	13	20	115	26	high	2322 662 96698
21	100	50	30	7	20	20	20	100	33	high	2322 662 96681

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 220 V, 50 Hz (AC) and at 25 °C.
2. Lower tolerances on resistance of degaussing PTC are available on request.
3. Lower minimum coil resistance is available on request.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Low cap: H = 18.4 mm; High cap: H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

Table 4 Electrical data and catalogue numbers; U_R **= 100 to 120 V (RMS)**. The shading indicates preferred types.

MINIMUM PEAK-TO-PEAK(1) INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK(1) RESIDUAL CURRENT (mA)			R_{25}(2) (Ω)		R_{coil}(3)(6) (Ω)		TYPICAL DECAY PERFORMANCE		CAP(7)	CATALOGUE NUMBER(8) 2322 662 .....
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME(4) (ms)	ALPHA MAX.(5) (%)		4e pitch
19	200	70	40	7	20	5	7	80	31	low	2322 662 96285
27	200	70	40	5	20	5	6	85	30	high	2322 662 96686
30	200	70	40	5	20	4	5	85	31	high	2322 662 96695
30	200	70	40	3	30/15	4	6	115	29	high	2322 662 96693

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 110 V 50 Hz (AC) and at 25 °C.
2. Lower tolerances on resistance of degaussing PTC are available on request.
3. Lower minimum coil resistance is available on request.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Low cap: H = 18.4 mm; High cap: H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

PTC thermistors for degaussing

Double mono cased 145 V to 276 V

FEATURES

- Extra long decay time
- Stable performance over a long time (>20000 operations)
- Self-extinguishing white plastic case *("UL 94.V.0")*
- Design-in support available.

APPLICATIONS

- Colour televisions
- Colour monitors.

DESCRIPTION

For good picture definition, colour televisions and 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.

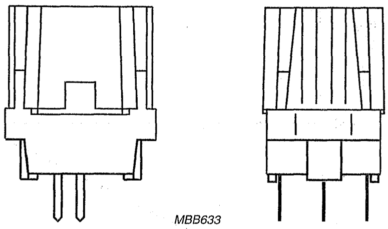


Fig.1 Double mono outlines.

QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Resistance of degaussing PTC (R_s) at 25 °C	1.5 to 9	Ω
Standard tolerance on resistance of degaussing PTC (R_s) at 25 °C	20 and 25	%
Standard tolerance on resistance of heater PTC (R_p) at 25 °C	75	%
Maximum AC voltage (RMS value)	145 to 276	V
Minimum inrush current (peak-to-peak value)	27 to 39	A
Temperature range (at maximum voltage)	0 to 60	°C
Available pitch:		
4e/2e	10.16 to 5.08	mm
Standard pin length	4.2	mm
Detailed specifications based on	CECC 44000/IEC 60 738	

INRUSH CURRENT

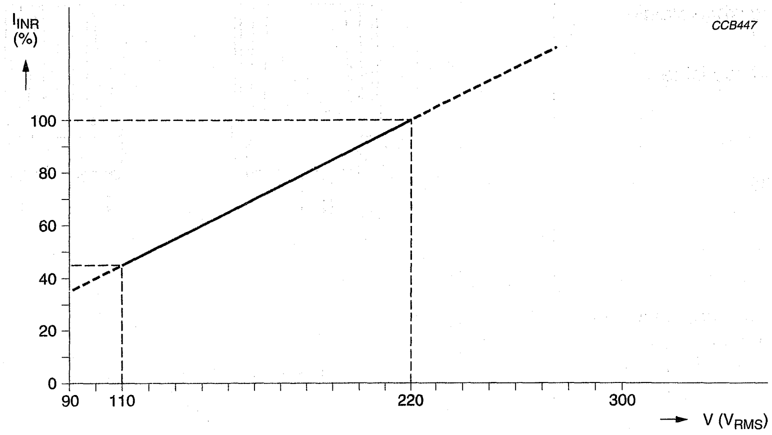
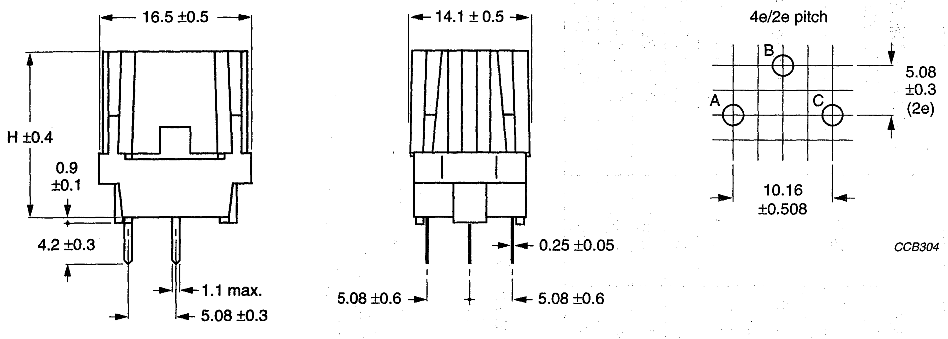


Fig.2 Minimum inrush current as a percentage of mains voltage.

Application specific data

The data shown in Tables 1 and 2 is obtained from measurements at reference parameters. If these parameters do not correspond to the application parameters required, refer to Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.

MECHANICAL DATA



Dimensions in mm.
High cap (H = 20.5 mm.).
For electrical data and ordering information, see Tables 1 and 2.

Fig.3 Double mono PTC pin configuration 4e/2e pitch.

ELECTRICAL DATA AND ORDERING INFORMATION

Double mono cased range

Table 1 Electrical data and catalogue numbers; **U_R = 220 to 240 V (RMS)**

MINIMUM PEAK-TO-PEAK(1) INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK(1) RESIDUAL CURRENT (mA)			R_{25}(3) (Ω)		R_{coil}(2)(6) (Ω)		TYPICAL DECAY PERFORMANCE		CAP(7)	CATALOGUE NUMBER(8) 2322 662 .....
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME(4)(6) (ms)	ALPHA MAX.(5) (%)		4e/2e pitch
33	200	35	25	9 (18 × 2)	25	7	10	80	31	high	2322 662 96754
34	200	35	25	7 (14 × 2)	25	7	10	80	31	high	2322 662 96752
36	200	35	25	6 (12 × 2)	20	7	10	85	31	high	2322 662 96756
33	200	40	30	4.5 (9 × 2)	20	10	13	130	27	high	2322 662 96758
35	200	40	30	3.5 (7 × 2)	20	13	13	135	27	high	2322 662 96759

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 220 V 50 Hz (AC) and at 25 °C.
2. Lower minimum coil resistance is available on request.
3. The indicated resistance value is the parallel combination of two degaussing PTCs.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Cap: high cap; H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

Table 2 Electrical data and catalogue numbers; U_R = **100 to 120 V (RMS)**

MINIMUM PEAK-TO-PEAK(1) INRUSH CURRENT (A)	MAXIMUM PEAK-TO-PEAK(1) RESIDUAL CURRENT (mA)			R_{25}(3) (Ω)		R_{coil}(2)(6) (Ω)		TYPICAL DECAY PERFORMANCE		CAP(7)	CATALOGUE NUMBER(8) 2322 662 .....
	after 5 s	after 30 s	after 180 s	R_s	±%	MIN.	TYP.	DECAY TIME(4)(6) (ms)	ALPHA MAX.(5) (%)		4e/2e pitch
27	250	80	45	3.5 (7 × 2)	20	3	7	255	16	high	2322 662 96757
34	250	80	45	2.5 (5 × 2)	20	3	6	200	19	high	2322 662 96755
39	250	80	45	1.5 (3 × 2)	20	3	6	265	20	high	2322 662 96753

Notes

1. All peak-to-peak currents are measured at typical resistance of the coil at 110 V 50 Hz (AC) and at 25 °C.
2. Lower minimum coil resistance is available on request.
3. The indicated resistance value is the parallel combination of two degaussing PTCs.
4. Decay time is the time from the moment of maximum peak current until the half of the maximum peak inrush current.
5. Alpha maximum is the maximum decrease in current expressed in percent between two successive peaks.
6. Inrush currents and decay times at other voltage coil combinations can be derived from Figures 7 to 13 in this data handbook, section *"Introduction, PTC thermistors for degaussing"*.
7. Cap: high cap; H = 20.5 mm.
8. Smallest packaging quantity (SPQ) = 600 units.

VARISTORS (VDR)

GENERAL

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 stand-by value to a very low conducting value. The transient is thus absorbed and clamped to a safe level, protecting sensitive circuit components.

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.

FEATURES

- 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 time of less than 20 ns, clamping the transient the instant it occurs.
- Low stand-by power - virtually no current is used in the stand-by 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 Volume 1, Section 1"*, and manufactured using UL approved flame retardant 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 environments. The lacquer is also resistant to cleaning solvents in accordance with *"IEC 60068-2-45"*.
- 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 on in-line control.

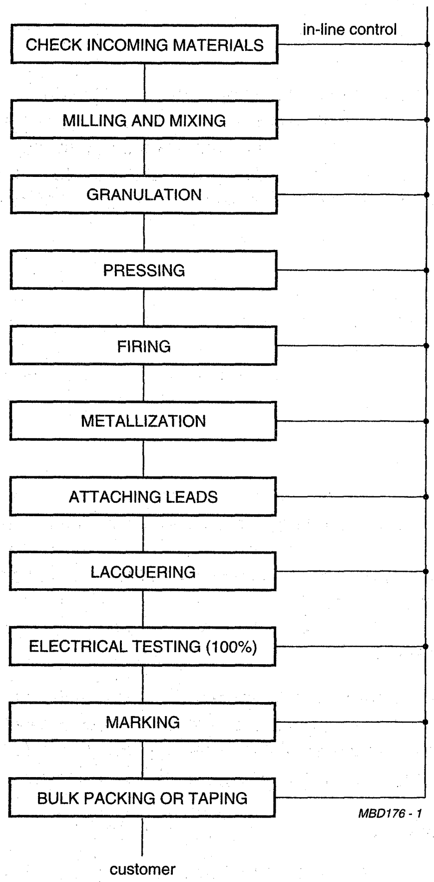


Fig.1 Manufacturing process flow chart.

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

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 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 strength tests are made. Three types of lead configuration are available; one with straight leads, one with straight leads and 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.

Electrical testing (100%)

The voltage of each component is normally checked at two reference currents (1 mA and another according to the application). Any rejects are automatically separated for further evaluation.

Marking

All components are laser marked.

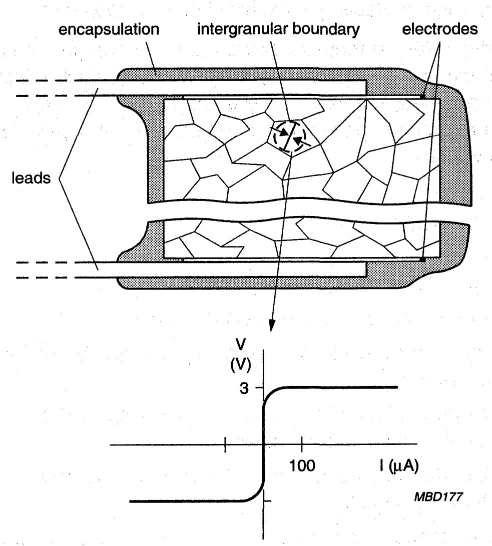


Fig.2 Structure of a varistor.

QUALITY

Approvals

- CECC 42201-802 of 1992
- UL E98144
- VDE 53138 E (for 30 V to 550 V ranges)
- CSA LR 86645 (for 130 V to 550 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 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 material suppliers is maintained. Incoming inspection and product 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 42000"* and *"IEC 61051-1"*. Each operator is actively engaged in quality checking. In addition, in-line inspectors and manufacturing operators make regulated spot checks as a part of our Statistical Process Control (SPC).

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 performances 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 × 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 pulse current of rise time 8 μs and decreasing time 20 μs (8 μs to 20 μs) is applied through the varistor in accordance with *"IEC 60060-2, 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 pulse 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 pulse current of 8 µs to 20 µs following *"IEC 60060-2"*, with such an amplitude that the varistor voltage measured at 1 mA does not change by more than 10% maximum.

A surge in excess of the specified withstanding surge current may cause short circuits or package rupture with expulsion of material; it is therefore recommended that a fuse be put in the circuit using the varistor, or the varistor be used in a protective box

If more than one pulse is applied or when the pulse 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% at 1 mA.

Maximum energy

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

- The amplitude of the current.
- The voltage corresponding to the peak current.
- The rise time of the pulse.
- The decrease time of the pulse; most of the energy is dissipated during the time 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 60060-2 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.

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

$$E = V_{peak} \times I_{peak} \times t_2 \times K$$

where:

I_{peak} = peak current

V_{peak} = voltage at peak current

β = given for $I = \frac{1}{2} \times I_{peak}$ to I_{peak}

K is a constant depending on t_2, when t_1 is 8 to 10 ms; see Table 3.

A low value of β corresponds to a low value of V_{peak} and then to a low value of E.

The maximum energy published does not then represent the quality of the varistor, but can be a valuable indication when comparing the various series of components which have the same varistor voltage. The maximum energy published is valid for a standard pulse of duration 10 µs to 1 000 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 dissipation are:

0.1 W for series 2322 592 .....

0.25 W for series 2322 593 .....

0.4 W for series 2322 594 .....

0.6 W for series 2322 595 .....

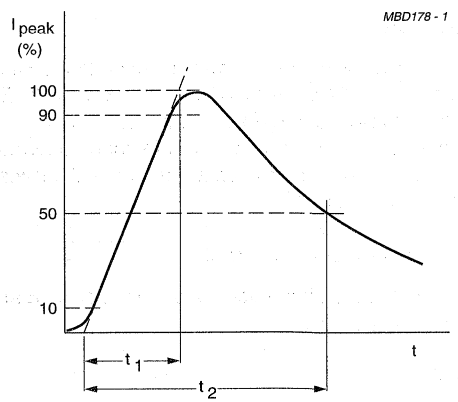


Fig.3 Maximum energy curve.

ELECTRICAL CHARACTERISTICS

Typical V/I characteristic of a ZnO varistor

The relationship between voltage and current of a varistor can be approximated to: $V = C \times I^{\beta}$

where:

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

EXAMPLES

When:

- C = 230 V at 1 A
- β = 0.035 (ZnO)
- $I = 10^{-3}$ A or 10^{2} A.

$V = C \times I^{\beta}$;
so that for current of 10^{-3} A: $V = 230 \times (10^{-3})^{0.035} = 180$ V
and for a current of 10^{2} A: $V = 230 \times (10^{2})^{0.035} = 270$ V.

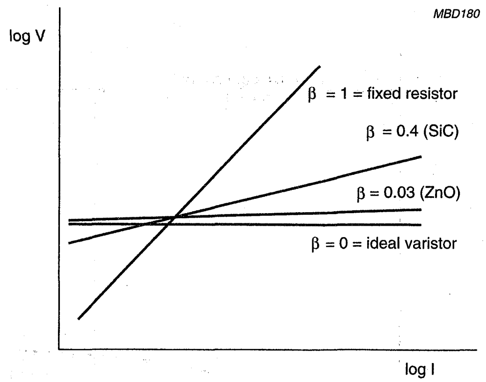
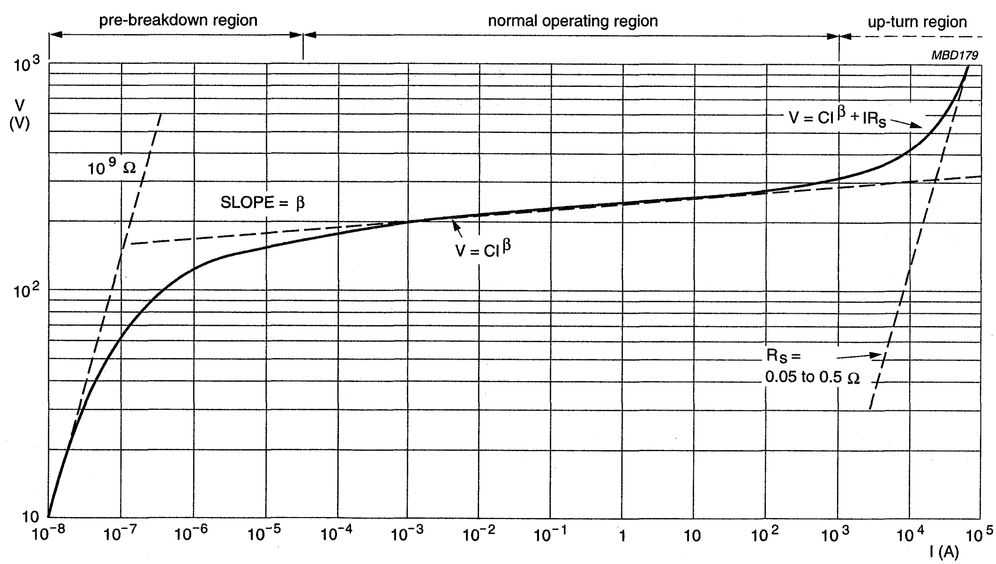


Fig.4 Varistor characteristics using different β values.



Pre-breakdown region: $V \approx \propto I$; highly temperature dependent.
Normal operating region: $V = C \times I^{\beta}$.
Up-turn region: $V = C \times I^{\beta} + I \times R_s$.

Fig.5 Typical V/I curve.

Specification of a varistor curve

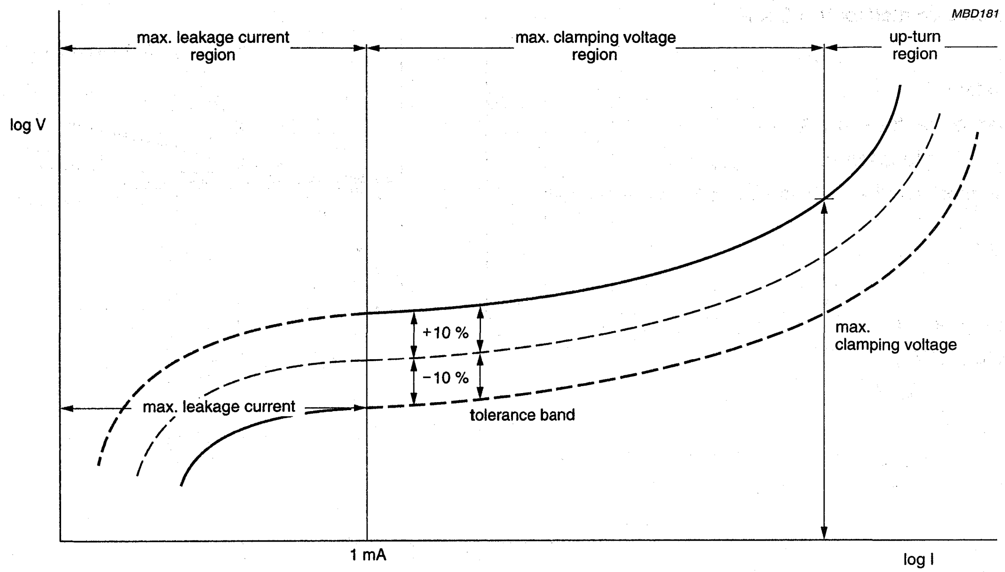


Fig.6 Working points on a varistor curve.

Figure 7 shows the various working points on the varistor curve using the series 2322 593 ....., 60 V type as an example. The electrical characteristic values are shown in Table 1.

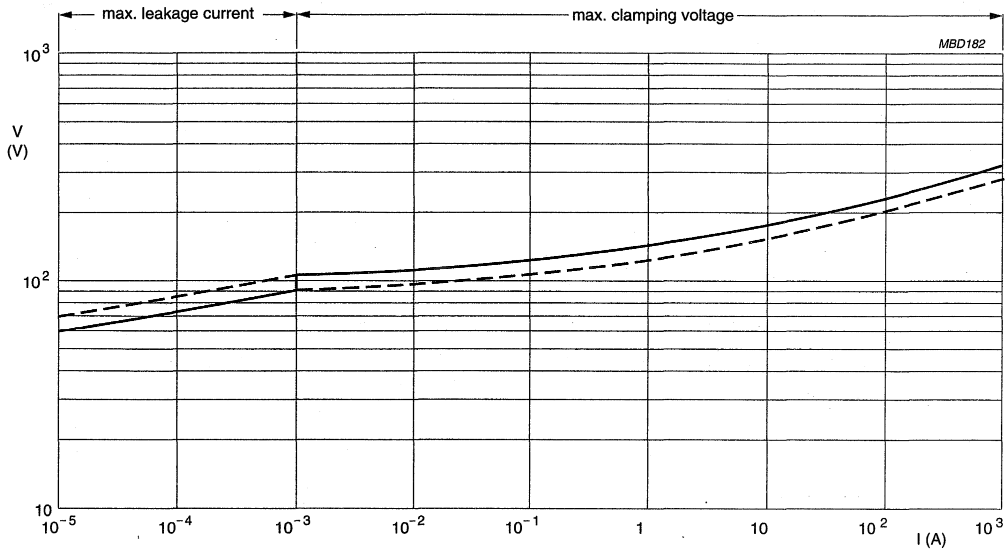
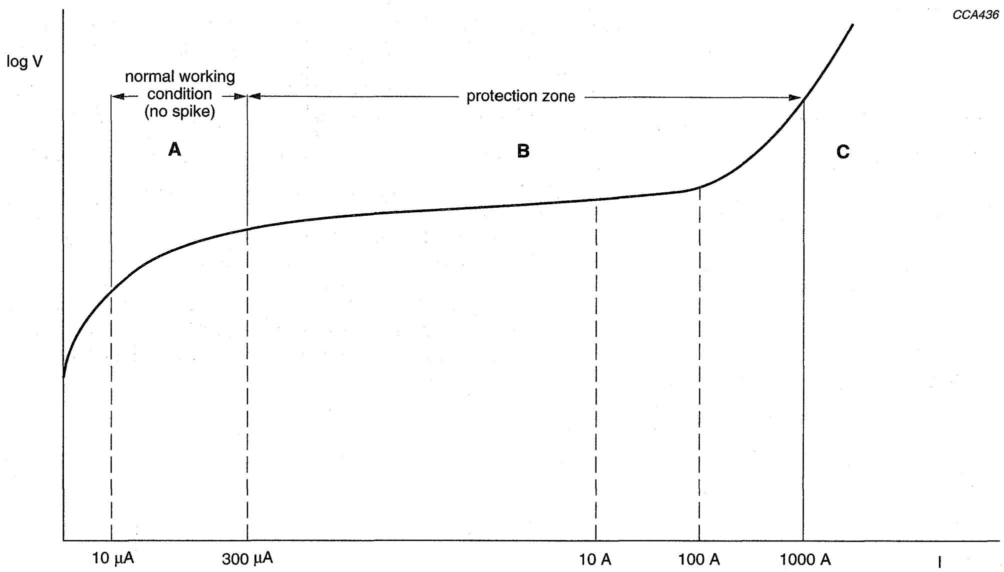


Fig.7 Curve for varistor type 2322 593 .6006

Table 1 Electrical characteristics

PARAMETER	VALUE
Maximum RMS voltage	60 V
Maximum DC working voltage	$\sqrt{2} \times 60$ V = 85 V
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} A
Transient energy	10 µs to 1000 µs: 8.3 J



The points A, B and C shown on the curve are defined in Table 2.

Fig.8 Definitions of the varistor curve.

Table 2 Varistor curve definitions

POINT	DESCRIPTION
A	Normal working zone: current is kept as low as possible in order to have low dissipation during continuous operation (between 10 μA to 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 lifetime.

TRANSIENT VOLTAGE LIMITATION WITH ZnO VARISTORS

Principles of voltage limitation

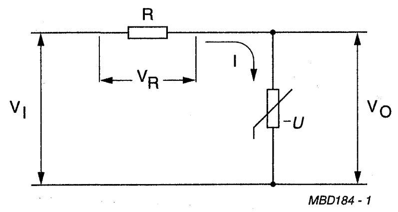


Fig.9 Voltage limitation using a varistor.

In Fig.9 the supply voltage V_I is derived by the resistance R (e.g. the line resistance) and the varistor (–U) selected for the application.

$V_I = V_R + V_O$

$V_I = R \times I + C \times I^{\beta}$

If the supply voltage varies by an amount of ΔV_I the current variation is ΔI and the supply voltage may be expressed as:

$(V_I + \Delta V_I) = R\ (I + \Delta I) + C\ (I + \Delta I)^{\beta}$

Given the small value of β (0.03 to 0.05), it is evident that the modification of $C \times I^{\beta}$ will be very small compared to the variation of $R \times I$ when V_I is increased to $V_I + \Delta V_I$.
A large increase of V_I will induce a large increase of V_R and a small increase of V_O.

EXAMPLES

The varistor is a typical component of the series 2322 592 52716 ($C = 520$; $\beta = 0.04$) and $R = 250\ \Omega$.

For $V_I = 315$ V (crest voltage of the 220 V supply voltage): $I = 10^{-5}$ A, $V_R = 2.5 \times 10^{-3}$ V and $V_O = 315$ V.

For $V_I = 500$ V: $I = 10^{-1}$ A, $V_R = 25$ V and $V_O = 475$ V.

For $V_I = 1000$ V: $I = 1.88$ A, $V_R = 470$ V and $V_O = 530$ V.

Figure 10 shows the influence of different values of series resistors on the varistor efficiency.

By drawing the load line, it is also possible to estimate the variation of the voltages V_R and V_O when V_I is increased to 500 V or 1000 V. This effect is shown in Figs 11 and 12 respectively.

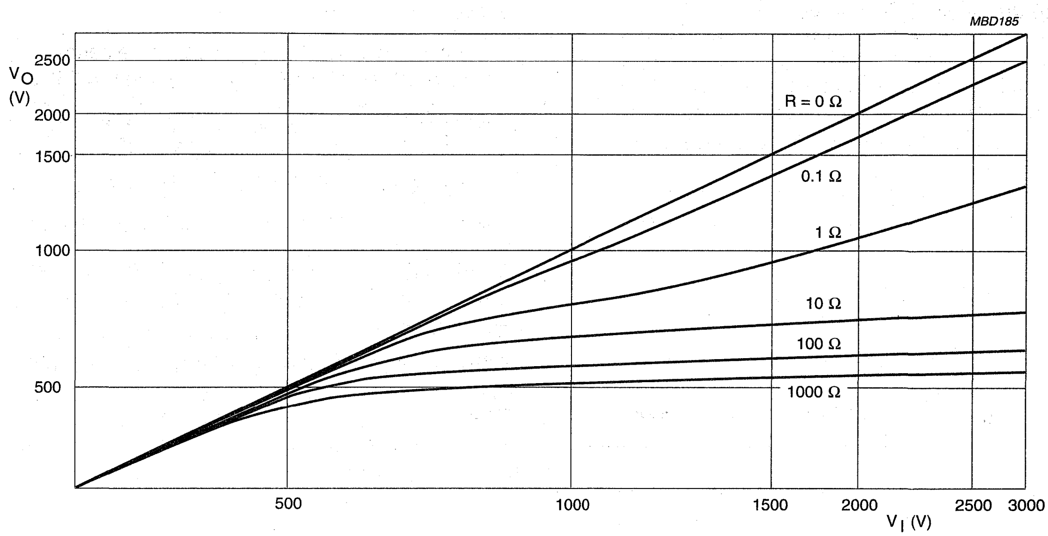


Fig.10 Influence of a series resistance on the varistor.

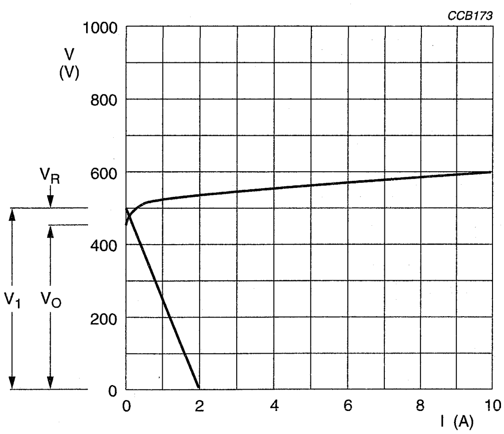


Fig.11 Influence on varistor when V_1 is 500 V (R = 250 Ω).

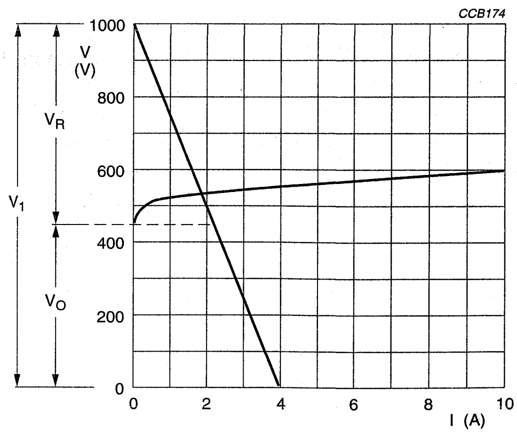


Fig.12 Influence on varistor when V_1 is 1 000 V (R = 250 Ω).

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. C_p and R_p are the capacitance and resistance of the intergranular layer respectively; R_g is the ZnO grain resistance. For low values of applied voltages, R_p behaves as an ohmic loss.

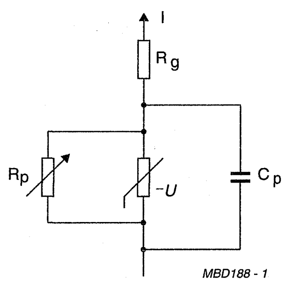


Fig.13 Equivalent circuit model.

Capacitance

Depending on area and thickness of the device, the capacitance of the varistor increases with the diameter of the disc, and decreases with its thickness.

In DC circuits, the capacitance of the varistor 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 characteristic 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 characteristic.

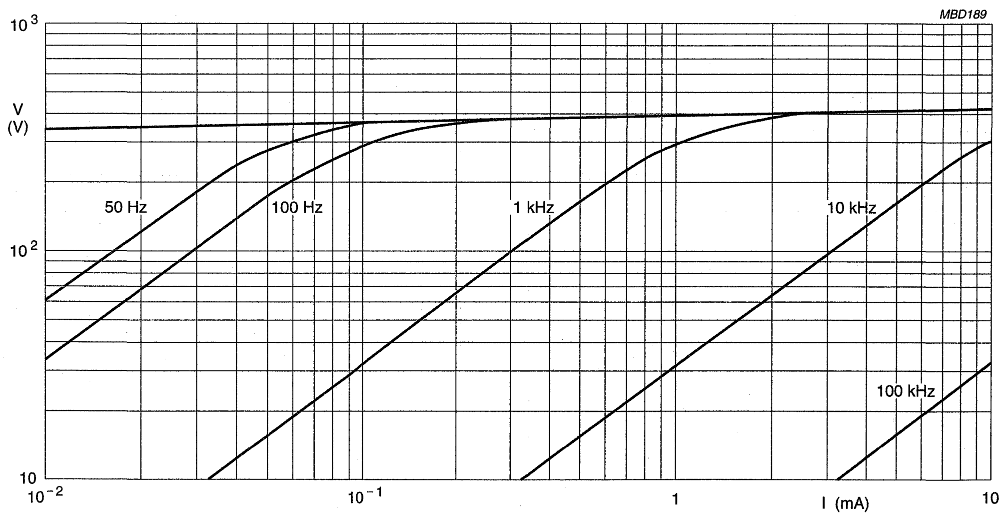


Fig.14 Effect of HF alternating current on varistor type 2322 595 52516; C = 480 pF.

Energy handling

Maximum allowable peak current and maximum allowable energy are standardized using defined pulses:

- Peak current (amperes); 8 µs to 20 µs, 1 pulse
- Energy (joules); 10 µs to 1000 µs, 1 pulse.

EXAMPLES

Pulse life time rating of 2322 593 ....., 60 V type.

Energy capability: $E = K \times V_p \times I_p \times t_2$

1 pulse; 8 µs to 20 µs: 1200 A = 1 × 8 J

10 pulses; 8 µs to 20 µs: 300 A = 10 × 1.45 J

1 pulse; 10 µs to 1000 µs: 33 A = 1 × 8.3 J

10 pulses; 10 µs to 1000 µs: 11 A = 10 × 2.5 J

The maximum specified energy is defined for a maximum shift (ΔV/V) 1 mA ≤ 10%:

I_p = pulse current.

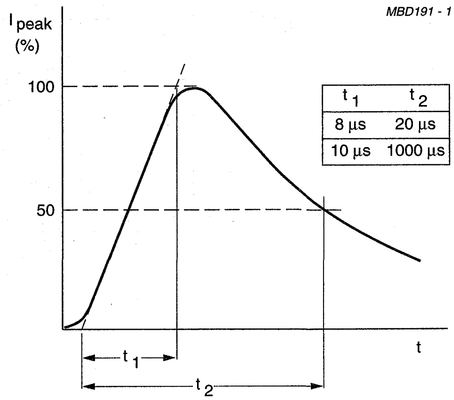
V_p = corresponding clamping voltage.

Table 3 K depends on t_2 when t_1 is 8 to 10 µs

t_2 (µs)	K
20	1
50	1.2
100	1.3
1000	1.4

Typical surge life rating curves (number of surges allowed as a function of pulse time and maximum current) are shown in Fig.16.

Internationally accepted pulses



t_1	t_2
8 µs	20 µs
10 µs	1000 µs

Fig.15 Standard pulse for current and maximum allowable energy calculation.

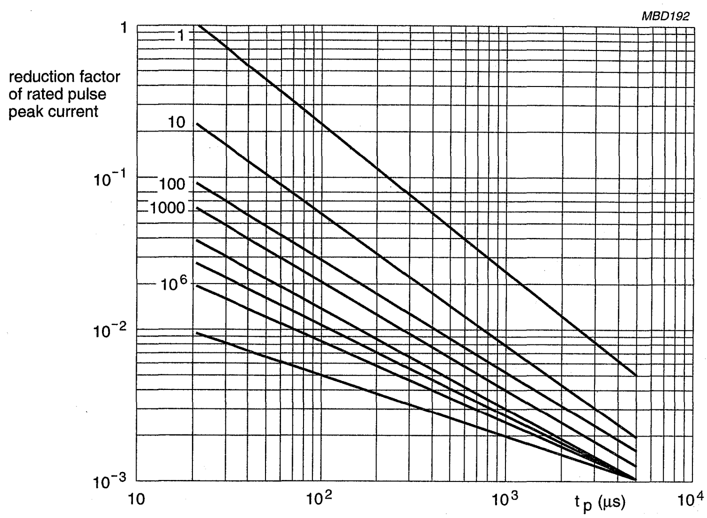
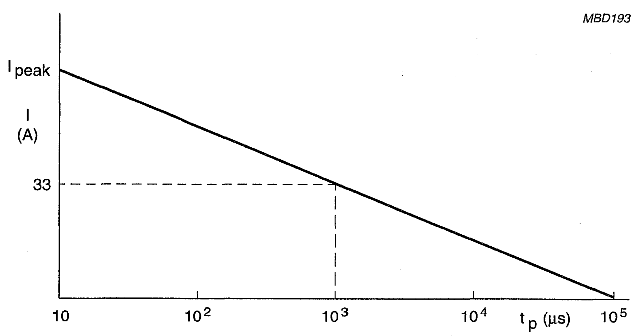
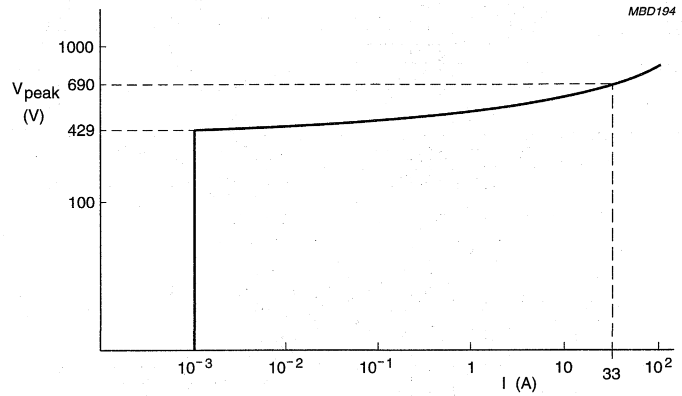


Fig.16 Maximum peak current for various number of pulses as a function of pulse duration.



Maximum energy (10 × 1000 µs): 1 pulse.
Example: 2322 593 52516 (250 V).

Fig.17 Example of selection of the maximum peak current as a function of pulse duration.



$E = K \times V_{peak} \times I_{peak} \times t_2 = 1.4 \times 700 \times 33 \times 10^{-3} = 32$ joules.

Fig.18 Example of calculation of energy for a 2322 593 52516 type, 1 pulse at the maximum peak current (33 A) for a duration $t_2 = 1000\ \mu s$ ($K = 1.4$).

DISSIPATED POWER

DC dissipation

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

$$W = I \times V = C \times I^{\beta+1} \text{ or } K \times V^{\alpha+1}$$

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, or the permissible rating will be exceeded.

This is even more cogent as the varistors have a negative temperature coefficient, which means that at a higher dissipation (and accordingly at a higher temperature) the resistance value will decrease and the dissipated power will increase further.

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:

$$P_{INST} = V \times I = V\left(K \times V^{\alpha}\right) = K \times V^{\alpha+1}$$

In the above equation, the value $V = V_{peak} \times \sin \omega t$.

During a half cycle, the dissipated power is given by:

$$P_{rms} = \frac{1}{\pi}\int_0^{\pi} K \times V_{peak}^{\alpha+1} \times (\sin \omega t)^{\alpha+1} \times dt$$

Since $V_{peak} = V_{rms} \times \sqrt{2}$

$$P_{rms} = \frac{1}{\pi} \times K \times V_{rms}^{\alpha+1} \times (\sqrt{2})^{a+1} \times \int_0^{\pi} (\sin \omega t)^{\alpha+1} \times dt$$

This integration is not easy to solve because of the exponent $(\alpha + 1)$ of $\sin \omega t$.

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 on the value of α and not more on the K value as shown in the formula:

$$P = \frac{\frac{1}{\pi} \times K \times V_{rms}^{\alpha+1} \times 2^{(a+1)/2} \times \int_0^{\pi} (\sin \omega t)^{\alpha+1} \times dt}{K \times V^{a+1}}$$

$$P = \frac{1}{\pi} \times 2^{(a+1)/2} \times \int_0^{\pi} (\sin \omega t)^{\alpha+1} \times dt$$

P has been calculated by successive application of a reduction formula; see Table 4.

Table 4 Power ratios

α	P	α	P	α	P	α	P	α	P
1	1.0	11	14.4	21	344	31	9135	41	255646
2	1.2	12	19.6	22	477	32	12776	42	358778
3	1.5	13	26.8	23	658	33	17734	43	499673
4	1.92	14	36.7	24	915	34	24822	44	701611
5	2.5	15	50.3	25	1264	35	34482	45	977622
6	3.29	16	69	26	1763	36	48301	46	1373365
7	4.375	17	95	27	2439	37	67149	47	1914510
8	5.85	18	131	28	3404	38	94126	48	2690675
9	7.875	19	180	29	4715	39	130941	49	3752439
10	10.64	20	249	30	6587	40	183660	50	5275834

Temperature coefficient

In the leakage current region of the V/I characteristic, the normal equation $V = C \times I^{\beta}$ 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 temperatures. The relationship between the temperature and the current at a given voltage can be expressed by:

$I = I_0 \times e^{KT}$

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 % per 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 into the capacitance of the coil which is generally very low.

$E = \frac{1}{2} \times L \times I^2 = \frac{1}{2} \times C \times V^2$

EXAMPLES, USING THE FOLLOWING VALUES

Mains voltage = 220 V (RMS);
allowable peak voltage = 340 V

Line inductance: $L = 20\ \mu H = 20 \times 10^{-6}$ H

Line capacitance: $C = 300$ nF $= 0.3 \times 10^{-6}$ H

Line resistance: 0.68 Ω.

In the event of a short circuit:

Load current: $I_L = \frac{V}{R} = \frac{340\ V}{0.68\ \Omega} = 500\ A$

Energy stored:
$E = \frac{1}{2} \times 20 \times 10^{-6} \times 25 \times 10^{4} = 2.5$ J(W.s).

In the event of a fuse going open circuit:

The energy goes from inductance L towards line capacitance:

$$V_C = \sqrt{\frac{2E}{C}} = \sqrt{\frac{2 \times 2.5}{0.3 \times 10^{-6}}} = 4082\ V$$

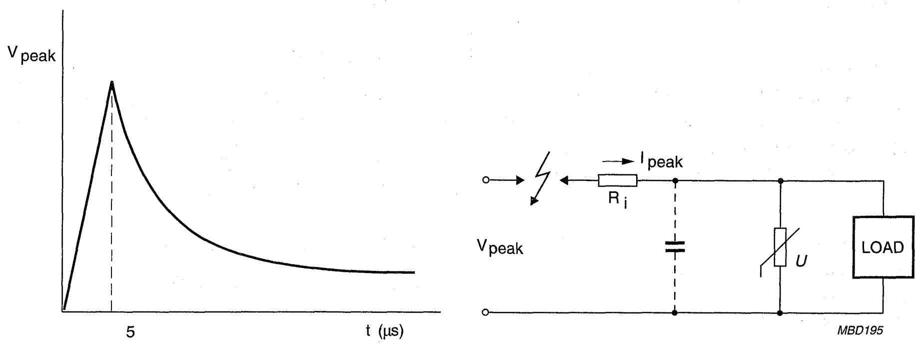


Fig.19 Source of transient.

The line impedance becomes high when the fuse goes open circuit (resistance against high voltage peak in a very short time).

$$R_i = \omega L = 2\pi f L$$

Since the rise time of the pulse is 5 µs, the frequency f = 50 kHz.

$$R_i = 6.28 \times 50 \times 10^3 \times 20 \times 10^{-6} = 6.28\ \Omega$$

$Z_i = 6.28 + 0.68 = 6.96\ \Omega$

$V_{Ri} = 6.96 \times 500 = 3480$ V

$V_{VDR} = 4082 - 3480 = 602$ V.

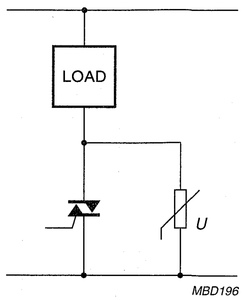
VARISTOR APPLICATIONS

Varistors may be used in many applications, including:

- Computers
- Timers
- Amplifiers
- Oscilloscopes
- Medical analysis equipment
- Street lighting
- Tuners
- Televisions
- Controllers
- Industrial power plants
- 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

For suppression of mains-borne transients in domestic appliances and industrial equipment, see Figs 20, 21, 22 and 23.



Type 2322 592 ..... or 2322 593 .....

Fig.20 Suppression via load.

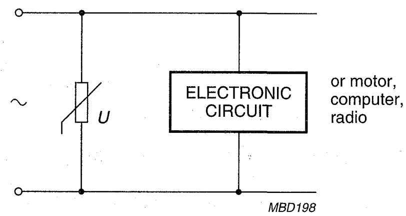


Fig.21 Suppression directly across mains.

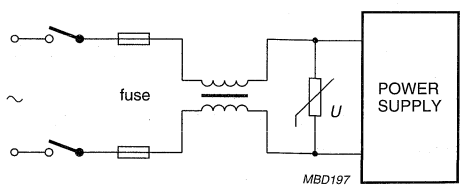


Fig.22 Switched-mode power supply protection.

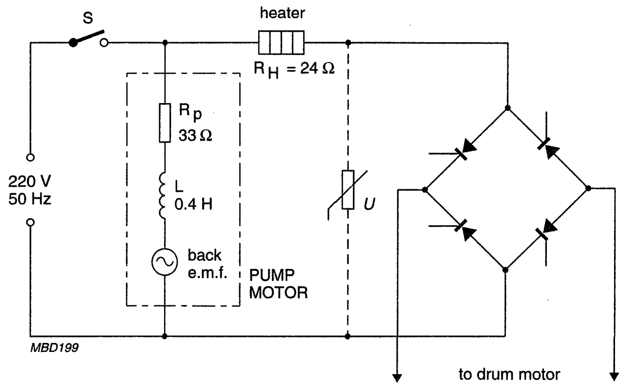


Fig.23 Protection of a thyristor bridge in a washing machine.

Behaviour of the circuit without varistor protection

The measured peak current through the pump motor when S is closed is 1 A (see Fig.23). The energy expended in establishing the electromagnetic field in the inductance of the motor is therefore:

$$I^2 \times \frac{L}{2} = \frac{0.4}{2} = 200 \text{ mJ}$$

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. Arching 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: $V = C_{MAX} \times I^{\beta} = 600$ 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.

For suppression of internally generated spikes in electronic circuits, see Figs 24 and 25.

In both examples shown in Figs 24 and 25, type 2322 592 ..... should be used for up to approximately 50 A, and type 2322 593 ..... up to approximately 120 A.

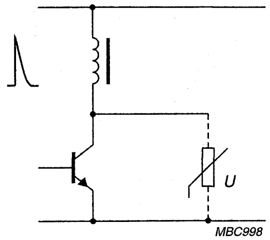


Fig.24 Varistor used across a transistor or coil in a television circuit.

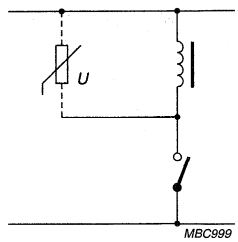


Fig.25 Varistor used across a switch or coil.

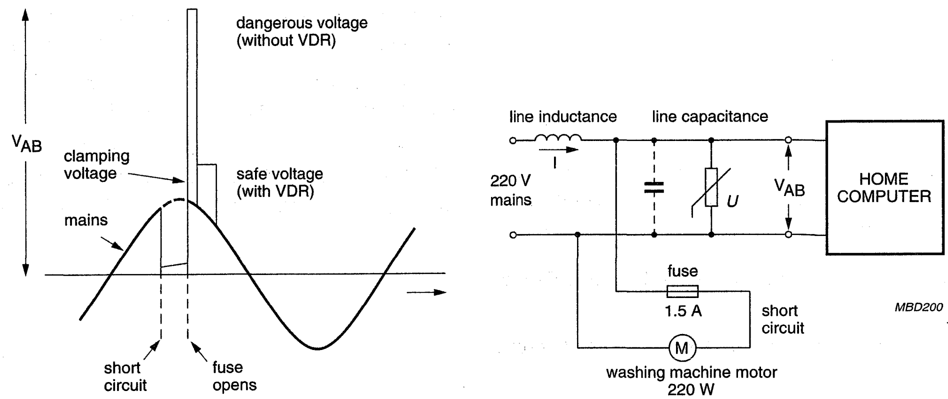


Fig.26 Influence of a transient on the mains voltage.

SELECTION OF THE CORRECT VARISTOR TYPE

In order to select a ZnO varistor for a specific application, the following points must first be considered:

1. The normal operating conditions of the apparatus or system, AC or 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, see Figs 27 and 28.

Figure 27 determines the necessary steady state voltage rating (i.e. working voltage) and Figure 28 determines the correct size (i.e. correct energy absorption).

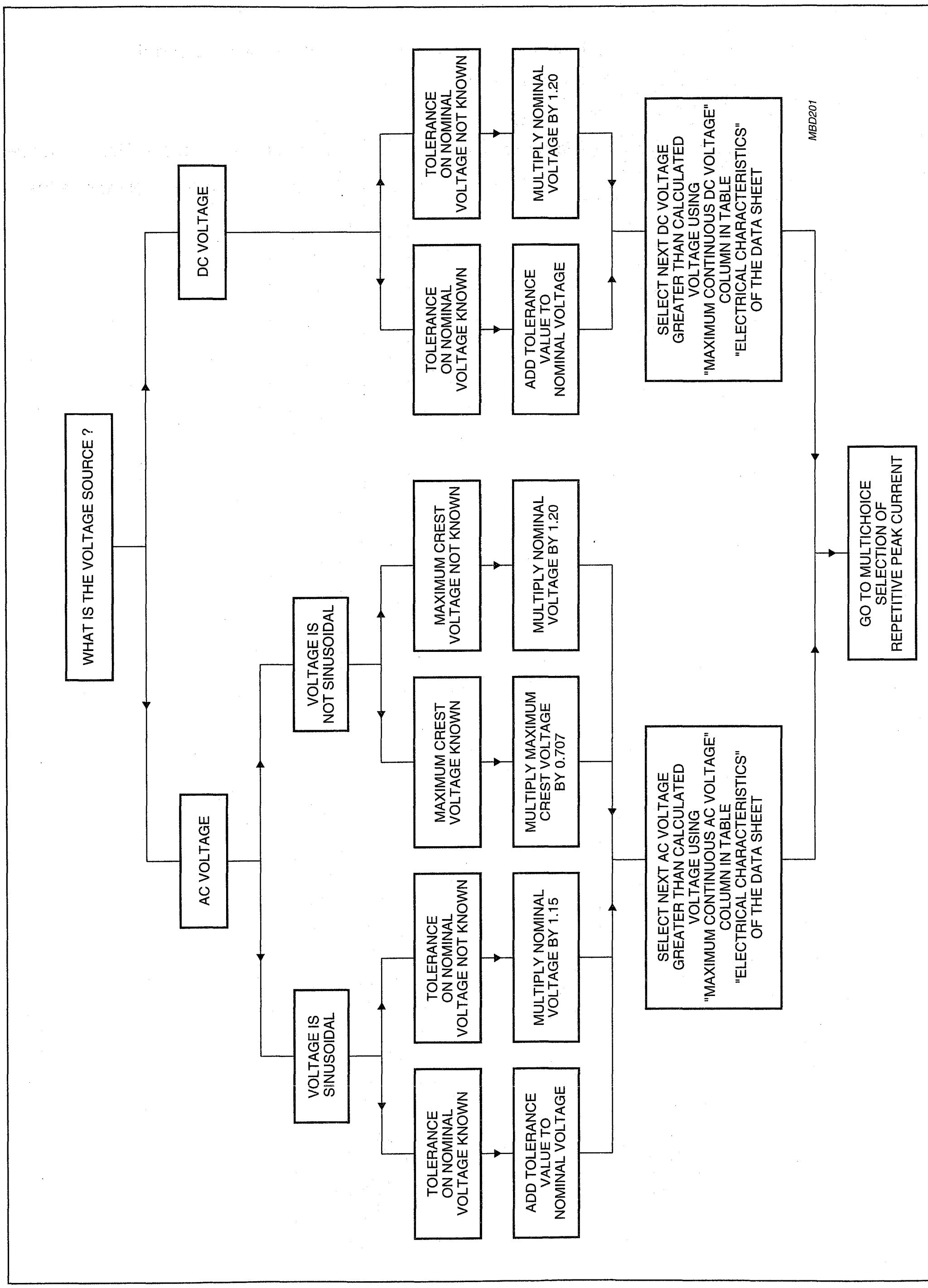


Fig.27 Multichoice selection chart to determine the necessary steady state voltage rating (i.e. working voltage).

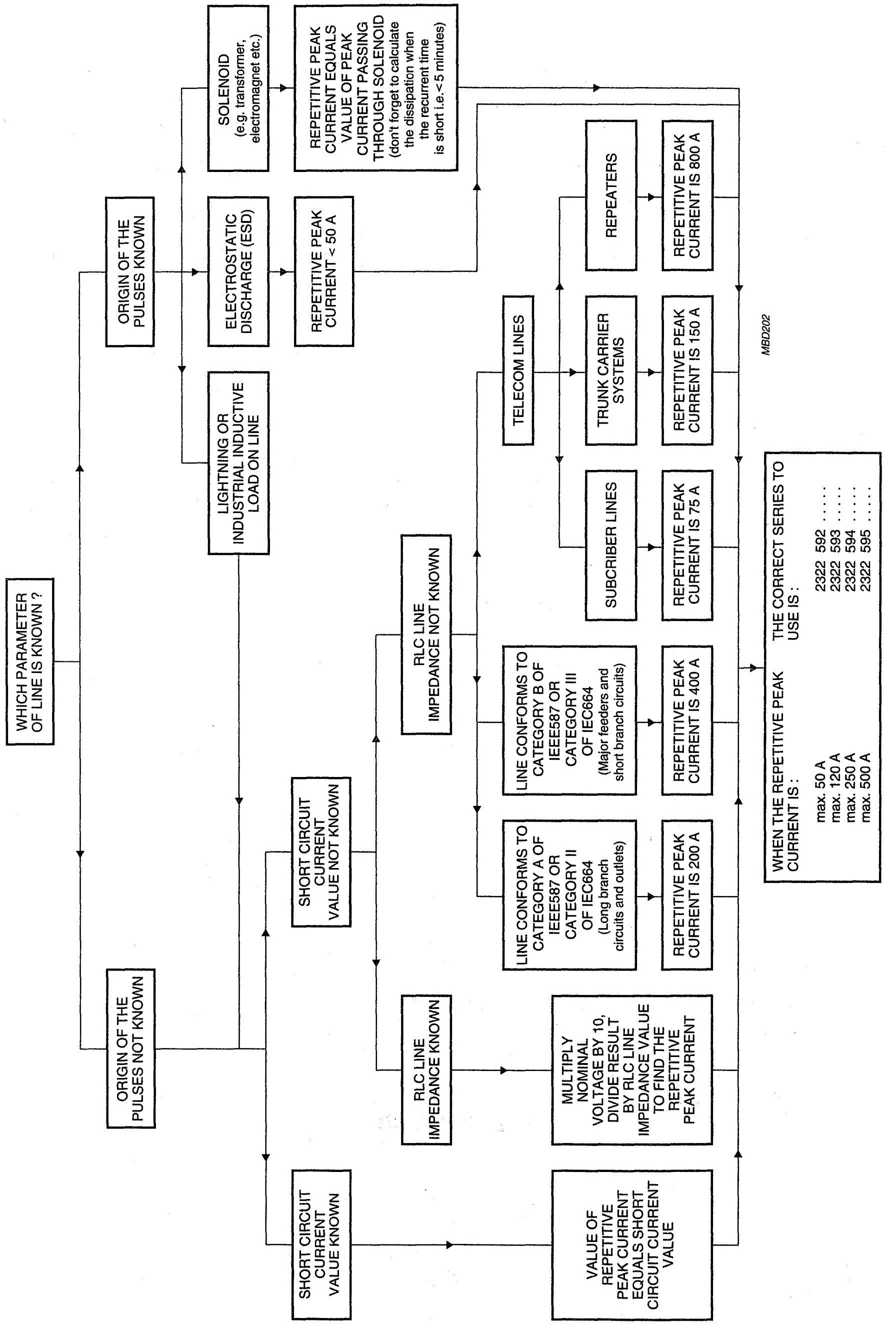


Fig.28 Multichoice selection chart to determine the correct size (i.e. correct energy absorption).

PREFERRED TYPES

For specific details refer to the relevant data sheet in this handbook.

VOLTAGE			CATALOGUE NUMBER 2322 592/3/4/5 .....
$U_{eff\ max}$ (V)	U_{max} (V)	U_V at 1 mA (V)	
30	38	47	53006
35	45	56	53506
40	56	68	54006
50	65	82	55006
60	85	100	56006
75	100	120	57506
95	125	150	59506
130	170	205	51316
140	180	220	51416
150	200	240	51516
175	225	275	51716
230	300	360	52316
250	320	390	52516
275	350	430	52716
300	385	470	53016
320	420	510	53216
385	505	620	53816
420	560	680	54216
460	615	750	54616
510	670	820	55116
550	745	910	55516

Varistors 2322 592 to 2322 595

FEATURES

- Zinc oxide disc, epoxy coated
- Straight leads
- Straight leads with flange (2322 592 and 593 series only)
- Kinked leads.

APPLICATION

- Suppression of transients.

DESCRIPTION

The varistors consist of a disc of low-β ceramic material with two tinned solid copper leads. They are coated with a layer of ochre coloured epoxy, which provides electrical, mechanical and climatic protection. The encapsulation is resistant to all cleaning solvents in accordance with *"IEC 60068-2-45"*.

MARKING

The varistors are marked with the following information:

- Maximum continuous RMS voltage
- Series number (592, 593, 594 or 595)
- Manufacturers logo
- Date of manufacture.

ORDERING INFORMATION

The varistors are available in a number of packaging options:

- Bulk
- On tape on reel
- On tape in ammopack.

The basic ordering code for each option is given in Tables 3, 4 and 5. To complete the catalogue number and to determine the required operating parameters, see Table 7.

MOUNTING

The varistors are suitable for processing on automatic insertion and cutting and bending equipment.

Varistors with flanged leads provide better positioning on printed-circuit boards (PCB) and more accurate control over component height. This is important for hand mounting and automatic insertion techniques; see Fig.4.

Soldering

≤240 °C; duration ≤5 s.

Resistance to heat

≤260 °C; duration ≤5 s.

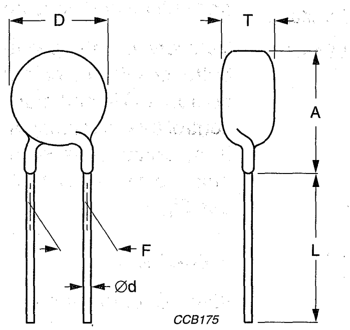
INFLAMMABILITY

The varistors are non-flammable.

QUICK REFERENCE DATA

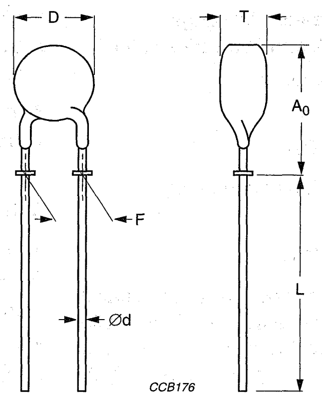
PARAMETER	VALUE	UNIT
Maximum continuous voltage:		
RMS	14 to 550	V
DC	18 to 745	V
Maximum non-repetitive transient current I_{nrp} (8 × 20 μs)	100 to 4500	A
Robustness of terminations	10	N
Drop test:		
Height of fall	1	m
Detailed specification	based on CECC 42000	
Climatic category	40/085/56	

MECHANICAL DATA



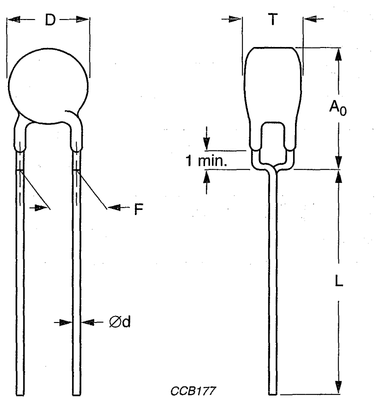
For dimensions, see Table 1.

Fig.1 Outline of component with straight leads.



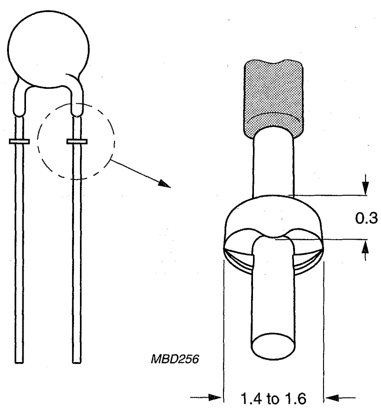
For dimensions, see Table 1.

Fig.2 Outline of component with straight leads and flange.



For dimensions, see Table 1.

Fig.3 Outline of component with kinked leads.



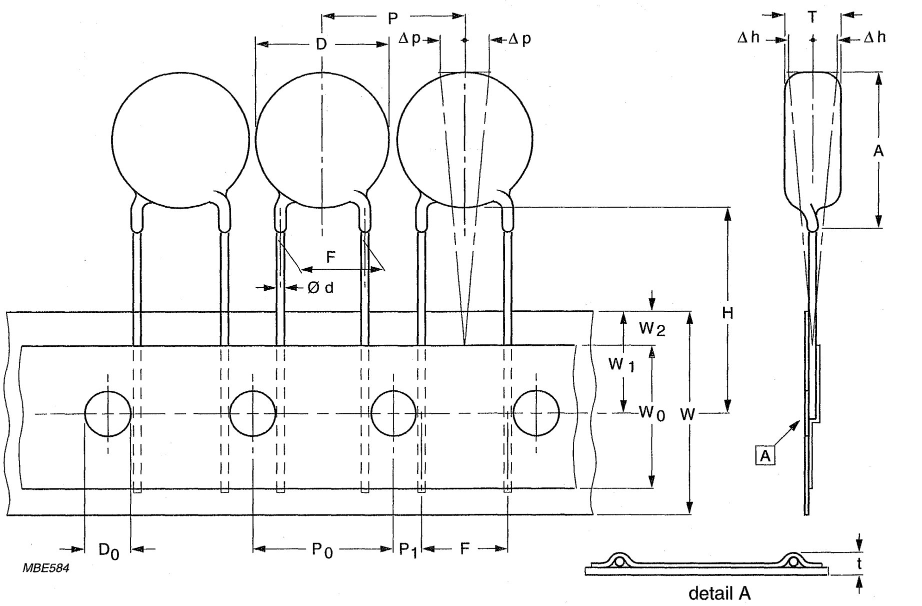
Dimensions in mm.

Fig.4 Outlines of flanged leads.

Table 1 Component dimensions and catalogue numbers

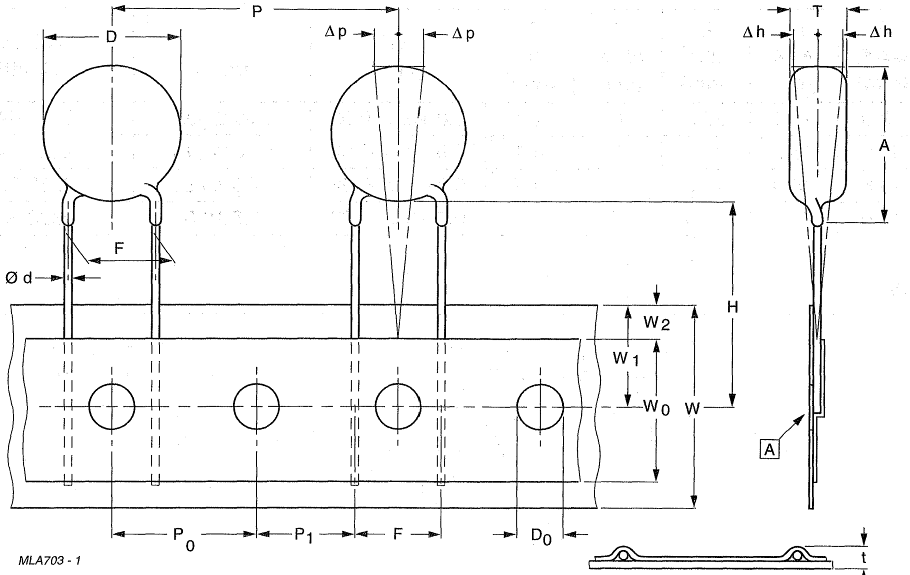
D MAX. (mm)	A MAX. (mm)	A_0 MAX. (mm)	L MIN. (mm)	T MAX. (mm)	T MIN. (mm)	Ød (mm)	F (mm)	CATALOGUE NUMBER
7.0	9.0	11.0	27.0	6	4.1	0.6 +0.0/–0.02	5 +0.6/–0.1	2322 592 .....
9.0	11.0	13.0	27.0	6	4.1	0.6 +0.0/–0.02	5 +0.6/–0.1	2322 593 .....
13.5	15.5	18.0	17.0	7	4.4	0.8 +0.0/–0.02	7.5 ±0.8	2322 594 .....
17.0	19.0	23.0	16.0	7	4.4	0.8 +0.0/–0.02	7.5 ±0.8	2322 595 .....

PACKAGING



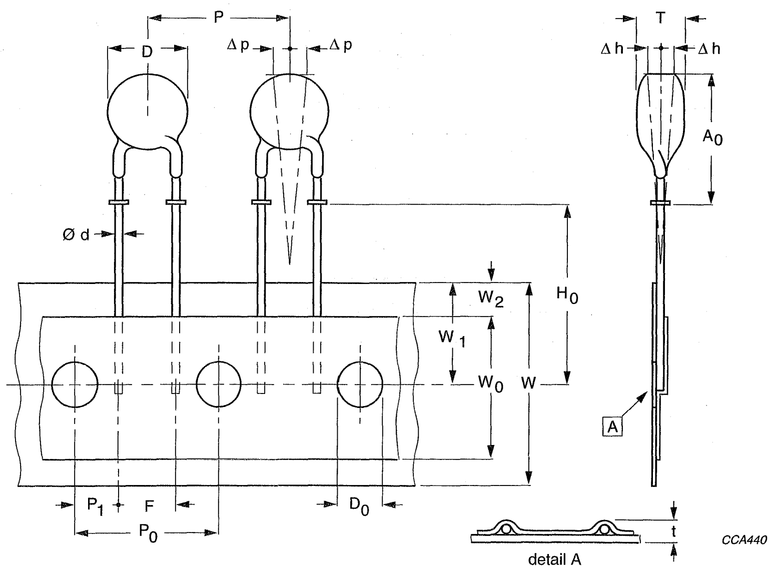
For dimensions, see Table 2.

Fig.5 Taped version with straight leads (only for 2322 592 and 2322 593 series).



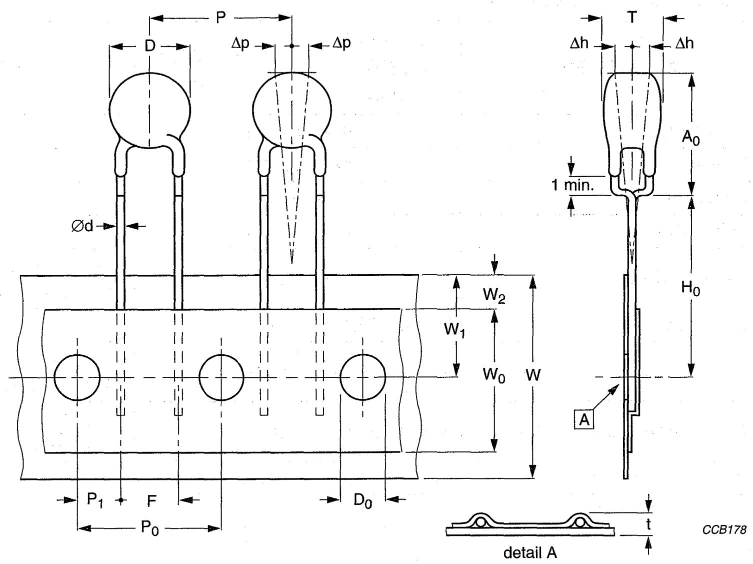
For dimensions, see Table 2.

Fig.6 Taped version with straight leads (only for 2322 594 and 2322 595 series).



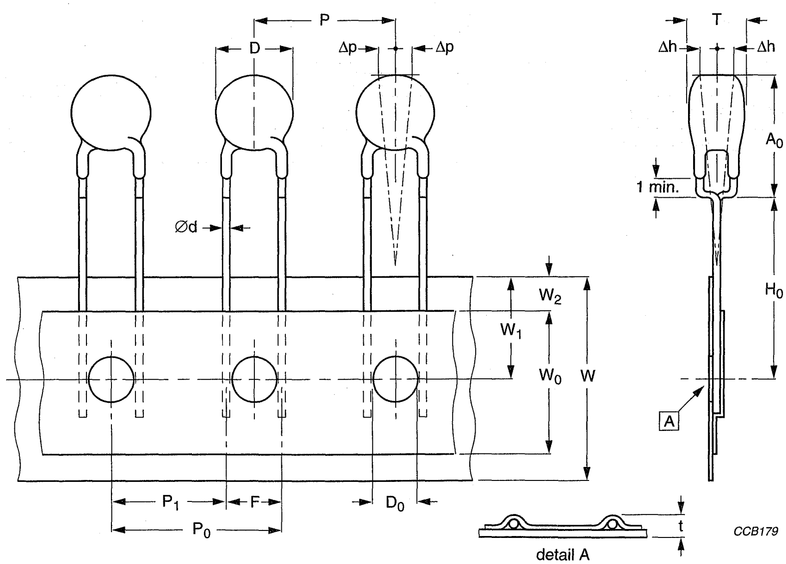
For dimensions, see Table 2.

Fig.7 Taped version with flanged leads (only for 2322 592 and 2322 593 series).



For dimensions, see Table 2.

Fig.8 Taped version with kinked leads (only for 2322 592 and 2322 593 series).



For dimensions, see Table 2.

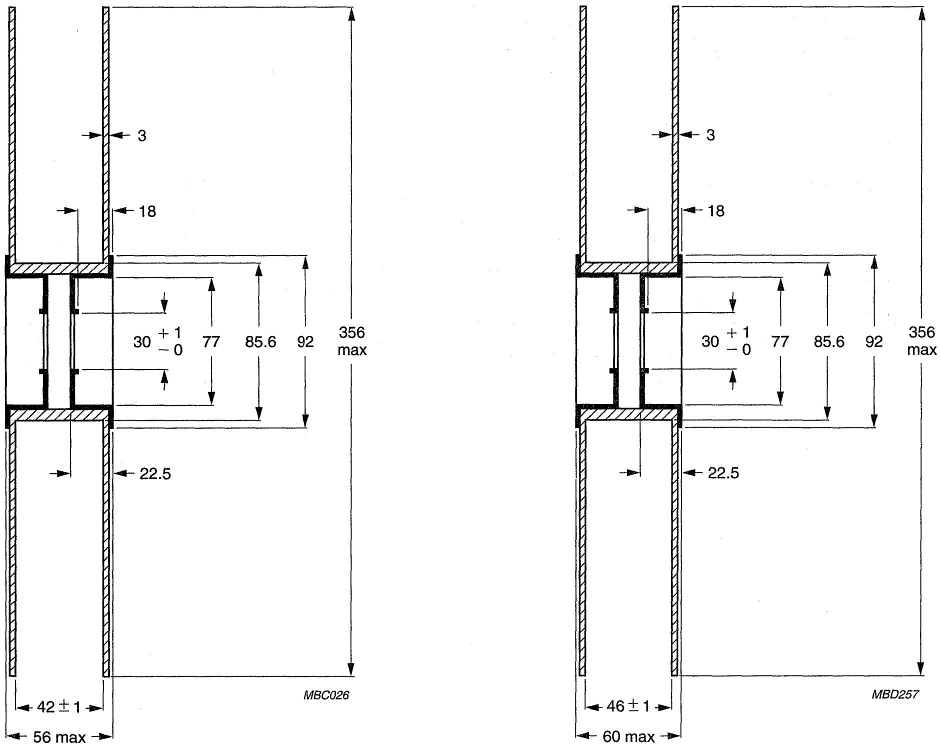
Fig.9 Taped version with kinked leads (only for 2322 594 and 2322 595 series).

Table 2 Taping data (based on *"IEC 60286-2"*)

SYMBOL	PARAMETER	DIMENSIONS NOMINAL (mm)	TOLERANCE (mm)	REMARKS
D	body diameter	see Table 1		
T	total thickness	see Table 1		
A_0; A	mounting height	see Table 1		
∅d	lead diameter	see Table 1		
F	lead to lead distance	see Table 1		guaranteed between component and tape
P	component pitch	12.7 or 25.4	±1.0	
P_0	feed hole pitch	12.7	±0.3	cumulative pitch error ±1 mm/20 pitches
P_1	feed hole centre to lead centre	3.85 or 8.95	±0.7	guaranteed between component and tape
Δp	component alignment	0.0	±1.3	
Δh	component alignment	0.0	±2.0	
W	tape width	18.0	+1.0/−0.5	
W_0	hold down tape width	≥12.5		
W_1	hole position	9.0	±0.5	
W_2	hold down tape position	≤3.0		
H	height between component and tape centre	18.0	+2.0/−0.0	straight lead version 2322 594 and 2322 585
		20.0	+2.0/−0.0	straight lead version 2322 592 and 2322 593
H_0	lead-wire flange height	16.0 or 18.25	±0.5	flanged and kinked lead versions
D_0	feed hole diameter	4.0	±0.2	
t	total tape thickness	≤1.4		with cardboard tape 0.5 ±0.1 mm

Table 3 Varistors on tape on reel

TYPE	2322 592 ..... ∅7 mm 14 V to 460 V	2322 593 ..... ∅9 mm 14 V to 460 V	2322 594 ..... ∅13.5 mm 14 V to 550 V	2322 595 ..... ∅17 mm 14 V to 460 V
Straight leads:				
H = 18 mm (2322 594 and 2322 595); see Fig.6	0...6	0...6	0...6	0...6
H = 20 mm (2322 592 and 2322 593); see Fig.5	0...6	0...6	0...6	0...6
Straight leads with flange; H_0 = 16 mm; see Fig.7	1...6	1...6	–	–
Straight leads with flange; H_0 = 18.25 mm; see Fig.7	2...6	2...6	–	–
Kinked leads; H_0 = 18.25 mm; see Fig.9	3...6	3...6	3...6	3...6
Kinked leads; H_0 = 16 mm; see Fig.8	8...6	8...6	8...6	8...6
Package quantities				
14 V to 460 V	3000	3000	1500	1500
510 V to 550 V	–	–	1200	1200

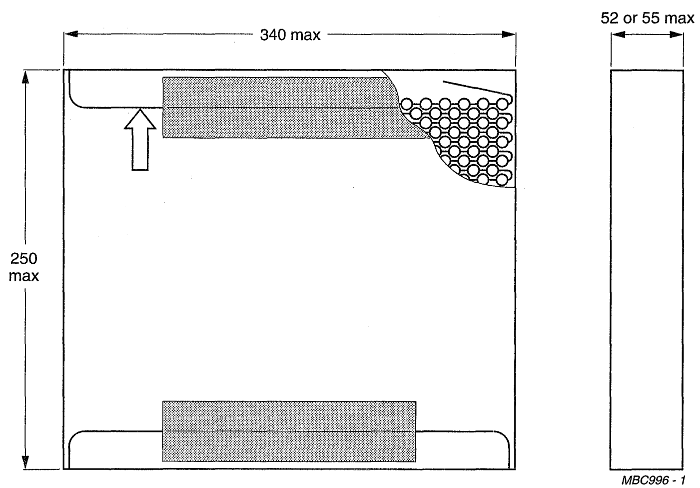


Dimensions in mm.

Fig.10 Dimensions of reels.

Table 4 Varistors on tape in ammopack

TYPE	2322 592 ..... ∅7 mm 14 V to 460 V	2322 593 ..... ∅9 mm 14 V to 460 V	2322 594 ..... ∅13.5 mm 14 V to 550 V	2322 595 ..... ∅17 mm 14 V to 550 V
Straight leads; H = 18 or 20 mm; see Figs 5 and 6	0...7	0...7	0...7	0...7
Straight leads with flange; H_0 = 16 mm; see Fig.7	1...7	1...7	–	–
Straight leads with flange; H_0 = 18.25 mm; see Fig.7	2...7	2...7	–	–
Kinked leads; H_0 = 18.25 mm; see Fig.9	3...7	3...7	3...7	3...7
Kinked leads; H_0 = 16 mm; see Fig.8	8...7	8...7	8...7	8...7
Package quantities				
14 to 175 V	1500	1500	750	750
230 to 460 V	1000	1000	–	–
230 to 300 V	–	–	600	600
320 to 550 V	–	–	500	500



Dimensions in mm.

Fig.11 Dimensions of ammopack.

Table 5 Varistors in bulk

TYPE	2322 592 ..... ∅7 mm 14 V to 460 V	2322 593 ..... ∅9 mm 14 V to 460 V	2322 594 ..... ∅13.5 mm 14 V to 550 V	2322 595 ..... ∅17 mm 14 V to 550 V
Straight leads; see Fig.1	5...6	5...6	5...6	5...6
Straight leads with flange; see Fig.2	7...6	7...6	–	–
Kinked leads; see Fig.3	6...6	6...6	6...6	6...6
Package quantities	250	250	250	100 and 250

ELECTRICAL CHARACTERISTICS

Table 6 Electrical data

PARAMETER	VALUE	UNIT
Maximum continuous voltage:		
RMS	14 to 550	V
DC	18 to 745	V
Maximum non-repetitive transient current (I_{nrp}) (8 × 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
Thermal resistance:		
2322 592	≈80	K/W
2322 593	≈70	K/W
2322 594	≈60	K/W
2322 595	≈50	K/W
Maximum dissipation:		
2322 592	100	mW
2322 593	250	mW
2322 594	400	mW
2322 595	600	mW
Temperature coefficient of voltage at 1 mA maximum	−0.065	%/K
Voltage proof between interconnected leads and case	2500	V
Climatic category	40/085/56	

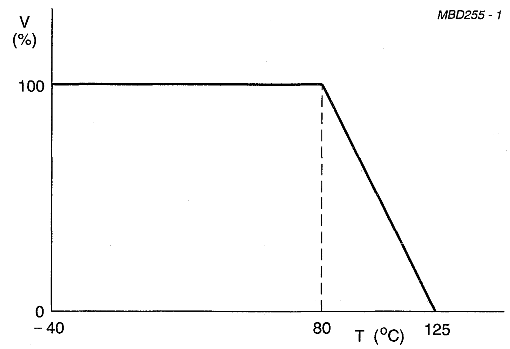


Fig.12 Derating curve.

Table 7 Electrical data and ordering information
Replace last digit of catalogue number with a ‘7’ for ordering on tape in ammopack.

MAXIMUM CONTINUOUS VOLTAGE		VOLTAGE[(2)] at 1 mA	MAXIMUM VOLTAGE at STATED CURRENT		MAXIMUM ENERGY[(3)] (10 × 1000 μs)	MAXIMUM NON-REP. TRANSIENT CURRENT[(4)] I_{nrp} (8 × 20 μs)	TYPICAL CAPACITANCE at 1 kHz	CATALOGUE NUMBERS
RMS[(1)] (V)	DC (V)	(V)	V (V)	I (A)	(J)	(A)	(pF)	2322 ... .
14	18	22	48	1.0	0.5	100	1300	592 .1406[(5)]
			43	2.5	1.7	250	2800	593 .1406[(5)]
			43	5.0	4.3	500	6000	594 .1406[(5)]
			43	10.0	5.4	1000	15000	595 .1406[(5)]
17	22	27	60	1.0	0.7	100	1050	592 .1706[(5)]
			53	2.5	2.0	250	2000	593 .1706[(5)]
			53	5.0	5.3	500	4000	594 .1706[(5)]
			53	10.0	6.9	1000	10000	595 .1706[(5)]
20	26	33	73	1.0	0.8	100	900	592 .2006[(5)]
			65	2.5	2.5	250	1500	593 .2006[(5)]
			65	5.0	6.5	500	3000	594 .2006[(5)]
			65	10.0	8.8	1000	7500	595 .2006[(5)]
25	31	39	86	1.0	0.9	100	500	592 .2506[(5)]
			77	2.5	3.0	250	1350	593 .2506[(5)]
			77	5.0	7.7	500	2600	594 .2506[(5)]
			77	10.0	9.4	1000	6500	595 .2506[(5)]
30	38	47	96	1.0	1.1	100	700	592 .3006[(6)]
			93	2.5	3.6	250	1600	593 .3006[(6)]
			93	5.0	9.2	500	2700	594 .3006[(6)]
			90	10.0	12.0	1000	6000	595 .3006[(6)]
35	45	56	123	1.0	1.4	100	560	592 .3506[(6)]
			115	2.5	4.4	250	1300	593 .3506[(6)]
			110	5.0	11.0	500	2200	594 .3506[(6)]
			105	10.0	14.0	1000	4800	595 .3506[(6)]
40	56	68	145	1.0	1.6	100	460	592 .4006[(6)]
			135	2.5	5.2	250	1000	593 .4006[(6)]
			130	5.0	13.0	500	1800	594 .4006[(6)]
			130	10.0	17.0	1000	3800	595 .4006[(6)]
50	65	82	145	5.0	2.6	400	370	592 .5006[(6)]
			140	10.0	7.0	1200	900	593 .5006[(6)]
			140	25.0	12.0	2500	1500	594 .5006[(6)]
			140	50.0	21.0	4500	3100	595 .5006[(6)]

MAXIMUM CONTINUOUS VOLTAGE		VOLTAGE[(2)] at 1 mA	MAXIMUM VOLTAGE at STATED CURRENT		MAXIMUM ENERGY[(3)] (10 × 1000 μs)	MAXIMUM NON-REP. TRANSIENT CURRENT[(4)] I_{nrp} (8 × 20 μs)	TYPICAL CAPACITANCE at 1 kHz	CATALOGUE NUMBERS
RMS[(1)] (V)	DC (V)	(V)	V (V)	I (A)	(J)	(A)	(pF)	2322 ... .
60	85	100	165	5.0	2.9	400	290	592 .6006[(6)]
			165	10.0	8.3	1200	700	593 .6006[(6)]
			165	25.0	15.0	2500	1200	594 .6006[(6)]
			165	50.0	24.0	4500	2300	595 .6006[(6)]
75	100	120	190	5.0	3.4	400	240	592 .7506[(6)]
			200	10.0	10.0	1200	530	593 .7506[(6)]
			200	25.0	18.0	2500	1000	594 .7506[(6)]
			200	50.0	29.0	4500	1900	595 .7506[(6)]
95	125	150	230	5.0	4.1	400	180	592 .9506[(6)]
			250	10.0	13.0	1200	450	593 .9506[(6)]
			250	25.0	22.0	2500	800	594 .9506[(6)]
			250	50.0	37.0	4500	1500	595 .9506[(6)]
130	170	205	310	5.0	5.5	400	130	592 .1316[(6)]
			340	10.0	17.0	1200	320	593 .1316[(6)]
			340	25.0	30.0	2500	580	594 .1316[(6)]
			340	50.0	56.0	4500	1050	595 .1316[(6)]
140	180	220	350	5.0	6.3	400	120	592 .1416[(6)]
			370	10.0	21.0	1200	290	593 .1416[(6)]
			370	25.0	33.0	2500	540	594 .1416[(6)]
			370	50.0	57.0	4500	950	595 .1416[(6)]
150	200	240	395	5.0	7.1	400	110	592 .1516[(6)]
			400	10.0	20.0	1200	270	593 .1516[(6)]
			400	25.0	36.0	2500	490	594 .1516[(6)]
			400	50.0	59.0	4500	850	595 .1516[(6)]
175	225	275	410	5.0	7.3	400	90	592 .1716[(6)]
			455	10.0	23.0	1200	230	593 .1716[(6)]
			455	25.0	41.0	2500	430	594 .1716[(6)]
			455	50.0	67.0	4500	750	595 .1716[(6)]
230	300	360	560	5.0	10.0	400	70	592 .2316[(6)]
			600	10.0	30.0	1200	170	593 .2316[(6)]
			600	25.0	54.0	2500	320	594 .2316[(6)]
			600	50.0	88.0	4500	540	595 .2316[(6)]

Varistors 2322 592 to 2322 595

MAXIMUM CONTINUOUS VOLTAGE		VOLTAGE(2) at 1 mA	MAXIMUM VOLTAGE at STATED CURRENT		MAXIMUM ENERGY(3) (10 × 1000 μs)	MAXIMUM NON-REP. TRANSIENT CURRENT(4) I_{nrp} (8 × 20 μs)	TYPICAL CAPACITANCE at 1 kHz	CATALOGUE NUMBERS
RMS(1) (V)	DC (V)	(V)	V (V)	I (A)	(J)	(A)	(pF)	2322 ... .
250	320	390	600	5.0	11.0	400	60	592 .2516(6)
			650	10.0	33.0	1200	160	593 .2516(6)
			650	25.0	58.0	2500	300	594 .2516(6)
			650	50.0	96.0	4500	480	595 .2516(6)
275	350	430	695	5.0	12.0	400	55	592 .2716(6)
			710	10.0	36.0	1200	140	593 .2716(6)
			710	25.0	63.0	2500	270	594 .2716(6)
			710	50.0	104.0	4500	440	595 .2716(6)
300	385	470	750	5.0	13.0	400	50	592 .3016(6)
			800	10.0	40.0	1200	130	593 .3016(6)
			800	25.0	71.0	2500	240	594 .3016(6)
			800	50.0	117.0	4500	400	595 .3016(6)
320	420	510	800	5.0	15.0	400	45	592 .3216(6)
			850	10.0	44.0	1200	120	593 .3216(6)
			850	25.0	77.0	2500	220	594 .3216(6)
			850	50.0	120.0	4500	370	595 .3216(6)
385	505	620	1000	5.0	18.0	400	40	592 .3816(6)
			1025	10.0	51.0	1200	95	593 .3816(6)
			1025	25.0	67.0	2500	180	594 .3816(6)
			1025	50.0	110.0	4500	280	595 .3816(6)
420	560	680	1100	5.0	20.0	400	35	592 .4216(6)
			1120	10.0	56.0	1200	85	593 .4216(6)
			1120	25.0	73.0	2500	165	594 .4216(6)
			1120	50.0	120.0	4500	250	595 .4216(6)
460	615	750	1200	5.0	21.0	400	30	592 .4616(6)
			1240	10.0	63.0	1200	75	593 .4616(6)
			1240	25.0	82.0	2500	150	594 .4616(6)
			1240	50.0	135.0	4500	225	595 .4616(6)
510	670	820	1355	25.0	89.0	2500	135	594 .5116(6)
			1355	50.0	145.0	4500	220	595 .5116(6)
550	745	910	1500	25.0	98.0	2500	120	594 .5516(6)
			1500	50.0	160.0	4500	180	595 .5516(6)

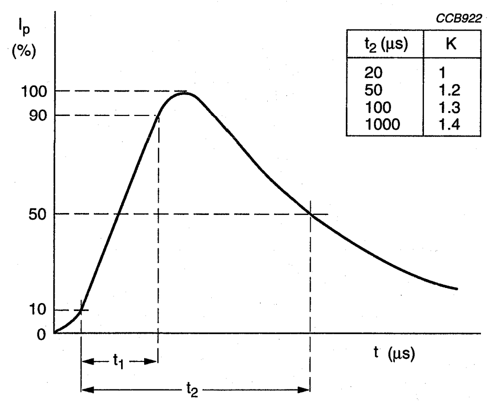
Notes to Table 7

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 *"paragraph 4.3 of CECC specification 42000"*. The tolerance on the voltage at 1 mA is ±10%.
3. High energy surges are generally of longer duration. The maximum energy for one pulse of 10 × 1 000 μs is given as a reference for longer duration pulses. This pulse can be characterised by peak current (I_p) and pulse width t_2 (virtual time of half I_p value, following *"IEC 60060-2, section 6"*). If V_p is the clamping voltage corresponding to I_p, the energy absorbed in the varistor is determined by the formula:

   $E = K \times V_p \times I_p \times t_2$

   where:

   K is dependent on the value of t_2 when the value of t_1 is between 8 μs and 10 μs; see Fig.13.
4. A current wave of 8 × 20 μs (requirement of *"paragraph B.2.10.1 of CECC specification 42000"*) is used as a standard for pulse current and clamping voltage ratings. The maximum non-repetitive transient current is given for one pulse applied during the life of the component.
5. Only available on request
6. CECC approved types.



t2 (μs)	K
20	1
50	1.2
100	1.3
1000	1.4

Fig.13 Peak current as a function of pulse width.

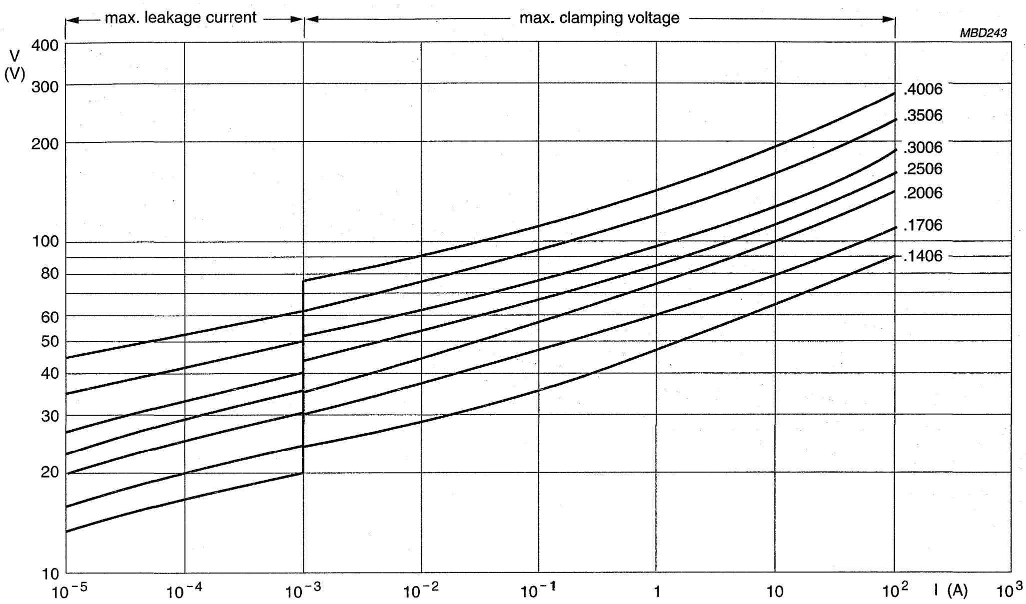


Fig.14 V/I characteristics, 14 V to 40 V (RMS); 2322 592 series.

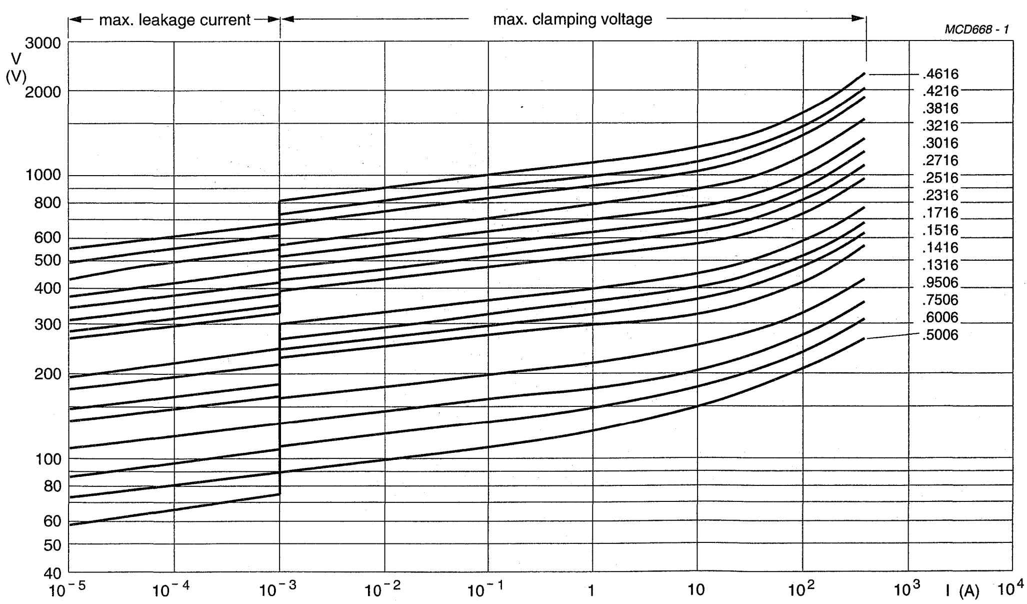


Fig.15 V/I characteristics, 50 V to 460 V (RMS); 2322 592 series.

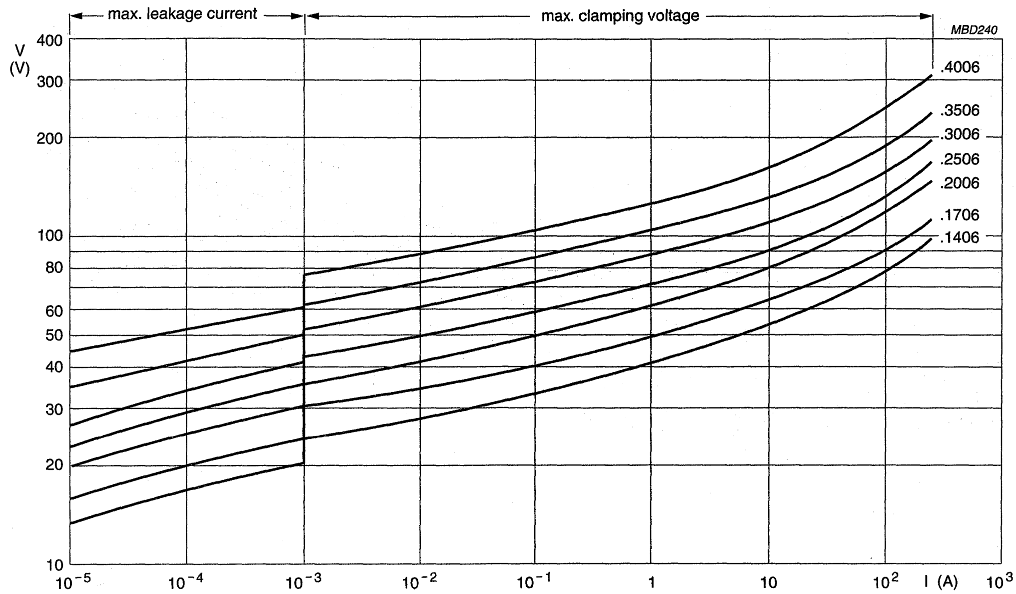


Fig.16 V/I characteristics, 14 V to 40 V (RMS); 2322 593 series.

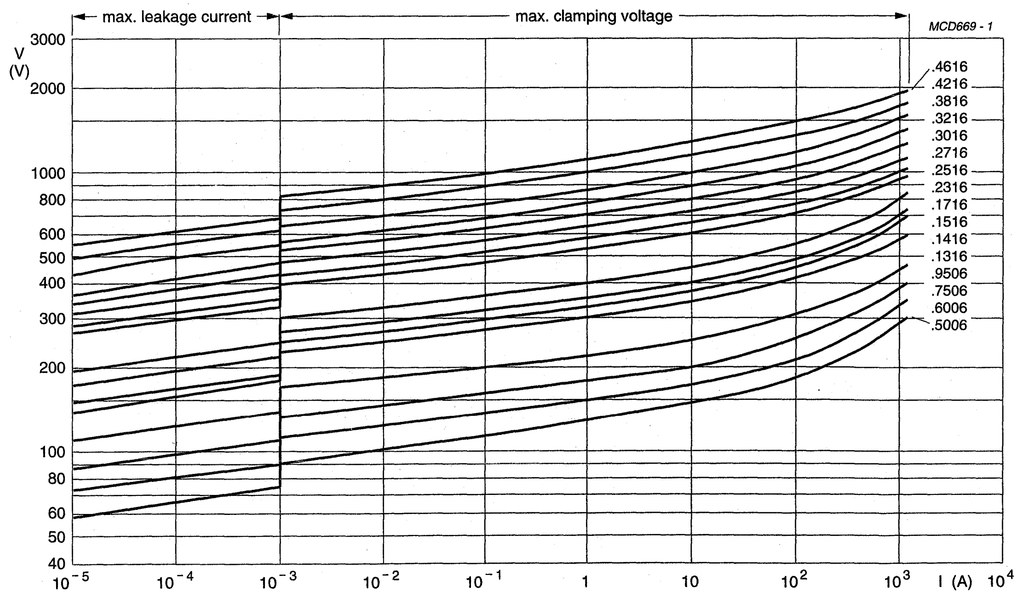


Fig.17 V/I characteristics, 50 V to 460 V (RMS); 2322 593 series.

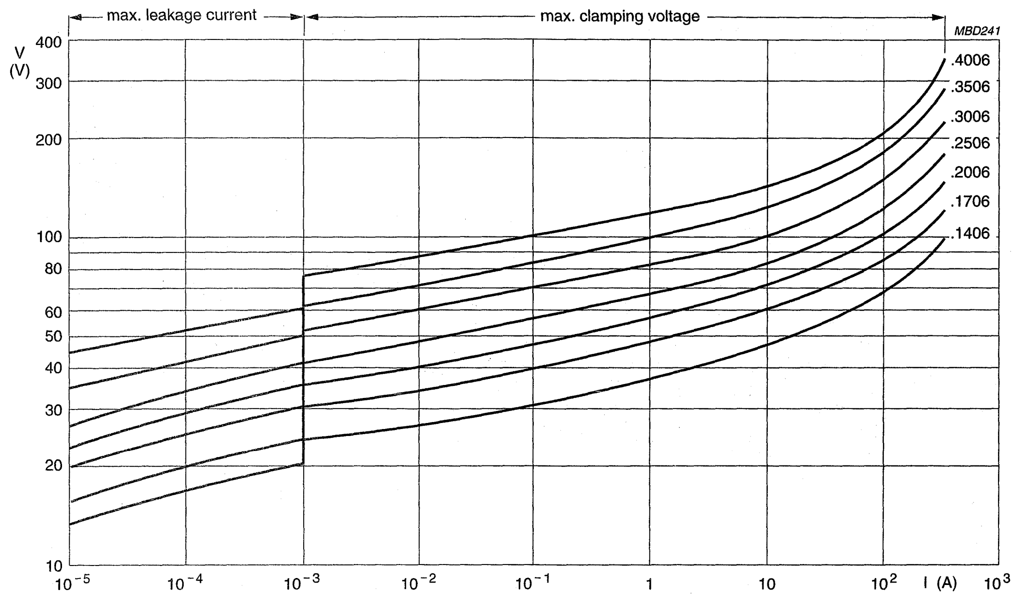


Fig.18 V/I characteristics, 14 V to 40 V (RMS); 2322 594 series.

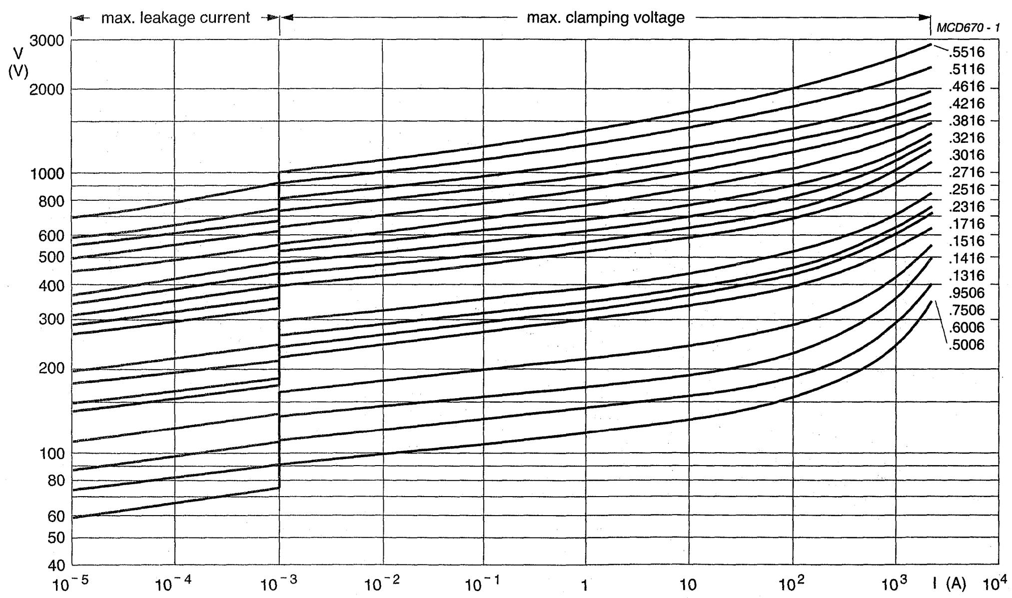


Fig.19 V/I characteristics, 50 V to 550 V (RMS); 2322 594 series.

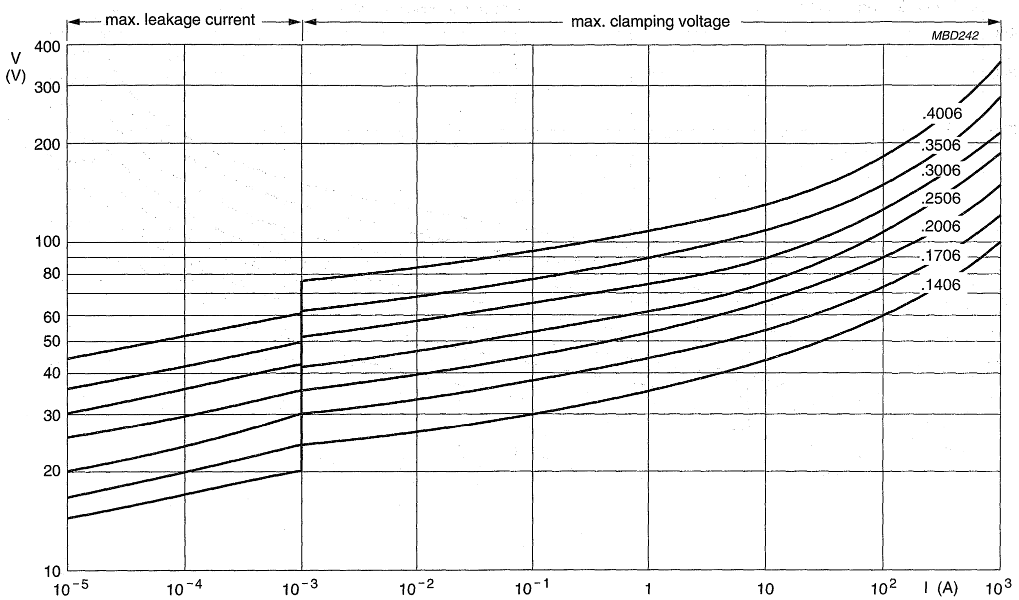


Fig.20 V/I characteristics, 14 V to 40 V (RMS); 2322 595 series.

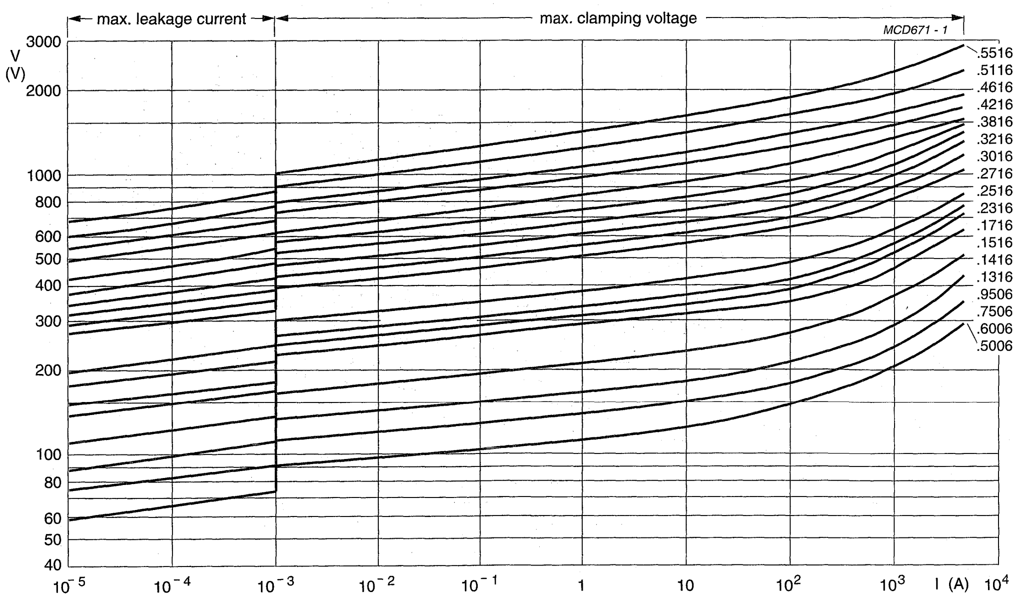


Fig.21 V/I characteristics, 50 V to 550 V (RMS); 2322 595 series.

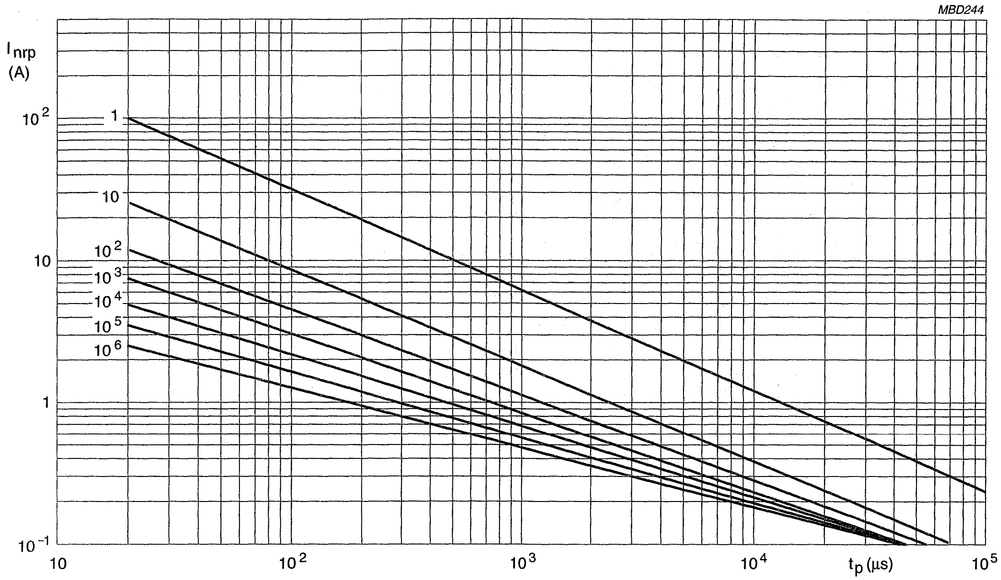


Fig.22 Maximum applicable transient current as a function of pulse duration, 14 V to 40 V (RMS); 2322 592 series.

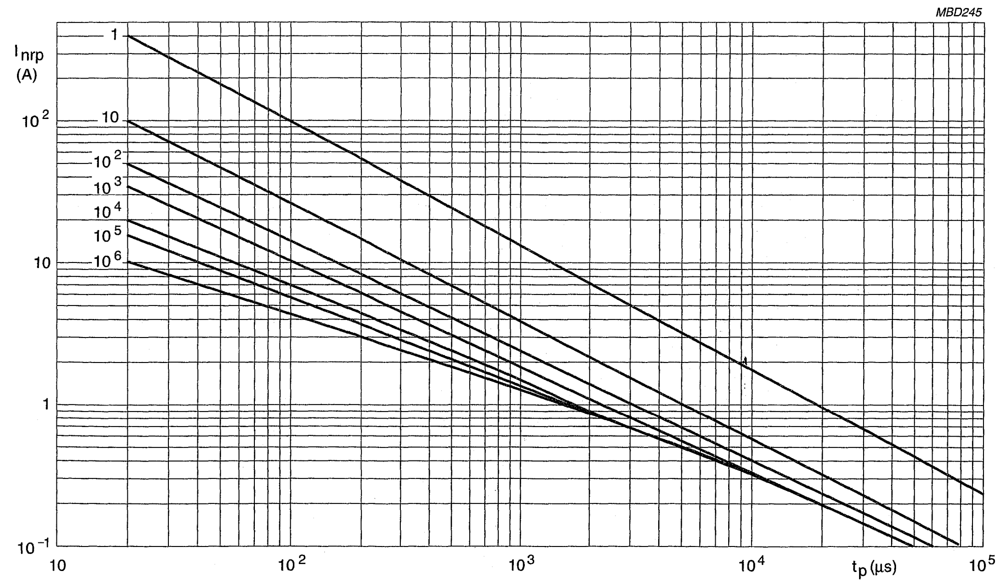


Fig.23 Maximum applicable transient current as a function of pulse duration, 50 V to 460 V (RMS); 2322 592 series.

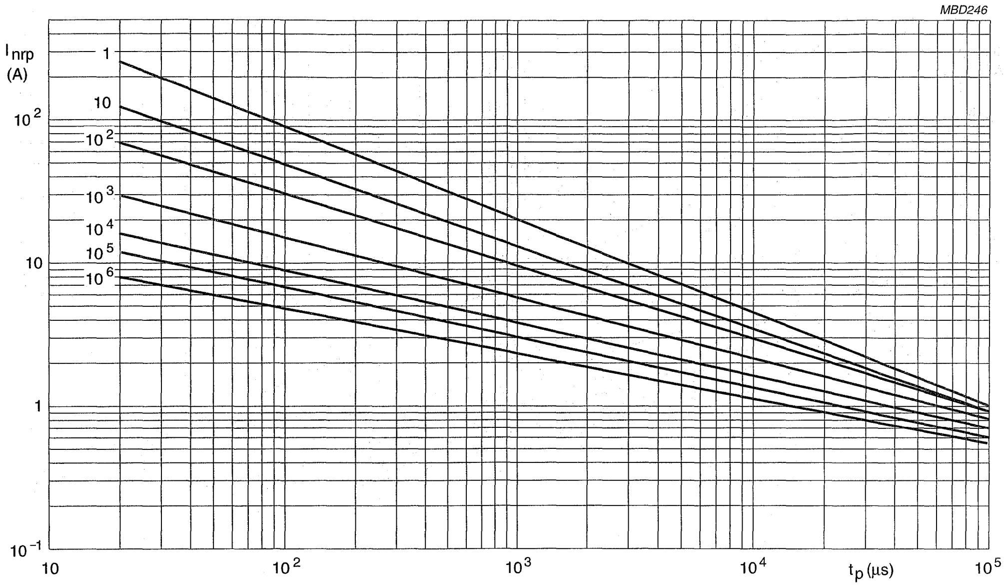


Fig.24 Maximum applicable transient current as a function of pulse duration, 14 V to 40 V (RMS); 2322 593 series.

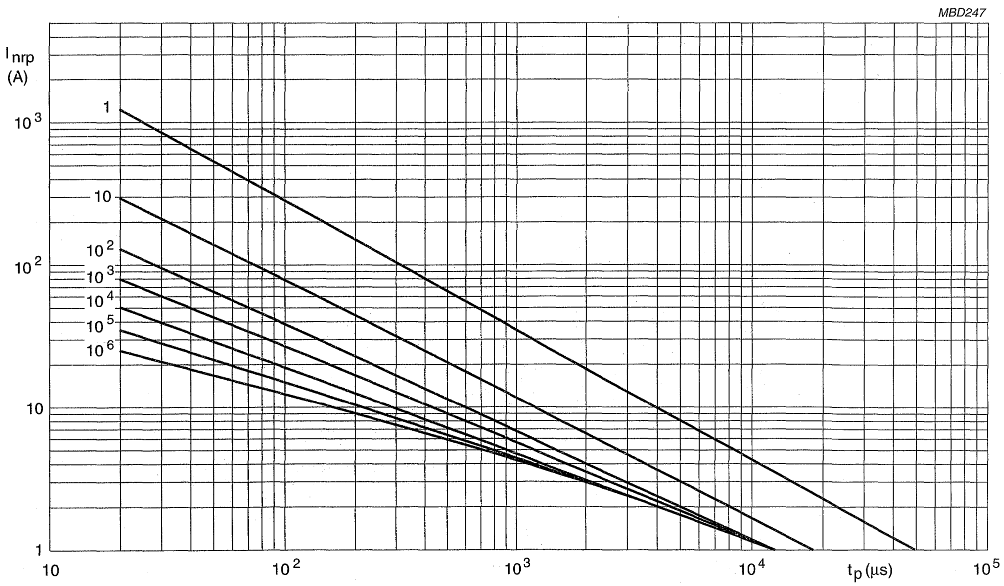


Fig.25 Maximum applicable transient current as a function of pulse duration, 50 V to 460 V (RMS); 2322 593 series.

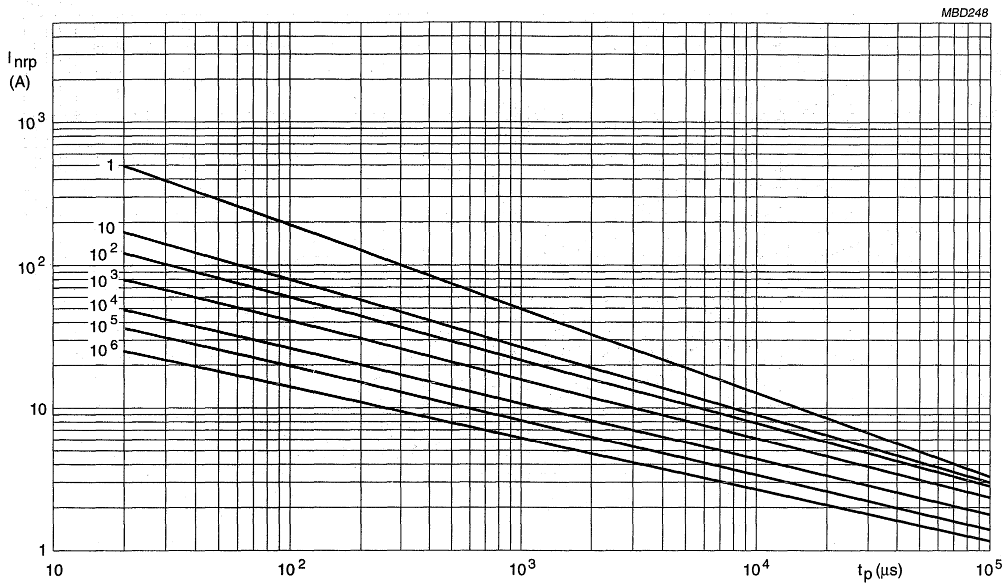


Fig.26 Maximum applicable transient current as a function of pulse duration, 14 V to 40 V (RMS); 2322 594 series.

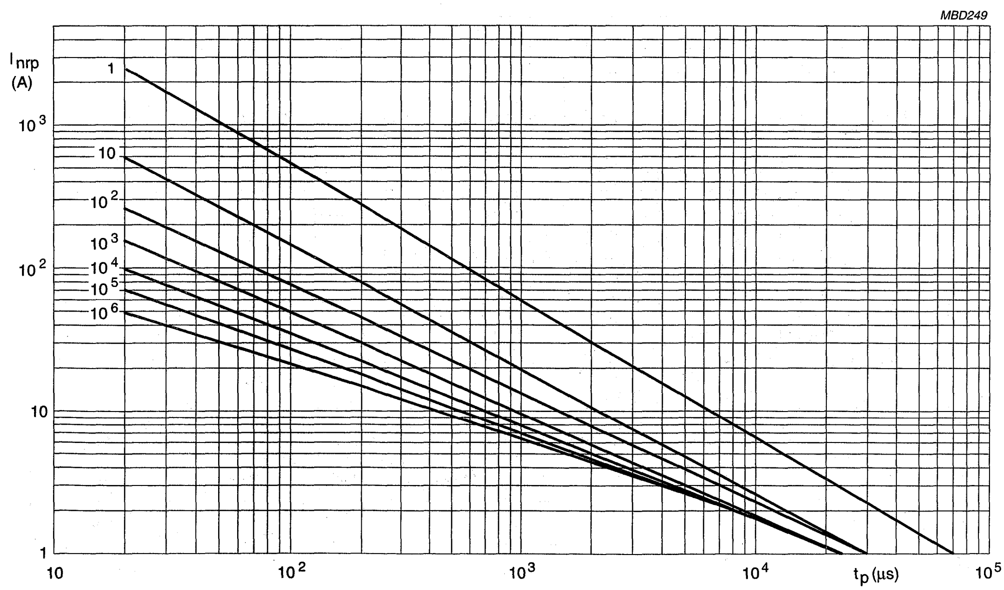


Fig.27 Maximum applicable transient current as a function of pulse duration, 50 V to 320 V (RMS); 2322 594 series.

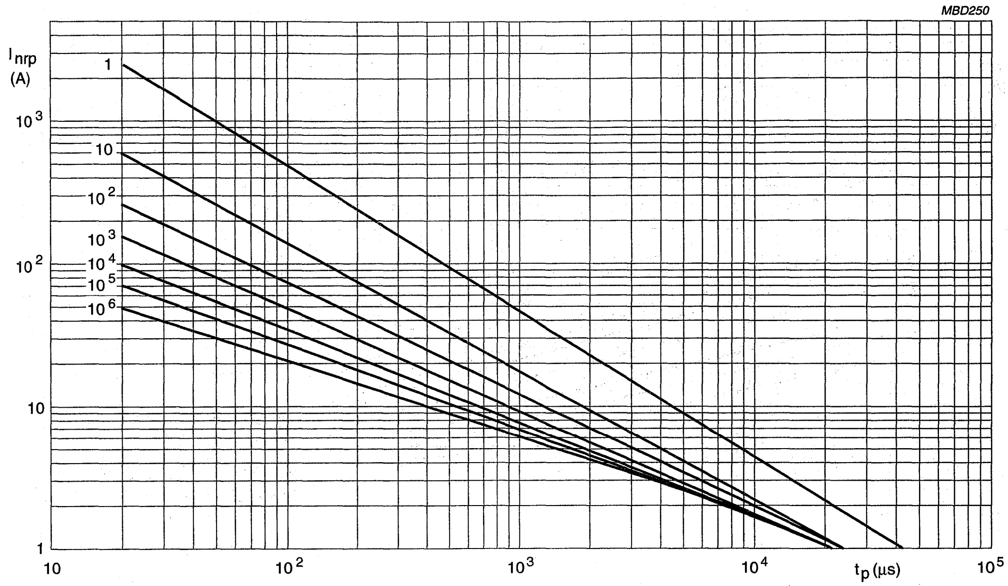


Fig.28 Maximum applicable transient current as a function of pulse duration, 385 V to 550 V (RMS); 2322 594 series.

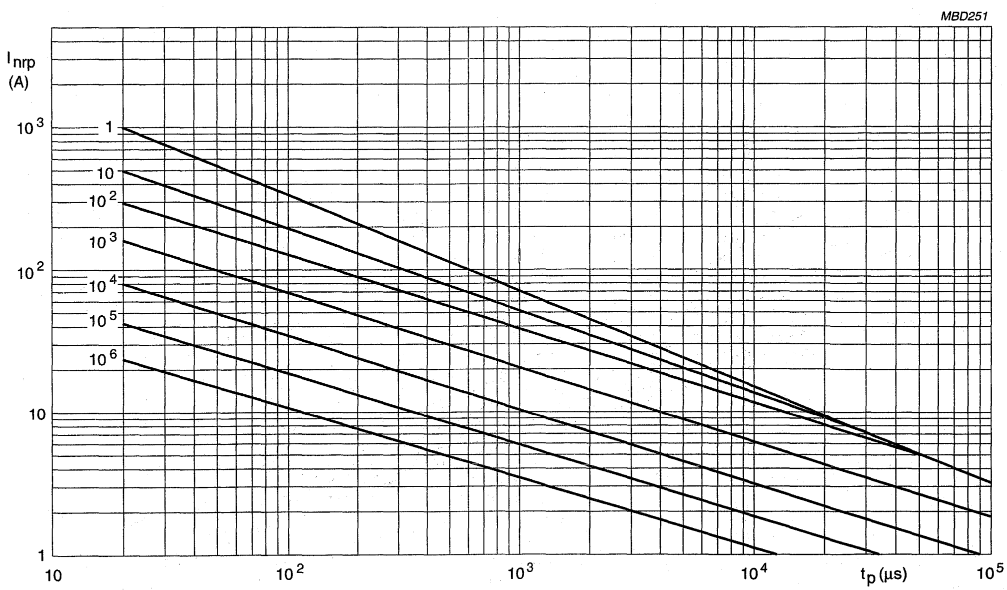


Fig.29 Maximum applicable transient current as a function of pulse duration, 14 V to 40 V (RMS); 2322 595 series.

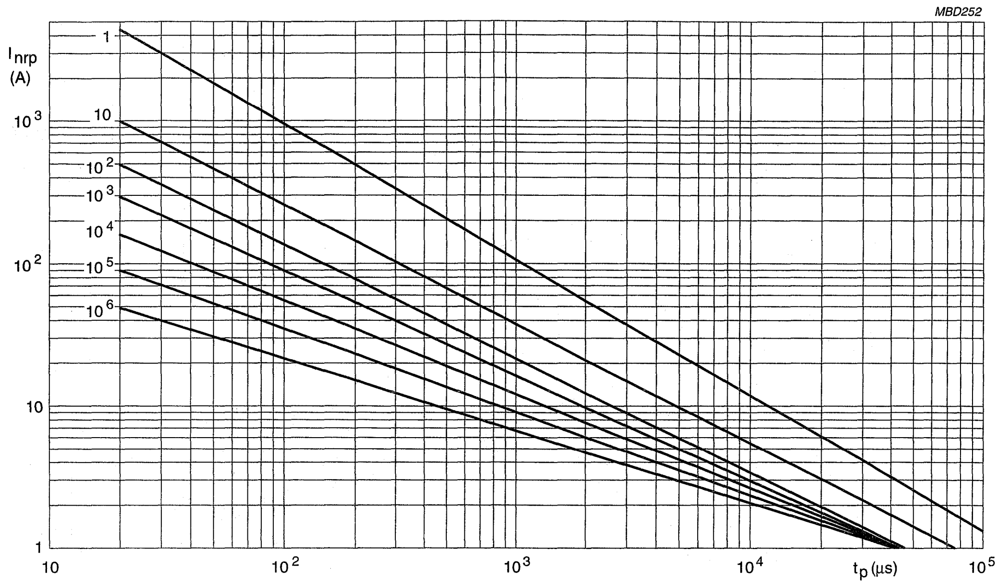


Fig.30 Maximum applicable transient current as a function of pulse duration, 50 V to 320 V (RMS); 2322 595 series.

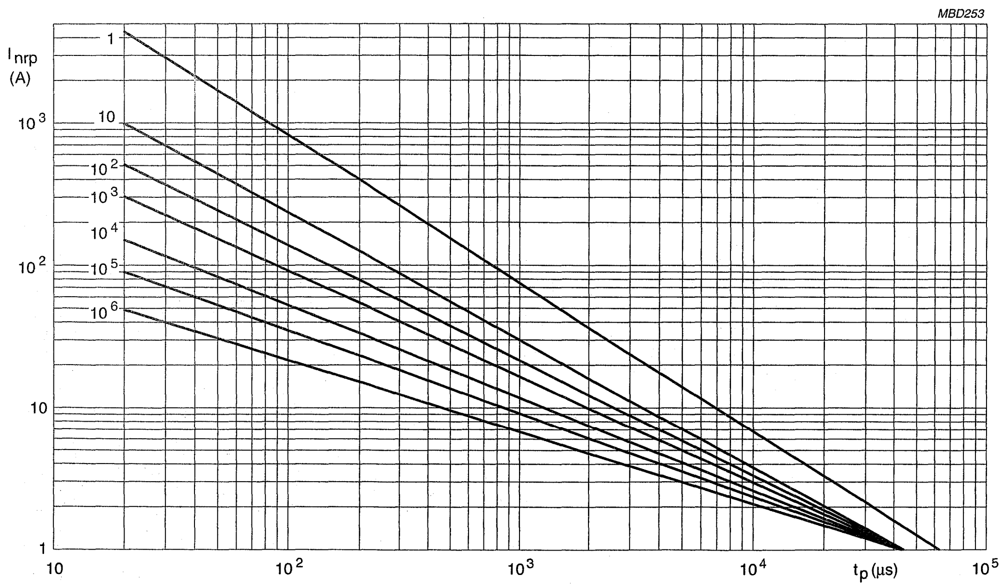


Fig.31 Maximum applicable transient current as a function of pulse duration, 385 V to 550 V (RMS); 2322 595 series.

HUMIDITY SENSOR

Humidity sensor 2322 691 90001

APPLICATIONS

- 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 which fit printed-circuit 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 incidental water condensation on the sensor foil. It should not be exposed to either acetone or chlorine vapours.

QUICK REFERENCE DATA

PARAMETER	VALUE	UNIT
Humidity range (RH)	10 to 90	%
Capacitance at +25 °C; 43% RH; 100 kHz	122 ±15%	pF
Sensitivity between 12 and 75% RH	0.4 ±0.05	pF/%RH
Frequency	1 to 1000	kHz
Maximum AC or DC voltage	15	V
Storage humidity range (RH)	0 to 100	%
Ambient temperature range:		
operating	0 to +85	°C
storage	−25 to +85	°C
Drop test:		
height of free fall	1	m
Mass	≈1.3	g

Humidity sensor 2322 691 90001

MECHANICAL DATA

Marking

PHILIPS H1.

Mounting

The device can be soldered directly on to a printed-circuit board or fastened with 3 mm bolts.

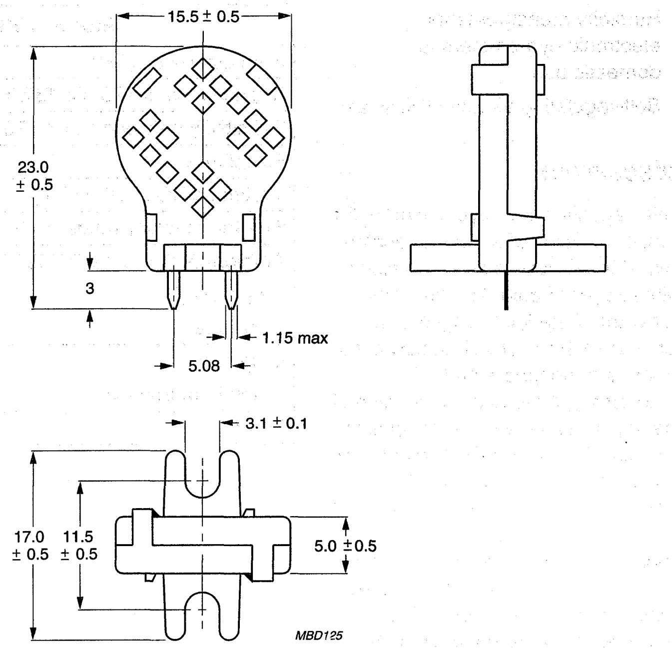
Soldering

Solderability: ≤240 °C; ≤4 s.

Resistance to heat: ≤240 °C; ≤4 s.

Robustness of terminations

Tensile strength: 10 N.



Dimensions in mm.

Fig.1 Component outline.

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, measurements are in accordance with *"IEC publication 60539"*.
Stability is in accordance with *"CECC 43000"* and *"IEC 60068-2"*.

PARAMETER	VALUE	UNIT
Humidity range (RH)	10 to 90	%
Capacitance at +25 °C; 43% RH; 100 kHz	122 ±15%	pF
Tan δ at +25 °C; 100 kHz; 43% RH	≤0.035	
Sensitivity between 12 and 75% RH	0.4 ±0.05	pF/%RH
Frequency range	1 to 1000	kHz
Temperature dependence	0.1	%RH/K
Response time in minutes (to 90% of indicated RH change at +25 °C, in circulating air):		
between 10 and 43% RH	<3	
between 43 and 90% RH	<5	
Hysteresis (for RH excursion of 10 to 90 to 10%)	≈3	%
Maximum AC or DC voltage	15	V
Storage humidity range (RH)	0 to 100	%
Ambient temperature range:		
operating	0 to +85	°C
storage	−25 to +85	°C
Mass	≈1.3	g

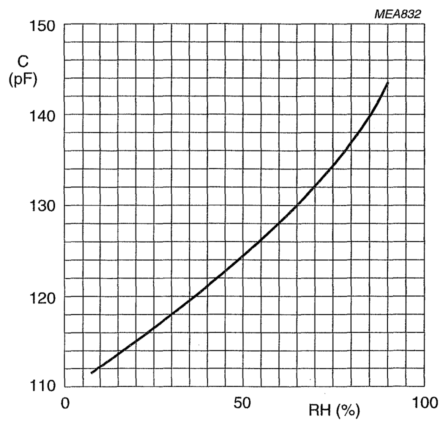


Fig.2 Typical capacitance as a function of relative humidity.

DATA HANDBOOK SYSTEM

Data handbook system

DATA HANDBOOK SYSTEM

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BC03	PA03	Potentiometers
BC04	PA04	Variable Capacitors
BC05	PA05	Film Capacitors
BC06	PA06b	Ceramic Capacitors
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According to *"IEC publication 60063"*.

E192	E96	E48	E192	E96	E48	E192	E96	E48	E192	E96	E48
100	100	100	178	178	178	316	316	316	562	562	562
101			180			320			569		
102	102		182	182		324	324		576	576	
104			184			328			583		
105	105	105	187	187	187	332	332	332	590	590	590
106			189			336			597		
107	107		191	191		340	340		604	604	
109			193			344			612		
110	110	110	196	196	196	348	348	348	619	619	619
111			198			352			626		
113	113		200	200		357	357		634	634	
114			203			361			642		
115	115	115	205	205	205	365	365	365	649	649	649
117			208			370			657		
118	118		210	210		374	374		665	665	
120			213			379			673		
121	121	121	215	215	215	383	383	383	681	681	681
123			218			388			690		
124	124		221	221		392	392		698	698	
126			223			397			706		
127	127	127	226	226	226	402	402	402	715	715	715
129			229			407			723		
130	130		232	232		412	412		732	732	
132			234			417			741		
133	133	133	237	237	237	422	422	422	750	750	750
135			240			427			759		
137	137		243	243		432	432		768	768	
138			246			437			777		
140	140	140	249	249	249	442	442	442	787	787	787
142			252			448			796		
143	143		255	255		453	453		806	806	
145			258			459			816		
147	147	147	261	261	261	464	464	464	825	825	825
149			264			470			835		
150	150		267	267		475	475		845	845	
152			271			481			856		
154	154	154	274	274	274	487	487	487	866	866	866
156			277			493			876		
158	158		280	280		499	499		887	887	
160			284			505			898		
162	162	162	287	287	287	511	511	511	909	909	909
164			291			517			920		
165	165		294	294		523	523		931	931	
167			298			530			942		
169	169	169	301	301	301	536	536	536	953	953	953
172			305			542			965		
174	174		309	309		549	549		976	976	
176			312			556			988		

E24	E12	E6	E3
10	10	10	10
11			
12	12		
13			
15	15	15	
16			
18	18		
20			
22	22	22	22
24			
27	27		
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33	33	33	
36			
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43			
47	47	47	47
51			
56	56		
62			
68	68	68	
75			
82	82		
91			

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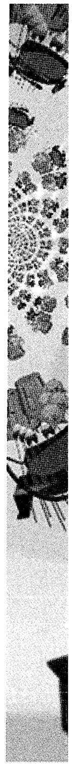

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