

INTRODUCTION

The data are presented - whenever possible - according to a "format", in which the following items are stated:

TITLE

QUICK REFERENCE DATA

APPLICATION

DESCRIPTION

MECHANICAL DATA

Mass

Mounting

Marking

ELECTRICAL DATA

Standard values of rated resistance and tolerance

COMPOSITION OF THE TYPE NUMBER

TESTS AND REQUIREMENTS

PACKAGING

DESCRIPTION

Most types of conventional resistors have a cylindrical ceramic body, either rod or tube. For special purposes, a high-grade aluminium ceramic is used.

The resistive element is either a carbon film, metal film, thick film or a wound wire element. Film types have been trimmed to the required ohmic resistance by cutting a helical groove in the resistive layer.

This process is controlled completely by computer and yields a high reliability.

The terminations are usually iron end caps onto which tinned connecting wires of electrolytic copper are welded.

All resistor bodies are coated with a colored lacquer or enamel for protection. Dependent on types, this lacquer provides electrical, mechanical and/or climatic protection - also against soldering flux and cleaning solvents, in accordance with MIL-STD-202E, method 215 and IEC 68-2-45.

MECHANICAL DATA

A dimensional sketch and if applicable, a table of dimensions is given. The lead length of axial types is not usually stated if the resistors are only available on tape.

The sketch does include however, length (L), diameter of the body (D) and the lead diameter (d). For certain types, the length is stated as L1 and L2; L1 is the body length, L2 is the body length plus lacquer on the leads. By specifying L1/L2, the dimensional "clean lead to clean lead" properties can be determined.

The length of the cylindrical body (L1) is measured by inserting the leads into the holes of two identical gauge plates (Fig.2) and moving these plates parallel to each other, until the resistor body is clamped without deformation (IEC publication 194).

This method does not apply to rectangular resistors, "stand-up" types and wire wound resistors with side terminations.

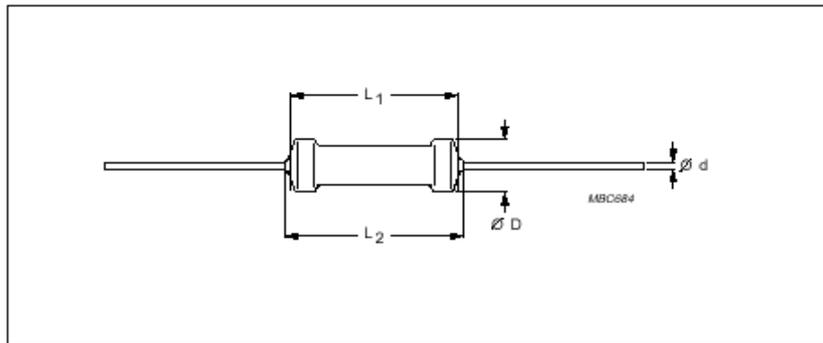


Fig. 1 Components outline

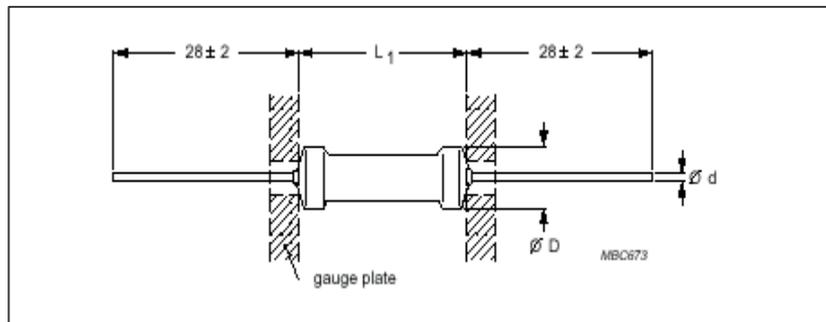


Fig. 2 Measurement of dimension (L1).

Table 1. The relationship between the diameter of the leads and the diameter of the holes in the gauge plate is shown below

d (mm)	Hole diameter
0.45	0.8
0.55 / 0.6	1.0
0.7	1.0
0.8	1.2

Mass

The mass weight is given per 100 resistors.

Mounting

Most types with straight axial leads and most in the "stand-up" version (radial leads), are suitable for processing on automatic insertion equipment, cutting and bending machines.

Marking

The resistors are either color coded or provided with an identification stamp. The color code consists of a number of colored bands according to IEC publication 62:

"Color code for fixed resistors". See also IEC 115-1 clause 4.5.

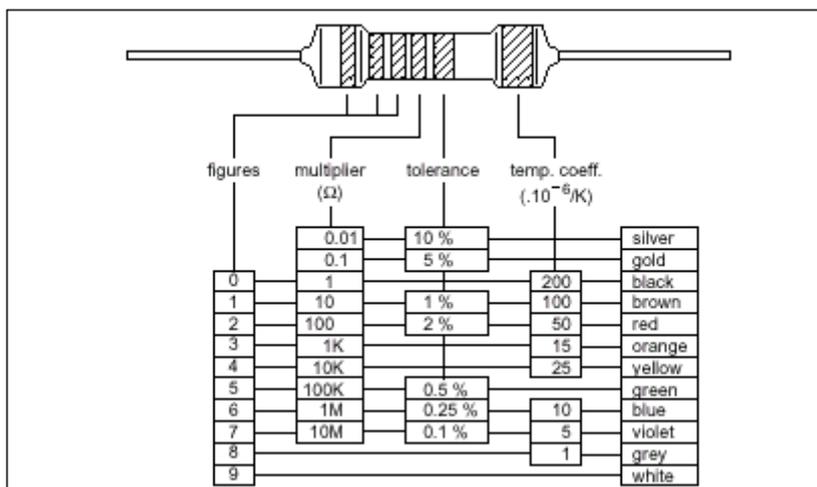
The colored bands indicate the nominal resistance, the tolerance on the resistance and, if applicable, the temperature coefficient. A maximum of bands may be used, but in some instances there are fewer, e.g. if the products are too small.

The resistance code consists of either three or four bands and is followed by a band representing the tolerance.

The resistance code includes the first two or three significant figures of the resistance value (in ohms), followed by an indicator. This is a factor by which the significant-figure value must be multiplied to find the relevant resistance value. Whether two or three significant figures are represented depends on the tolerance:

±2% and higher, requires two bands; ±1% and lower, requires three bands.

The "figures" refer to the first two or three digits of the resistance value of the standard series of values in a decade, in accordance with IEC publication 63 and as indicated in the relevant data sheet and printed at the back of this book.



Body colors

Table 2. the resistor bodies are lacquered in different colors to simplify identification

Color	Type
Light green	SFR25
Grey	NFR25, NFR25H, NFR1W
Light blue	SFR16S, MSR25
Red	PPRR1W, PPRR2W, BR0.5W, BR1W
Red-brown	SFR25H
Dark-green	NFR2W, PPRR3W
Blue	SR52, MSR52
Brown	SR25, SR37, SR37L, MSR16, MSR25, MSR37, MSR37L, MSR52, PFR1W
Light brown	WWR1W, WWR2W, WWR3W (Non inductive)
Light green	WWR1W, WWR2W, WWR3W (Inductive)
Black	WWR5W, WWR10W, HNR 0.25, HNR 0.25, HNR 0.5, HNR 1.5, HNR 2.5, HNR 3.0, HNR 4.5

ELECTRICAL DATA

The electrical data includes: nominal resistance range and tolerance, limiting voltage, temperature coefficient, absolute maximum dissipation, climatic category and stability.

The limiting voltage(DC or RMS)is the maximum voltage that may be continuously applied; see IEC publications 115-1 and 115-2. Where applicable, derating details and performance nomograms are given, showing the relationship between power dissipation, ambient temperature, hot-spot temperature and maximum resistance drift after prolonged operation.

For power resistors, graphs indicate the relationship between temperature rise and dissipation with lead-length or heatsinks as parameters.

The temperature rise in a resistor due to power dissipation, is determined by the laws of heat-conduction, convection and radiation. The maximum body temperature usually occurs in the middle of the resistor and is called the hot-spot temperature.

Heat conducted by the leads - which can be considerable in power types - must not reach the melting point of the solder at the joint. This condition may require the use of heatsinks and/or longer leads.

In the normal operating temperature range of film resistors the temperature rise at the hot-spot, ΔT , is proportional to the power dissipated: $\Delta T = A \times P$. The proportionally constant 'A' gives the temperature rise per watt of dissipated power and can be interpreted as a thermal resistance in K/W. This thermal resistance is a function of the dimensions of the resistor, the heat conductivity of the materials used and to a lesser degree, the way of mounting. The sum of the temperature rise and the ambient temperature is:

$$T_m = T_{amb} + \Delta T.$$

where

- T_m = hot-spot temperature
- T_{amb} = ambient temperature
- ΔT = temperature rise at hot-spot.

The stability of a film resistor during endurance tests is mainly determined by the hot-spot temperature and the resistance. The lower the resistance - other conditions remaining constant - the higher the stability due to greater film thickness.

Summarizing

dimensions and conductance of materials determine	heat resistance
heat resistance x dissipation	= temperature rise
temperature rise + ambient temperature	= hot spot temperature
hot-spot temperature and resistance value determine	stability

Performance

When specifying the performance of a resistor, the dissipation is given as a function of the hot-spot temperature, With the ambient temperature as a parameter.

From $\Delta T = A \times P$ and $T_m = T_{amb} + \Delta T$ it follows that:

$$P = \frac{T_m - T_{amb}}{A}$$

if P is plotted against T_m for a constant value of A, parallel straight lines are obtained for different values of the ambient temperature. The slope of these lines,

$$\frac{dP}{dT_m} = \frac{1}{A}$$

is the reciprocal of the heat resistance and is the characteristic for the resistor.

The stability $\frac{\Delta R}{R}$ can be determined experimentally, for instance after 1000h, as a function of the hot-spot temperature with the resistance value as a parameter. It has been found

that the resistance changes exponentially with temperature, giving a straight line when

$$\log \frac{\Delta R}{R}$$

is plotted against T_m .

A combination of the graphs of P and $\frac{\Delta R}{R}$ against T_m gives a nomogram from which

the values of several variables can be determined for a resistor of a given size under different working conditions. An example of such a nomogram with fictitious values is given in Fig.3. The intersection of the broken line with the horizontal axis gives the hot-spot temperature under chosen conditions.

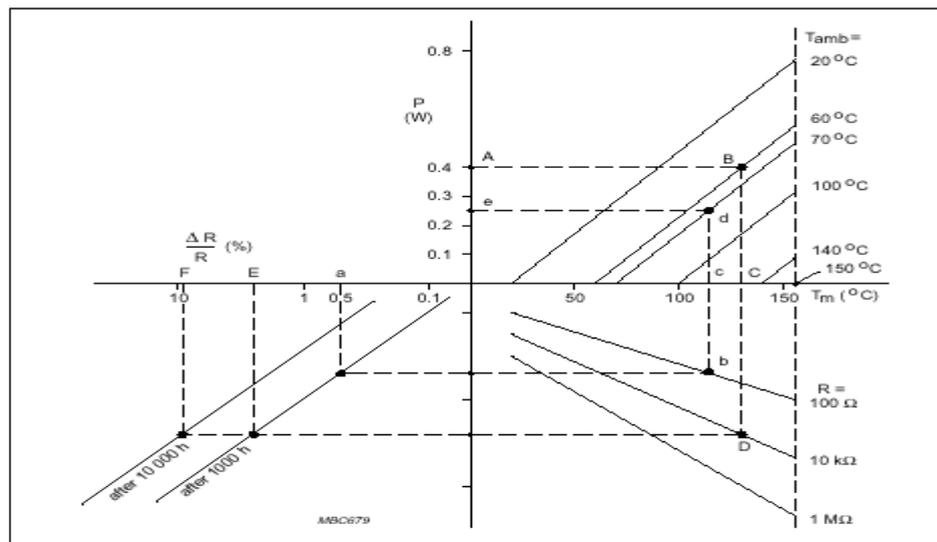


Fig. 3 Performance nomogram (for fictitious resistor) illustrating the way of specifying the performance of film resistors.

Example: If the temperature coefficient of a resistor of $R_{nom} = 1 \text{ M}\Omega$ between -55°C and $+155^\circ\text{C}$ is $\pm 100 \cdot 10^{-6}/\text{K}$ its resistance will be:

at 25°C :

$1,000,000 \text{ }\Omega$ (nominal = rated value)

at $+155^\circ\text{C}$:

$1,000,000 \text{ }\Omega \pm (130 \cdot 100 \cdot 10^{-6}) \times 1,000,000 \text{ }\Omega = 1,013,000 \text{ }\Omega$ or $987,000 \text{ }\Omega$

at -55°C :

$1,000,000 \text{ }\Omega \pm (80 \cdot 100 \cdot 10^{-6}) \times 1,000,000 \text{ }\Omega$ or $1,008,000 \text{ }\Omega$

If the temperature coefficient is specified as $\leq 100 \cdot 10^{-6}/\text{K}$ the resistance will be within the shaded area.

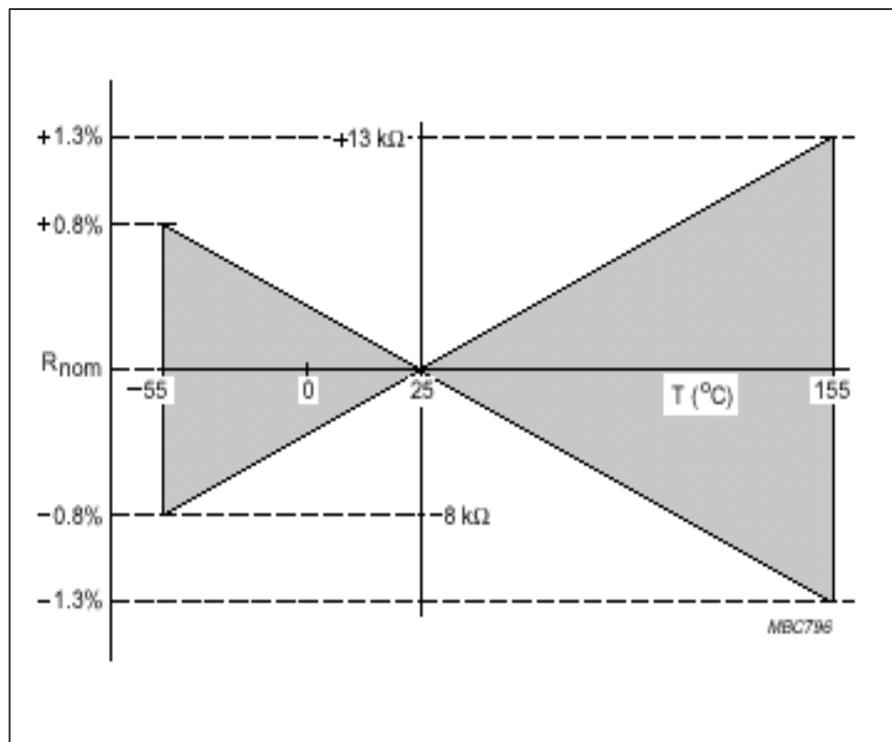


Fig.4 Temperature coefficient

HEAT RESISTANCE(R_{th})

Heat resistance is the thermal resistance that prohibits the release of heat generated within the resistor to the surrounding environment. It is expressed in K/W and defines the surface temperature (T_{HS}) of the resistor in relation to the ambient temperature (T_{amb}) and the load (P) of the resistor, as follows:

$$T_{HS} = T_{amb} + P \times R_{th}$$

The thermal resistance given in the specification is determined according to the following arrangement (Part DIN 44050) (T_{amb} between 20 and 25°C).

The resistor is mounted on a PCB which is set up vertically, with the resistor horizontal. Using an infrared camera, a thermal image is made of the resistor, thus defining the hot-spot and solder-spot temperatures.

It should be noted that different ways of mounting give differing results, i.e. mounting with a higher heat conductance gives a lower thermal resistance figure; mounting with a lower heat conductance gives a higher thermal resistance figure.

PULSE-LOAD BEHAVIOUR

Knowing the thermal characteristics of a resistor, it is possible to calculate the load due to a single pulse, which will cause a resistor to fail by going open circuit.

This theoretical maximum can be expressed in terms of peak pulse power, P , and pulse duration, t ; the straight line in Fig.6 is a typical example for a film resistor. In practice, owing to variations in the resistance film, substrate, or spiralling, resistors fail at loads less than this theoretical maximum; the dashed line in Fig.6 shows the observed maximum for a resistor under single-pulse loading.

The magnitude of a single pulse at which failure occurs is of little practical value. More usually, the resistor must withstand a continuous train of pulses of repetition time t_p during which only a small resistance change is acceptable. This resistance change $\Delta R/R$ is equal to the change permissible under continuous load conditions.

The continuous pulse train and small permissible resistance change both reduce the maximum handling capability.

Using a computer program which takes account of all factors affecting behaviour under pulse loads, curves similar to those of Fig.6 are being produced for all resistor ranges.

Measurements have shown that the calculated value is accurate to within 10% of the true value. However, maximum peak pulses as indicated in Fig.7, should not be exceeded.

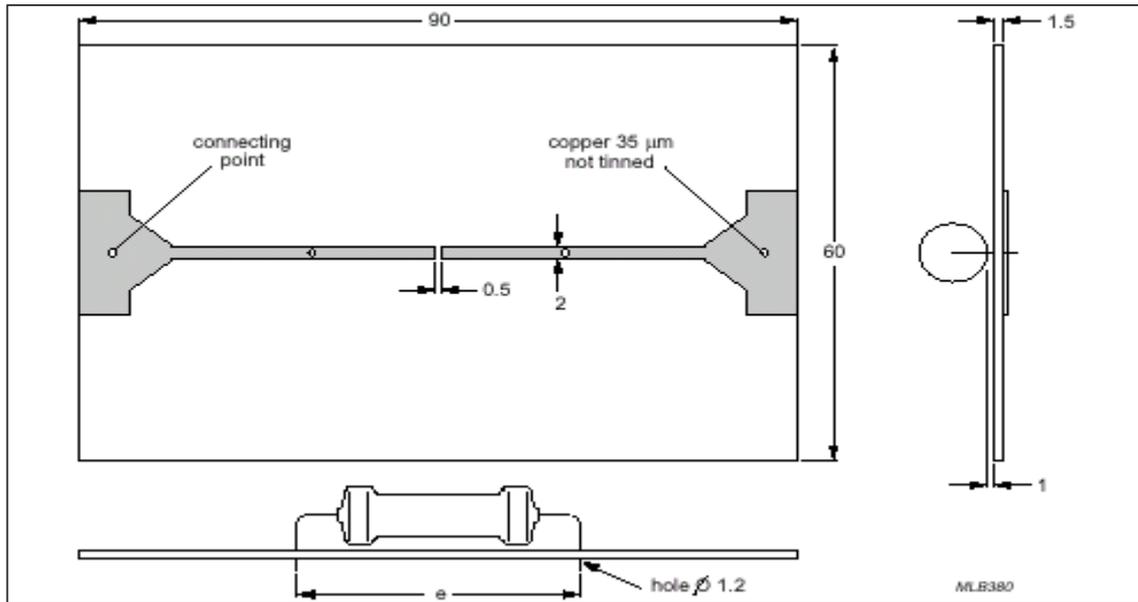


Fig5. Mounting dimensions.

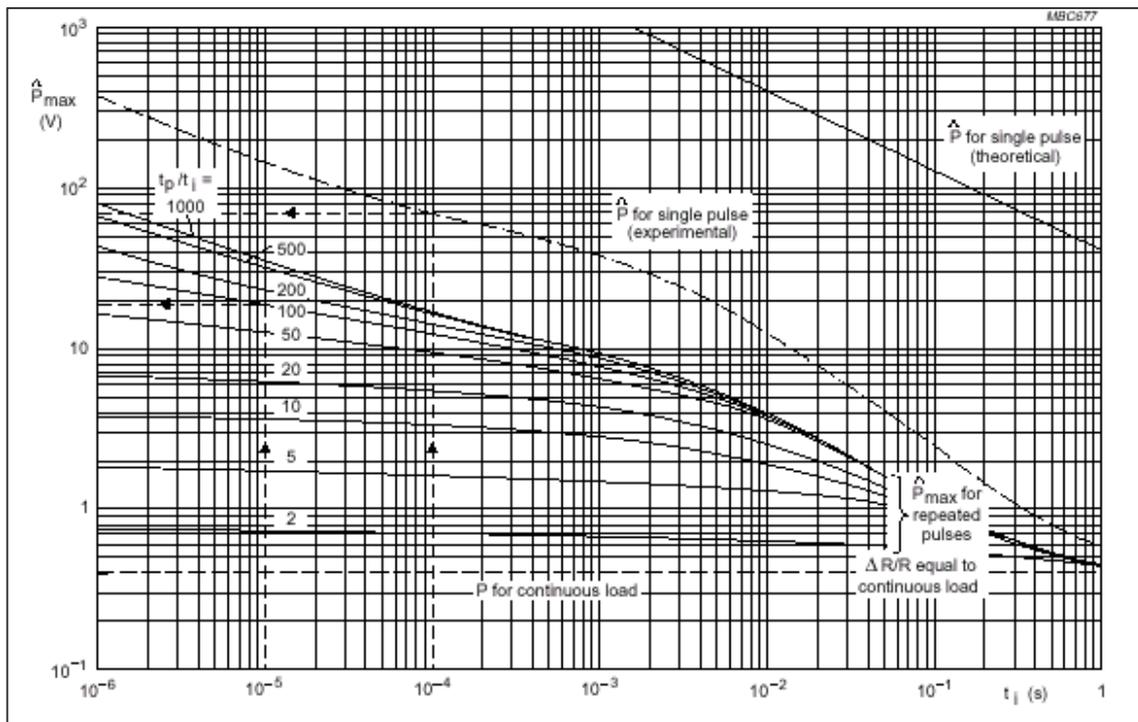


Fig. 6 Maximum permissible peak pulse(P_{max}) as a function of pulse duration (t_j) for a typical resistor.

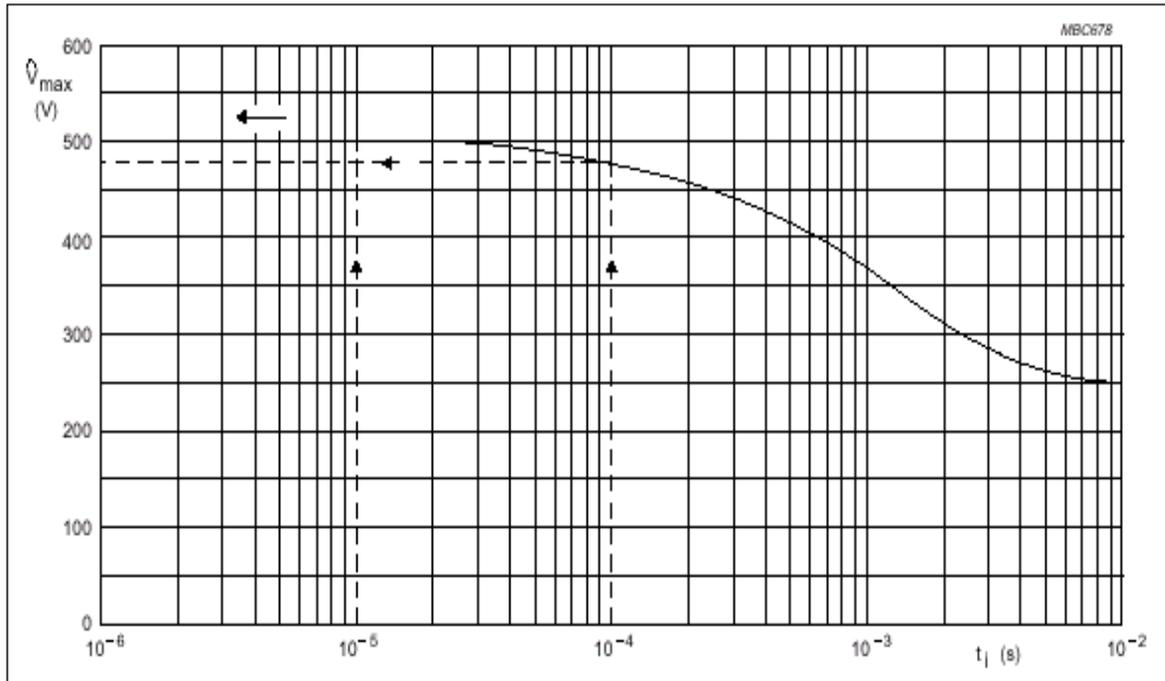


Fig. 7 Max. permissible peak pulse voltage (V_{max}) as a function of pulse duration (t_l) for a typical resistors

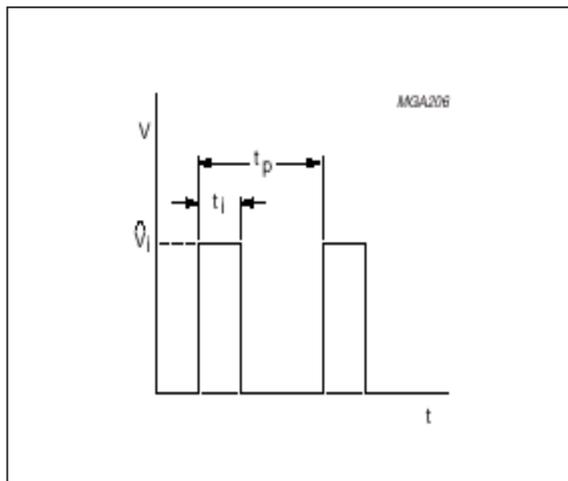


Fig. 8 Rectangular pulse.

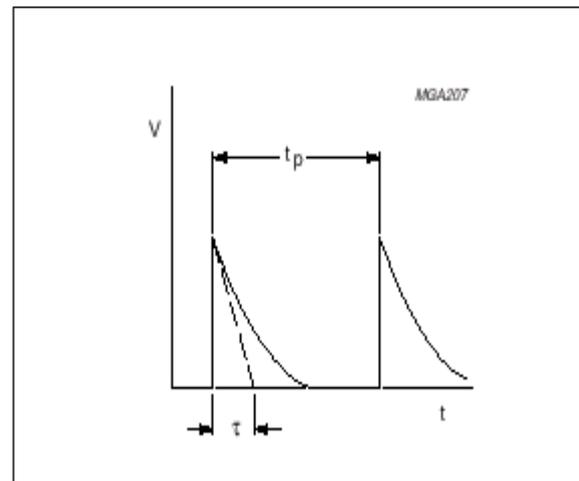


Fig. 9 Exponential pulses.

Definition of symbols used in Figs 6, 7, 8 and 9

- P** = applied peak pulse power
P_{max} = maximum permissible peak pulse power (Fig.6)
- V_i** = applied peak pulse voltage (Figs 8 and 9)
V_{max} = maximum permissible peak pulse voltage (Fig.7)
- R_{nom}** = nominal resistance value
- t_i** = pulse duration (rectangular pulses)
- t_p** = pulse repetition time
- r** = time constant (exponential pulses)
- T_{amb}** = ambient temperature
- T_{hsp}** = maximum hot-spot temperature of the resistor.

Definitions of pulse load behavior; metal film resistors (R > 10 Ω)

SINGLE PULSE

The resistor is considered to be operating under single pulse conditions if, during its life, it is loaded with a limited number (approx. 1500) of pulses over long time intervals (greater than one hour).

REPETITIVE PULSE

The resistor is operating under repetitive pulse conditions if it is loaded by a continuous train of pulses of similar power.

Determination of pulse loading

The graphs in Figs 6 and 7 may be used to determine the maximum pulse loading for a resistor. The calculations assume:

- T_{amb} = 70 °C
- T_{hsp} is the maximum permissible hot-spot temperature for the relevant resistor family
- ΔR/R equal to the permitted value for 1000 hours at continuous level.

- For repetitive rectangular pulses:

$\frac{V_i^2}{R}$ must be lower than the value of P_{\max} given by the solid lines of Fig.6 for the

applicable value of t_i and duty cycle t_p/t_i .

- V_i must be lower than the value of V_{\max} given in Fig.7 for the applicable value of t_i

- For repetitive exponential pulses:

- As for rectangular pulses, except that $t_i = 0.5 r$.

- For single rectangular pulses:

$\frac{V_i^2}{R}$ must be lower than the P_{\max} given by the dashed line of Fig.6 for the

applicable value of t_i .

- V_i must be lower than the value of V_{\max} given in Fig.7 for the applicable value of t_i .

Examples

Determine the stability of a typical resistor for operation under the following pulse-load conditions.

1. CONTINUOUS PULSE TRAIN

A 100 Ω resistor is required to operate under the following conditions: $V_i = 40$ V;

$$t_i = 10^{-5} \text{ s}; t_p = 10^{-3} \text{ s}.$$

Therefore:

$$P = \frac{40^2}{100} = 16 \text{ W} \text{ and } \frac{t_p}{t_i} = \frac{10^{-3}}{10^{-5}} = 100$$

For

$$t_i = 10^{-5} \text{ s} \text{ and } \frac{t_p}{t_i} = 100$$

Fig. 6 gives $P_{\max} = 19$ W and Fig. 7 gives $V_{\max} = 500$ V. As the operating conditions $P = 16$ W and $V_i = 40$ V are lower than these limiting values, this resistor can be safely used.

SINGLE PULSE

A 1000 Ω resistor is required to operate under the following conditions:

$$V_i = 200 \text{ V}; t_i = 10^{-4}.$$

Therefore:

$$P_{\max} = \frac{200^2}{1000} = 40 \text{ W}.$$

The dashed curve of Fig.6 shows that at $t_i = 10^{-4}$ s, the permissible $P_{\max} = 70 \text{ W}$ and Fig.7 shows a permissible V_{\max} of 480 V, so again this resistor may be used.

COMPOSITION OF THE CATALOGUE NUMBER

Resistors are ordered by their catalogue number, a 12-digit number. The packaging method is an integral part of this number, and so is the resistance code.

TESTS AND REQUIREMENTS

Essentially all tests on resistors are carried out according to the schedule of IEC publication 115-1 in the specified climatic category and in accordance with IEC publication 68, "Recommended basic climatic and mechanical robustness testing procedure for electronic components".

In some instances deviations from the IEC recommendations are made.

STANDARD PACKING

Most types may be processed automatically and are supplied on tape for this purpose, i.e. a bandolier which fits most commonly used automatic mounting machines.

Not all bandolier configurations are identical, the deviating parameters are given in Figs 10 and 11.