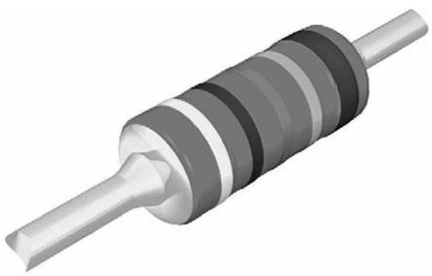
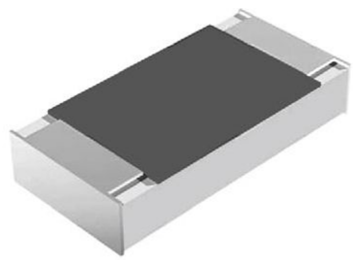
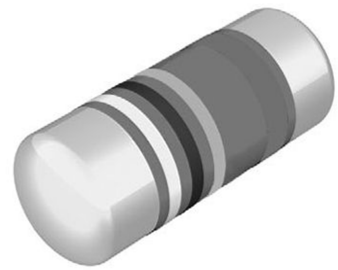
Pulse Load Handling for Fixed Linear Resistors

By Chris Marten Kaatz and Ove Hach

The power and thermal behavior of fixed linear resistors are mostly based on DC or RMS loads, but pulse loads, like single energy pulse or a continuous flow of pulses, become more and more an important factor in professional electronics. Pulse load situations for film resistors are not allowed to exceed the following limits:

- Single pulses have to be limited in peak power for a given pulse duration
- The average power load P of the continuous pulse load shall not exceed the rated power dissipation P_{70}
- The maximum amplitude of pulse voltage, and single and continuous pulses, has to be limited for high ohmic values

1. SINGLE PULSE LOAD

The maximum permitted single peak power of the specified resistor is shown in the pulse load diagrams of our Vishay Draloric Beyschlag datasheets as a function of pulse duration time. All these diagrams are based on rectangular single pulse shape.

For different pulse shapes, the energy of a single pulse has to be calculated.

$$W = \int_{t_1}^{t_2} P_{(t)} \times dt$$

The result of the energy has to be compared with a similar rectangular pulse shape. The power amplitudes of the real single pulse and the similar rectangular pulse must be equal.

$$\hat{P} = \hat{P}_{\text{rec - cal}}$$

Now it is easy to calculate the appropriated duration time of the rectangular single pulse.

$$W = W_{\text{rec - cal}} = \hat{P}_{\text{rec - cal}} \times t_{\text{rec - cal}}$$

The individual single pulse is now transformed into a similar rectangular pulse shape which can be compared with the single pulse diagrams of the resistor datasheet.

If the amplitude of the power is lower than the maximum permitted peak power of the resistor, then the permitted pulse duration can be read out of the single pulse diagram. If the calculated rectangular duration time is lower or equal to the maximum permitted pulse duration out of the datasheet, then the resistor is suitable for the application.

$$W = W_{\text{rec - cal}} = \hat{P}_{\text{rec - cal}} \times t_{\text{rec - cal}} \leq W_{\text{Diagram}}$$

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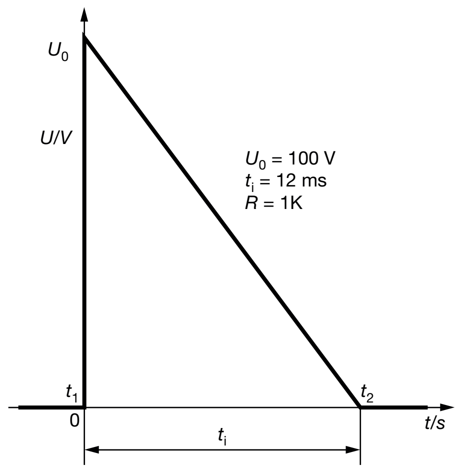
The following example is a calculation for a professional MINI-MELF resistor MMA 0204 for a triangle pulse shape:



$$u_{(t)} = \frac{-U_0}{t_i} \times t + U_0$$

for the time $0 \leq t \leq t_i$

Energy of a triangle voltage pulse:

$$W = \int_{t_1}^{t_2} P_{(t)} \times dt$$

$$W = \frac{1}{R} \int_{t_1}^{t_2} u^2{}_{(t)} \times dt$$

$$W = \frac{U_0{}^2}{R} \times \frac{t_i}{3}$$

$$W = \hat{P} \times \frac{t_i}{3}$$

with a peak power of:

$$\hat{P} = \hat{P}_{\text{rec - cal}} = \frac{U_0{}^2}{R}$$

$$\hat{P} = 10\ W$$

and compared with a similar rectangular pulse:

$$W = W_{\text{rec - cal}} = \hat{P}_{\text{rec - cal}} \times t_{\text{rec - cal}}$$

in a similar pulse duration time:

$$t_{\text{rec - cal}} = \frac{t_i}{3}$$

$$t_{\text{rec - cal}} = \frac{12\ \text{ms}}{3}$$

$$t_{\text{rec - cal}} = 4\ \text{ms}$$

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Figure 1 shows that the peak power $\hat{P}$ is lower than the maximum permitted peak power of a professional MMA 0204 (up to 30 W). With a peak power $\hat{P}$ of 10 W the diagram shows that the maximum permitted duration $t_{rec\text{ - }data}$ is around 7 ms. Based on the calculation above, the calculated rectangular pulse duration $t_{rec\text{ - }cal}$ is lower than the maximum permitted pulse duration $t_{rec\text{ - }data}$.

A professional MINI-MELF resistor MMA 0204 with a resistance value of 1 kΩ is suitable for this pulse load application.

Single pulses with short duration times (t_i < 200 µs to 300 µs) require resistors which are able to withstand the pulse energy without a permitted change of resistance value or a breakdown. The heat flow out of the resistive layer is very slow compared to the pulse duration, so the maximum permitted peak power reaches a constant value for short duration times.

The capability of similar resistor styles to withstand single energy pulses is dependent on the resistive technology. For extreme pulse load conditions Vishay carbon film, metal glaze, and wirewound resistors are preferable.

With increasing duration times the maximum peak power becomes more and more equal to the rated power dissipation. This is based on the effect that the heat penetrates more into the ceramic and least into the printed circuit board and environment.

The professional thin film resistor families offer in combination with excellent long term stability, low temperature coefficient, high reliability, low current noise, and extended pulse load capability.

The permissible single pulse load for thin film resistors leads to a specified resistance change - different to other pulse load tests, e.g. fail to open-circuit. This specified resistance change is given for the extended endurance test (film temperature at 125 °C) after 8000 h.

SINGLE PULSE

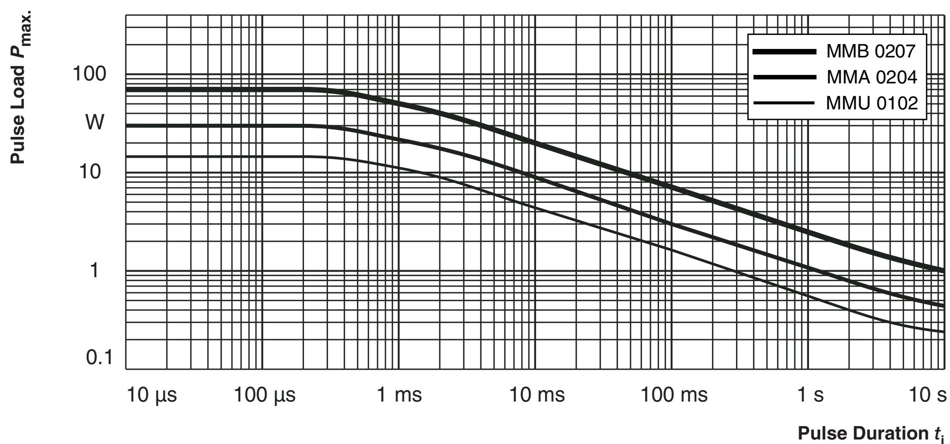

Fig. 1 - Single pulse diagram of thin film MELF resistors

2. CONTINUOUS PULSE LOAD

The average value P of a continuous pulse load has to be calculated by the following equation:

$$P = \bar{p} = \frac{1}{T}\int_0^T p_{(t)} \times dt \leq P_{70}$$

For resistance values above the critical resistance R_{crit} the rated power dissipation is given by the resistance value and the limiting element voltage:

$$R_n \geq R_{crit} = \frac{U^2_{max.}}{P_{70}}$$

$$P_{70} = \frac{U^2_{max.}}{R_n}$$

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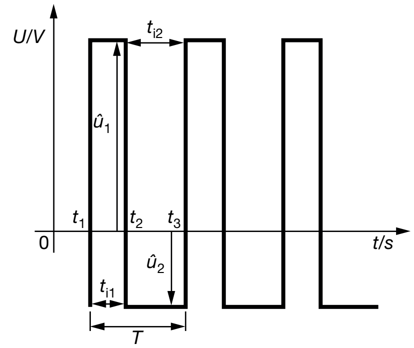
2.1. For Rectangular Continuous Pulses the Average Power of the Pulse Calculates to:

Rectangular pulse with alternating voltage amplitude:

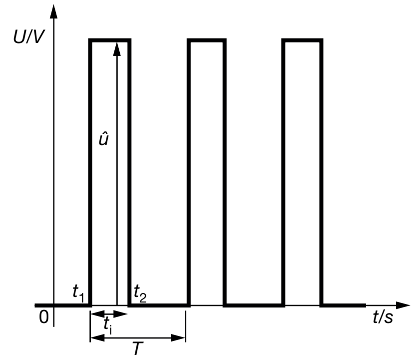


$$P_{rec} = \frac{1}{T} \times \frac{1}{R} \times (\hat{u}_1^2 \times t_{i1} + \hat{u}_2^2 \times t_{i2})$$

with $t_{i1} = t_2 - t_1$

and $t_{i2} = t_3 - t_2$

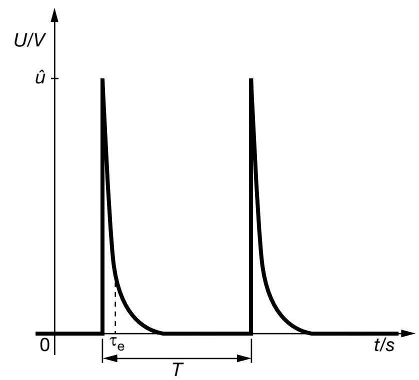
Rectangular pulse with positive voltage amplitude:



$$P_{rec} = \frac{t_i}{T} \times \hat{P} = \frac{t_i}{T} \times \frac{\hat{u}^2}{R}$$

with $t_i = t_2 - t_1$

2.2. For Exponential Continuous Pulses the Average Power of the Pulse Calculates to:



$$P_e = \frac{1}{T} \times \frac{\tau_e}{2} \times \hat{p} = \frac{1}{T} \times \frac{\tau_e}{2} \times \frac{\hat{u}^2}{R}$$

with $\tau_e = R \times C$ or $\tau_e = \frac{L}{R}$

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2.3. Pulse Load Diagrams

The diagrams for continuous pulse loads show the maximum rated peak pulse load for a rectangular pulse shape with positive voltage amplitude. The equation for rectangular pulses with positive amplitude shows that power dissipation is dependent not only on peak power. It is also dependent on duration time ti and period T.

$$P_{\text{rec}} = \frac{t_{\text{i}}}{T} \times \hat{p}$$

To create readable diagrams, the inverse ratio of duration and time period time must be limited. The dotted line is the peak power limitation for single power pulses.

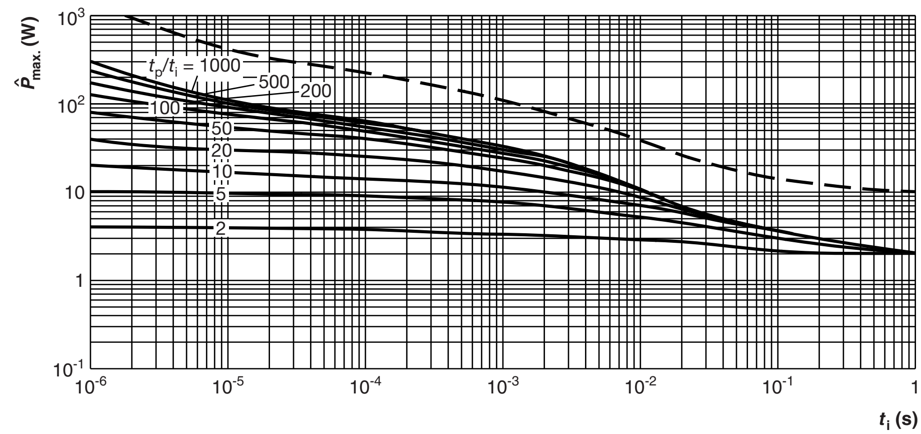

Fig. 2 - Pulse on a regular basis; maximum permissible peak pulse power as a function of pulse duration (t_i)

A further possibility to show the peak power capability for continuous pulses is to leave the ration of period T and duration time t_{i} and to show only the maximum permitted peak power for a given duration time t_{i} without exceeding the rated power dissipation P_{70}.

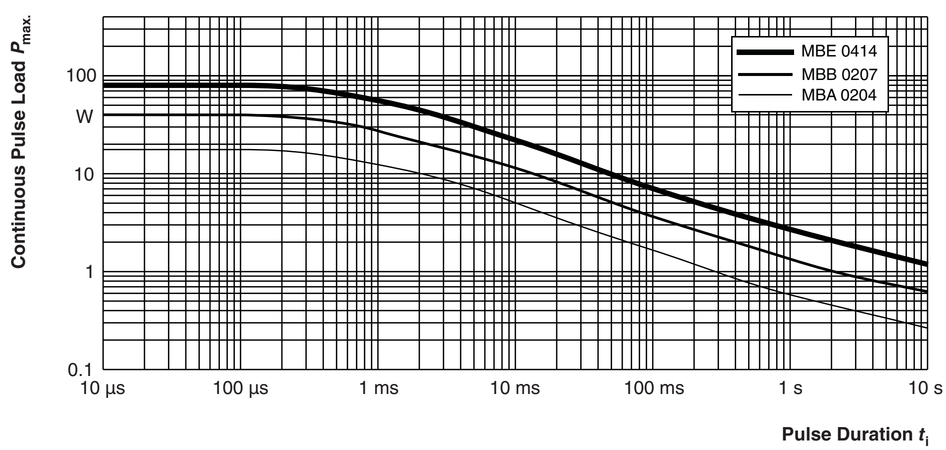

Fig. 3 - Maximum pulse load, continuous pulses; for permissible resistance change equivalent to 8000 h operation

Designers have to calculate the rated frequency by the following equation and compare the result with the frequency of the application. If the frequency of the application is lower or equal than the rated frequency, the resistor is suitable for the application.

$$P_{\text{rec}} = \frac{t_{\text{i}}}{T} \times \hat{p} \leq P_{70}$$

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$$f_{\text{rated}} = \frac{1}{t_i} \times \frac{P_{70}}{\hat{p}}$$

$$f_{\text{appl}} \leq f_{\text{rated}}$$

Other pulse shapes, like triangular or exponential continuous pulses, can be transferred into similar rectangular pulses under the same conditions as mentioned for single pulses. The results of these calculations can be compared with the data diagrams in the datasheets.

For thin film resistors the permissible continuous pulse load is determined by the resistance change as given for the extended endurance test (film temperature at 125 °C) after 8000 h.

3. PULSE VOLTAGE LIMIT

Resistors with resistance values above the critical value R_{crit} have to be protected against high pulse voltage. This is valid for single and continuous pulses. This limitation protects the resistor elements against high electrical field strength. An example for the maximum permissible impulse voltage $\hat{U}_{max.}$ of professional thin film flat chip resistors is shown in Figure 4. For thin film resistors the permissible pulse voltage is determined by the resistance change as given for the extended endurance test (film temperature at 125 °C) after 8000 h.

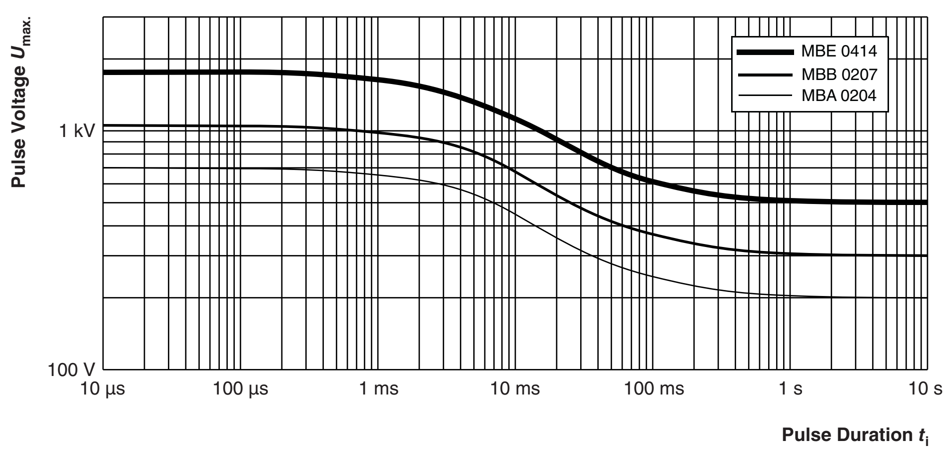

Fig. 4 - Maximum pulse voltage, single and continuous pulses

4. PULSE LOAD RATING IN ACCORDANCE WITH IEC 60115-1, 4.27

As mentioned in chapter 1, 2, and 3 the permissible pulse load depends on the shape and on the duration of the pulse. The standard lighting pulse (LEMP) is one of the main EMC test pulses for electronic and electrical equipment. The EN standard EN 60115-1, clause 4.27 defines two different pulse generators for single high voltage pulses (source pulse):

- 1.2/50 µs
- 10/700 µs

The value shown before the slash is the front time T_1 in µs of the pulse voltage and the figure after the slash is the time to half value T_2 of the peak value as shown in Figure 5.

The test conditions are:

- 5 pulses of 1.2/50 µs with a period of not less than 12 s
- 10 pulses of 10/700 µs with a period of not less than 1 min

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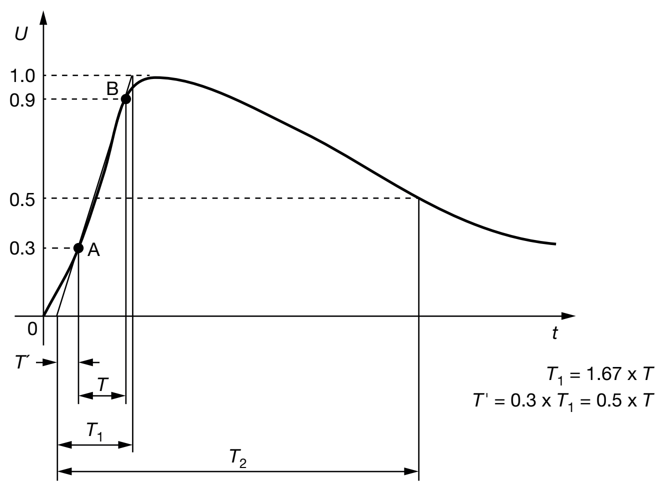

Fig. 5 - 1.2/50 µs or 10/700 µs single high voltage pulse

As a means of comparing different resistor styles and as a guiding value for development purposes, the pulse load capability in accordance with IEC 60115-1, clause 4.27 may be applied. An example is the pulse load capability of a carbon film MINI-MELF resistor CMA 0204 as shown in Figure 6.

For thin film products the diagram gives the voltage limits resulting in the maximum resistance value change of 0.5 %. Exceeding the limit may result in an exponential rise of the change and can introduce the destruction of the resistor.

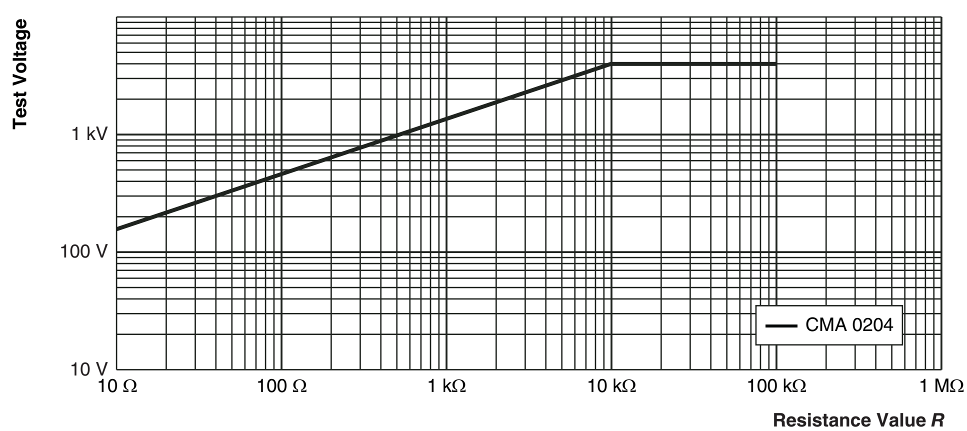

Fig. 6 - Source pulse capability of carbon film MINI-MELF resistors CMA 0204