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12 THINGS TO KNOW ABOUT RESISTORS IN PULSE LOAD APPLICATIONS

1 RESISTORS MAY FAIL UNDER PULSE LOAD

The **pulse power** is **dissipated** in the resistor's **resistive element.**

Depending on the **pulse energy**, **heat** is generated.

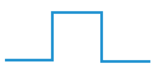
The **heat** causes an **increase** in the **resistor's temperature.**

Overheating damages the resistive element, leading to a **resistance change** or, finally, **opening** of the device.

2 RESISTORS CAN WITHSTAND PULSE LOADS HIGHER THAN THEIR RATED DISSIPATION P_{70}

Heat generation and transfer in the resistor take time, so a resistor's pulse load capability depends on pulse duration.

Short Pulse



For short pulses (adiabatic condition), the heat remains in the resistive element but the shortness of the pulse limits its effect on the resistive element temperature, even for high pulse loads.

$\hat{P}_{pulse} > P_{70}$

Long Pulse

Prolonged heat generation causes a more significant temperature rise in the resistive element, although this will be limited by heat removal already setting in during the pulse.

$\hat{P}_{pulse} \rightarrow P_{70}$

3 THE NUMBER OF PULSES COUNTS

The difference between a single pulse load and a continuous pulse load is a function of the number of pulses and the time interval between them.

	Single Pulse Load	Continuous Pulse Load
Time interval T between pulses	Long, allows for cooling of the resistor between pulses	Short, prevents cooling of the resistor between pulses
Applicable pulse parameters	$\hat{P} \leq \hat{P}_{specified}$, $\hat{U} \leq \hat{U}_{specified}$, average pulse power $\bar{P} \rightarrow 0$	$\hat{P} \leq \hat{P}_{specified}$, $\hat{U} \leq \hat{U}_{specified}$, average pulse power $\bar{P}$: $P_{70} \geq \bar{P} > 0$

4 THE PULSE SHAPE MAKES THE DIFFERENCE

Pulse shapes vary, ranging from rectangular or triangular to the typical exponential decay of a capacitor discharge or the sharp surge pulse.

For **energy pulses** of low power and long duration, the pulse energy is the limiting parameter, and pulse shapes can be converted to **rectangular shape** to compare with the resistor's pulse load diagram:

- Calculation of pulse energy
- Determination of the duration of the **rectangular pulse of same energy** and peak power

For sharp **surge pulses** the pulse voltage is the limiting parameter, and conversion to rectangular shape is not applicable. Instead, common surge pulse shapes are described by **standardized transients** and referenced in the resistor's datasheet accordingly:

- **Surge pulse**: 1.2/50 and 10/700 (IEC 60115-1, 4.27)
- **Electrostatic discharge:** human body model (IEC 60115-1, 4.38; IEC 61340-3-1)

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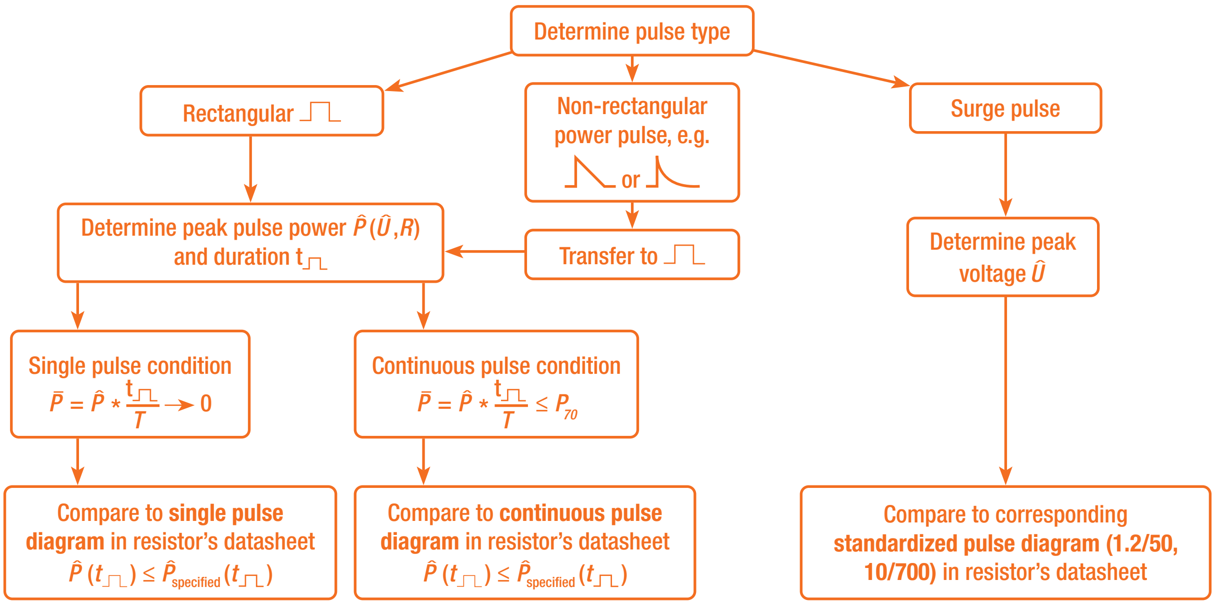
5 FINDING THE RIGHT RESISTOR IS NO MIRACLE

Finding a suitable resistor for a pulse load application requires determination of the actual pulse condition. Parameters, such as peak power $\hat{P}$, pulse duration t, or period T, need to be identified and compared to the resistor's specified pulse load capability:



6 ENVIRONMENTAL CONDITIONS CAN LIMIT THE RESISTOR'S PERMISSIBLE PULSE LOAD

Pulse load diagrams are typically defined at room temperature. If your component needs to operate in a higher ambient temperature, or if your application calls for additional continuous power loads that increase the resistive element's temperature, then a resistor with a higher pulse load capability is probably needed.

7 WHICH PULSE LOAD SPECIFICATION CAN I TRUST?

Information on a resistor's capability to withstand pulses is presented in pulse load diagrams. What these diagrams have in common is that they specify a maximum permissible peak pulse power per pulse duration for pulses of rectangular shape. Apart from that, their information value may differ strongly:

1. Check whether the diagram covers peak power per pulse duration for just a single resistance value or the full available resistance range for the resistor series. Only in the latter case is the specified peak pulse power reliable, as it is defined by the weakest performing resistance value of this range.

2. The pulse will stress the resistor, and affects its resistance value. The pulse load specification must therefore also state the maximum permissible resistance change, e.g. 0.25 % R, for the pulse conditions given in the pulse load diagram.

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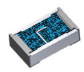
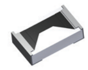
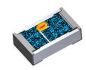
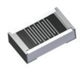
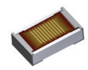
8 WHAT IS THE BETTER CHOICE: THIN OR THICK FILM RESISTORS

Film resistors are available in different technologies that come with different pulse load capability. Main factors influencing the pulse load capability of film resistors are the resistive film material, the trimming pattern, and the available resistive area.

	Resistive Film	Trimming Pattern	Available Resistive Area	Heat Distribution	Pulse Load Capability
Thick Film Chip	Screen-printed inhomogeneous metal glaze film	Simple I- / L-cut 	Smallest 	Hot spot formation 	**Limited**
Thin Film Chip	Homogeneously sputtered metal film	Meander cut 	Medium 	Homogeneous 	**Excellent**
Thin Film MELF		Helical cut 	Largest, due to cylindrical shape 	Homogeneous 	**Highest**

9 HOW TO IMPROVE THE PULSE LOAD CAPABILITY OF THICK FILM RESISTORS

The limited pulse load capability of standard thick film resistors is related to the inhomogeneous resistive film material and the simple trimming pattern that limits the available resistive area. There are, however, ways to push the limits further:

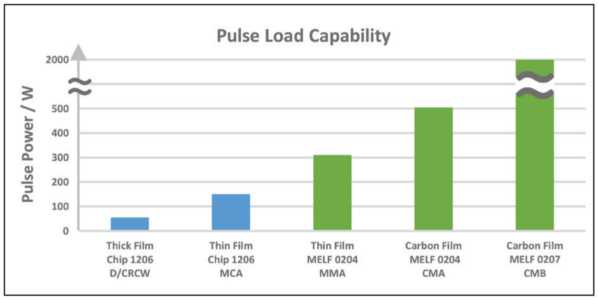
1. Printing the resistive film on both the top and bottom sides of the resistor's ceramic body allows for distribution of the pulse-induced heat over twice the resistive area and significantly decreases the pulse-related temperature increase in the resistive film. Double-sided thick film resistors are featured in the CRCW-HP series.

2. Omitting the trimming cut allows for full utilization of the resistive film area for current flow. Therefore distribution of the pulse-induced heat in the resistive film is improved and hot spots are avoided. Non-trimmed thick film resistors are featured in the CRCW-IF and RCS series.

10 THE SMD PULSE LOAD CHAMPION: CARBON FILM MELF RESISTORS

The SMD champion in pulse load capability is the CMB 0207 carbon film MELF resistor. Its performance is more than an order of magnitude better than equivalent case size resistors, as it combines the most important characteristics for high pulse load capability:

- Features a proven pulse-resistant **cylindrical design**, offering the largest effective resistive film area
- **Helical trimming pattern**, avoiding locally enhanced current densities
- **Carbon film material** with its unrivaled thermal stability



Typical destructive pulse load limits for Vishay film resistors (R = 1 kΩ). Pulses were applied by capacitor discharge, with a pulse length corresponding to a 3 ms rectangular pulse.

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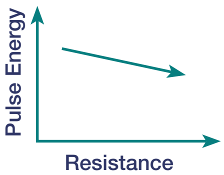
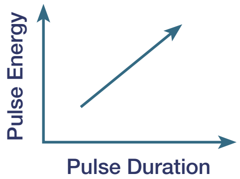
11 WIREWOUND RESISTORS

In wirewound resistors the resistive element is composed of a metal wire that is wound around a cylindrical ceramic core. Due to the comparably large mass of the wire, a much higher pulse energy of up to 60 kJ can be dissipated in the wire for very short pulse durations. Since the wirewound resistor's resistance value is adjusted by wire diameter and length, resulting in a different wire mass, its pulse load capability is also strongly resistance-dependent.

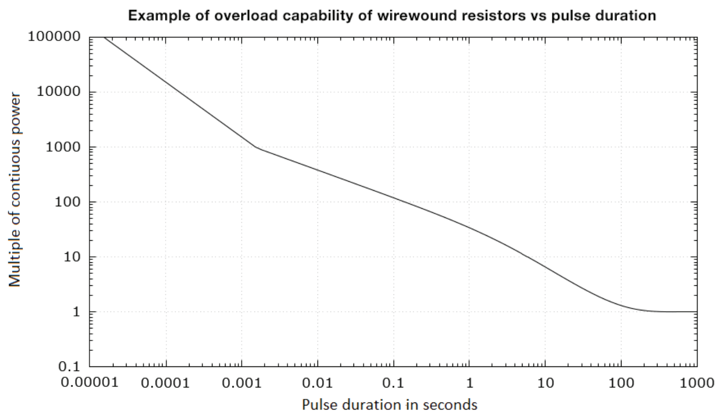




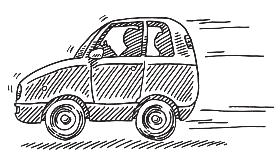
For long pulse durations, though the energy is still dissipated in the wire, a significant part of the generated heat can escape from the wire during the pulse. Thus, for those durations the pulse energy handling capability of the entire resistor is much higher than that of the wire itself.

Protecting the wire with a vitreous enamel coating, instead of a cement coating, further improves the wirewound resistor's pulse load capability as it can withstand higher temperatures.

The diagram on the right shows an example of an overload limit as a multiple of continuous power for Vishay wirewound resistors for different pulse durations.



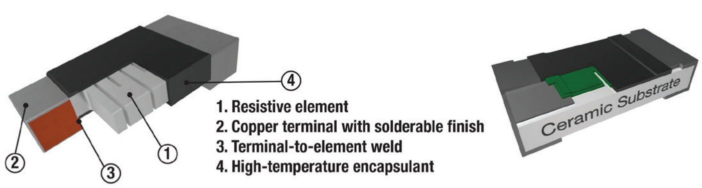
A typical Vishay wirewound resistor can handle about 1000 times its rated power for 3 ms. As an example, the G207 is rated with a continuous power of 17 W. Therefore, for a single pulse of 3 ms duration, the resistor is able to withstand a 17 kW pulse without destruction.

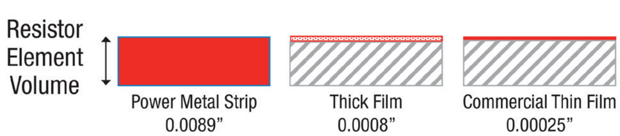


A single Vishay wirewound resistor can handle a pulse energy that would correspond to the braking energy of a 1000 kg vehicle when braking from 70 km/h to a standstill within 5 s.

12 POWER METAL STRIP® RESISTORS

When compared to other 1 Ω to 0.0001 Ω current sense resistor technologies, the Power Metal Strip® series provides superior pulse performance for short duration transients because of its large element mass. This is because the all-metal welded construction does not rely on a substrate for support, and so the element is thick enough to be self-supporting, which results in a large resistance element mass that can absorb more energy before it reaches a thermal limit that causes resistance values to change.





The illustration shows a comparison of the resistance element thicknesses of common current sense technologies. Notice that the substrate is a substantial portion of the resistor's total mass, but the resistive element is a small fraction. Mass = pulse performance. The substrate provides support for the thin resistance element and for a constant transfer of heat energy from the resistance element to the PCB, which does not contribute to fast transient energy events.

For Power Metal Strip pulse capabilities, refer to the online calculator at https://www.vishay.com/en/resistors/joulewizard/.
Or for a technical contact refer to ww2bresistors@Vishay.com.

For technical questions, contact resistorstechsupport@vishay.com