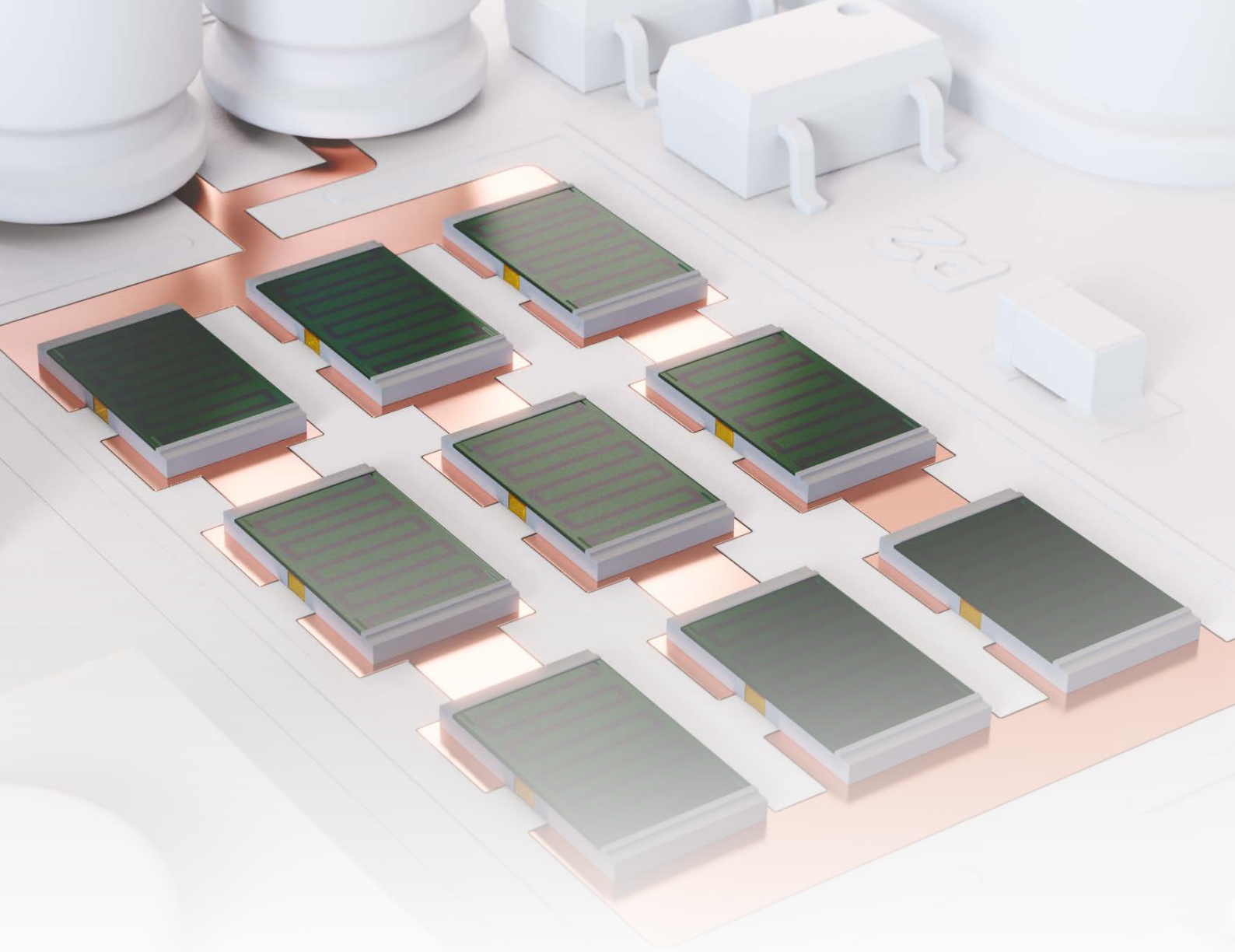
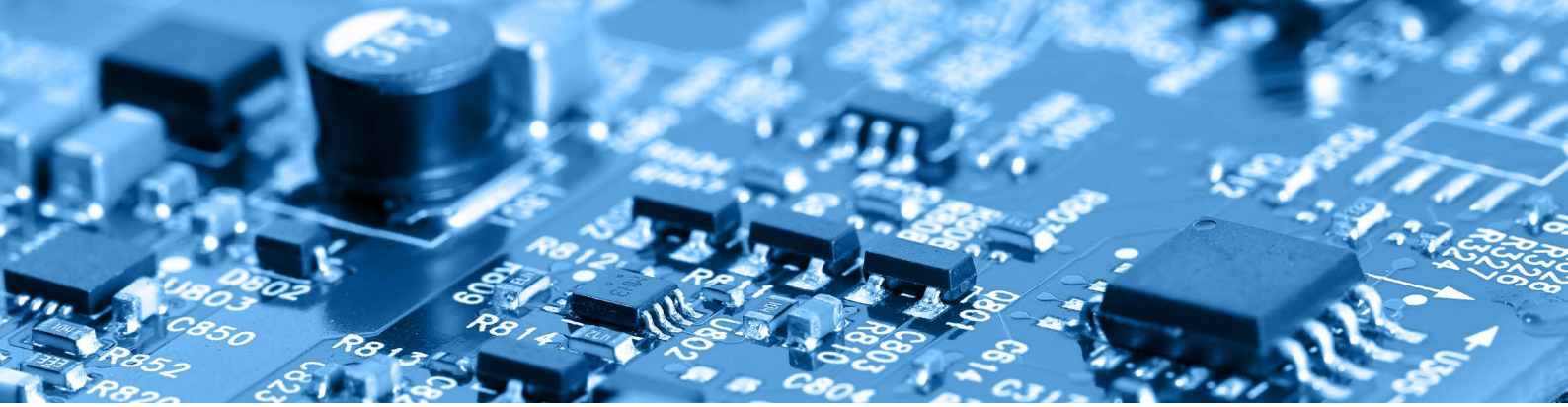


// WHITEPAPER

SAFE ABSORPTION OF VOLTAGE PEAKS

ISABELLENHÜTTE



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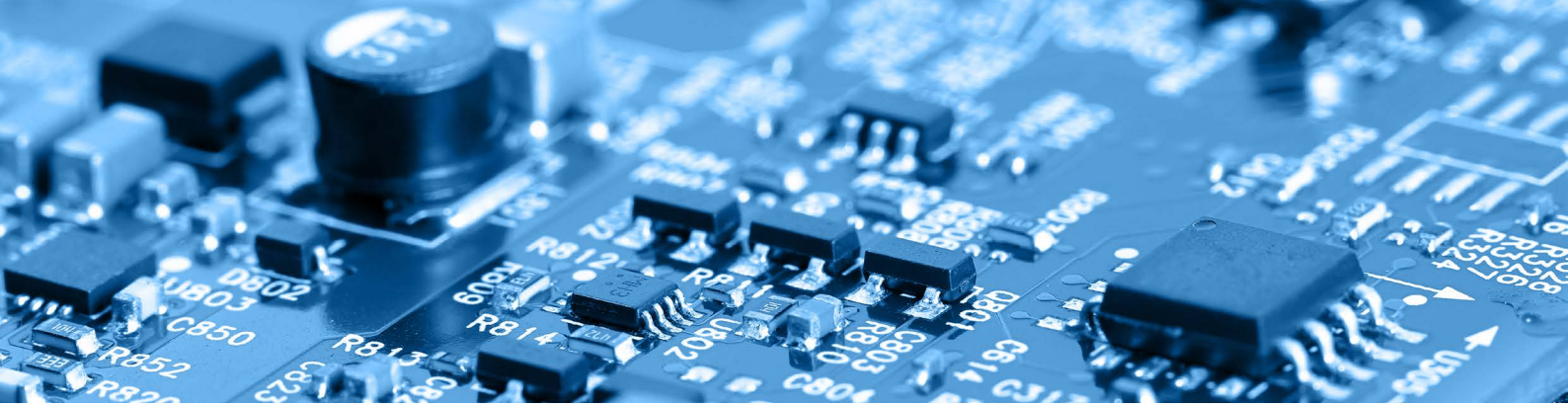
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// 1
WHY VOLTAGE PEAKS ARE BECOMING AN INCREASING CHALLENGE

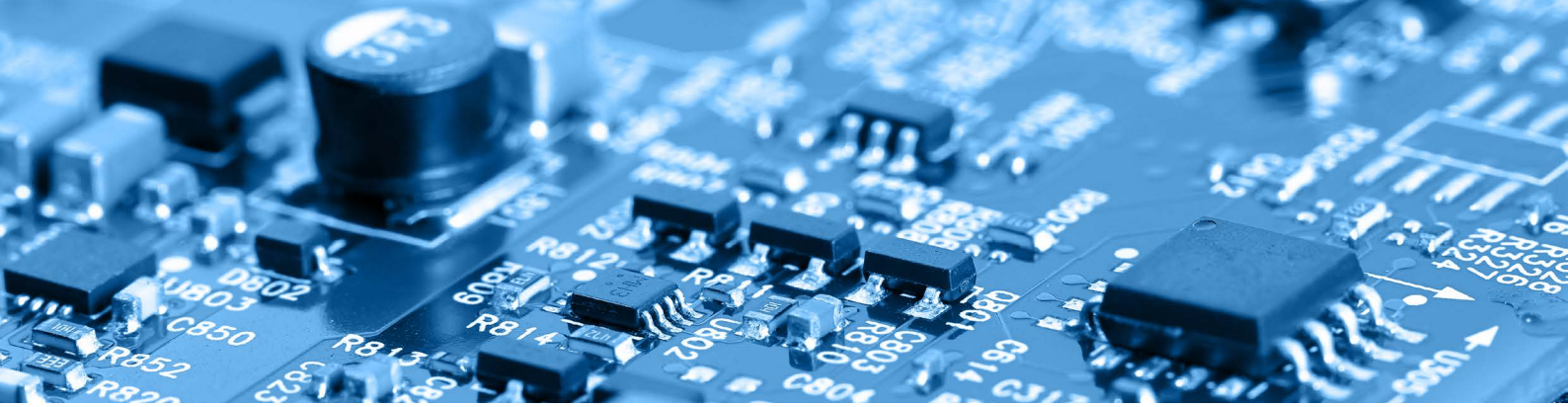
In the automotive sector, there is growing demand for compact, space-saving components that operate efficiently and safely. As power density increases, and fast switching operations continue to rise in modern power electronics, protection concepts against voltage peaks are becoming increasingly important. Inductances within the electrical circuit can further amplify these voltage peaks and damage or destroy sensitive semiconductors and other electronic components. As a result, fast and reliable shutdown mechanisms are required to effectively protect components and circuits. This Whitepaper demonstrates how high pulse energies can be safely absorbed and dissipated in a controlled manner.

Typical applications where voltage peaks may occur:

- E-fuses
- DC/DC converters
- Inverters
- Onboard chargers
- HV distribution systems
- Precharge circuits

Requirements for a pulse power resistor

Snubber circuits are commonly used to limit voltage peaks. The resistor used in the circuit must reliably absorb high pulse energies and efficiently dissipate the resulting heat. At the same time, engineers are under increasing pressure to reduce PCB space requirements and utilize automated manufacturing processes. As a result, there is a growing need for solutions that combine high pulse load capability, compact design, and easy integration.



// 2
THE PMx SERIES AS A SOLUTION

The PMx series was specifically developed for the absorption of high-voltage pulses. These resistors are based on the proven ISA-PLAN® principle* and combine high pulse load capability with a compact SMD design. Unlike current-sensing shunts, they are not intended for precise current measurement but rather for the controlled absorption and dissipation of pulse energy.

2.1 Design Concept

The PMT pulse power resistor is based on the same design principle as current sensing shunts. A foil made of the proprietary NOVENTIN® resistance material is mounted on a copper substrate. NOVENTIN® further optimizes the PMT with regard to pulse load capability. NOVENTIN® has an approximately two to three times higher specific resistance than the resistance alloys commonly used in current sensing resistors.

The pulse energy introduced by voltage peaks is initially absorbed by the resistance material and subsequently dissipated as heat through the large copper terminals into the PCB. Therefore, a sufficient amount of resistance material must be available. Despite this requirement, the design remains extremely compact, similar to current sensing shunts, allowing valuable PCB space to be saved. The NOVENTIN® foil on the top side is designed in a meander structure that is optimized for pulse load capability, installation space, and resistance value. The large solid-copper terminals support heat dissipation from the component hot spot into the PCB by acting as a heat sink (see Figure 1).

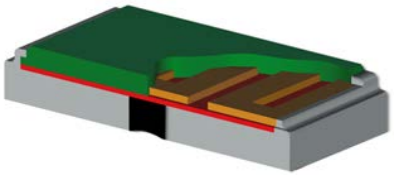
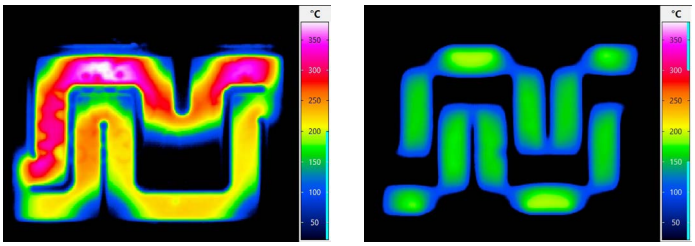


Figure 1: PMT Design

2.2 Operating Principle

Pulse power resistors are not intended for measurement purposes. Instead, they absorb high pulse loads that occur in power electronic systems during fast switching events. The energy generated by voltage peaks is temporarily stored in the NOVENTIN® resistance material and dissipated uniformly as heat into the PCB through the large copper terminals. A direct comparison between a conventional current sensing resistor and a pulse power resistor is shown in the infrared image in Figure 2. The infrared image illustrates the difference in heat distribution between a standard current sensing resistor and a pulse power resistor of the same package size. Owing to the specialized PMT design, the generated heat is distributed significantly more evenly and transferred into the PCB more efficiently. As a result, higher pulse energies can be absorbed without generating critical hot spots.

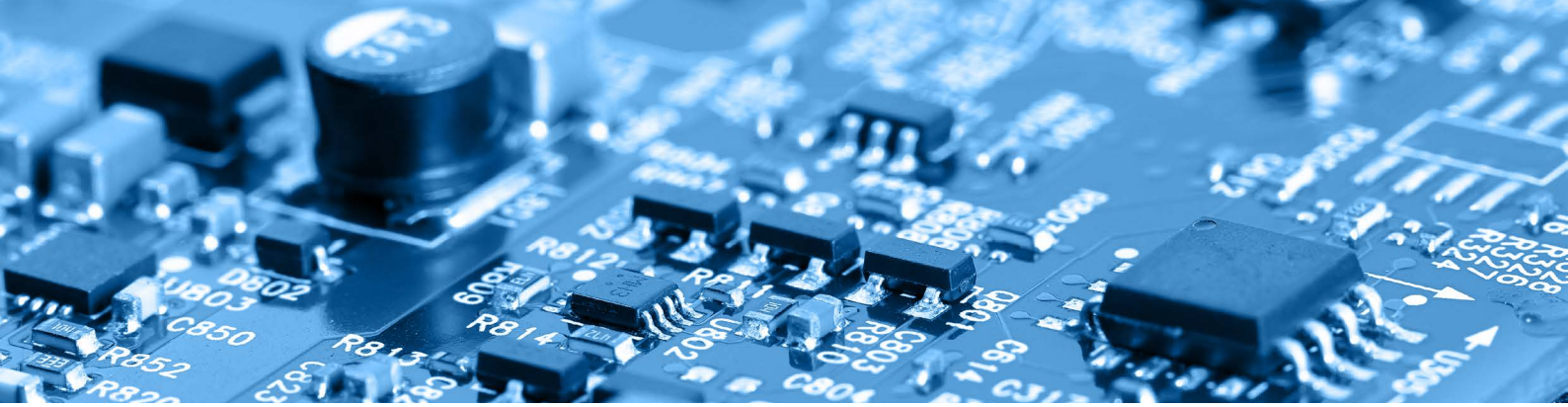


$T_{hot\text{-}spot}$ ~ 380 °C
Standard measuring resistor 2817

$T_{hot\text{-}spot}$ ~ 180 °C
Pulse power resistor PMT 2817

Figure 2: Comparison of a current sensing resistor and a pulse power resistor of the same package size under load

*ISA-PLAN® manufacturing technology utilizes resistance foils made of ZERANIN®, MANGANIN®, and NOVENTIN®, which are produced using photochemical etching and electrically insulated before being mounted onto a thermally conductive copper substrate.



2.3 Pulse Load Capability Under Continuous Operation

The maximum pulse energy that a single pulse power resistor can absorb depends on the pulse duration and pulse repetition rate. Figure 3 illustrates the pulse load capability of the PMT series under continuously recurring load conditions. For pulse events (left, flat section of the graph), the PMT series provides up to eight times higher pulse load capability compared to a comparable SMT component. Under continuous load conditions (right, rising section of the graph), both resistor technologies exhibit equivalent performance.

Depending on the application requirements, a single pulse power resistor may be sufficient to safely dissipate voltage peaks. If higher pulse energies must be absorbed, multiple resistors can be combined to distribute the load evenly.

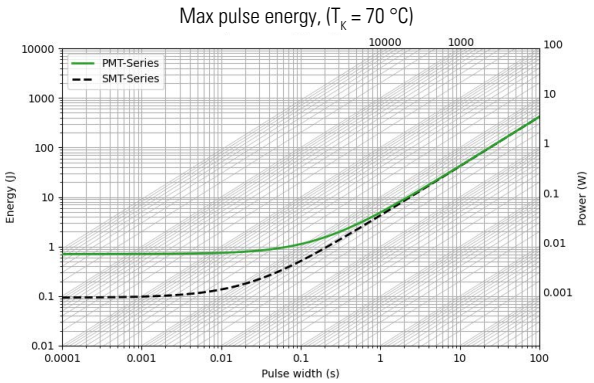


Figure 3: Maximum Pulse Energy Diagram

2.3.1 Pulse Load Capability for Single Events

In addition to continuously recurring pulses, the number of individual pulse events occurring over the product´s lifetime must also be considered. The pulse load capability shown in Figure 3 applies to pulse events that can be repeated an unlimited number of times. However, if a load event occurs only a limited number of times during the lifetime of a product, the PMT series can absorb significantly higher pulse energies. Figure 4 illustrates this relationship.

For example, under continuous load conditions, four PMT-1R00-10.0 components may be required in a resistor array configuration to absorb 1 joule of pulse energy. However, if this load event occurs only a few hundred times during the entire service life, a single PMT-1R00-10.0 component may already be sufficient. According to the characteristic curve, approximately 400 pulses at 1 joule are possible.

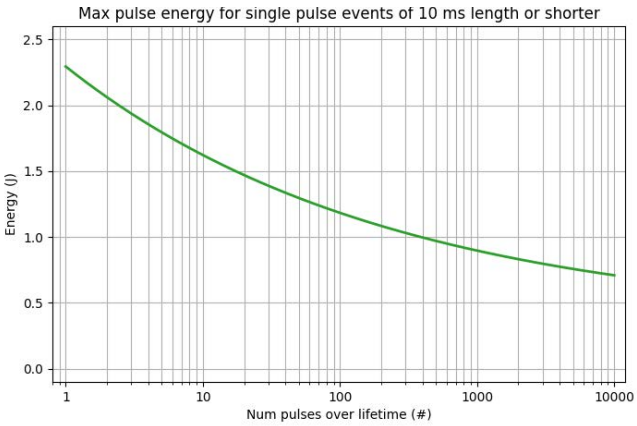
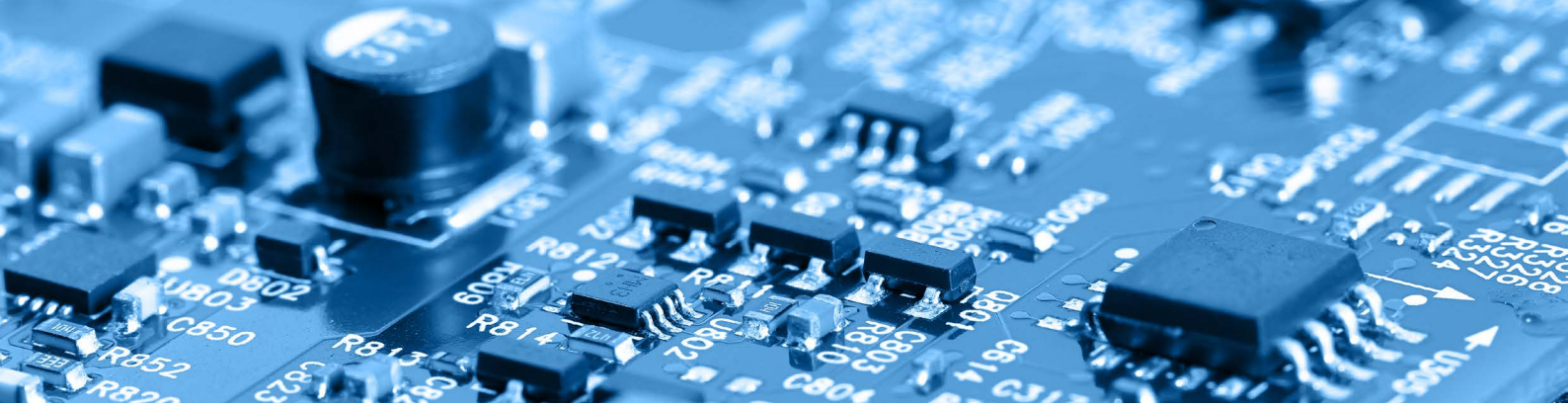


Figure 4: Maximum Pulse Energy Diagram for Single Pulses



2.3.2 Resistor Array Configurations for Higher Pulse Energies

If the pulse load capability of a single resistor is insufficient, multiple PMT resistors can be connected in series and/or parallel. This enables significantly higher pulse energies to be absorbed.

The resistor array configuration depends on the required pulse energy, the target resistance value, and the available PCB space. Depending on pulse energy requirements and installation constraints, different resistor array configurations can be implemented. The following overview shows example configurations for various resistance values and pulse energy levels.

Load (J)	Array-Resistance (Ω)	Used Part	Array		#Shunts
			series	parallel	
1	0.025	PMT-R050-10.0	1	2	2
1	1	PMT-1R00-10.0	2	2	4
3	5	PMT-1R00-10.0	5	1	5
3	10	PMT-2R50-10.0	4	1	4
5	0.083	PMT-R500-10.0	1	6	6
5	0.5	PMT-R500-10.0	3	3	9
5	0.5	PMT-1R00-10.0	2	4	8
5	1.5	PMT-R500-10.0	6	2	12
10	5	PMT-2R50-10.0	6	3	18
10	10	PMT-2R50-10.0	8	2	16
25	10	PMT-1R00-10.0	20	2	40
50	35	PMT-2R50-10.0	28	2	56

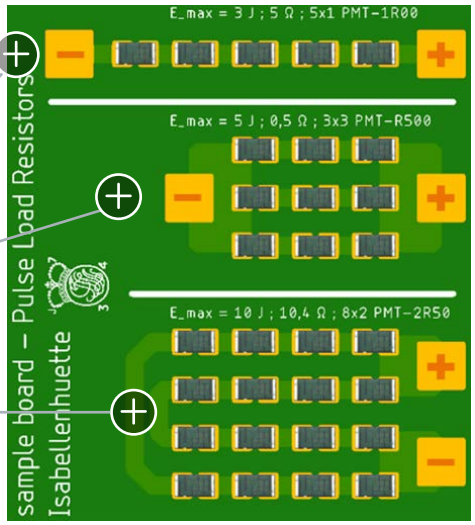
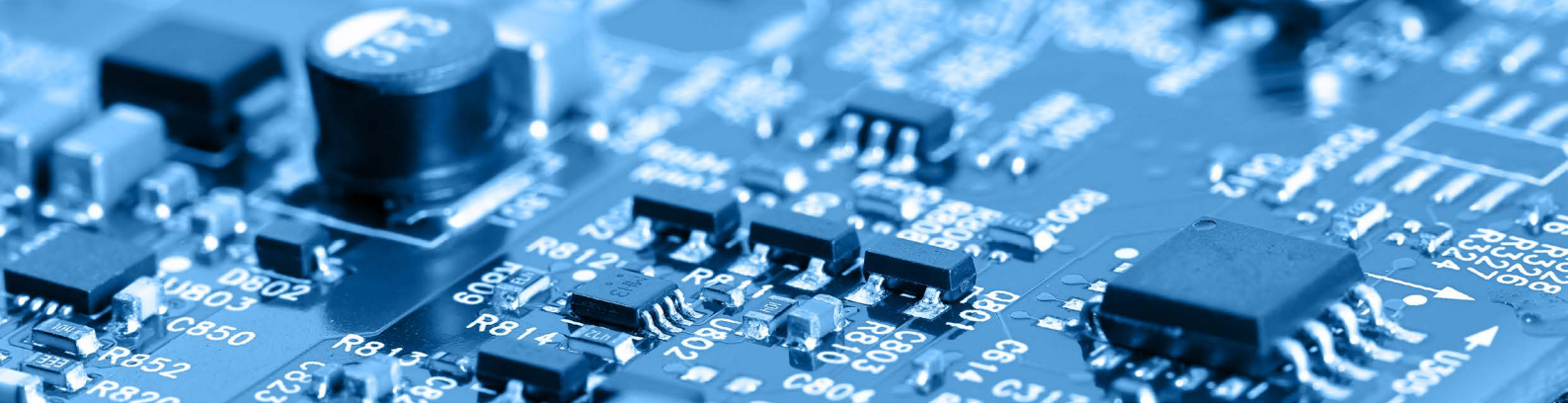


Figure 5: Arrays of PMT components to increase the interceptable pulse energy

To absorb a pulse energy of 3 joules, for example, five PMT resistors with a resistance value of 1 Ω each can be connected in series. For a pulse energy of 5 joules, three parallel branches consisting of three PMT-R500-10.0 resistors connected in series can be used. In the last example, eight PMT-2R50-10.0 resistors are combined in a double parallel configuration to absorb a total of 10 joules of pulse energy.

The possible resistor array configurations depend on the expected pulse load, the available PCB space, and the required resistance values. A typical application involves integrating a pulse power resistor into a snubber circuit consisting of a resistor and a capacitor. The pulse energy is first absorbed by the capacitor and then discharged through the resistor, where it is dissipated as heat. By selecting the appropriate capacitor value and resistance value, the discharge behavior can be adjusted as required. Consequently, the total resistance of the resistor array configuration is also a key design parameter when defining the discharge curve.

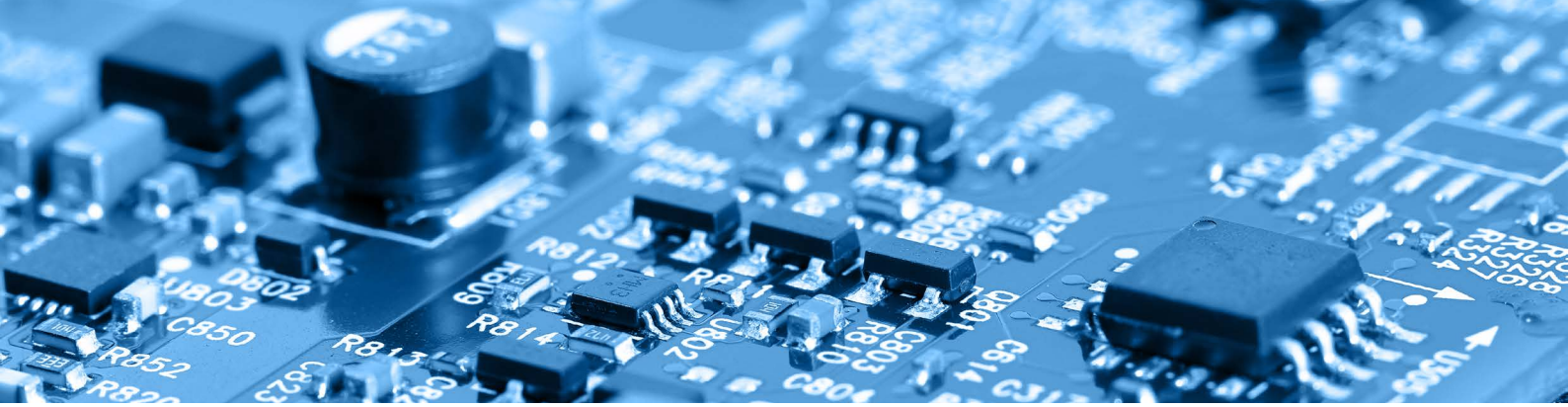


2.3 Benefits of the PMx Series for Design Engineers

Various resistor technologies are available for limiting voltage peaks. Depending on the application, multiple components may be required, or bulky THT components must be used, increasing both space requirements and manufacturing complexity.

The PMx pulse power resistor Series Offers Several Advantages:

- Thanks to the thermally stable NOVENTIN® resistance material, its high specific resistance, and the ISA-PLAN® design, the PMx series provides exceptional pulse load capability throughout its entire service life. Efficient heat dissipation into the PCB ensures high reliability.
- The space-saving PMT design significantly reduces both PCB footprint and component height. THT resistors are commonly used for pulse suppression is typically larger and more difficult to process, often requiring manual assembly that considerably slows manufacturing. Despite its compact design, the PMT delivers high pulse load capability while minimizing PCB space requirements.
- The PMT is supplied in tape-and-reel packaging for efficient automated SMD assembly.
- Design and design-in support: Isabellenhütte assists customers in selecting suitable resistance values, performing thermal evaluations, and developing optimized resistor array configurations.



// 3
APPLICATION EXAMPLE: SNUBBER RESISTOR FOR E-FUSES

E-fuses are increasingly replacing conventional melting fuses in modern vehicle architectures. Unlike traditional fuses, E-fuses can be reset after tripping and enabling fast, selective interruption of electrical circuits. However, the rapid interruption of current flow can generate voltage peaks caused by system inductances. Snubber circuits are commonly used to control and dissipate these transients.

When the E-fuse disconnects the circuit, the snubber circuit is activated. In combination with a capacitor, the pulse power resistor suppresses voltage peaks within the circuit.

This process operates as follows:

When the circuit is rapidly interrupted by the E-fuse, high voltage peaks occur as a result of parasitic inductances. To prevent these transients from damaging sensitive circuit components, the resulting pulse energy is initially absorbed by the capacitor.
The capacitor subsequently discharges through the connected pulse power resistor, which converts the pulse energy into heat and dissipates it into the PCB through its copper terminals. The capacitor discharge curve can be adjusted through the selection of the appropriate resistance value or resistor array configuration.

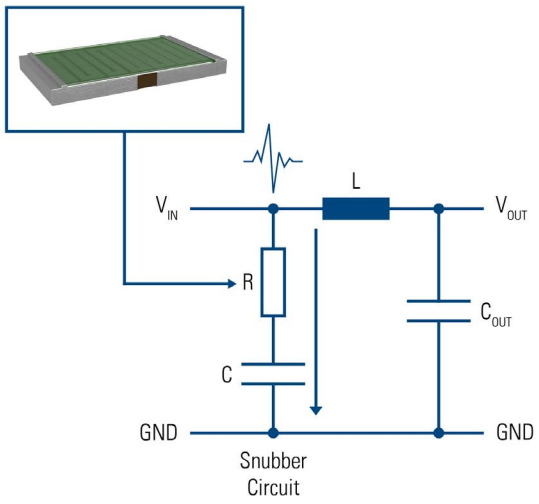
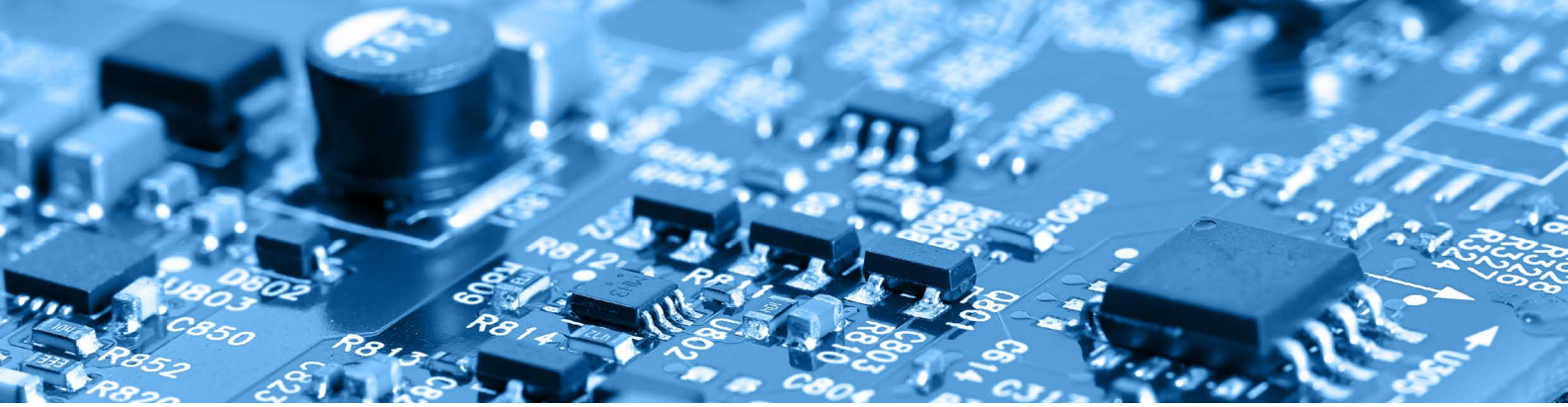


Figure 6: Snubber Circuit



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TECHNICAL SUPPORT FOR CUSTOM INTEGRATION

Integration and Design Support

Integrating the PMT into your PCB design is straightforward. Samples are available for initial application testing. If your pulse load requirements exceed the capabilities of a standard configuration, we provide support in selecting suitable resistors and determining the required quantity, dimensions, resistor array configuration, and design-in strategy.

Thermal Simulation

As a first step, a thermal simulation can be performed.
Based on the specific conditions of your application, we use simulation software to evaluate the expected heat generation and heat dissipation behavior. This allows the fundamental feasibility of the application to be assessed at an early stage.
Based on these results, the most suitable resistor array configuration can be determined. As a result, the need for extensive laboratory testing and associated development efforts can be significantly reduced.

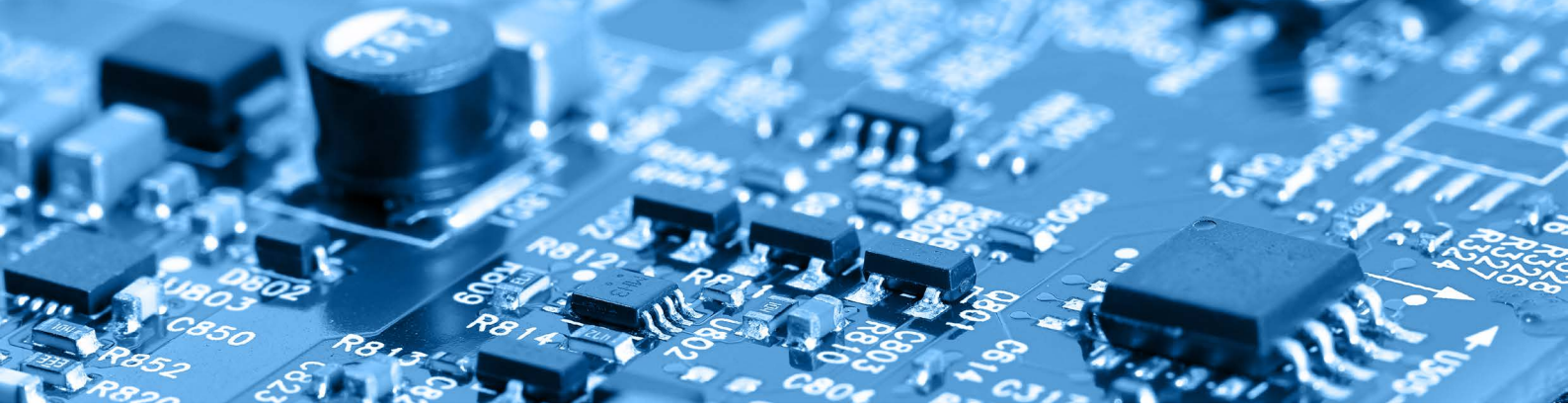
Design and Parameter Optimization

Upon request, we also support resistor sizing and parameter optimization, particularly for applications operating outside the conditions specified in the datasheet. Based on the three key parameters—pulse load, required resistance value, and available PCB space – we develop an application-specific resistor array configuration using simulation tools and thermal models. Prototype assemblies are then built to enable initial testing within the target application and to validate the assumptions used during the design phase.

One important aspect of practical validation is the actual heat dissipation achieved in the application. Real-world conditions may differ from the assumptions used in the simulation model. If the thermal resistance is found to be higher than expected, the resistor configuration must be adjusted accordingly. Similarly, the behavior of the capacitor within the snubber circuit may result in higher pulse loads than originally assumed. In such cases, we work together with customers to optimize resistance values and resistor array configurations.

Assembly Support

Additional benefits are provided through the simple integration of PMx resistors into existing manufacturing processes. Thanks to their SMD design, the components can be processed on standard SMD assembly lines and are supplied in tape-and-reel packaging. As a result, labor-intensive manual or semi-automated assembly operations that are often required for conventional THT resistors can be reduced or eliminated entirely. Processes such as manual soldering and wave soldering can therefore be minimized or avoided.



// 5
CONCLUSION

Modern power electronics place demanding requirements on protection against voltage peaks. At the same time, compact package sizes, increasing power density and automated manufacturing processes are becoming increasingly important. The PMx series combines high pulse load capability with the advantages of a compact SMD design. This makes it particularly suitable for applications requiring the reliable absorption of high pulse energies and efficient heat dissipation. Thanks to flexible resistor array configurations, a wide range of resistance values and load profiles can be realized. As part of a snubber circuit, PMx resistors help limit voltage peaks in a controlled manner and effectively protect sensitive power semiconductors. Supported from initial design through design-in.

Looking to safely manage voltage peaks in your application while reducing PCB space requirements and manufacturing effort?

We support you in the selection, thermal evaluation, and design of an optimized solution—from simulation and prototyping through integration into your application. Together, we develop a solution tailored to your requirements.

REQUEST SAMPLE NOW!

https://www.isabellenhuette.com/pmt

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