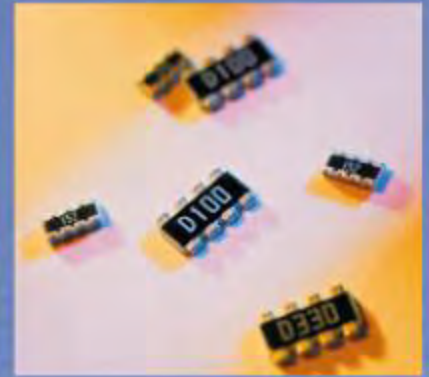
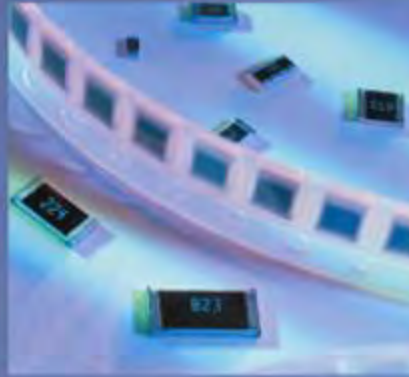


SEI

Stackpole Electronics, Inc.
Resistive Product Solutions



Pulse Handling Resistors PTM

Purpose

- ◆ To explain the characteristics and tradeoffs for pulse handling resistors

Objectives

- ◆ To provide an overview of the unique materials, design, and processes used to build pulse voltage and pulse power handling resistors

Content

- ◆ 21 pages

Learning Time

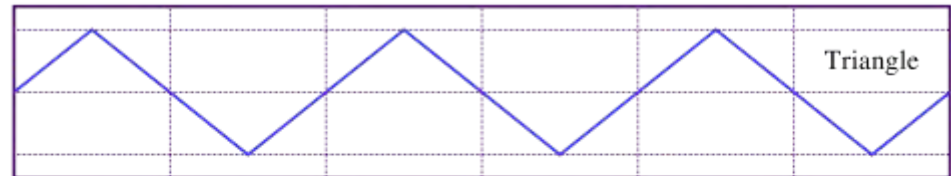
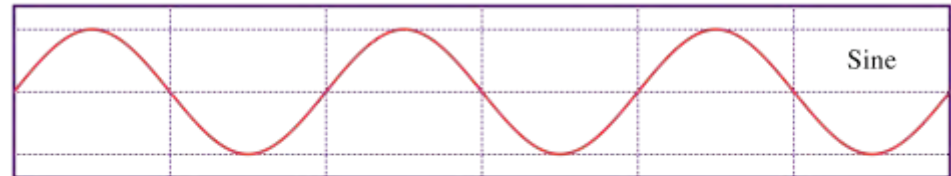
- ◆ 20 minutes

Welcome to Stackpole's pulse handling resistor solutions product training module. This training module will provide a foundation to help design engineers understand the strengths and limitations of resistors designed to withstand high voltage pulses and those designed to withstand high power pulses.

- Pulse definitions and types
- High Voltage Resistor Technologies
 - Axial Leaded Resistors
 - SMD Chip Resistors
- High Power Resistor Technologies
 - Axial Leaded Resistors
 - Carbon Composition
 - Wirewound
 - SMD Chip Resistors
- Conclusion

Surge handling for electronic products is becoming more and more important with increased electronic content. In many cases, legacy designs simply used the biggest or most robust resistor that would fit. Now that many of those designs are becoming obsolete or at least are being redesigned, there is an opportunity for downsizing and cost reduction if the proper pulse handling resistor is chosen.

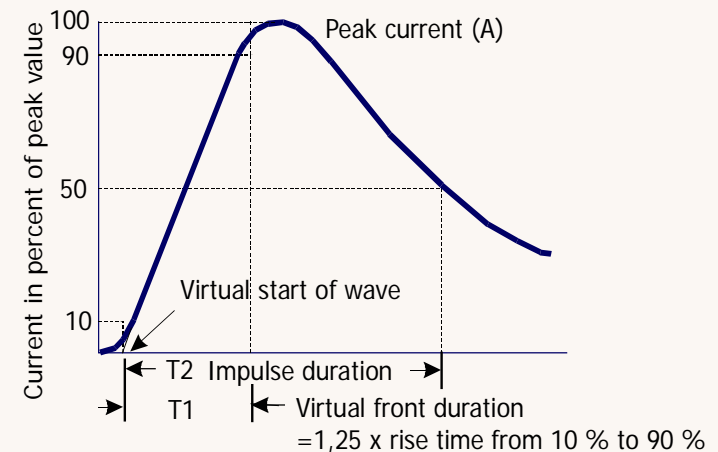
- In addition to these pulse types, resistors regularly encounter exponential rise or decay such as from a capacitor charge or discharge.
- Typically resistor pulse testing is done with a square wave of varying duration.
- Single pulse ratings are more common for a majority of resistor types; only pulse withstanding resistors are characterized for continuous pulse operation.



Pulse events can occur from a wide variety of sources. Power IC's turning on and off, inductive load switching, lightning and ESD are a few of the most common. The pulse shapes and repetition rates are equally varied. Many different types of pulse handling resistors exist because of this. It is important to understand the strengths and weaknesses of each technology in order to select the proper component for a particular application.

Definition of Pulse Current Waveform T1/T2 s

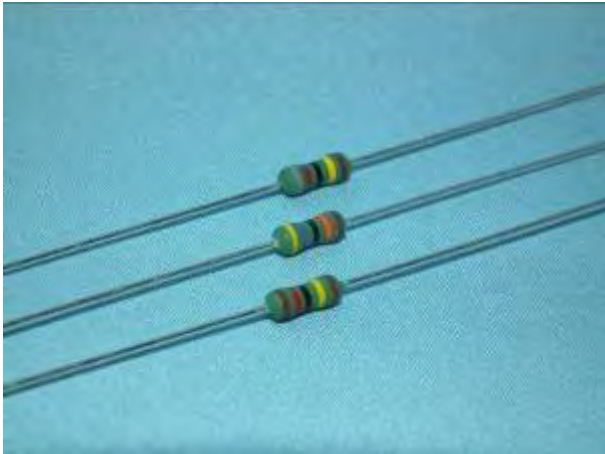
Pulse Type	Parameter measured	Application
1.2/50 us	Voltage, current	General
10 / 700 us	Voltage, energy	General
8/20 us	Voltage, current	General
10/350 us	Voltage, current	Industrial
7/100 us	Voltage, current	Telecom
2-7 ns	Voltage, current	ESD
10/400 ms	Voltage, current	Automotive



Single pulse waveforms are most commonly described as the ratio of rise time from zero to peak amplitude over the time to decay to $\frac{1}{2}$ the peak amplitude. Of the pulses shown in the above table, the first two are most commonly used for lightning pulse withstanding for resistors, in accordance with IEC 60115-1.

High Voltage Leaded Resistors - RNV

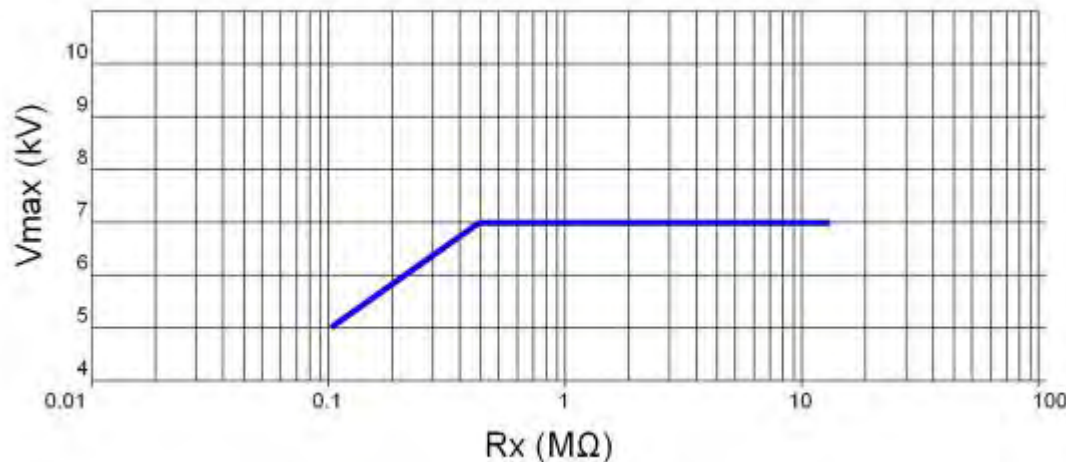
➤ The RNV is a high voltage withstanding axial leaded film resistor with robust environmental performance.



- Rated for 1600 volts working voltage and 3200 volts max overload voltage
- Withstands 50 surges from a 1nF capacitor charged to up to 10KV, 12 discharges per minute with less than 1% resistance shift
- Is designed for high temperature withstanding with low resistance shift
- Can reliably be used in high humidity applications with no risk of corrosion or failure
- However the RNV is only available in ¼ watt power rating at this time

Stackpole developed the RNV in response to increased customer demand for a robust film resistor that can withstand surge events and harsh environmental conditions. For higher voltages, power ratings, or resistance values, other products must be considered.

- Maximum working voltage for the RNV14 is 1600 VDC, and overload voltage is 3200 VDC. Typical working voltage on a metal film resistor this size would be 250 VDC and overload voltage would be 500 VDC.
- Per IEC60065.14.1 the RNV14 can withstand 50 surges of a 1nF capacitor charged to V_{max} , 12 discharges per minute, and must remain within 1% of the initial resistance value. The graph below shows the resistance value dependent voltage for those surges.



The RNV series metal film element is designed for high continuous voltage handling and high voltage surge handling. This capability is critical in many types of power inverter applications and switching power supplies, such as AC power adaptors.

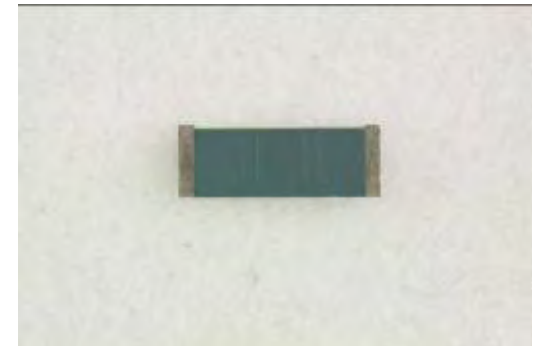
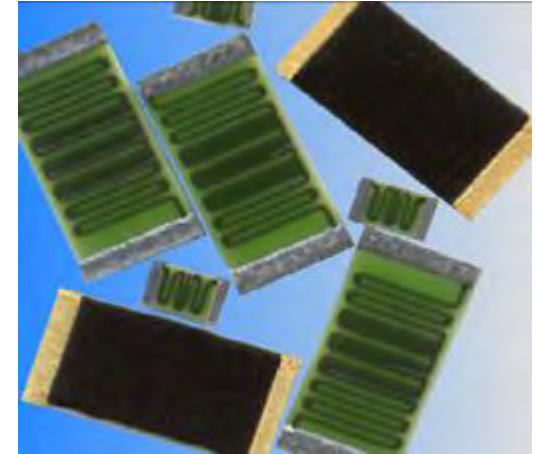
- MG / MGM series is metal glaze or thick film technology
 - Working voltages from 1600 volts up to 3500 volts.
 - Surge voltage handling up to 10KV
 - Power ratings ½, 1, 2, and 3 watts
 - Resistance values from 100K ohms up to 1G ohms.



- ASR / ASRM series are also metal film technology
 - Working voltages from 1600 volts up to 5000 volts.
 - Surge voltage handling up to 10KV
 - Power ratings ¼, ½, and 1 watts
 - Resistance values from 100K ohms up to 12Meg ohms.

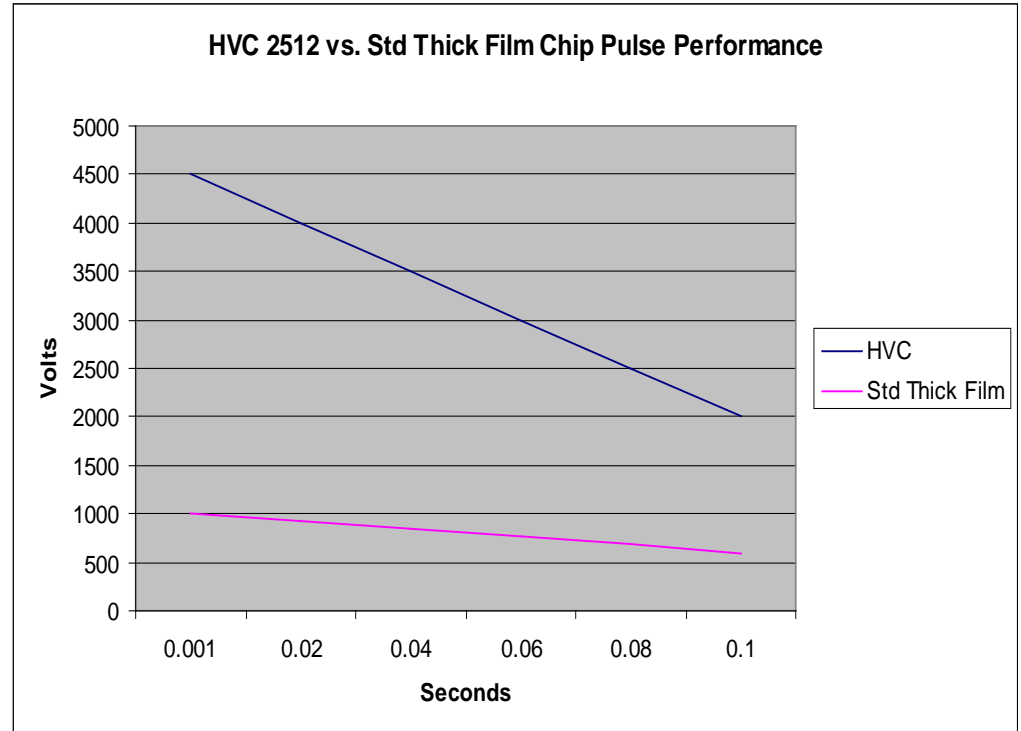
These two series offer a wider range of power ratings and resistance values, as well as higher working voltages than the RNV. The MG and MGM offer high working and overload voltages and the highest resistance values in an axial leaded part. The ASR and mini ASR have the highest working voltages and are specifically designed for handling thousands of high voltage pulse events.

- The HVC is Stackpole's high voltage chip resistor series
 - Sizes 0603, 0805, 1206, 2010, 2512, and 3512
 - Resistance values up to 50G ohms
 - Working voltages up to 3500 volts
 - Surge voltage handling up to 40KV with proper terminal isolation
 - High precision – TCR's as low as 25 ppm and tolerances down to 0.1%
 - Low VCR to 1ppm per volt



The HVC is Stackpole's premier surface mount high voltage product. No other product currently available offers the high voltage handling, high pulse voltage handling, high resistance values, and tight precision that the HVC offers.

- ◆ The data shown here is for a 100K ohm resistance value, which is the lowest available for the HVC and the worst case scenario for high voltage pulse handling.
- ◆ For resistance values at the upper end of the range, pulse handling up to 40KV can be achieved.



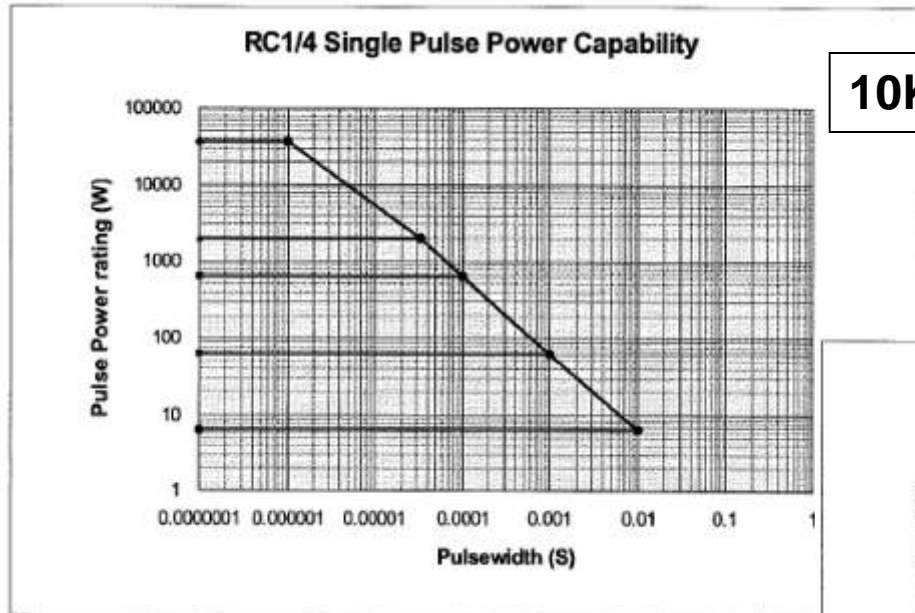
The HVC series is able to withstand high voltage pulses better than the competition because of the superior and unique fine line process for depositing the resistor on the substrate. This deposition method allows for lower voltage stress on the film per unit length.



- Carbon Composition resistors have long been known for their outstanding pulse power and pulse energy handling. The 1 watt size carbon comp can handle up to 10J of energy.
- Inductance for carbon comps is extremely low, making them very popular for high speed switching power supplies.
- Carbon comps are known to be susceptible to resistance shifts due to moisture, although these effects can usually be reversed through a high temperature bake of the components.

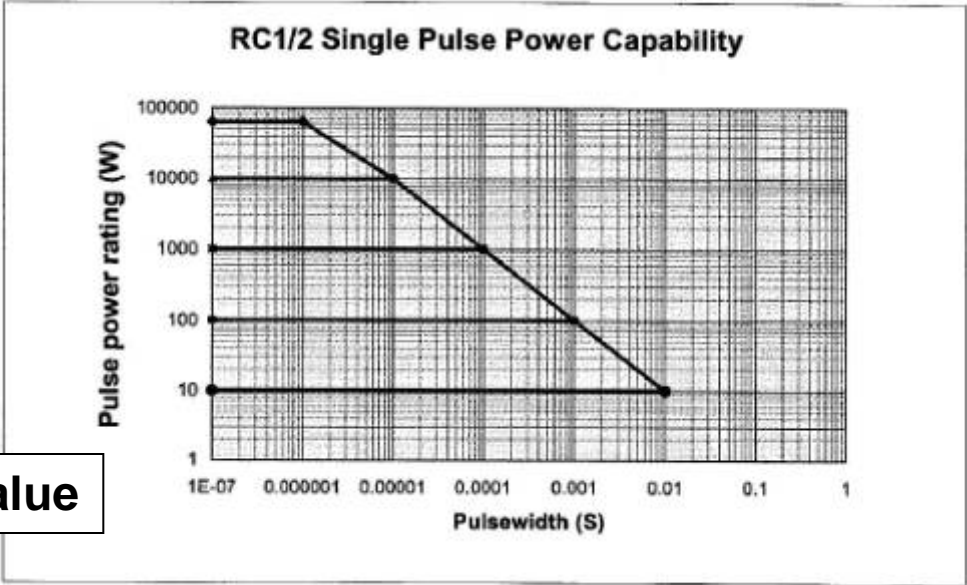
The RC series from Stackpole remains a popular choice for applications requiring high pulse power or pulse energy and low inductance. It has better pulse handling capacity than film based surge resistors, lower inductance than wirewound based resistors and a broader resistance range as well as lower cost than ceramic composition resistors.

➤ Test Conditions : 100 discharges of a 2.0 nF capacitor,



10K ohm Resistance Value

100 Ohm Resistance Value



For short duration pulses, carbon composition resistors can withstand pulses of well over 70,000 watts. The pulse power handling characteristic of carbon comps is resistance value dependent with higher values performing better, as demonstrated in the data above

- Wirewound resistors are also used for handling high energy or high power pulses.
- Wirewound resistance elements are much more robust than power film elements.
- Wirewounds can handle tens of thousands of watts safely and have no wear out mechanism due to pulse handling; this makes them a great choice for repetitive pulse handling requirements.
- Wirewounds are inherently inductive. They can be wound using non-inductive Ayrton Perry windings, but may still have several nH of inductance depending on the size and resistance value of the part.



Welded wirewound elements are extremely reliable under long term repetitive pulse exposure. These elements can also be designed to maximize the pulse power handling by choosing the ideal wire to maximize the element mass and by limiting the calibration trimming operation.



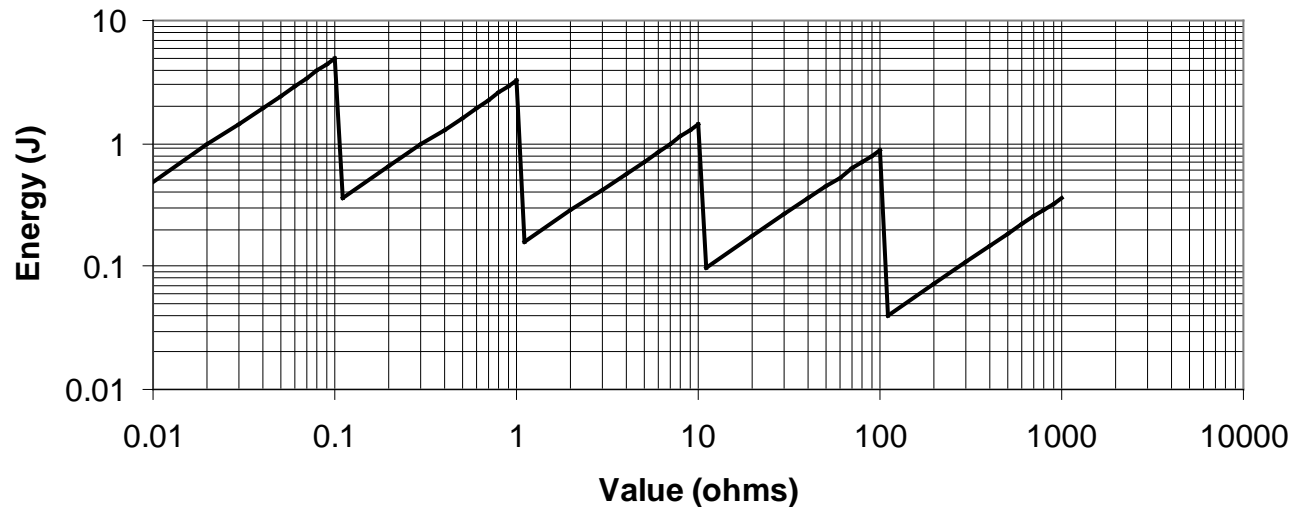
Pulse Energy Handling Capacity For Axial Leaded Wirewounds

<u>Wirewound Energy Handling Capacity</u>			
Part Number	Power Rating (W)	R - Value (ohms)	Energy Capacity (J)
WW10__4R70	10	4.7	495
WWP10__2R00	10	2	164
WW5__18R0	5	18	18.2
WWP4__50R0	4	50	12.6
WWH__300R	0.5	300	0.5
SP3A__33R0	3	33	3.1
SP3A__100R	3	100	1.6

- ◆ Energy handling depends on the mass of wire used to build the resistor. While it is logical that larger resistors with higher power ratings will have better pulse handling, this isn't always the case.
- ◆ For the WW10 part numbers, the 4.7 ohm value has much better energy handling since both parts use the same wire.
- ◆ For the SP3A, the 100 ohm value requires a smaller diameter wire, limiting its energy handling.

For applications that aren't sensitive to inductance or have high switching speeds, wirewound resistors offer a good blend of robust pulse handling and relatively low cost. In addition, wirewounds can be adjusted to offer higher surge energy handling, lower inductance, higher voltage handling, and specialized fusing characteristics.

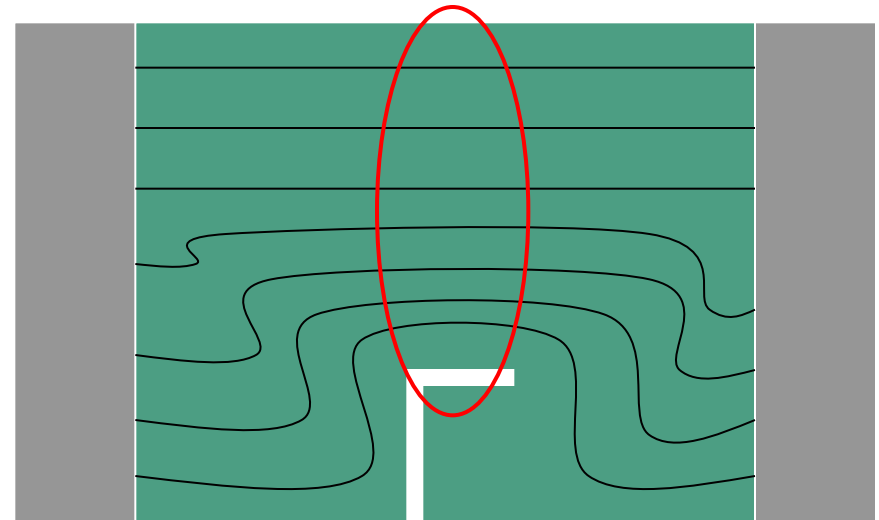
Energy Capacity SMP2615



- ◆ Wirewound resistors of any size have an ideal wire alloy and size to balance the power handling, pulse handling, and inductance characteristics
- ◆ Most wirewound resistors are designed to have 12 to 16 turns of wire from end to end
- ◆ Most size and value combinations however, allow for several different wires to be used.

The graph above shows wirewound pulse handling dependence on size and resistance value. The discontinuity points show where a smaller diameter wire is needed to achieve the higher resistance values. From those points to the next, the pulse handling improves due to the increased mass of wire needed to achieve the value

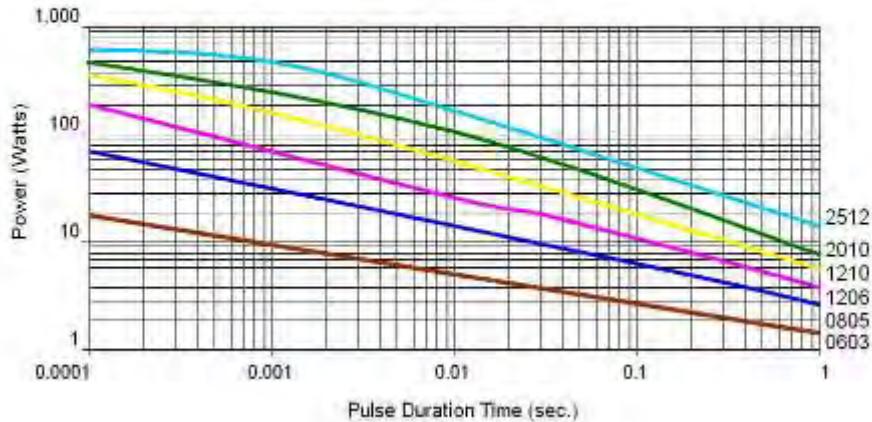
- ▶ RPC is designed specifically to withstand pulse current and pulse power events by limiting the laser trimming allowed for calibration.
- ▶ Current crowding occurs where the resistor is trimmed which creates a hot spot and limits the amount of pulse power the part can withstand.



General purpose thick film chips can have laser trims which reduce the width of the resistor element by up to 40%, which can greatly reduce the pulse handling of the device. This variability creates an equally variable pulse handling behaviour and makes using them for pulse applications risky.

RPC Series Pulse Handling

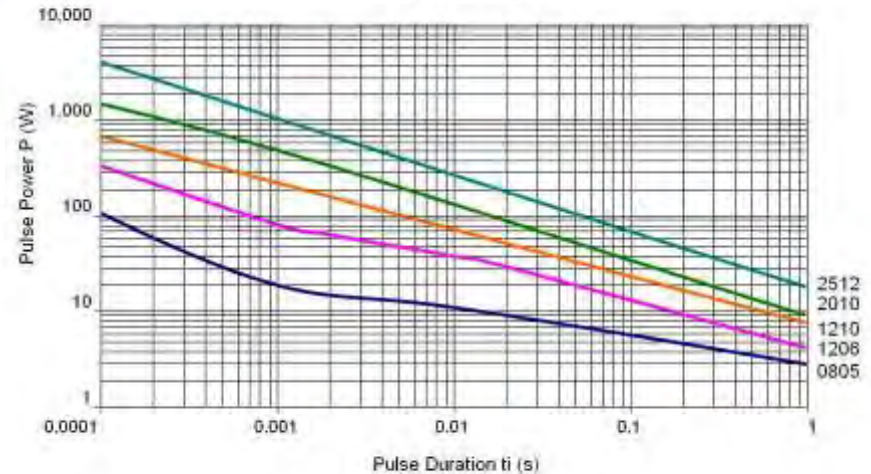
Single Pulse Power
RPC 100 ohm 1%



For shorter duration pulses than shown here, the pulse capability begins to level off

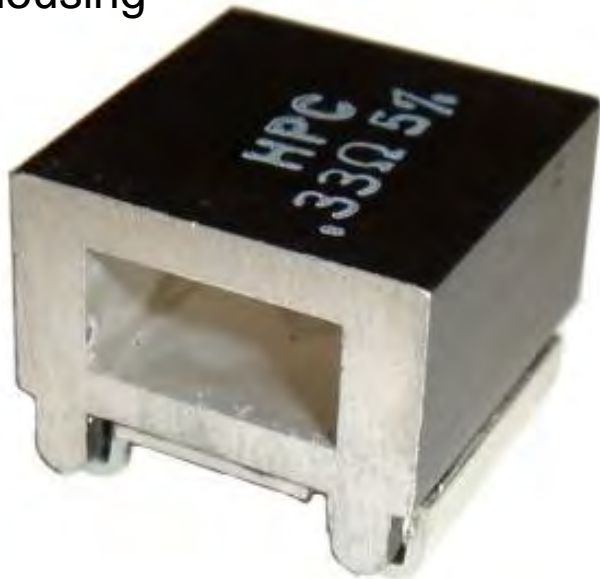
100 ohm resistance values chosen as benchmark; pulse handling for lower resistance values may be better, while higher values may have reduced pulse handling

Single Pulse Power
RPC 100 ohm 5%

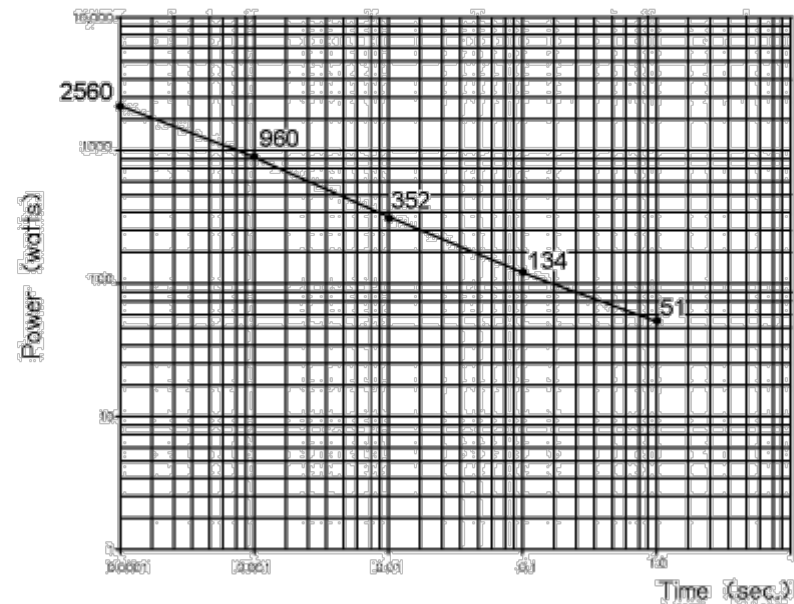


The RPC series offers guaranteed pulse handling many times better than standard general purpose thick film chips. The RPC 5% tolerance has best in class pulse handling performance compared to surge handling film chip resistors from leading competitors.

- The HPC12 is constructed with 4 parallel 2512 size thick film chip resistor elements attached to an extruded aluminium heat sink housing



HPC 12 Surge Characteristics



The HPC12 is rated for 5 watts power handling in free air and has excellent pulse handling for pulse durations of 0.01 seconds and longer. For shorter duration pulses, the RPC2512 5% tolerance is still better and the RPC has guaranteed pulse withstanding.



Stackpole Electronics, Inc.
Resistive Product Solutions

Pulse Energy Handling Capacity for Surface Mount Wirewounds

Surface Mount Wirewound Energy Capacity			
<u>Part number</u>	<u>Power Rating (W)</u>	<u>Resistance Value (ohms)</u>	<u>Energy Capacity (J)</u>
SM2615__1R00	1	1	1.7
SM2615__10R0	1	10	0.7
SM4124__1R00	2	1	2.7
SM4124__10R0	2	10	1.6
SM6227__1R00	3	1	17.2
SM6227__10R0	3	10	7.0
SM8035__1R00	4	1	43.3
SM8035__10R0	4	10	16.8

◆ Pulse power handling for the SM series is up to 10KW

Wirewound technology offers a good blend of pulse power and pulse energy handling and relative low cost for applications which don't have high switching speeds or sensitivity to inductance. Surface mount resistors that can handle up to 50J are rare, yet surface mount wirewounds can and are readily available.





Stackpole Electronics, Inc.
Resistive Product Solutions

Pulse Handling Resistor Summary

Pulse Withstanding Resistor Summary

Axial Leaded Resistors

Product	Power Range (W)	Resistance Range (ohms)	Pulse Voltage Capability (V)	Pulse Power Capability (W)	Pulse Energy Capability (J)
RNV	1/4	100K - 15M	7KV	NA	NA
ASR / ASRM	1/4 - 1	10 - 12M	10KV	NA	NA
MG / MGM	1/4 - 3	100K - 1G	10KV	NA	NA
RC	1/4 - 1	1 - 22M	NA	~80K	~10
Wirewound	1/2 - 25	.01 - 150K	NA	~100K	~500

Surface Mount Resistors

Product	Power Range (W)	Resistance Range (ohms)	Pulse Voltage Capability (V)	Pulse Power Capability (W)	Pulse Energy Capability (J)
HVC	0.06 - 3	10K - 50G	40KV	NA	NA
RPC	0.1 - 1.5	1 - 20M	~5KV	~4400	NA
HPC	5.0	.025 - 250K	NA	~2560	NA
SM	1 - 4	0.01 - 5K	NA	~10K	~50

The above products utilize film, carbon composition, and wirewound resistor technologies. Each product offers distinct advantages for its target applications. By selecting the correct product, design engineers can downsize their designs, reduce weight, and reduce costs while maximizing the long term reliability of their end product.



- For pulse voltage handling, film technologies can offer outstanding characteristics at relatively low cost.
- Pulse energy and pulse power handling however require resistance element mass, making carbon composition and wirewound technologies a better choice.
- Stackpole's axial leaded resistors have options which can handle pulse voltages up to 10KV, pulse power up to 80KW, and pulse energy up to 500J.
- Stackpole's surface mount resistors have products that can handle pulse voltages up to 40KV, pulse power up to 4400W, and pulse energy up to 50J.

Today's power design engineers have an abundance of choices in resistors, technologies, and manufacturers. By selecting the right surge withstanding component, the end product can be made smaller, lighter, and with increased function thereby creating increased value for the consumer.