



WIREWOUND RESISTORS

Pulse Handling Capabilities

Vishay Dale



Pulse Handling Capabilities

Power wirewound resistors have steady-state power and voltage ratings which indicate the maximum temperatures that the units should attain. For short durations of 5 seconds or less, these ratings are satisfactory; however, the resistors are capable of handling much higher levels of power and voltage for short periods of time (less than 100 ms). For instance, the RS005 has a continuous rating of 5 W, but for a duration of 1 ms the unit can handle 24.5 kW, and for 1 μ s the unit can handle 24.5 MW. The reason for this seemingly high power capability is the fact that energy, which is the product of power and time, is what creates heat; not just power alone. Vishay Dale can provide solutions for your application if provided with information detailed on page two.

Short Pulses (Less Than 100 Millisecond)

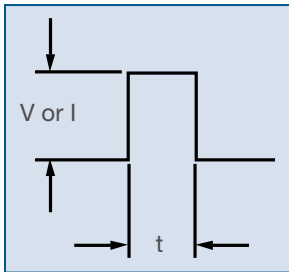
For short pulses, it is necessary to determine the energy applied to the resistor. For pulses less than 100 ms, Vishay Dale engineering assumes all of the pulse energy is dissipated in the resistance element (wire). In order for the resistor to maintain its performance characteristics over the life of the product, Vishay Dale bases analysis and recommendations on the amount of energy required to raise the resistance element to + 350 °C with no heat loss to the core, coating, or leads.

The pulse handling capability is different for each resistor model and value, as it is based on the mass and specific heat of the resistance element. Once the power and energy have been defined, Vishay Dale can determine the best resistor choice for the application.

Pulse applications often fall into one of three categories: square wave, capacitive charge/discharge, or exponential decay. An example of the pulse energy calculation for each of these will be shown in the following sections.

Square Wave

A constant voltage or current is applied across a resistor for a given pulse duration.



$$E = Pt$$

$$P = \frac{V^2}{R} \text{ or } I^2R$$

Where:

E = Energy (watt-seconds, W·s, or Joules, J)

P = Pulse power (watts, W)

t = Pulse duration (seconds, s)

V = Pulse voltage (volts, V)

R = Resistance (ohms, Ω)

I = Pulse current (amps, A)

Example

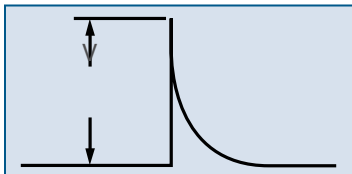
A single square wave pulse having an amplitude of 100 V_{DC} for 1 ms is applied to a 10 Ω resistor. What is the pulse energy?

$$P = \frac{V^2}{R} = \frac{(100 \text{ V})^2}{10 \Omega} = 1 \text{ kW}$$

$$E = Pt = 1 \text{ kW} \times 1 \text{ ms} = 1 \text{ W}\cdot\text{s} \text{ or } \text{J}$$

Capacitive Charge/Discharge

A capacitor is charged to a given voltage and then discharged through a wirewound resistor.



$$E = \frac{CV^2}{2}$$

Where:

E = Energy (W·s or J)

C = Capacitance (farads, F)

V = Peak voltage (V): V_{DC} or V_{RMS} $\times \sqrt{2}$

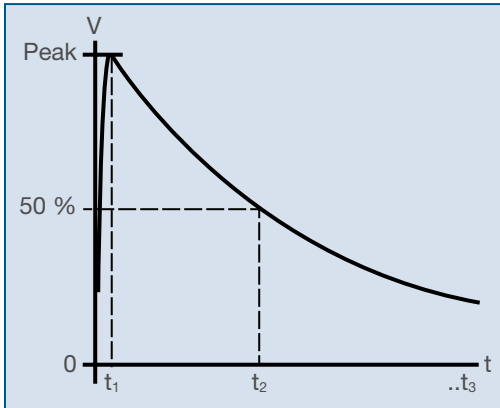
Example

A 2 μ F capacitor is charged to 400 V_{DC} and discharged into a 1 k Ω resistor. What is the pulse energy this will produce?

$$E = \frac{CV^2}{2} = \frac{2 \mu\text{F} \times (400 \text{ V})^2}{2} = 0.16 \text{ W}\cdot\text{s} \text{ or } \text{J}$$

Exponential Decay/Lightning Surge

The application reaches a peak voltage and decreases at a rate proportional to its value. This is typically modeled by DO-160E WF4 or IEC 6100-4-5 and represents a lightning surge.



$$E = \left(\frac{1}{3} \times \frac{V^2}{R} \times t_1 \right) + \left(\left(\frac{V^2 \times \tau}{-2 \times R} \right) \times \left(e^{-\frac{2 \times t_3}{\tau}} - e^{-\frac{2 \times t_1}{\tau}} \right) \right)$$

Where:

E = Energy (W·s or J)

V = Peak voltage (V): V_{DC} or $V_{RMS} \times \sqrt{2}$

R = Resistance (Ω)

t_1 = Time to peak voltage (s)

t_2 = Time to 50 % of peak voltage (s)

t_3 = Time to negligible voltage (s)*

τ = Exponential rate of decay

*Note that if no t_3 is provided, it is assumed to be greater than 20 times t_2

Example

Following DO-160E WF4, the peak voltage is 4 kV over a 100 Ω resistor, with corresponding times:

$t_1 = 1.2 \mu\text{s}$

$t_2 = 50 \mu\text{s}$

$t_3 =$ not provided; for calculation it will be $20 \times 50 \mu\text{s} = 1 \text{ ms}$

$$\tau = -\frac{(t_2 - t_1)}{\ln(0.50)} = -\frac{(50 \mu\text{s} - 1.2 \mu\text{s})}{\ln(0.50)} = 70.4 \mu\text{s}$$

$$E = \left(\frac{1}{3} \times \frac{(4 \text{ kV})^2}{100 \Omega} \times 1.2 \mu\text{s} \right) + \left(\left(\frac{(4 \text{ kV})^2 \times 70.4 \mu\text{s}}{-2 \times 100 \Omega} \right) \times \left(e^{-\frac{2 \times 1 \text{ ms}}{70.4 \mu\text{s}}} - e^{-\frac{2 \times 1.2 \mu\text{s}}{70.4 \mu\text{s}}} \right) \right) = 5.51 \text{ W}\cdot\text{s, or J}$$

Information Required to Determine Pulse Capability

Type of Pulse

- Single Square Wave
 - Resistor value and tolerance?
 - Voltage or current?
 - Duration?
 - Repeated?
 - Maximum ambient temperature?
 - Is there any other power applied during the pulse?
- Exponential Decay/Lightning Surge
 - Resistor value and tolerance?
 - Rise time?
 - Peak voltage?
 - Time to 1/2 voltage?
 - Maximum ambient temperature?
 - Is there any other power applied during the pulse?
- Capacitor Discharge
 - Resistor value and tolerance?
 - Capacitance?
 - Charge voltage?
 - Repeated?
 - Maximum ambient temperature?
 - Is there any other power applied during the pulse?
- Repetitive Pulse
 - Resistor value and tolerance?
 - Voltage or current?
 - On time - off time?
 - Number of repetitions?
 - Maximum ambient temperature?
 - Is there any other power applied during the pulse?

Along with the above information we need to know the Vishay resistor model you have in mind.

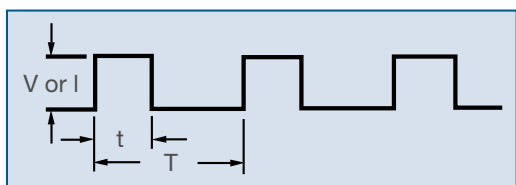
Equally Spaced Repetitive Pulses

When calculating pulse handling capability for repetitive pulses, the average power as well as the individual pulse energy must be considered. This is because the average power establishes some average heat rise on the part, which uses up some percentage of the part's energy capability. That portion of the energy not used by average power is then available to handle the instantaneous pulse energy. When the two percentages (average power to rated power and pulse energy to pulse handling capability) are added together, they must not exceed 100 % of the part's overall rating.

Example

The following example is provided based upon an equally spaced repetitive square wave pulse.

Where:



V = Pulse voltage (V)
 I = Pulse current (A)
 t = Pulse width (s)
 T = Cycle time (s)
 P = Pulse power (W)
 P_{Avg} = Average power (W)
 E = Energy (W·s or J)

1. The pulse power, $P = \frac{V^2}{R}$ or I^2R , is calculated for a single pulse.
2. The average power is calculated as follows: $P_{Avg} = \frac{Pt}{T}$
3. Calculate the pulse energy: $E = Pt$
4. Calculate the percentage of average power to rated power (P_R):

$$\text{Percentage (power)} = \frac{P_{Avg}}{P_R} \times 100$$
5. Vishay Dale engineering can provide the pulse handling capability (E_R) given a resistor model, resistance value, and ambient temperature.
6. Calculate the percentage of pulse energy to pulse handling capability:

$$\text{Percentage (energy)} = \frac{E}{E_R} \times 100$$
7. Add the percentages in (4) and (6). If the percentage is less than 100 %, the resistor chosen is acceptable. If the percentage is greater than 100 %, a resistor with a higher power rating or higher pulse handling capability should be selected. Contact Vishay Dale engineering to determine the best resistor choice for your application.

Example

A series of equally spaced square wave pulses, having an amplitude of 200 V_{DC}, a pulse width of 20 ms, and a cycle time of 20 s, is applied to a RS007 100 Ω resistor at an ambient temperature of 25 °C.

1. The pulse power is: $P = \frac{V^2}{R} = \frac{(200 \text{ V})^2}{100 \Omega} = 400 \text{ W}$
2. The average power is: $P_{Avg} = \frac{Pt}{T} = \frac{400 \text{ W} \times 0.02 \text{ s}}{20 \text{ s}} = 0.4 \text{ W}$
3. The pulse energy is calculated: $E = Pt = 400 \text{ W} \times 0.02 \text{ s} = 8.0 \text{ W}\cdot\text{s}$, or J
4. The RS007 resistor has a rated power (P_R) of 7 W. The percentage of average power to rated power is calculated:

$$\frac{P_{Avg}}{P_R} \times 100 = \frac{0.4 \text{ W}}{7.0 \text{ W}} \times 100 = 5.7 \%$$
5. The pulse handling capability (E_R) provided by Vishay Dale engineering at an ambient temperature of 25 °C is 15.3 J.
6. The percentage of pulse energy to pulse handling capability is calculated: $\frac{E}{E_R} \times 100 = \frac{8.0 \text{ J}}{15.3 \text{ J}} \times 100 = 52.3 \%$
7. The percentages calculated in (4) and (6) are added: 5.7 % + 52.3 % = 58 %

Since this percentage is less than 100 % of the overall rating, the RS007 style resistor will sufficiently handle the pulse.

Non-Inductive Resistors

Non-inductive power resistors consist of two windings, each of which is twice the finished resistance value. For this reason, the energy capability will nearly always be greater than a standard wound unit. To calculate the energy capability needed for non-inductive styles, compute the energy per ohm (J/ Ω) by dividing the energy by four times the resistance value.

Example

What is the energy per ohm pulse handling capability required to handle a 0.2 J pulse applied to a 500 Ω resistor?

The energy per ohm needed is: $\frac{E}{4R} = \frac{0.2 \text{ J}}{4 \times 500 \Omega} = 100 \times 10^{-6} \text{ J}/\Omega$

This can be provided to Vishay Dale engineering in order to find the best product for the application.

Long Pulses (100 Millisecond to 5 Seconds)

For long pulses, much of the heat is dissipated in the core, leads, and coating. As a result, the calculations used for short pulses are far too conservative. For long pulse applications, the short time overload ratings from the datasheets are used. Note that repeated pulses consisting of the short time overload magnitude are extremely stressful and can cause some resistor styles to fail.

- To find the overload power for a 5 s pulse, multiply the power rating by either 5 or 10 as stated on datasheet
- To find the overload power capability for 1 to 5 s, convert the overload power to energy by multiplying by 5 s, then convert back to power by dividing by the pulse width in seconds
- For pulse durations between 100 ms and 1 s, use the overload power computed for 1 s

Example

1. What is the overload power for an RS005?
From the datasheet, an RS005 is rated at 5 W and will take 10 times rated power for 5 s: $10 \times 5 \text{ W} = 50 \text{ W}$
2. What is the energy capability of an RS005 for 5 s?
For 5 s, the energy capability is: $50 \text{ W} \times 5 \text{ s} = 250 \text{ W}\cdot\text{s}$ or J
3. What is the overload power capability of an RS005 for 1 s?
For 1 s, the overload power capability is $250 \text{ W}\cdot\text{s} / 1 \text{ s} = 250 \text{ W}$
4. What is the energy capability of an RS005 for 0.5 s?
For 0.5 s, the energy capability is $250 \text{ W} \times 0.5 \text{ s} = 125 \text{ W}\cdot\text{s}$ or J

Voltage Limitations

Short pulses – No overload voltage rating has ever been established for wirewound resistors when pulsed for short durations. Sandia Corporation has performed a study on our NS and RS resistors using 20 μs pulses. This study indicates that this type unit will take about 20 kV per inch as long as the pulse handling capability is not exceeded.

Long pulses – For pulses between 100 ms to 5 s the recommended maximum overload is $\sqrt{10}$ times the maximum working voltage for the 4 W size and larger, and $\sqrt{5}$ times the maximum working voltage for sizes smaller than 4 W.

Fusible Resistors

If the goal of the application is for the resistor to fuse open under a specific condition, Vishay Dale offers Fusible Resistors. Reference page five for common resistor types, or click the following link for the entire datasheet: www.vishay.com/doc?30232

Fast Acting, Molded Styles, Custom Designed For Your Application

Features

- Low temperature coefficient (down to 30 ppm/°C)
- High temperature silicone molded package (derated to 200 °C)
- Performs function of resistor and series fuse and provides predictable fusing times
- Complete welded construction
- No flaming or distortion of unit under fusing conditions
- Ideal for Squib circuit applications and protection of semi-conductor devices
- Negligible noise and voltage coefficient



TYPICAL ELECTRICAL SPECIFICATIONS

The following are offered as examples of reliable designs. Hundreds of possible combinations are available for meeting your requirements. Contact factory by using email address in the footer of this page, for assistance. Higher wattages available.

GLOBAL MODEL	HISTORICAL MODEL	FUSING PARAMETERS		RESISTANCE RANGE Ω	TOLERANCE \pm %	1.0 W CONTINUOUS POWER ⁽¹⁾	
		FUSING CURRENT A	TYPICAL FUSING TIME ms			CONTINUOUS CURRENT A	CROSSOVER VALUE Ω
RS01A...209	RS-1A-209	0.5	4	49 - 500	5, 10	0.10	100.0
RS01A...118	RS-1A-118	1.0	9	6.8 - 185	5, 10	0.25	16.0
RS01A...212	RS-1A-212	1.25	8	4.7 - 107	5, 10	0.30	11.11
RS01A...213	RS-1A-213	1.5	15	3.5 - 68	5, 10	0.35	8.16
RS01A...143	RS-1A-143	2.0	15	2.2 - 35	5, 10	0.40	6.25
RS01A...214	RS-1A-214	2.5	23	1.7 - 23	5, 10	0.45	4.94
RS01A...162	RS-1A-162	3.0	48	1.1 - 12	5, 10	0.55	3.31
RS01A...208	RS-1A-208	4.0	47	0.72 - 6.44	5, 10	0.75	1.78
RS01A...207	RS-1A-207	6.0	70	0.35 - 2.17	5, 10	1.0	1.0
RS01A...215	RS-1A-215	8.0	48	0.29 - 1.61	5, 10	1.25	0.64
RS01A...173	RS-1A-173	10.0	50	0.23 - 1.16	5, 10	1.50	0.44
RS01A...216	RS-1A-216	15.0	35	0.19 - 0.82	5, 10	1.75	0.33
RS01A...217	RS-1A-217	20.0	46	0.12 - 0.42	5, 10	2.0	0.25

Note

- ⁽¹⁾ The Continuous Current Rating applies only to values equal to or less than the Crossover Value. The Continuous Power Rating applies only to values equal to or higher than the Crossover Value.
- Be aware that the inherent compromise involved between resistive and fusing functions sometimes makes certain exact combinations unattainable. However, in nearly all cases, this does not prevent the production of a functional, reliable fuse resistor thoroughly capable of meeting application requirements.

GLOBAL PART NUMBER INFORMATION

Global Part Numbering example: RS01A402R0JS70209

R S 0 1 A 4 0 2 R 0 J S 7 0 2 0 9

GLOBAL MODEL	VALUE	TOLERANCE	PACKAGING	SPECIAL
(See Typical Electrical Specifications Global Model column for options)	R = Decimal 15R00 = 15 Ω	J = \pm 5.0 % K = \pm 10.0 %	E70 = Lead (Pb)-free, tape/reel E12 = Lead (Pb)-free, bulk S70 = Tin/lead, tape/reel B12 = Tin/lead, bulk	(Dash Number) (up to 3 digits) From 1 - 999 as applicable

Historical Part Numbering example: RS-1A-209 402 Ω 5 % S70

RS-1A-209	402 Ω	5 %	S70
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

If a MODEL listed in TYPICAL ELECTRICAL SPECIFICATIONS table does not meet your requirements, then please include the following information. It will enable us to choose the best design for your application.

1. Operating wattage or current, ambient temperature and required resistance stability. (% Δ R/1000 h)
2. Fusing wattage or current and maximum "blow" time. Also, minimum "blow" time, if applicable.
3. Nominal resistance and maximum allowable resistance tolerance, (5 % to 10 % preferred).
4. Maximum allowable physical size.
5. Voltage to be interrupted.
6. Frequency of power source, wave form and a brief description of your application.

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