Pulse Capabilities for Thick Film Power Resistors

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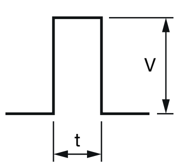
Vishay Sfernice offers a wide range of thick film power resistors. Our resistors are able to dissipate from 5 W up to 1100 W with a large range of ohmic values (10 mΩ up to 1 MΩ).
The pulse capability of our resistors is a key specification for many customer applications.
The energy curve in the datasheets shows the maximum energy that can be applied over a given period.

In this application note, we use the example of our LPS 800 resistor to explain a method to evaluate whether the resistor is appropriate for a given application. This method can be used for each resistor type using the corresponding pulse curve or limiting voltage from the corresponding datasheet.

If we take the following example:
A capacity of 5 µF charged to 1140 V will be discharged through an LPS 800 80 Ω with a frequency of 100 Hz. The ambient temperature is 25 °C (see next page for the determination of the ambient temperature).

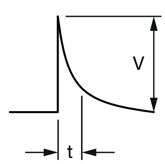
1. The maximum pulse voltage for LPS 800 indicated on the datasheet is 5000 V. This voltage is not exceeded by the discharge of the capacitor, so LPS 800 is compatible with this application.

2. Calculation of the energy stored by the capacitor for one pulse: represented below are the most common voltage curves and the formula used for each of them.



$$E = \frac{V^2 t}{R}$$

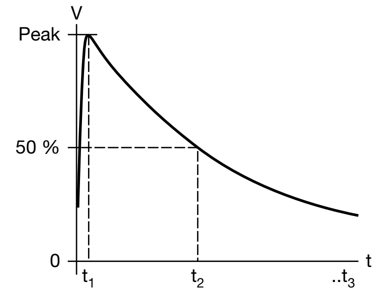
Square pulse



$$E = \frac{1}{2} \times C \times V^2$$

$$t = R \times C$$

Capacitor discharge



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

Lightning pulse

Unity:

E = Energy in J

t = Time in s

V = Voltage in V

R = Resistance in Ω

C = Capacity in F

Square pulse: A constant voltage V is applied to the resistor R during a period t.
Capacity discharge: A capacitor C is charged to a given voltage V and discharged into the resistor R.

Lightning pulse: The voltage rises up to V_{peak} and decreases at an exponential rate. This pulse is the pulse defined in the IEC 61000-4-5 with

t_1 = Time to peak voltage (s)

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

t_3 = Time to negligible voltage > 20 x t2

τ = Exponential rate of decay = - $(t_2 - t_1)/\ln(0.50)$

In our example introduced above, we have C = 5 µF and V = 1140 V:

$$E = \frac{1}{2} CV^2 \Rightarrow E = \frac{1}{2} \times 5.10^{-6} \times 1140^2 \Rightarrow E = 3.25 \text{ J}$$

$$t = RC \Rightarrow t = 80 \times 5.10^{-6} \Rightarrow t = 400 \text{ µs}$$

We can now examine the energy curve of proposed use.

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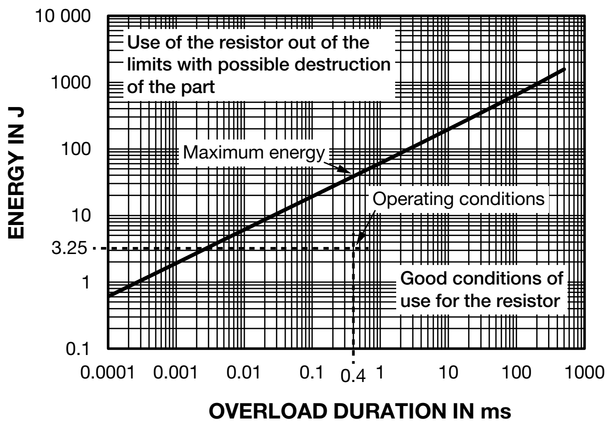
3. Check of the chosen operating point on the energy curve of LPS 800:

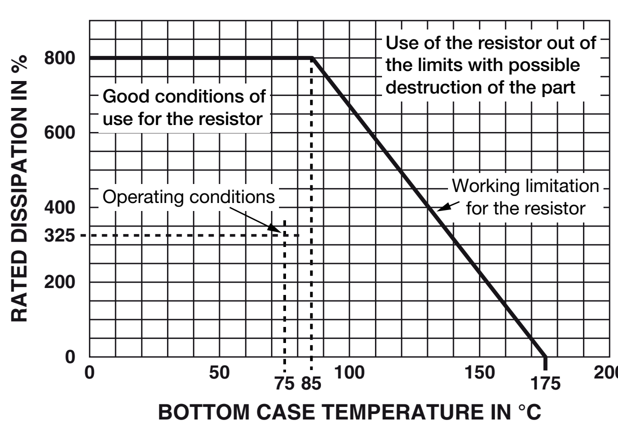


Each point on the curve corresponds to a single test at 25 °C for the ambient temperature.
The operating conditions are in the zone corresponding to good conditions of use for the resistor.
Now, we must calculate the average power dissipated by the component.

4. Calculation of the average power dissipated LPS 800 for this example:
In case of multiple pulses applications, we need to use the formula linking the energy of the pulse and the frequency of repetition of this pulse (f = 100 Hz for this example):

5. $P_{average} = E / t = E \times f \Rightarrow P_{average} = 3.25 \times 100 \Rightarrow$
$P_{average} = 325$ W

6. With the derating curve, we can see if LPS 800 can be used at 325 W with a case temperature, backside of the resistor, at 75 °C for example.



Note

- Our operating conditions are in the acceptable zone for the component. It remains for us to determine the size of the heatsink.

To define the size of our heatsink, we take the formula:

$$(Rth_{(c-h)} - Rth_{(h-a)})_{max.} = \frac{\Delta T}{P_{average}} - Rth_{(j-c)} = \frac{T_{j\ max.} - T_a}{P_{average}} - Rth_{(j-c)}$$

$Rth_{(j-c)}$ = Thermal resistance value measured between resistive layer and outer side of the resistor.

$Rth_{(c-h)}$ = Thermal resistance value measured between outer side of the resistor and upper side of the heatsink. This is the thermal resistance of the interface (grease, thermal pad), and the quality of the fastening device.

$Rth_{(h-a)}$ = Thermal resistance of the heatsink.

$T_{j\ max.}$ = Temperature of the resistive element (maximum 175 °C for LPS 800).

T_a = Ambient temperature (determinated by the measurement of the temperature of the junction without any power or the temperature of the water for a water cooling heatsink.)

Take the example of a thermal interface of 0.2 °C/W for the interface between the component and the heatsink.

$$Rth_{(h-a)\ max.} = \frac{T_{j\ max.} - T_a}{P} - Rth_{(j-c)} - Rth_{(c-h)}$$

$$Rth_{(h-a)\ max.} = \frac{175 - 25}{325} - 0.112 - 0.2 = 0.15\ °C/W$$

In this example, we must therefore choose a heatsink with a Rth ≤ 0.15 °C/W

CP15 from Lytron
(water cooling heatsink)

LA 14 from Fischer Elektronik
(air cooling heatsink with fan)

To avoid any damage to the resistor by excessive pulse loading, the specifics of the customer's application must be checked.

See the following link:
www.vishay.com/resistors/pulse-energy-calculator/