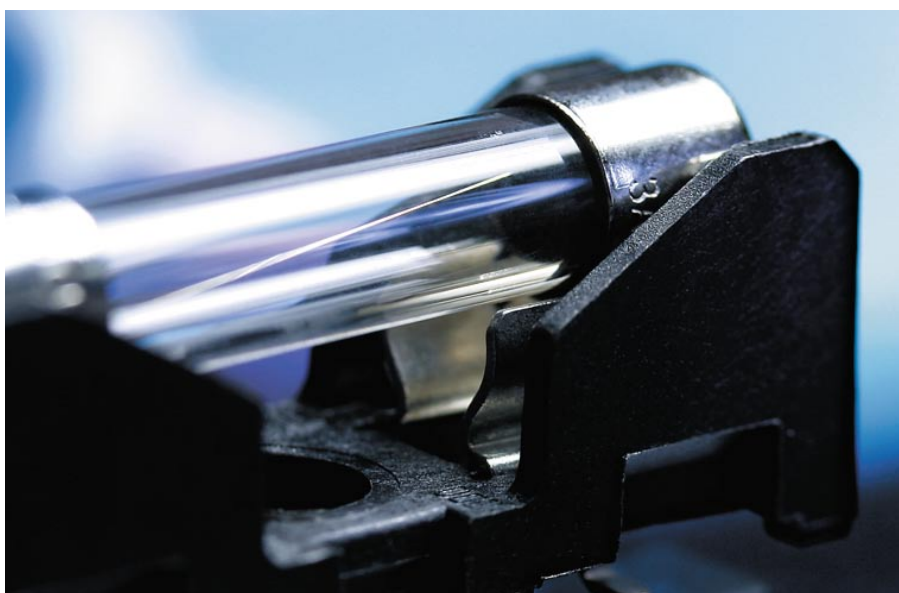# Find the Right Fuse!

Criteria for Correct Fuse Selection

Circuitry overcurrent protection rarely receives the attention it deserves. An inadequately thought out selection of fuses can lead to the breakdown of equipment and installation, resulting in high replacement costs and dissatisfied customers. This technical article focuses on the correct selection criteria for fuses and fuseholders, and should help you take the more important aspects into consideration.

Normal operation after switching ON is explained under point 1. This point should always be taken into consideration.

Point 2 is only necessary with capacitive loads, present when the charging of capacitors after switching ON, leads to high in-rush current peaks and the rated current of the fuse is exceeded by many multiples.

Important facts with regard to fuseholders are given under point 3, where the correct selection of fuse and fuseholder combinations is explained.
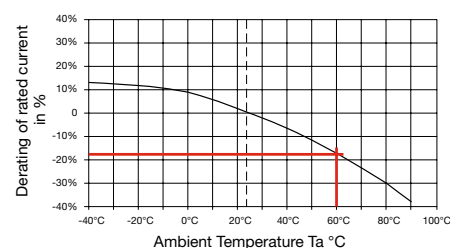

Fig. 1: shows the de-rating curve of the time-lag SMD fuse UMT 250.

Point 1:
Normal Operation After Switching ON
Under normal operating conditions, a fuse is subjected to a maximum operating current and a maximum operating temperature. A «derating» of the rated current is therefore usually necessary since a fuse is rarely operated at the set ambient temperature of 23 °C. As an example, let's look at a scenario using a time-lag SMD fuse such as the UMT 250 from SCHURTER. With an operating temperature of 60 °C, in accordance with fig. 1 the fuse needs to be derated by 17%, i.e., when the operat-

The function of a fuse is to interrupt an uncontrolled fault current or overcurrent before serious damage can occur, such as the overheating of equipment. Because a fuse is designed using a fusing element, it is particularly suited for reliable interruption of short-circuits.

With overcurrents up to 2x or 3x the rated current, a fuse becomes less accurate and, as such, not so well suited for these conditions. Other overcurrent protection measures such as electronic protection, thermal overload elements or additional fuses are then necessary.

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ing current is 1 A @ 60 °C, a rounded-up fuse value of 1.25A (1A / 0.83) is necessary.
Fuses can be in accordance with IEC 60127 or UL 248-14. Because of the different definitions between the two standards, fuses are not directly interchangeable as follows: fuses in accordance with IEC 60127 may be operated continually at 100% of the rated current value, whereas fuses in accordance with UL 248-14 only at 75%. UL 248-14 specifies a minimum of 4h operating time at rated current (table 1).

The self-heating effect of time-lag fuses is less than that of quick-acting. This can be seen from the typical values of voltage drop. For example, a 2 A 5x20 mm glass time-lag fuse has a typical voltage drop of 60 mV, whereas a typical quick-acting version is 90 mV. This difference is evident by the thicker fuse element (higher melting value I^2t, see point 2) that is necessary for time-lag fuses. It should also be noted that fuses are heated by the current until

Pre-Arcing Time

Rated Current In	1.0 x In min.	2.0 x In max.
0.375 A - 5 A	4 h	60 s

Table 1: Pre-arcing time of a fuse according to UL 248-14.

a certain temperature has been reached when the fuse element melts (opens) and interrupts the circuit.
All measures for cooling such as ventilation, heat sinks, large solder surfaces or heat accumulators (fig. 2) change the time/current characteristic of the fuse and thus should be avoided.

Point 2: In-Rush Current Peaks

In-rush current peaks (fig. 3) arise through capacitors that are initially charged when switched

ON. These pulses can be many multiples of the rated current of the fuse, but are mostly of a very short duration.
The area beneath the curve is called the melting integral or I^2t value. The I^2t value is defined as that amount of energy necessary to heat
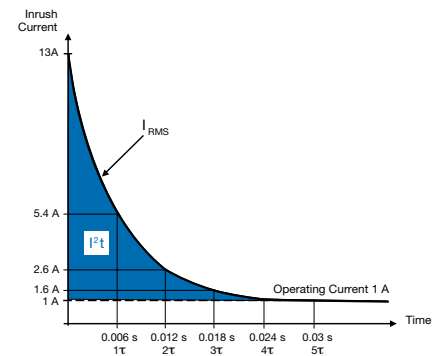

Fig. 3: Typical switch-on curve of a SMPS when capacitors need to be charged.

up and melt a wire or fuse element. Generally this is an exponential curve having a peak current value of I_P over a period of time called τ, at which point the current has reached 37% of the peak current value. As an example, let's take the time-lag SMD fuse UMT 250, 1 A. The I^2t-value can be calculated with the following formula using a peak current of $I_P = 13$ A and a $\tau = 6$ ms:

$$I^2t_{Application} = 0.5 * I_P{}^2 * \tau$$

$$I^2t_{Application} = 0.5 * (13 A)^2 * 6 \text{ ms} = 0.507 \text{ A}^2s$$

In addition to the start-up current, the number of pulses over the life of the equipment must be taken into account since premature ageing of the fuese needs to be considered. A factor of 0.29 is used for 10 000 pulses with time-lag fuses (see table 2).

$$I^2t_{min\_Fuse\_T} = I^2t_{Application}/F$$

$$I^2t_{min\_Fuse\_T} = 0.507 \text{ A}^2s/0.29 = 1.748 \text{ A}^2s$$

Manufacturers provide the melting integral value in the catalog for each fuse type and rated current. For example, (table 3) with the IEC time-lag SMD fuse UMT 250. The 1 A rated current fuse has an I^2t value of 2.8 A^{2}s, that is, with an over-current (short-circuit) or an inrush
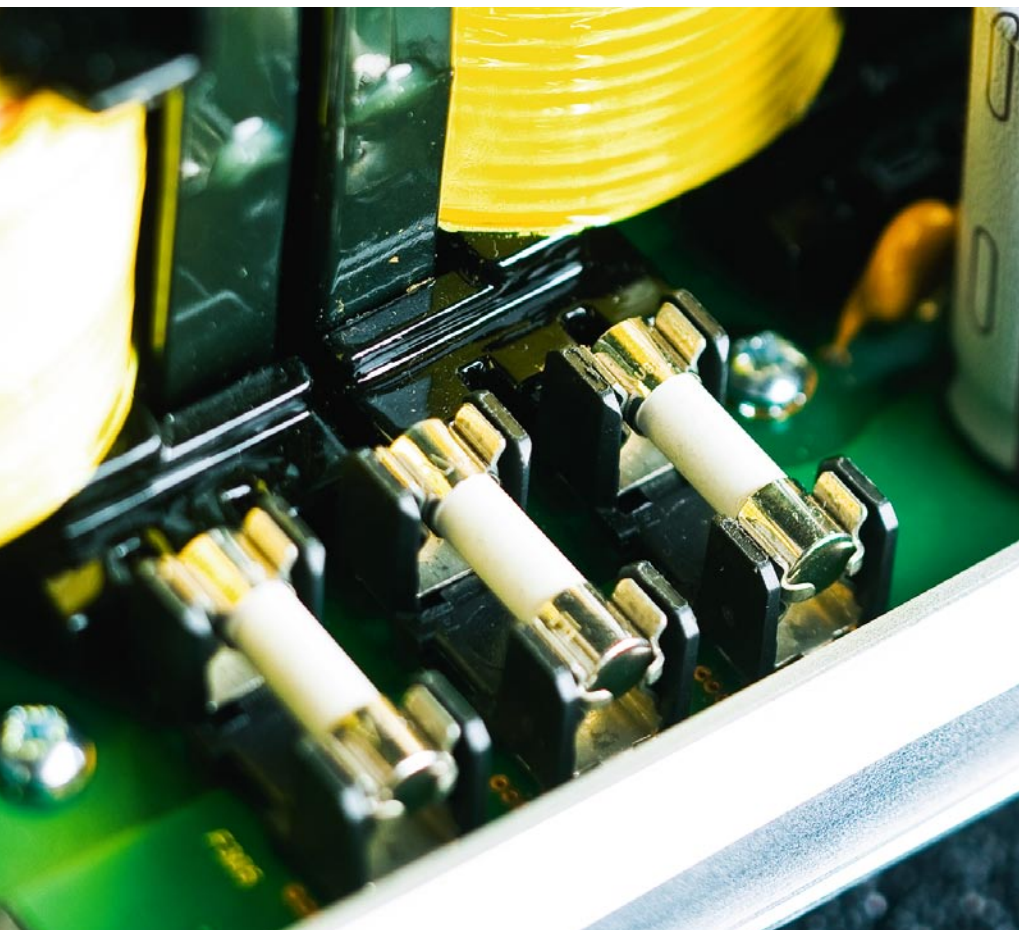

Fig. 2: Fuses mounted in holders can influence each other with regard to temperature.

Variants

Order Number	Rated Current [A]	Rated Voltage [VAC]	Rated Voltage [VDC]	Breaking Capacity	Voltage Drop 1.0 In max. [mV]	Voltage Drop 1.0 In typ. [mV]	Power Dissipation 1.25 In typ. [mW]	Melting I^2t 10.0 In typ. [A^2s]	VDE	UL	cURus	PSE JET	CCC	K
3403.0155.xx	0.08	250	125	1)	1300	850	200	0.025	•		•			
3403.0161.xx	0.315	250	125	1)	750	343	500	0.27	•	•	•		•	•
3403.0162.xx	0.4	250	125	1)	700	290	500	0.4	•	•	•		•	•
3403.0163.xx	0.5	250	125	1)	600	257	500	0.54	•	•	•		•	•
3403.0164.xx	0.63	250	125	1)	500	216	500	1.1	•	•	•		•	•
3403.0165.xx	0.8	250	125	1)	400	190	500	1.4	•	•	•		•	•
3403.0166.xx	1	250	125	2)	300	164	500	→ 2.8	•	•	•		•	•
3403.0167.xx	1.25	250	125	2)	300	138	1000	4.5	•	•	•	•	•	•
3403.0168.xx	1.6	250	125	2)	300	124	1000	6.9	•	•	•	•	•	•

Table 3: Versions of UMT 250 with details of the melting integrals, voltage drops and power losses for every current rating.

current peak in excess of this value, the fusing element melts and interrupts the circuit. In our example the I^2t value of the fuse (2.8 A^2s) is higher than the calculated value (1.748 A^2s); that is, the selection would be correct for this application.

In-rush pulses, particularly when they occur often, cause fuses to age prematurely. This can lead to failures in the field later on, which can be avoided using this calculation. In order to obtain a high I^2t, time-lag fuses usually have a tin-plated melting wire. Over time, the tin diffuses in the wire, which leads to a change in the time/current characteristic of the fuse. In general, quick-acting fuses are more resistant to pulses than time-lag, but time-lag fuses need to be used because of their higher I^2t capability values than those for quick-acting.

	Time-lag	Quick-acting
100 pulses	0.5	0.6
10 000 pulses	0.29	0.49
1 Mio. pulses	0.19	0.42

Table 2: Factors for time-lag and quick-acting fuse types with different numbers of pulses.

Point 3: Combination of Fuses and Fuseholders

5x20 mm fuses are used widely in industrial applications, since they are easily available worldwide and can be replaced by the end customer or a service technician. In applications such as these, a fuseholder is usually needed. Like fuses, the difference between IEC and UL standards also needs to be observed when selecting fuseholders. Fuseholders approved to the IEC 60127-6 standard need to fulfill, amongst other requirements, the following: rated power acceptance (e.g. 2.5 W / 10 A @ 23 °C), rated current (e.g. 10 A) and rated voltage (e.g. 250 V). For fuseholders approved to UL 512 and CSA C22.2 no. 39, only the rated current (e.g. 16 A) and rated voltage (e.g. 250 V) are specified.

The maximum rated current with UL is usually higher than IEC because of the following reasons:

IEC uses a dummy fuse, e.g., 40 mΩ = 4.0 W /(10 A)^2 (fig. 4). This dummy fuse, together with the contact resistance between fuse and clip generate heat. The fuseholder must withstand this condition for 500h and accessible parts are not allowed to exceed a temperature of 85 °C.
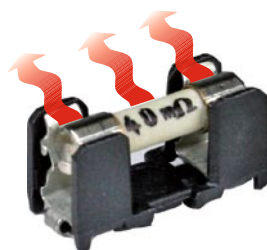

**Fig. 4:
IEC test with dummy fuse**

**Fig. 5:
UL/CSA test with silver tube**

On the other hand, UL/CSA uses a silver tube having ≈0Ω (fig. 5). That means heat is only produced by the contact resistance between fuse and clip, which leads to the fact that a fuseholder tested under UL/CSA conditions can withstand a higher rated current than those tested under IEC conditions. Since every fuse has its own resistive value and thus generating heat, the IEC consideration is closer to reality. The UL/CSA really only tests the fuseholder itself, which does not simulate real world application.

The fuse standards (IEC 60127-2 to 4) check general electrical properties such as, for example, the minimum/maximum pre-arcing times. The standard for fuseholders (IEC 60127-6) checks thermal properties such as conditions of temperature at rated power and current over an operating period of 500h. Therefore, the customer is obliged to carry out his own calculations. The following approach is well tried and tested:

For example, we expect to have an operating current of 5 A @ 60 °C. As a result of the increased temperature in the fuseholder, derating, as described under point 1, must also be taken into consideration. In the example, the derating for standard fuses is around 20%, which means a rounded up current rating of 6.3 A (5 A / 0.8).

The fuse power dissipation is calculated with the rated current and typical voltage drop value (voltage level over the fuse at rated current) according to the catalog. Ceramic fuses such as, SPT 5x20, 6.3 A have a typical voltage drop of 70 mV at rated current.

$$P_{Fuse} = I_N * U_{VoltageDrop\_typ}$$

$$P_{Fuse} = 6.3 \text{ A} * 70 \text{ mV} = 441 \text{ mW}$$

With a fuseholder, e.g. FPG1, having a rated power acceptance of 2.5 W @ 10 A, the recommended derating curve as shown in fig. 6 must be taken into account. At 60 °C and a rated current of 5 A, the curve I = << I_n, is used since the operating current is 5 A and the admissible current of the fuseholder under IEC is 10 A. In the example, this gives a maximum rated power acceptance $P_{Fuseholder}$ of 1.3 W.

According to the IEC standard, the contact resistance R_c between fuse and clip is a maximum of 5 mΩ. Power dissipation can be calculated using the following formula:

$$P_{Contact} = R_c * I_N^2$$

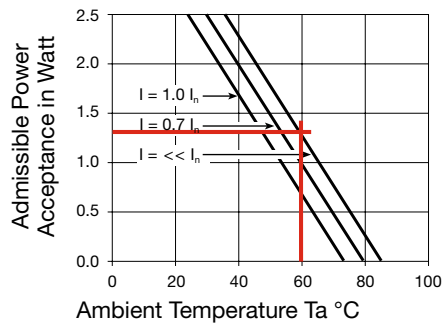$$P_{Contact} = 5 \text{ mΩ} * (6.3 \text{ A})^2 = 198 \text{ mW}$$

Fig. 6: Derating curve of a shock-safe fuseholder as e.g. FPG1.

Correct dimensioning can be ascertained through the use of the following equation:

$$P_{Fuseholder} = 1.3 \text{ W}$$

$$P_{Fuse} + P_{Contact} = 441 \text{ mW} + 198 \text{ mW}$$

$$P_{Fuse} + P_{Contact} = 639 \text{ mW}$$

Combination is correct layed out, when
$$P_{Fuseholder} > P_{Fuse} + P_{Contact}$$

and this is the case in the example.

The following operational modes can be an additional burden to the fuseholder and must be specially evaluated: changes in electrical loads, continuous operation (>500 h) at currents >0.7*IN and the effects of ventilation, cooling, heat accumulation, etc. Even after consideration of these selection criteria, extensive tests under worst-case conditions are critical in order to ensure safe and reliable operation in equipment and installations.

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