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SIBA technical background information:
Know-how on electrical fuses

A small component, yet a high degree of safety

SMD Fuses for “real” short circuits:
A new design which is able to interrupt 4000 A

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SMD Fuses for “real” short circuits

A new design which is able to interrupt 4000 A

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Compared with the established SMD fuses the new SIBA SMD fuses presented here appear quite large, even huge. The requirements for these components, however, are also huge: after all, they are intended to interrupt short-circuit currents of several hundred amperes and, in cases of faults, to isolate defective components or devices from the mains. How and why this works is described in this article. [**1**]

The whole family

Surface-mount fuses, i.e. SMD fuses, are used when it comes to monitoring and interrupting overcurrents on as small a space as possible. In order to achieve this, various constructions which make optimum use of the space available on a printed circuit board exist for the most diverse applications. **Table 1** gives an overview of the most commonly used SMD fuses from the collection of types offered worldwide.

Table 1: Overview of SMD Fuses

Fuse type	Sizes	Characteristic	Rated voltage	Rated current	Breaking capacity
Chip-type SMD	0402 to 1206	FF	32 to 63 V	250 mA to 5 A	50 A
Block-type SMD	2,6 x 6,1 mm	F and T	125 V	62 mA to 15 A	50 A
Block-type SMD	4,5 x 8 mm	F and T	250 V	32 mA to 6,3 A	100 A
cylindrical SMD	5 x 20 mm	F and T	250 V	1 to 6,3 A	1500 A

The smallest members of the SMD fuse family are the chip-type ones (**Figure 1a**). With widths of, e.g., less than 1 mm they are used in mobile phones, shavers and other small appliances. They serve as “saving anchors” in cases of faults in the lithium battery. Typical voltage classes are 10 V, 20 V, 30 V or 40 V, partly for AC and partly for DC operation.

Fuses for operating voltages of 100 V and more are slightly larger. Being designed as SMD block types (**Figure 1b**), in most cases they have a ceramic housing and, in comparison with the chip-type fuses, they are “hard to miss”, having an edge dimension of, e.g., 6 mm. This group comprises also fuses with a rated voltage of 250 V. Thanks to a maximum breaking capacity of 100 A at 250 V they are able to provide short-circuit protection in secondary circuits.

As far as protection in cases of “real” short circuits of some hundred amperes is concerned, so far, specially prepared cylindrical fuses with dimensions of 5 mm × 20 mm (**Figure 1c**) for surface mounting have been available. As compared with the standard design, the temperature stability required for the reflow soldering process is ensured by means of the solder in the fuse melting at higher temperatures. Instead of being nickel-plated, often the contact caps are gold-coated. These fuses are able, without any problems, to interrupt currents of 1500 A in accordance with the standardized classification "H", even at a mains voltage of 230 V; this is why they are preferably used in the primary circuits of power supply units.

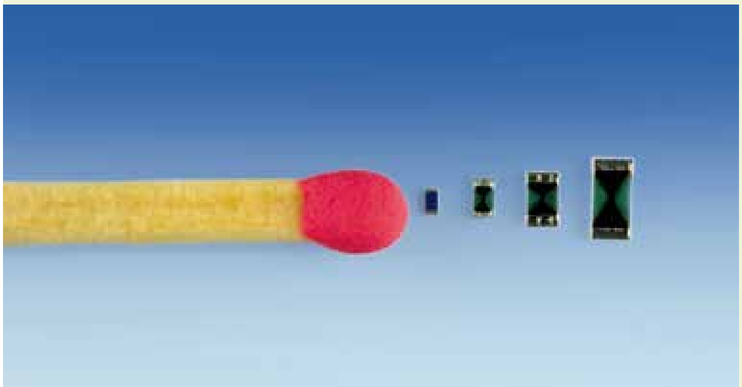


Figure 1a
Chip-Type SMD Fuse

Figure 1b
Block-Type SMD Fuse

Figure 1c
Cylindrical SMD Fuse
with gold contact

Figure 1: Basic types of SMD Fuses

The new big brother

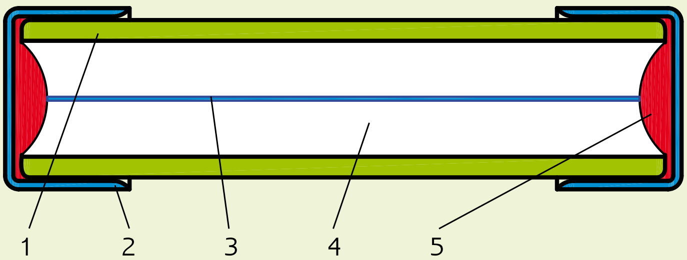
What had been missing until now was a fuse with the before-mentioned performance data which would "not roll away" during processing. Now this gap could be bridged by developing the rectangular 250 V rated voltage fuse presented here which is even able to interrupt breaking currents exceeding 1500 A.

And all this is achieved by a fuse with dimensions of 4,5 mm × 16 mm (**Figure 2**). On the one hand, this fuse is by far larger than a chip-type SMD fuse; on the other hand, however, it is still quite smaller than a cylindrical SMD fuse with similar performance data.

So far, leaded 5 mm × 20 mm fuses (**Figure 2**) have been used in many applications. Compared to this variant, the new rectangular SMD fuse offers considerable advantages for the production process in almost all cases. And there is a positive "side effect", too: as the rated current is always clearly identifiable, no hard-to-decipher colour codes on the fuses are required any more.

This fuse's construction principle is nothing new. Its materials are the same as those for the cylindrical fuses which have been in use for decades: the visible parts are the ceramic tube and the contact caps which tightly seal the room in which the fuse-element is located. In order to be able to contact the fuse-element inside the fuse, a solder melting at higher temperatures is used which, at the same time, provides for adherence between the contact caps and the insulating body.

Cross-section of the new SMD fuse
1 Insulating body
2 Contact caps
3 Fuse-element
4 Quartz sand
5 Solder



Size comparison
Top: leaded fuse (5 x 20 mm)
Centre: cylindrical SMD (5 x 20 mm)
Bottom: new SMD fuse (4,5 x 16 mm)

Figure 2: 250 V SMD Fuse with a high breaking capacity

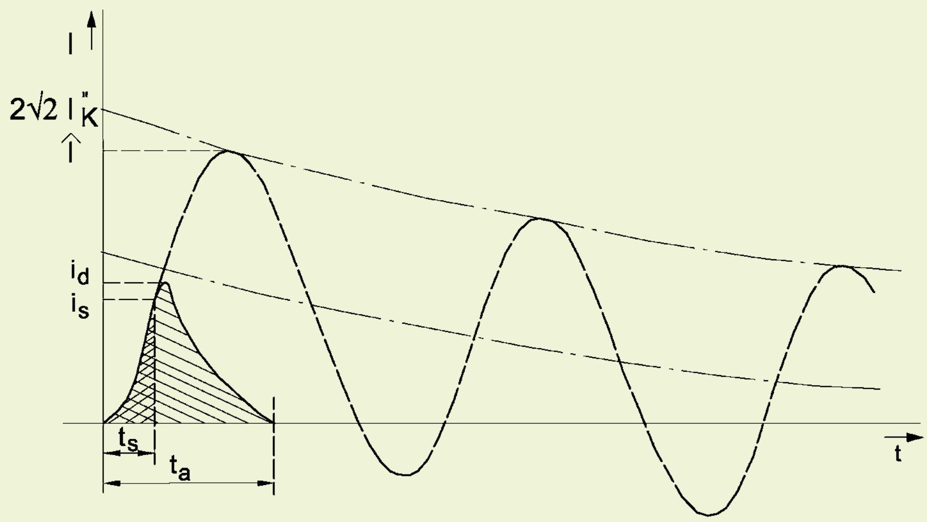
After all, all these parts have to withstand the high temperatures arising in reflow soldering. The construction is designed to withstand a preheating temperature increasing from of 150 °C to 200 °C within 60 s to 120 s as well as a reflow temperature of > 217 °C over 60 s to 90 s, with a peak of 250 °C over approximately 30 s.

In accordance with the standard on SMD fuses, VDE 0820, Part 4, these fuses exhibit a time-lag performance (T), i.e. they operate at ten times the rated current, within 10 ms to 100 ms: this makes them resistant to peak inrush currents on the transformer's primary side. In the case of overloads, on the other hand, they operate comparatively fast: they detect and interrupt currents of twice the rated current as fast as after approximately one minute. [2]

Finally, the most important fact: the fuses have a "high breaking capacity", identifiable by the letter "H". In accordance with the relevant standards this means that they are able to interrupt a current of 1500 A at 250 V AC. Since, however, short circuits are known to be possible in the current range of up to 4000 A, this value has already been taken into consideration when designing the fuses. This way, any potential device short circuits should be covered and the fuse be suitable for all applications on the primary side of a power supply unit.

"Real" short circuits

But how can a component as small as this be able to "stand" short-circuit currents of 4000 A? The reason for this lies in the fuses' ability to interrupt any short-circuit currents as early as during their



Key
I_k – prospective short-circuit current (r.m.s. value)
I_d – current limited by the fuse (instantaneous value)
t_s – pre-arcing time
t_a – operating time

Figure 3: Current-limiting effect of Fuses

rises – i.e. they operate in a “current-limiting” way. In **Figure 3**, this is illustrated using the example of a short-circuit current of 4000 A. If there was no fuse in the shorted circuit, the 4000 A would flow over some half-waves until the adoption of the breaking function by another upstream protective device, e.g., the circuit-breaker for household applications. By then, however, it would be too late for the device in which the short circuit had occurred: unless worse had happened, the accidental arc had, at least, already left its marks.

In contrast to this, the fuse on the printed circuit board does not let this situation arise in the first place. Due to the high current density associated with the breaking operation, the fine wire element in the fuse melts and evaporates within a few milliseconds.

Table 2: Cut-Off Currents and Operating Times for 4000 A

Rated current In	Pre-arcing integral I^2t	Cut-off current Id	Pre-arcing time ts	Operating time ts
1 A	4,5 A^2s	200 A	0,2 ms	0,5 ms
10 A	280 A^2S	1100 A	0,65 ms	1,5 ms

During this process the metal particles of the fuse-element condense on the sand grains. The result is a small arc which lasts until the quartz sand/metal mixture has formed an isolating distance. Operation is of the current-limiting type: the fuse-element interrupts the fault current even before the maximum of the current half-wave is reached.

In **Table 2**, the maximum cut-off currents to be expected and the operating times of fuses for rated currents of 1 A and 10 A are summarized as examples. In this example, the 1 A fuse interrupts a short-circuit current of 4000 A within 0,5 ms, thereby limiting the current during its rise, at 200 A.

Now, what to do with them?

Well, maybe one could “stack” them; after all, they cannot roll away ... – the author apologizes for this lame joke. Of course, the purpose of the new SMDs is, e.g., to protect power supply units in primary circuit. The maximum rated current of 10 A enables also power supply units of a higher capacity to be protected effectively. With rated currents of up to 6,3 A, the fuses are even designed for an operating voltage of 277 V, i.e., for U.S. applications; so, of course, they have received the appropriate UL agency approval as well. [**3**]

As early as when developing the fuses, their potential use in explosion protection was taken into consideration. In order to meet the requirements of the standard relevant for this field, IEC 60079-11, a sufficiently large distance between the caps of 10 mm on average was selected. Thus, the fuse additionally meets the requirements of the North American testing bodies. [**4**]

Further possible applications are all those cases where high short-circuit currents are to be expected at a mains voltage of 230 V – that is, for example, in line adapters, control circuits, sensor technology, measuring fields, explosion proof, interfaces, controllers. Moreover, it makes DC rating of 1500 A at 250 V DC an allrounder.

Bibliography

[1] www.siba.de
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[3] www.ul.com
[4] IEC 60079-11:2006 or DIN IEC 60079-11 (VDE 0170-7), Draft standard 2008-04: Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"

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