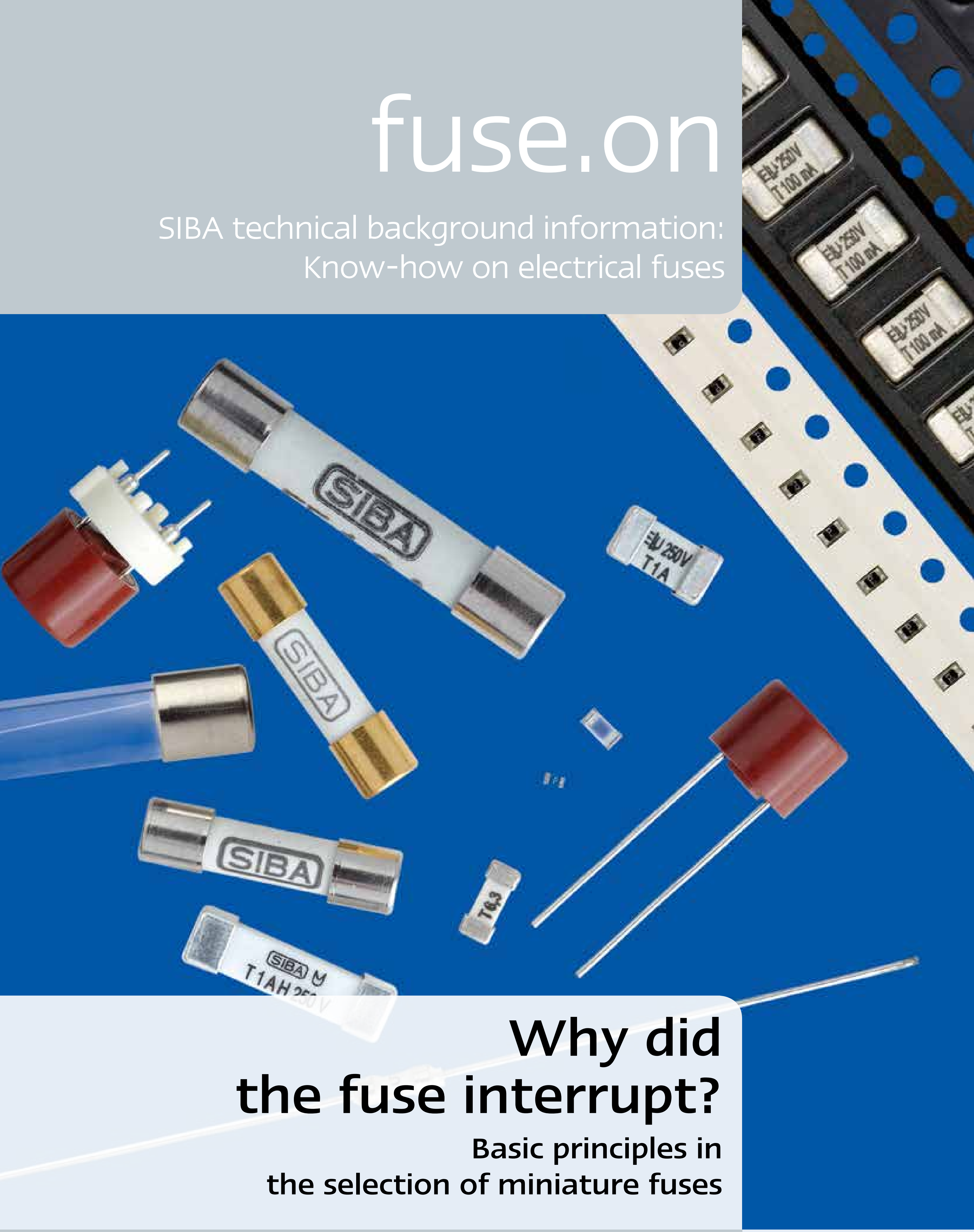
fuse.on

SIBA technical background information:
Know-how on electrical fuses



Why did the fuse interrupt?

Basic principles in the selection of miniature fuses

Our Protection.
Your Benefit.

SIBA
Sicherungen | Fuses

Why did the fuse interrupt?

Basic principles in the selection of miniature fuses

Von
Andreas Grünig
Application Engineer
SIBA GmbH

1 Introduction

Miniature fuses are designed to protect electrical installations, equipment and assemblies from unacceptably high current loads. Their application is wide-ranging. Miniature fuses are used to protect power supply systems and power output stages. In industry they are often employed to separate defective assemblies from the power supply whenever a fault arises, before more serious damage can be caused. When choosing the right miniature fuse a number of factors have to be considered that are crucial for the life expectancy and function of the fuse. The fuse link should only interrupt when a fault occurs, thereby protecting the electronics from more serious damage, and should not result in undesirable system outages simply because someone failed to take all the influencing factors into account when choosing the type of fuse to be used.

2 Fuse type, operating characteristics and voltages

When you think of miniature fuses you usually have a mental image of the conventional 5 x 20 mm cylindrical insert. But there are in fact a wide range of fuse types and operating properties to choose from.

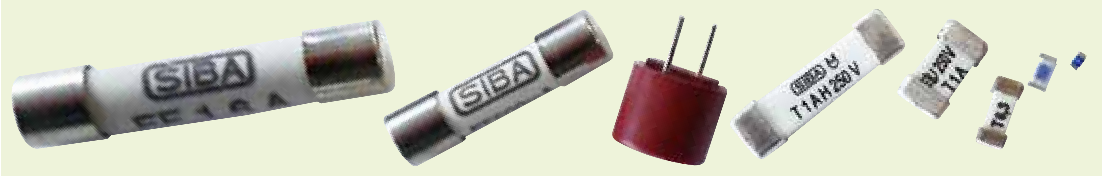


Figure 1: Fuse designs

Cylindrical fuses come in 5 x 25 mm, 5 x 30 mm and 6.3 x 32 mm sizes, and many other different dimensions can also be supplied. There are wired fuses for mounting on printed circuit boards, sub-miniature fuses and of course SMD fuses. Their operating characteristics range from superfast fuses (FF), such as those used to protect semiconductors or instruments, to super-time-lag (TT) fuses that do not interrupt, even in the face of very large load pulses or starting currents. Fuses are used in a wide range of instances requiring safe and reliable circuit breaking, from the smallest voltages up to applications of 1,000 V and above, and this in both alternating current and direct current systems.

3 Selection criteria

Fuses are usually selected solely on the basis of current rating, voltage rating and characteristic. Here it is generally assumed that the rated current stated on the fuse is able to pass through the fuse unit on a permanent basis. Unfortunately, however, this only applies in the rarest of cases!

When determining the current rating the relevant standards are always based on the optimum operating conditions for that particular fuse (23 °C ambient temperature, unrestricted heat dissipation, continuous current flow…).

This draws our attention to the most important factors influencing the correct choice of fuse, and to those factors which, for the particular application in question, ensure that the fuse will suddenly no longer provide a connecting passage for the current flow.

The ambient temperature affects both the continuous current capacity and the melting integral of the fuse. Starting currents and pulse loads that exceed the current rating of the fuse also play a key role. These influencing factors will be examined below in more detail.

Effect of ambient temperature on the current rating of the fuse link

Safety fuses operate on a very simple principle. If current is flowing the fusible element in the fuse link will become warm. If the current increases the fusible element will become even warmer until finally the lowest fusing current of the fuse is reached and the temperature in the fusible element is so high that the element melts and interrupts the current flow. It is therefore immediately obvious that while the response behaviour will be affected by the temperatures generated by the load current, the ambient temperature levels will also have an impact on the long-term resilience of the fuse link.

As stated above, fuses are designed in accordance with standard specifications for an ambient temperature of 23 °C. If the ambient temperatures are higher than this, the possible long-term current load will be reduced accordingly. The heat generated in the fusible element can no longer be adequately dissipated and this can result in the fuse being tripped below its current rating. The reverse applies when the temperature is below 23 °C. In such cases the fuse will only respond at correspondingly higher currents, as it is being 'cooled' from an external source and therefore exhibits better heat dissipation than under normal conditions.

Figure 2 can be used to determine the 'derating' effect of ambient temperature on the current rating of different fuse types.

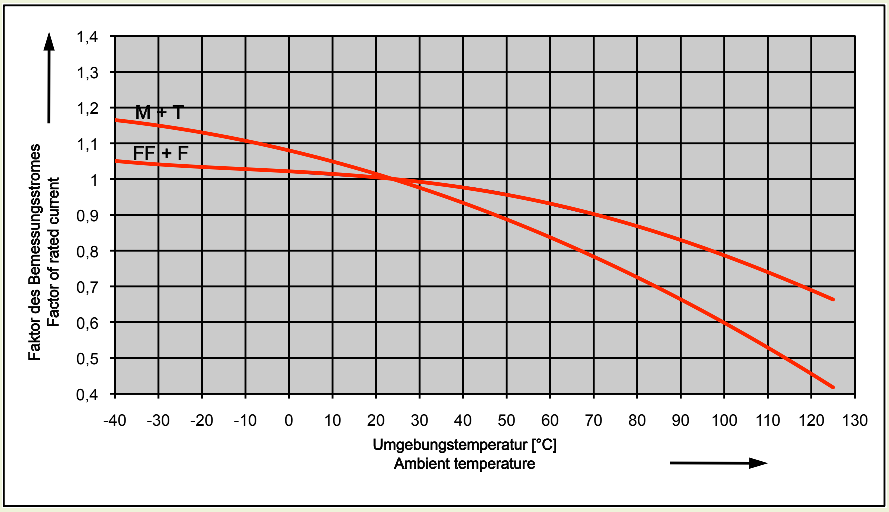


Figure 2: Effect of ambient temperature on the current rating

If for example a time-lag fuse is required that has to cope with a current flow of 1 A and operate at an ambient temperature of 70 °C, the rated current of the fuse can be calculated as follows:

$I_{rat} = I_L / Kf = 1\ A / 0.78 = 1.28\ A$
I_{rat}: resulting fuse current rating
I_L: load current
Kf: correction factor taken from the graph

The chosen fuse should therefore have a current rating of at least 1.28 A so that the load current of 1 A can flow permanently across the fuse at an ambient temperature of 70 °C without the fuse being tripped prematurely and unintentionally. As the next current rating according to the standard is 1.6 A, then a 1.6 A fuse should be selected.

Effect of ambient temperature on the melting integral of the fuse

Ambient temperature does not just affect the maximum continuous current of the fuse, it also influences the behaviour of the melting integral. Here too the values given in the current data sheets for the melting integral of a fuse link only apply to normal room temperatures. If the latter move into a higher range, which tends to be the case in electronics applications, the melting integral of the fuse, as stated in the data sheets, will be decreased. If the temperatures are below 20 °C, an increased melting integral has to be considered.

Figure 3 shows the correction factor that has to be used when calculating the melting integral.

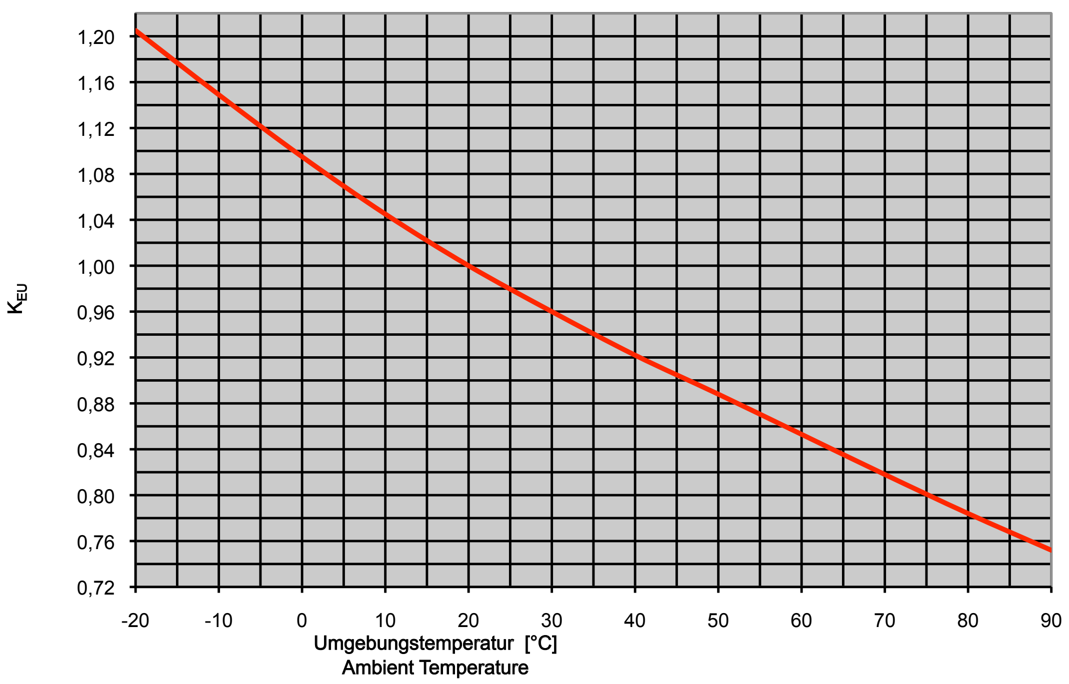


Figure 3: Effect of ambient temperature on the melting integral

Calculation of the actual melting integral:

$I^2ts` = I^2t \times K_{EU}$
$I^2ts`$: actual melting integral
I^2t: melting integral taken from data sheet
K_{EU}: correction factor determined from the graph

In actual applications, as the ambient temperature is usually higher than normal, allowance therefore has to be made for a lower melting integral than specified in the fuse data sheets. This corrected melting integral can then be used for all further calculations.

Assessment of inrush currents

The unintentional tripping of a fuse link is most commonly caused by one-off loads, often of short duration and not originally allowed-for, which exceed the current rating of the fuse. These are frequently starting currents that may only occur a few times, though in many cases they will be generated thousands of times over the lifetime of the electronics. Such loads can lead to premature damage such that the fuse will interrupt at some point even under normal operating conditions.
There are various methods available for assessing the starting current. The method most commonly used for checking whether or not the 'inrush' can be carried by the fuse is to compare the starting current with the time/current curve of the fuse. Here the amplitude of the starting current and the period of time for which this current flows are both entered into the characteristic curve. From this it is possible to determine very quickly whether or not the inrush current will cause the fuse to trip. However, if premature fuse damage is to be avoided there must be an adequate margin between the starting current and the actual melting current of the fuse. As a guideline value the starting current should be about 60 % of the tripping current.
This correlation can be illustrated clearly in the following example (Figure 4):

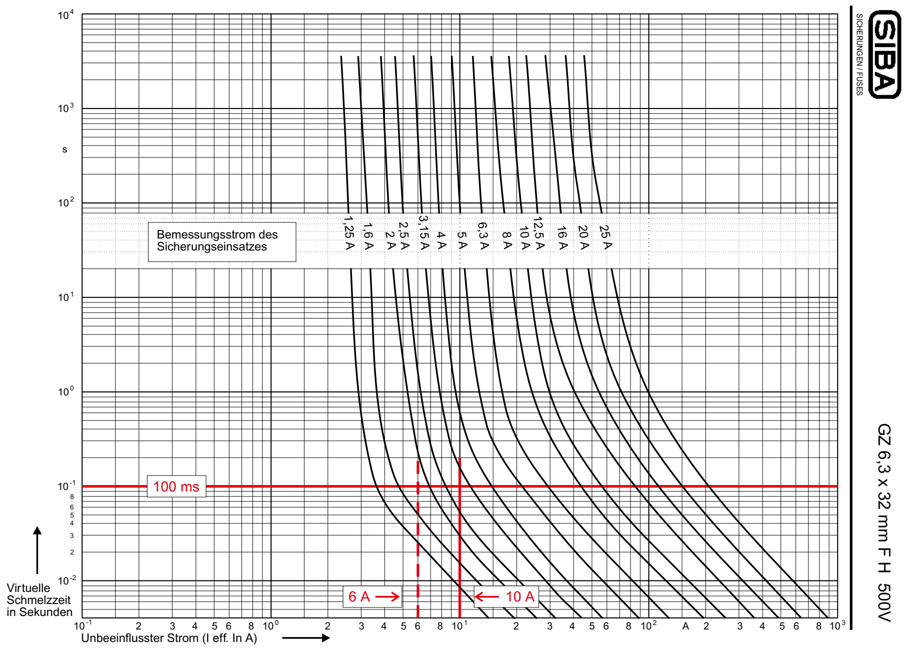
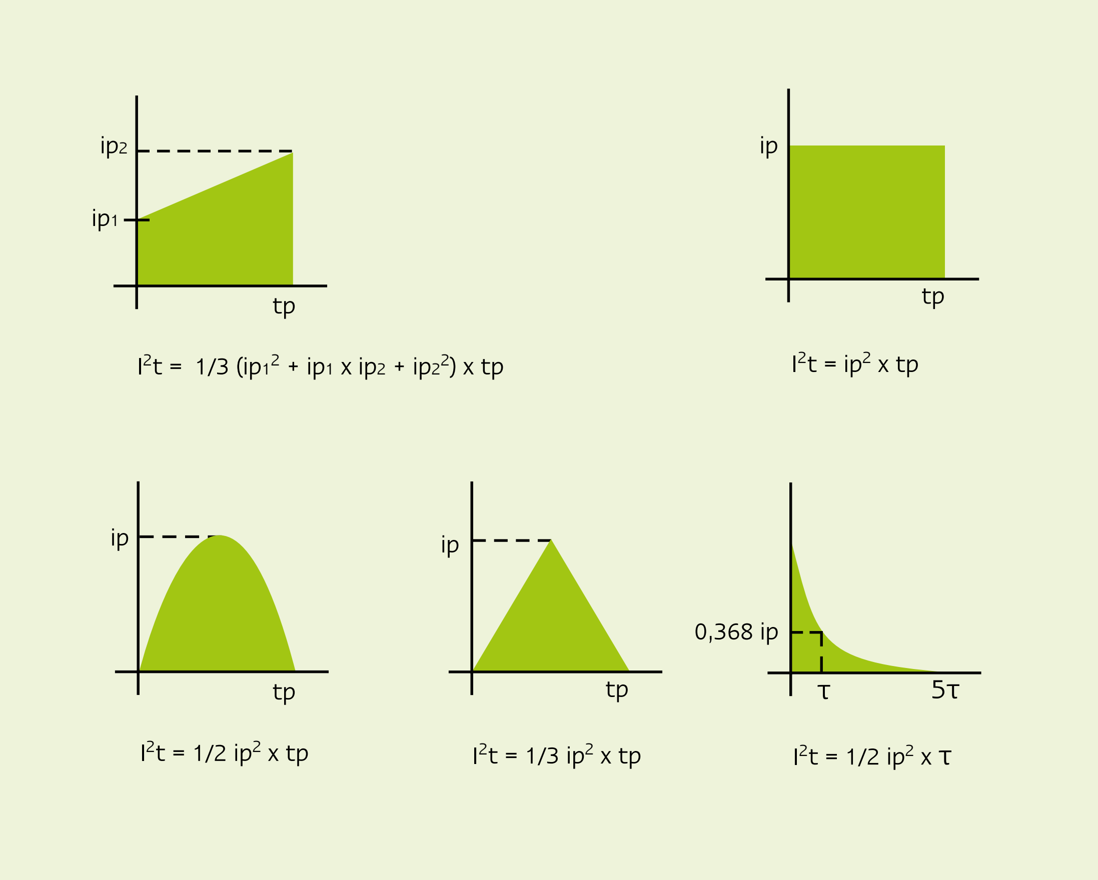


Figure 4: Inrush: 6 A | Duration: 100 ms

This means that by applying the aforementioned 60% rule it is possible to select a fuse that exhibits a melting current of 10 A at 100 ms. In this case the selected fuse should be rated at 3.15 A.

Influence of pulse loads

One possible way of correctly determining the pulse loads and short-duration starting currents is by comparing the load integral with the fuse melting integral. This first involves establishing the energy yield of the load acting on the fuse, which if no appropriate data is available can be done by using the following approximations.



$$I^2t = 1/3\,(ip_1^2 + ip_1 \times ip_2 + ip_2^2) \times tp$$

$$I^2t = ip^2 \times tp$$

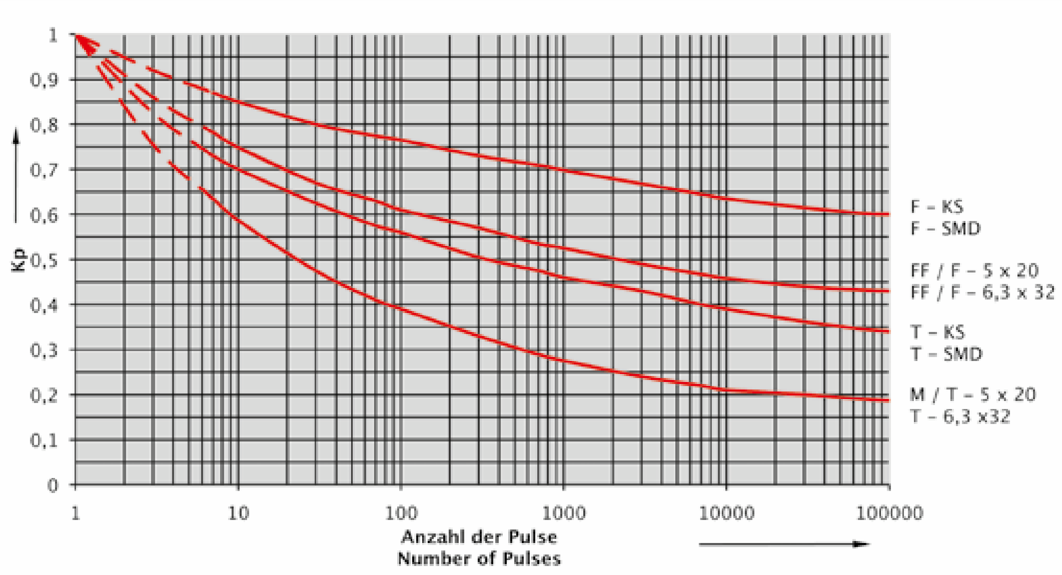
$$I^2t = 1/2\,ip^2 \times tp$$

$$I^2t = 1/3\,ip^2 \times tp$$

$$I^2t = 1/2\,ip^2 \times \tau$$

Figure 5: Determining the integral

The pulse integral established here can be compared with the melting integral of the fuse as obtained from the data sheet. If this pulse is present only once, or only a few times over the entire life-cycle of the electronics, it is sufficient if the melting integral of the fuse is greater than the measured pulse integral. However, if the load is a more frequently recurring event it is necessary to ensure a sufficient margin between the melting integral of the fuse and the pulse integral. The more frequent is the pulse, the greater this margin has to be. Different types of fuse and fuse-element alloys, with their respective characteristics, will exhibit quite significant differences in the degree of sensitivity to pulse loads. The following graph shows which correction factor to use as a function of the number of pulses (Figure 6).



FF = superfast | F = fast | M = medium-time-lag | T = time-lag | SMD = SMD fuses | KS = sub-miniature fuses | 5 x 20 = cyl. type-G fuse links 5 x 20 mm | 6.3 x 32 = cyl. type-G fuse links 6.3 x 32 mm

Figure 6: Calculating the melting integral as a function of the number of pulses

Calculation of the required melting integral of the fuse as a function of the anticipated number of pulses:

$I^2t_s\text{min} = I^2tp / Kp$
$I^2t_s\text{min}$: min. required melting integral of the fuse as taken from the data sheet
I^2tp: pulse integral
Kp: correction factor of pulse integral

By using the minimum required melting integral as established above you select a fuse that will not interrupt unintentionally at switch-on.

4 Summary

Choosing the right miniature fuse depends on more than just the permanent load current, the type of equipment or semiconductor. It is equally important to consider the various factors that have an effect on the fuse link so that the operating life of the fuse is not compromised right from the point of selection.
For this reason it is essential to consider the type of ambient temperatures to which the fuse is liable to be exposed. And will particular loads come into play at the moment of switch-on or will the starting currents be of recurrent frequency?

We do not want you to be asking yourself soon after fitting:
'Why did the fuse interrupt?'

Hauptsitz / Head Office
SIBA GmbH
Borker Straße 20-22
D-44534 Lünen
Postfach 1940
D-44509 Lünen
Tel.: +49-2306-7001-0
Fax: +49-2306-7001-10
info@siba.de
www.siba.de

SIBA Unit Miniature Fuses
Tel.: +49-2306-7001-295
Fax: +49-2306-7001-99
elu@siba.de

Deutschland / Germany

SIBA Vertriebsbüro Freiberg
Untergasse 12
D-09599 Freiberg
Tel.: +49-3731-202283
Fax: +49-3731-202462
alexander.kolbe@siba.de

SIBA Vertriebsbüro Rhein/Ruhr
Espelweg 25
D-58730 Fröndenberg
Tel.: +49-2373-1753141
Fax: +49-2373-1753142
joerg.mattusch@siba.de

SIBA Vertriebsbüro Süd-West
Germersheimer Str. 101a
D-67360 Lingenfeld
Tel.: +49-6344-937510
Fax: +49-6344-937511
erwin.leuthner@siba.de

SIBA Vertriebsbüro Kassel
Sieberweg 20
D-34225 Baunatal
Tel.: +49-5601-965300
Fax: +49-5601-965301
achim.fischer@siba.de

SIBA Vertriebsbüro Bayern
Kirchstraße 12
D-86316 Friedberg
Tel.: +49-821-58955260
Fax: +49-821-58955261
guenter.heinz@siba.de

International

SIBA Sicherungen- und Schalterbau Ges.m.b.H & Co. KG (Austria)
Ortsstraße 18 · A-2331 Vösendorf bei Wien
Tel.: +43-1-6994053 und 6992592
Fax: +43-1-699405316 und 699259216
info.siba@aon.at
www.siba-sicherungen.at

SIBA GmbH Beijing Rep. Office (China)
Rm 1609, Block B, Lucky Tower
No. 3, Dongsanhuan Beilu , Chaoyang district
Beijing 100027
Tel.: +86-10-65817776
Fax: +86-10-64686648
siba_china@sibafuse.cn
www.sibafuse.cn

SIBA Písek s.r.o. (Czech Rep.)
U Vodárny 1506 · 397 01 Písek
Tel.: +420-38-2265746
Fax: +420-38-2265746
sibacz@iol.cz · www.siba-pojistky.cz

SIBA Sikringer Danmark A/S (Denmark)
ehemals/former Ole Andersen A/S
Lunikvej 24 B · DK-2670 Greve
Tel.: +45-86828175 · Fax: +45-86814565
info@sikringer.dk · www.siba-sikringer.dk

SIBA Nederland B.V. (Netherlands)
Van Gentstraat 16
NL-5612 KM Eindhoven
Tel.: +31-40-2467071
Fax: +31-40-2439916
info@sibafuses.nl · www.siba-zekeringen.nl

SIBA Polska sp. z o.o. (Poland)
ul. Grzybowa 5G
05-092 Łomianki Dąbrowa Leśna
Tel.: +48-22-8321477
Fax: +48-22-8339118
siba@siba-bezpieczniki.pl
www.siba-bezpieczniki.pl

„SIBA GmbH“ (Russia)
ul. Petrovka 27
Moskva 107031
Tel.: +7-495-9871413
Fax: +7-495-9871774
info@siba-predohraniteli.ru
www.siba-predohraniteli.ru

SIBA Fuses SA PTY. LTD. (South Africa)
P.O. Box 34261
Jeppestown 2043
Tel.: +27-11334-6560 / 4
Fax: +27-11334-7140
sibafuses@universe.co.za
www.siba-fuses.co.za

SIBA Far East Pte. LTD. (South East Asia)
24 Sin Ming Lane, # 07 – 105
Midview City, Singapore 573970, Republic of Singapore
Tel.: +65-66599449
Fax: +65-66594994
info@sibafuse.com.sg
www.sibafuse.com.sg

SIBA (UK) LTD. (United Kingdom)
19 Duke Street
Loughborough. Leics. LE11 1ED
Tel.: +44-1509-269719
Fax: +44-1509-236024
siba.uk@btconnect.com
www.siba-fuses.co.uk

SIBA Fuses LLC (United States of America)
29 Fairfield Place
West Caldwell, NJ 07006
Tel.: +1-973575-7422 (973-575-SIBA)
Fax: +1-973575-5858
info@sibafuses.com
www.sibafuses.com

Weitere Vertriebspartner weltweit /
Further distribution partners worldwide:
www.siba.de / www.siba-fuses.com

fuse.on 3/2012/ Druck 8/2016

Sicherungen | Fuses

Our Protection.
Your Benefit.

Photos: GM (front page), SIBA Archiv