How to Select the Right Fuse

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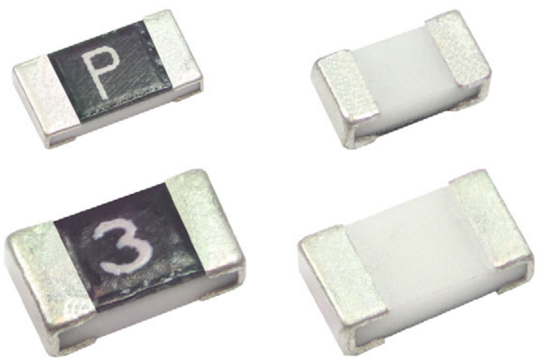
ABSTRACT

Under overcurrent conditions (overload), the function of fuses is two-fold: to protect people against injury and electronic circuits from major fatal damage. Therefore, fuse parameters must be evaluated by taking electrical and environmental conditions of the application into account. This application note provides a guide to help designers choose the right component.



The data within this document only represents a few of the total contributing parameters, so it is highly recommended to perform application testing to validate a chosen component.

Depending on initial conditions, specifications must include the general security margin, energy level involved, and eventuality of cumulated electrical pulses for a relevant component choice.

ACTUATING CHARACTERISTICS

Depending on the reaction time needed, five classes are available on the market (IEC 60127-1 standard):

- FF: very quick acting
- F: quick acting
- M: medium time-lag
- T: time-lag
- TT: long time-lag

First, the customer must choose the appropriate class for their particular application.

MOUNTING

The components must be brazed on a PCB following IEC 60127-4 recommendations for reflow parameters.

The PCB must be designed using the IEC 60127-4 standard as a guideline to avoid issues like excessive heating or oversized pads.

The thermal influence of other components (resistors, capacitors, transformers, etc.) mounted on the same PCB must be considered, as they affect the temperature rise around the fuse.

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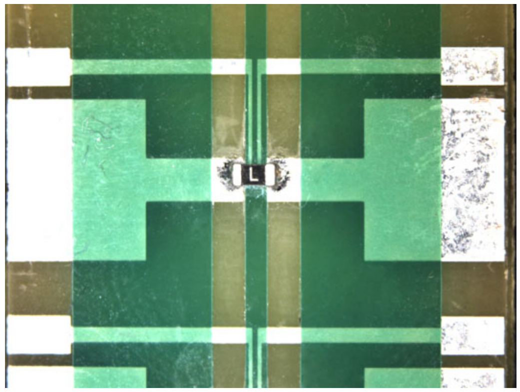


SAFETY COEFFICIENT

From practical experience, a 70 % safety coefficient is necessary.

This compensates for common variations in operating conditions, such as contact resistance, air movement, transient spikes, changes in connecting cable size, process reproducibility, and more.

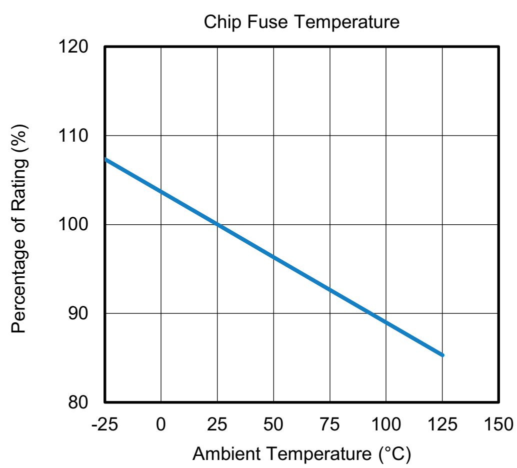
So, if the customer needs to apply 7 A of current, a 10 A fuse meets the criteria for this first selection step.

TEMPERATURE DERATING

The considered components in this document are temperature-sensitive, and their ratings have been established at 25 °C.

The temperature of the fuse's active area increases with the current passing through (due to the Joule effect), so compensation has to be applied:

- Normal ambient temperature: 25 °C
- Operating temperature range: -25 °C to +125 °C, with the proper derating factor (shown below):



For example, if the ambient temperature is 60 °C, the derating coefficient would be 95 %.

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CASE 1: APPLICATION WITH NORMAL OPERATING CURRENT

For this example, the requirements are:

- 0603 size
- I = 1.5 A continuously
- U = 12 V
- Ambient T = 60 °C → T derating = 95 %

As an example, among the S2F fast acting series, the available 0603 parts are classified in the following table (from the S2F datasheet):

PART DESIGNATION	MARKING	RATED CURRENT	FUSING TIME	RESISTANCE* (mΩ) TOLERANCE: ± 25 %	RATED VOLTAGE	BREAKING CAPACITY
S2F060350VA400T	E	0.40 A	Open within 1 m at 200 % rated current	496	50 V_{DC}	50 V_{DC} 50 A
S2F060350VA500T	F	0.50 A		290		
S2F060332VA630T	I	0.63 A		205	32 V_{DC}	32 V_{DC} 50 A
S2F060332VA800T	K	0.80 A		132		
S2F060332V1A00T	L	1.00 A		84		
S2F060332V1A25T	M	1.25 A		63		
S2F060332V1A50T	P	1.50 A		50.5		
S2F060332V1A60T	N	1.60 A		45		
S2F060332V2A00T	S	2.00 A		34		
S2F060332V2A50T	T	2.50 A		24.5		
S2F060332V3A00T	3	3.00 A		20		
S2F060332V3A15T	U	3.15 A		19		
S2F060332V4A00T	W	4.00 A		13		
S2F060332V5A00T	Y	5.00 A		11		

The maximal acceptable current can be calculated in this way:

$$I = \frac{1.5}{0.7 \times 0.95} = 2.256\ A$$

(with 0.7 = safety coefficient and 0.95 = temperature derating).

Considering this result, the suggested model is the **S2F060332V2R50T** (I_N = 2.50 A).

In addition to this result, the temperature rise must also be checked, because it should not exceed 75 K, as recommended in the UL 248-14 standard.

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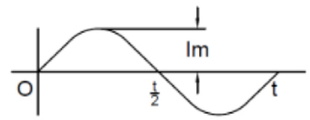
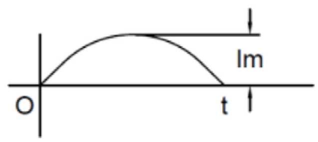
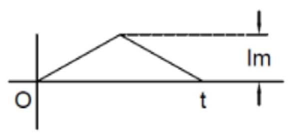
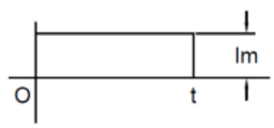
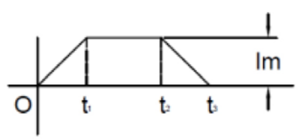
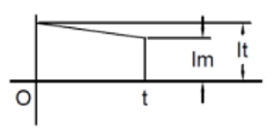
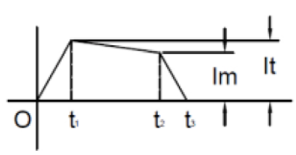
CASE 2: APPLICATION WITH INRUSH CURRENT

The most usual inrush current waveforms and calculated Joule ($\int_{t=0}^{t} i^2.dt$) integral values are:

NUMBER	TYPE	WAVEFORM	CALCULATED JOULE INTEGRAL
1	Sinusoidal waveform (1 cycle)		$\frac{1}{2}I_m^2 t$
2	Sinusoidal waveform (1/2 cycle)		$\frac{1}{2}I_m^2 t$
3	Triangle waveform		$\frac{1}{3}I_m^2 t$
4	Rectangular waveform		$I_m^2 t$
5	Trapezoidal waveform		$\frac{1}{3}I_m^2 t + I_m^2(t_1 - t_2) + \frac{1}{3}I_m^2(t_2 - t_3)$
6	Various waveform 1		$I_1 I_2 t + \frac{1}{3}(I_1 - I_2)^2 t$
7	Various waveform 2		$I_1 I_2 t + \left[I_1 I_2 t + \frac{(I_1 - I_2)^2}{3}\right] * (t_2 - t_1) + \frac{1}{3}(I_2)^2(t_3 - t_2)$

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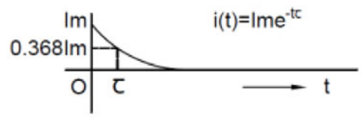
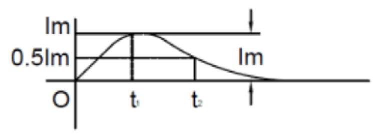
NUMBER	TYPE	WAVEFORM	CALCULATED JOULE INTEGRAL
8	Charge / discharge waveform		$\frac{1}{2}(I_m{}^2\tau)$
9	Lightning surge waveform		$I_m{}^2\left[\frac{t_1}{3}+0.721(t_2-t_1)\right]$

Therefore, after calculation of the accurate energy required for the application, the typical maximum I^2.t value recommended for safe use, measured at 10 x rated current, has to be chosen in the following table (excerpt of S2F datasheet):

S2F FUSE I^2t (A^2s)					
PART NUMBER	**TYPICAL I^2t (A^2s)**	**PART NUMBER**	**TYPICAL I^2t (A^2s)**	**PART NUMBER**	**TYPICAL I^2t (A^2s)**
S2F040232VA315T	0.00203	S2F060350VA400T	0.004	S2F120663VA500T	0.011
S2F040232VA500T	0.00317	S2F060350VA500T	0.005	S2F120663VA800T	0.031
S2F040232VA750T	0.00402	S2F060332VA630T	0.007	S2F120663V1A00T	0.034
S2F040232VA800T	0.00532	S2F060332VA800T	0.014	S2F120663V1A25T	0.062
S2F040232V1A00T	0.00724	S2F060332V1A00T	0.016	S2F120663V1A50T	0.144
S2F040232V1A25T	0.01344	S2F060332V1A25T	0.027	S2F120663V2A00T	0.181
S2F040232V1A50T	0.01356	S2F060332V1A50T	0.037	S2F120632V2A50T	0.351
S2F040232V1A60T	0.01672	S2F060332V1A60T	0.041	S2F120632V3A00T	0.501
S2F040232V2A00T	0.01983	S2F060332V2A00T	0.044	S2F120632V4A00T	0.954
S2F040232V2A50T	0.03763	S2F060332V2A50T	0.055	S2F120632V5A00T	0.966
S2F040232V3A00T	0.05427	S2F060332V3A00T	0.082	S2F120632V7A00T	3.250
S2F040232V3A15T	0.06304	S2F060332V3A15T	0.089		
S2F040232V4A00T	0.08960	S2F060332V4A00T	0.239		
		S2F060332V5A00T	0.433		

For technical questions, contact: sferthinfilm@vishay.com

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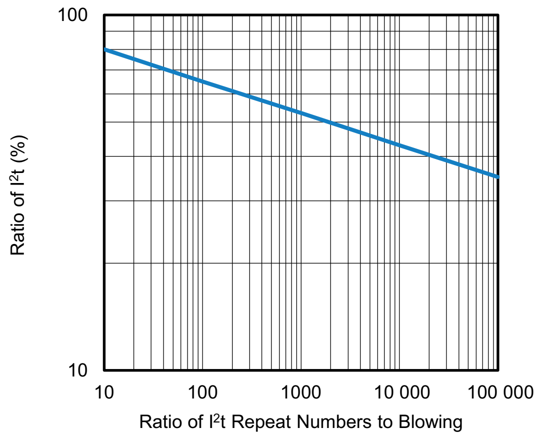
Furthermore, for repeated numbers of inrush current, another specific derating must be applied:



For this example, the requirements are:

- 0603 size
- rectangular waveform of the pulse
- I_m = 4 A
- t = 1 ms
- 100 000 times

The integral Joule calculation for the rectangular waveform leads to: $I^2.t = 4^2 \times 1 \times 10^{-3}$ = **0.016 A^2**.s.

The "100 000 times" choice of the inrush current curve allows for the selection of a 0.35 ratio.

If we consider both parameters, we must choose a $I^2.t > \frac{0.016}{0.35} = 0.0457\ A^2.s$.

Therefore, the **S2F060332V2R50T** reference is able to meet the circuit's application, because its typical I^2.t is 0.055 A^2.s.