TECHNICAL PAPER

Fuse Selection Guide: Raychem Surface Mount Chip Fuses

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Selecting Raychem Surface Mount Chip Fuses

Fuse selection seems straightforward in that you pick one which has a current rating just a bit higher than your worst-case system operating current. Unfortunately, it's not that simple. There are derating considerations for operating current and application temperature. Turn-on and other system operations (like processor speed changes or motor start up) cause current surges or spikes that also require consideration when selecting a fuse. So selecting the right fuse for your application is not as simple as knowing the nominal current drawn by the system. However, by following the guideline presented in this paper, selecting the proper fuse does become a straightforward process.

Fuse Selection Flowchart

The basic considerations for fuse selection are shown in the flowchart presented in Figure 1. Following this flow chart will help you select a fuse best suited for your application conditions.

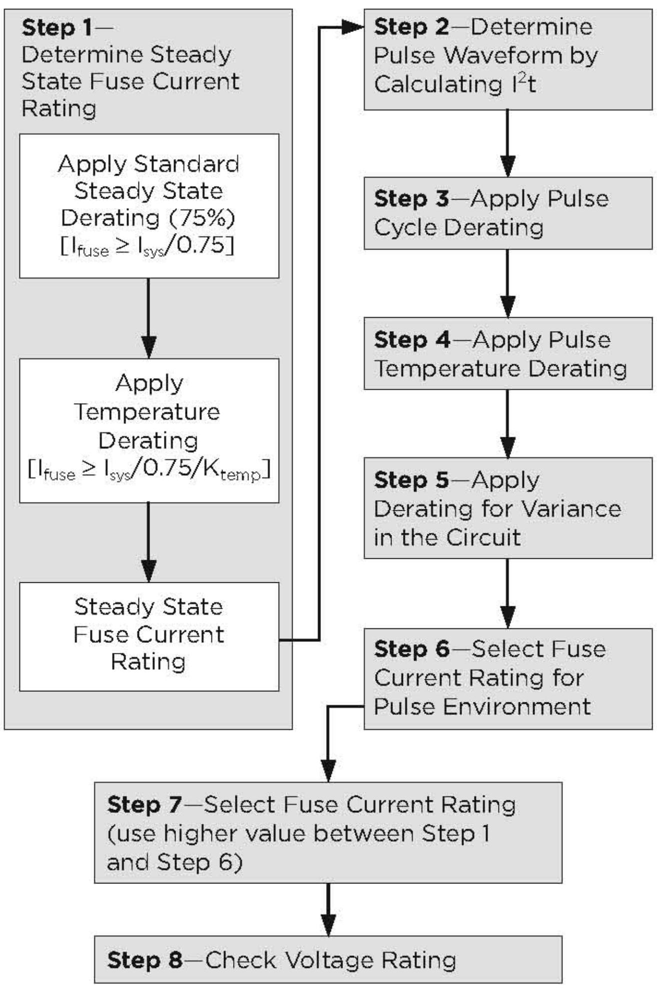


Figure 1. Fuse Selection Flowchart

Application Current

Fuses require derating for both steady state and transient state conditions. The final current rating for the fuse used in any application will be a combination of both of these effects. It is easiest to analyze the derating requirements separately for the two conditions. Some applications may not require consideration of transient currents.

Steady State Derating

It is recommended that Raychem surface mount chip fuses not be operated at steady state currents greater than 75% of the nominal 25°C current rating.

Apply Standard Derating (75%)

$I_{fuse} \geq I_{sys}/0.75$

Where:

I_{fuse} is the rated data sheet current at 25°C

I_{sys} is the nominal steady state system current

Temperature Derating

A fuse is a temperature sensitive device. Therefore, operating temperature will have an effect on fuse performance and lifetime. Operating temperature should be taken into consideration when selecting the fuse current rating. The Thermal Derating Curve for Raychem surface mount chip fuses is presented in Figure 2. Use it to determine the derating percentage based on operating temperature and apply it to the derated system current.

Apply Temperature Derating

The minimum fuse current rating is determined by the following formula:

$I_{fuse} \geq (I_{sys}/0.75)/K_{temp}$

Where:

K_{temp} is the % derating determined from the Thermal Derating Curve in Figure 2

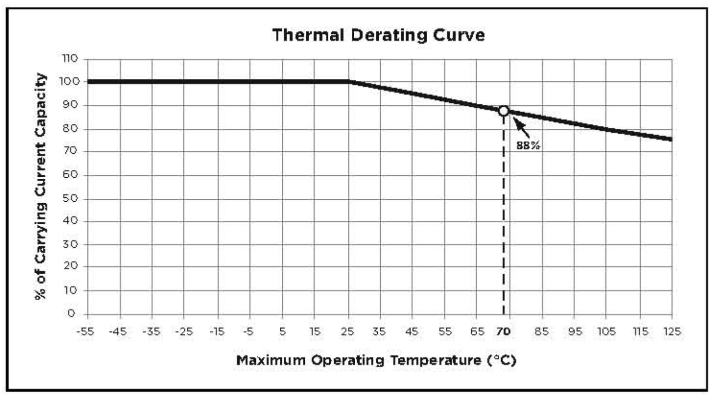


Figure 2. Thermal Derating Curve

If there are no pulse currents present in the application, then the fuse current rating may be selected. Finally, only the voltage rating must be reviewed for final fuse part number selection.

Example 1—Select a fuse for a system that draws 1.0 amp steady state during normal operation and operates at ambient temperatures up to 70°C. Ignoring for now the voltage requirement, what is the minimum required current rating for the fuse in this application?

$I_{fuse} \geq (I_{sys}/0.75)/K_{temp}$

Where:

I_{sys} = 1.0A

K_{temp} = 88% (determined from Figure 2)

$I_{fuse} \geq (1.0A/0.75)/0.88$

$\mathbf{I_{fuse} \geq 1.52A}$

So a fuse with a current rating above 1.52A should be selected.

Transient State or Pulse Derating

The term "Pulse" is used to describe any type of transient current that may be applied to the fuse. Common examples of pulses are inrush currents observed at system turn-on, motor start-up currents and more extended duration peak currents observed during high speed processing activity in computing systems.

These pulses have an effect on the fuse element because the transient heating they induce causes thermal cycling within the device. Over a large number of pulses, this can affect the life of the fuse. Therefore, the pulse energy and the number of times the fuse may be subjected to the pulse must be considered when selecting the proper fuse for the application.

The I^2t parameter provides a measure of the fuse's ability to withstand the energy of a pulse. By determining the I^2t energy of the pulse, it can be compared to the fuse's I^2t curve to determine what the rated current of the fuse must be to help ensure reliable operation of the fuse.

Determine Pulse Waveform

Calculating Pulse I^2t—The energy contained in a current pulse depends on the pulse waveform's shape, peak current and duration. The basic formula for I^2t is:

$$I^2t = \int_0^t [A\ (t)]^2\, dt$$

Figure 3 presents the most common current waveforms and simplified equations for their I^2t. In most systems, current waveforms could be approximated as either one of those on Figure 3 or their sequence. In case of such a sequence the resulting I^2t is the sum of I^2t of those individual waveforms.

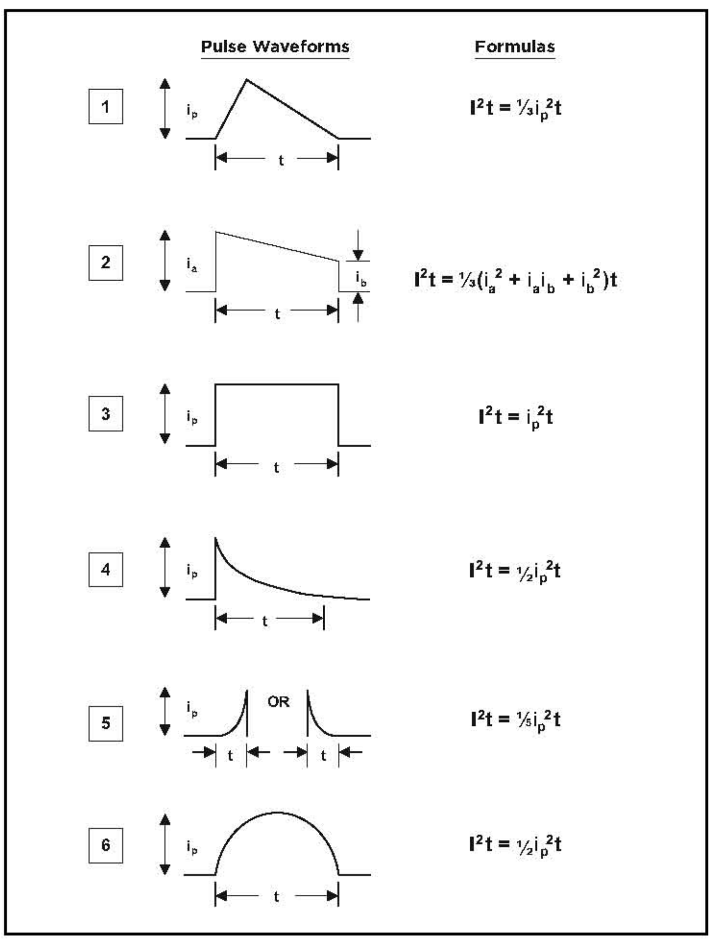


Figure 3. Waveform I^2t Formulas

Pulse Cycle Derating

Once the I^2t value for the application waveform has been determined, it must be derated based on the number of cycles expected over the system lifetime. Since the stress induced by the current pulse is mechanical in nature, the number of times the stress is applied has significant bearing on how much derating must be applied to the fuse rating. Figure 4 presents the current pulse derating curve for Raychem surface mount chip fuses up to 100,000 cycles.

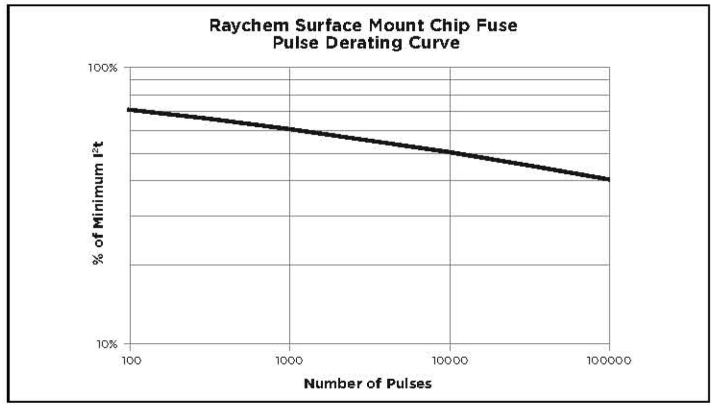


Figure 4. Raychem Surface Mount Chip Fuse Pulse Derating Curve

Pulse Temperature Derating

Once the pulse cycle derating has been applied to the calculated I^2t value, derating for operating temperature should be applied according to the thermal derating curve shown in Figure 2.

Allowance for Circuit Variation

Apply an additional 30% safety margin to tolerate the variances introduced by other components in the circuit.

The derated I^2t value can then be used to determine the rated fuse current. This is done by referring to the minimal fuse I^2t vs clear time curves. The best way to explain how this is done is through an example.

Example 2—Select a 0603 size fuse that can handle a 1.0A steady state system current, is subjected to a capacitor charging turn-on pulse, peaks at 6 amps and lasts .005sec. The system runs at $24V_{DC}$, expects to see 100,000 cycles over its lifetime and normally operates at 70°C.

- Step 1—Apply the 75% steady state derating and the 88% thermal derating at 70°C as determined in Example 1.

$I_{fuse} \geq (I_{sys}/0.75)/K_{temp}$

Where:

$I_{sys} = 1.0A$

K_{temp} = 88% (determined from Figure 2)

$I_{fuse} \geq (1.0A/0.75)/0.88$

$\mathbf{I_{fuse} \geq 1.52A}$

This is the minimum current rating the fuse must have to properly protect the system under steady state conditions only. Reviewing the datasheet indicates the 0603SFF200F/32 is the recommended device. (See tables in Appendix E.)

- Step 2—Determine which pulse waveform in Figure 3 most closely represents the application and calculate the waveform's I^2t value.

Since a capacitor must be charged every time the system is powered, the fuse will be subjected to a current pulse most like that of waveform #4 in Figure 3. Using the associated formula, the I^2t value is calculated as:

$I^2t_{pulse} = (1/2)(6A)^2 \times 0.005sec$
$I^2t_{pulse} = 0.09\ A^2sec$

- Step 3—Apply Pulse Cycle Derating—Derate the I^2t value based on the number of cycles required by the application.

At 100,000 pulses, Figure 4 indicates a 40% derating of the I^2t value is required.

$I^2t_{dpulse} = 0.09/0.4\ A^2sec$
$I^2t_{dpulse} = 0.225\ A^2sec$
Where: I^2t_{dpulse} is the derated value for pulse waveforms.

- Step 4—Apply Pulse Temperature Derating—Derate the I^2t value based on system operating temperature. In this example apply 88% thermal derating at 70°C from Figure 2.

$I^2t_{dpulse} = 0.225/0.88\ A^2sec$
$I^2t_{dpulse} = 0.256\ A^2sec$

- Step 5—Apply Derating for Variance in the Circuit—Apply 30% safety margin (divide by 0.7) for variance introduced by other components in the application.

$I^2t_{dpulse} = 0.256/0.7\ A^2sec$
$I^2t_{dpulse} = 0.365\ A^2sec$

- Step 6—Select Fuse Current Rating for Pulse Environment—Determine which fuse has an I^2t rating greater than I^2t_{dpulse} at .005sec. The minimum I^2t versus clear time can be found in Figure 5 for Fast Acting Fuses and Figure 6 for Slow Blow Fuses. (Larger charts are available in Appendices A and C).

Using Figure 5, the Fast Acting 0603SFF Family Minimum I^2t vs Clear Time curves, it can be determined that Curve H has an I^2t value greater than 0.365 A^2sec at .005sec. This means that a 3.5A fuse, part number 0603SFF350F/32, would meet the pulse and cycle derating requirements for this application example. Refer to Appendix E for part number selection.

Using the Slow Blow 0603SFS Family Minimum I^2t vs Clear Time Curves in Figure 6, it can be determined that Curve C has an I^2t value greater than 0.365 A^2sec at .005sec. This means that a 2.0A fuse, 0603SFS200F/32, will meet this application example requirement. Refer to Appendix E for part number selection.

- Step 7—Select Fuse Current Rating—Compare the steady state current requirement from Step 1 to the current requirement for the pulse environment in Step 6 and determine which value is higher. The higher value will define the final fuse current rating.

In this case for the steady state condition, a 2.0A Fast Acting Fuse from the 0603SFF Family is recommended. However, applying the pulse condition, a 3.5A Fast Acting Fuse from the 0603SFF Family or a 2.0A Slow Blow Fuse from the 0603SFS Family could be used. The 3.5A Fast Acting Fuse has a higher current rating than the 2.0A Fast Acting Fuse; therefore, the 2.0A Fast Acting Fuse can be eliminated as an option for this application example. Now, the choice is between the 3.5A Fast Acting Fuse and the 2.0A Slow Blow Fuse. Fast Acting Fuses open very quickly in response to an overcurrent condition and transient current spikes not part of their normal operation. Slow Blow Fuses have a delayed opening sustained in overcurrent conditions or expected pulsed currents. Since this is an application where the fuse will be subjected to a current pulse, a Slow Blow Fuse is a better choice.

- Step 8—Check Voltage Rating—The system voltage is 24V. The 0603SFF350F/32 and 0603SFS200F/32 are rated for use at $32V_{DC}$. They both meet the voltage requirements.

NOTE: The fuse selection method presented in this paper is intended as a guideline to determine the fuse most suitable for an application. We recommend testing the fuse in the actual application with the worst case scenario to confirm suitable performance. We also recommend verifying fuse clearing time to ensure that the right fuse is selected to provide the protection needed for the circuit and complies with required regulatory and safety standards.

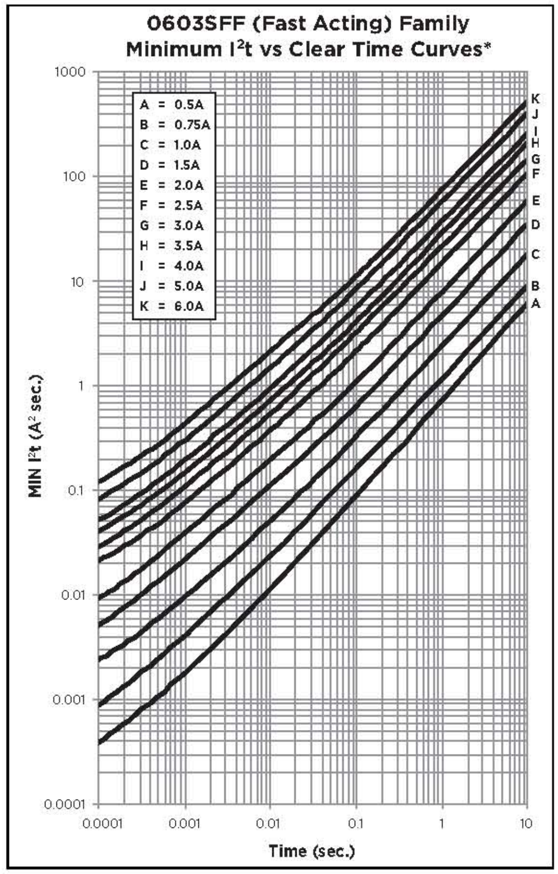


Figure 5. 0603SFF (Fast Actiing) Family Minimum I^2t vs Clear Time Curves

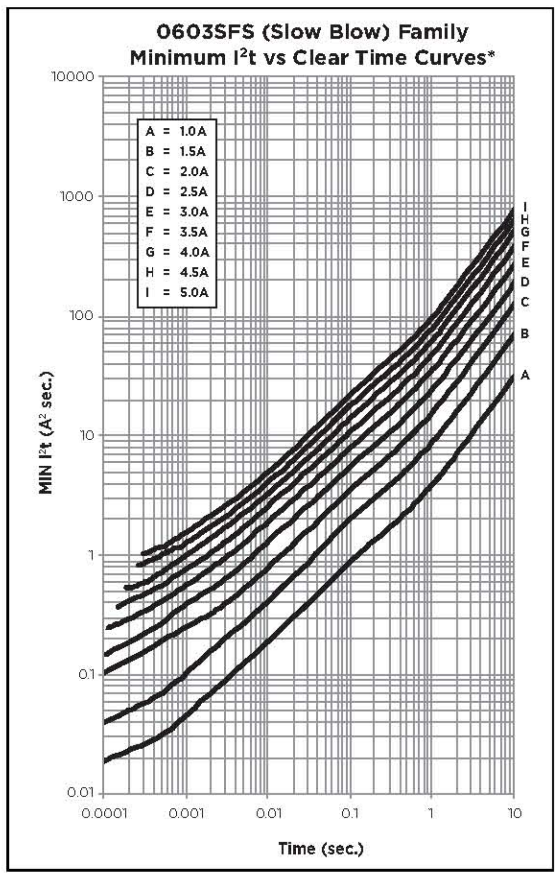
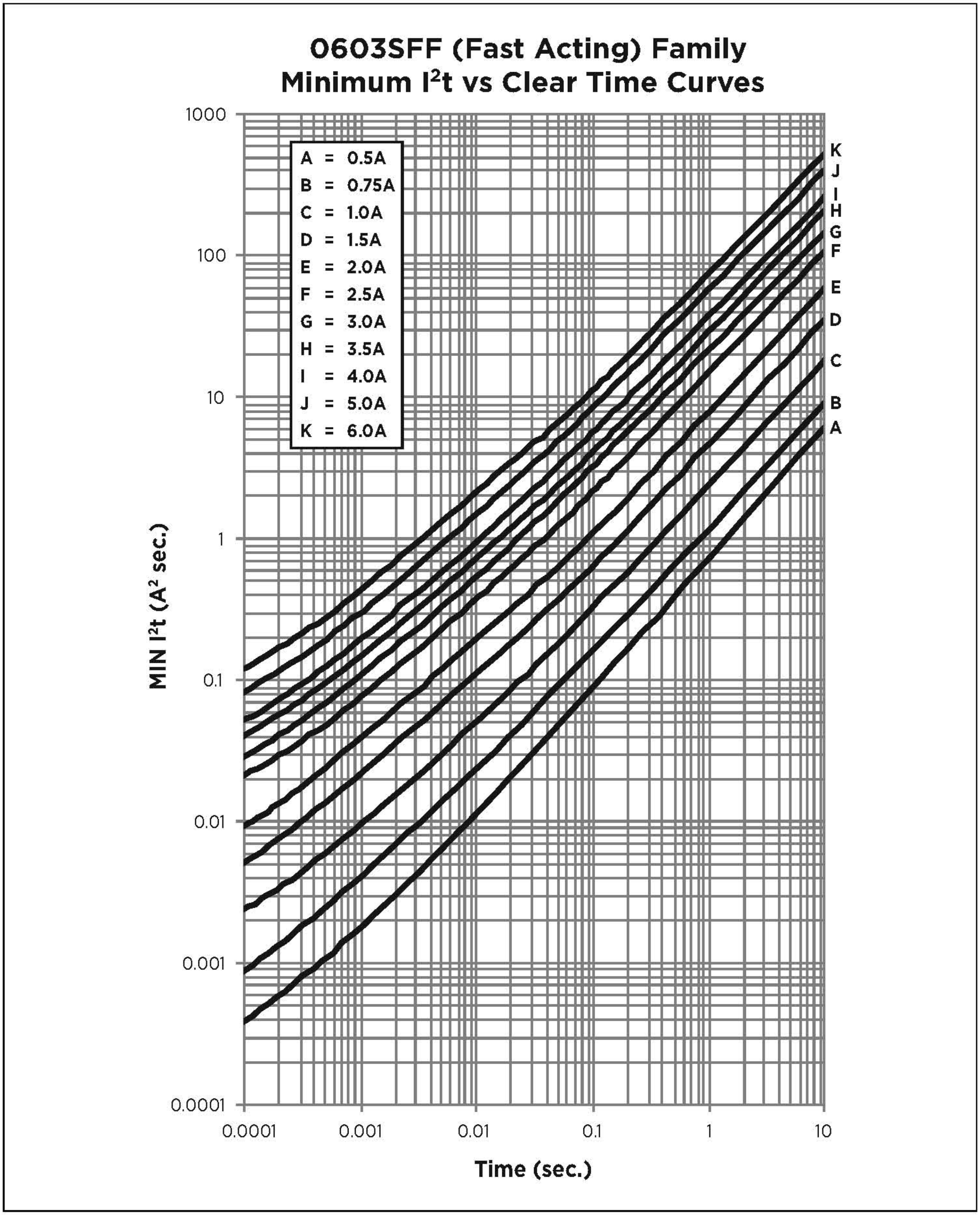
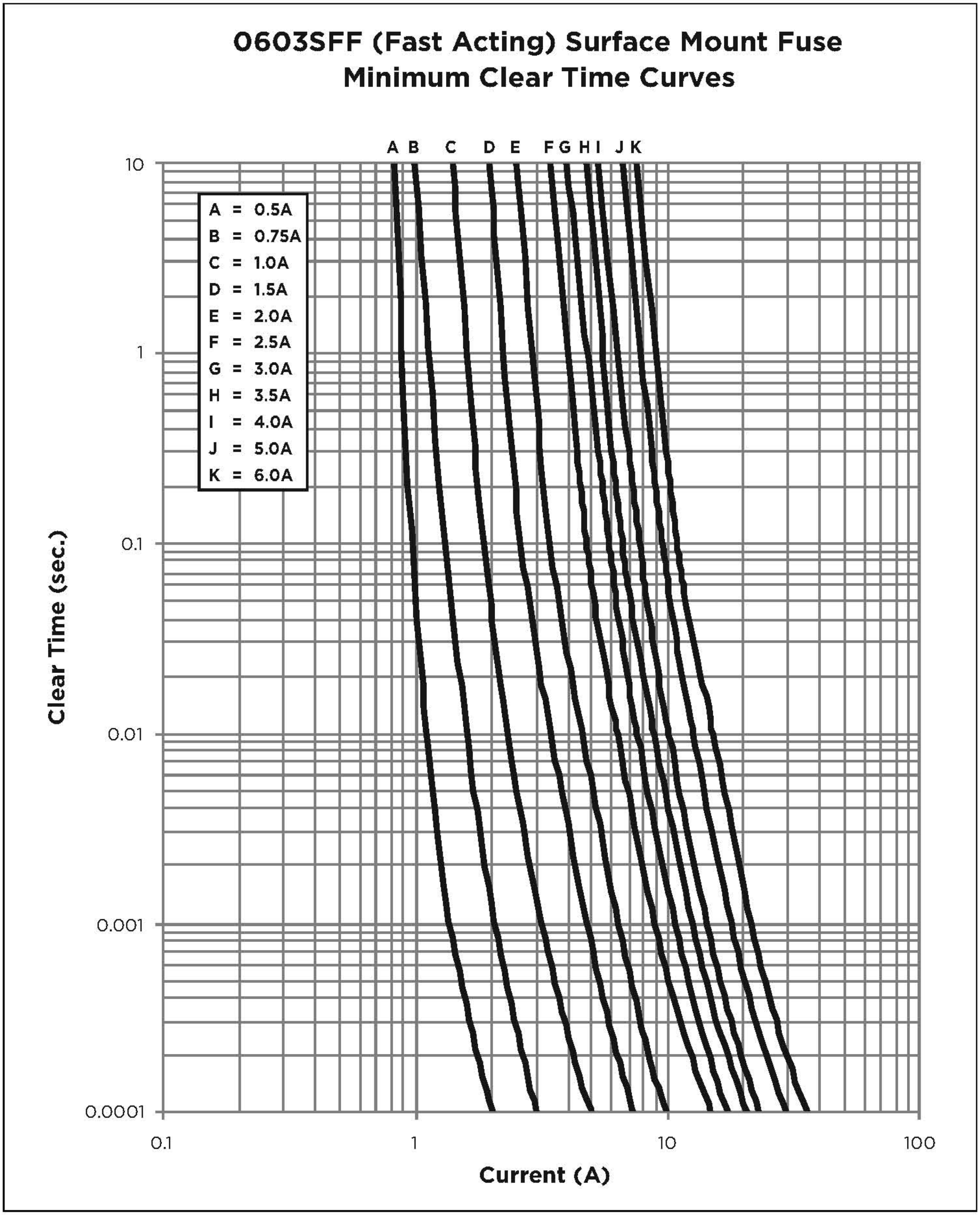
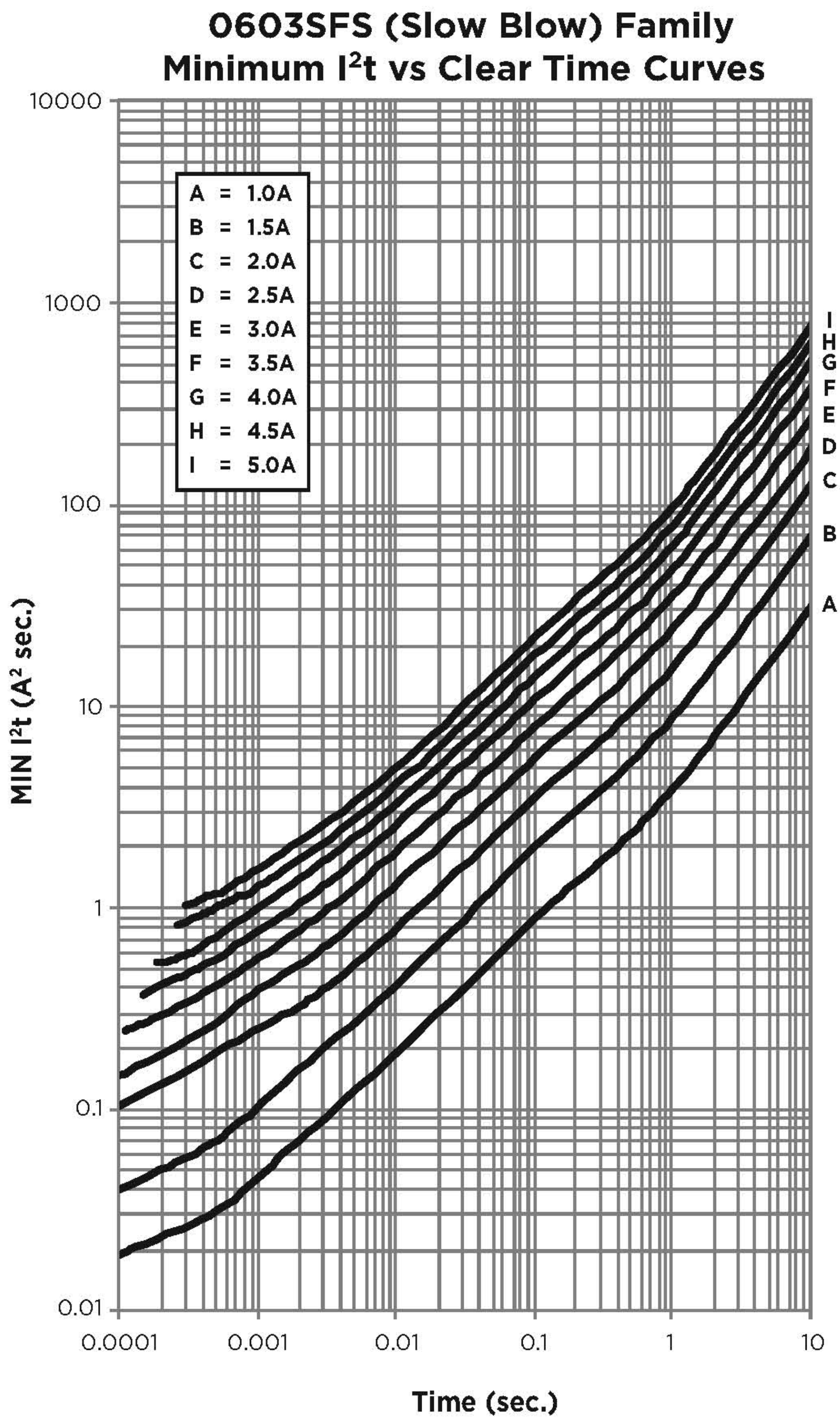


Figure 6. 0603SFS (Slow Blow) Family Minimum I^2t vs Clear Time Curves

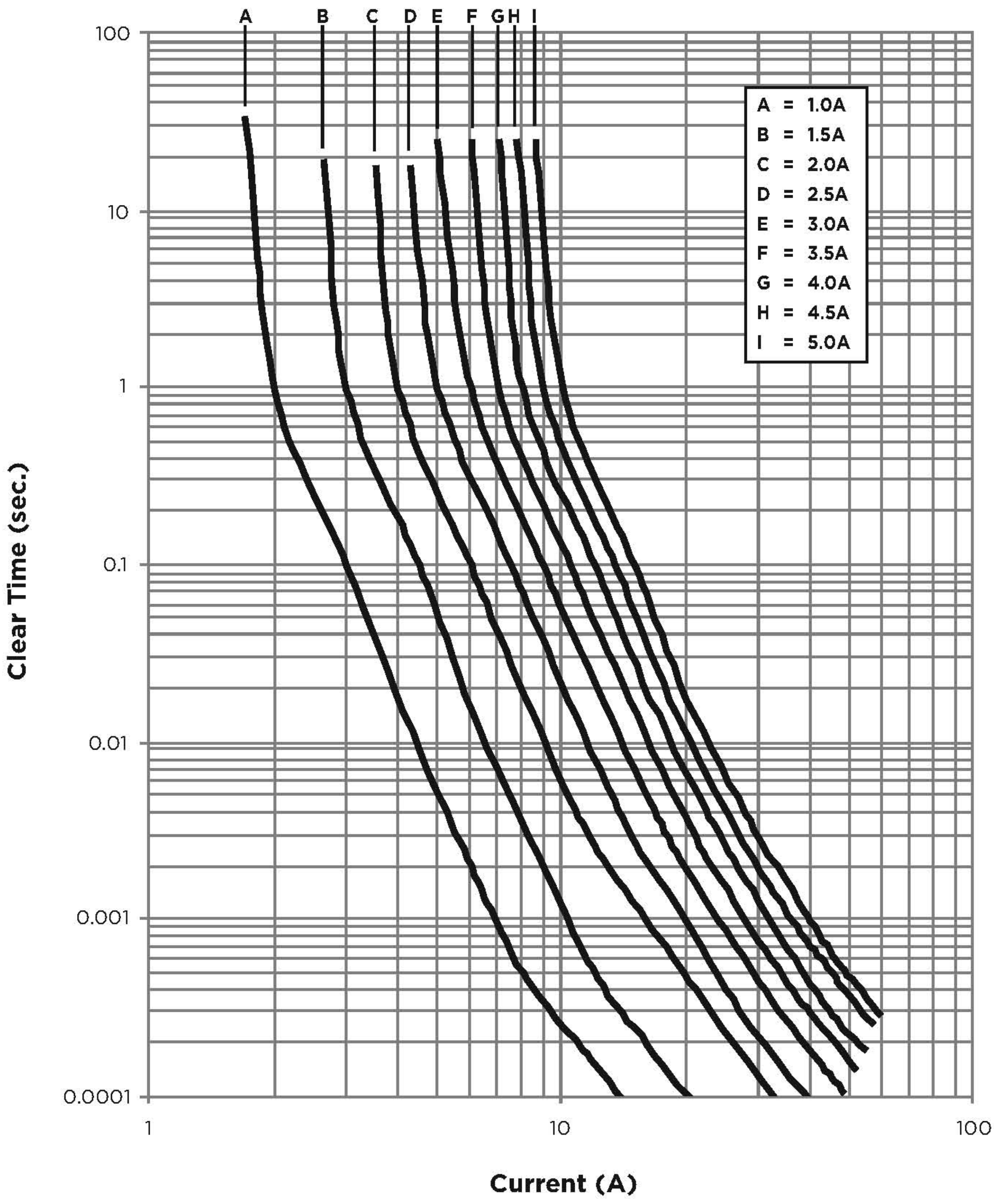
* Please note clear time curves are minimum threshold, not typical.


0603SFF (Fast Acting) Family
Minimum I^2t vs Clear Time Curves
A = 0.5A
B = 0.75A
C = 1.0A
D = 1.5A
E = 2.0A
F = 2.5A
G = 3.0A
H = 3.5A
I = 4.0A
J = 5.0A
K = 6.0A
MIN I^2t (A^2 sec.)
Time (sec.)
1000
100
10
1
0.1
0.01
0.001
0.0001
0.0001
0.001
0.01
0.1
1
10
K
J
I
H
G
F
E
D
C
B
A


0603SFF (Fast Acting) Surface Mount Fuse
Minimum Clear Time Curves
A B C D E F G H I J K
A = 0.5A
B = 0.75A
C = 1.0A
D = 1.5A
E = 2.0A
F = 2.5A
G = 3.0A
H = 3.5A
I = 4.0A
J = 5.0A
K = 6.0A
Clear Time (sec.)
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
Current (A)

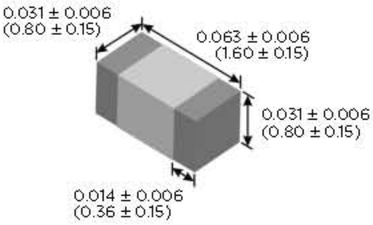

0603SFS (Slow Blow) Family
Minimum I²t vs Clear Time Curves
A = 1.0A
B = 1.5A
C = 2.0A
D = 2.5A
E = 3.0A
F = 3.5A
G = 4.0A
H = 4.5A
I = 5.0A
MIN I²t (A² sec.)
10000
1000
100
10
1
0.1
0.01
0.0001
0.001
0.01
0.1
1
10
Time (sec.)
I
H
G
F
E
D
C
B
A

0603SFS (Slow Blow) Surface Mount Fuse Minimum Clear Time Curves

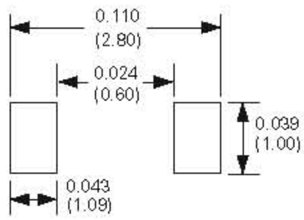


Appendix E

Shape and Dimensions Inch (mm)



Recommended Pad Layout Inch (mm)

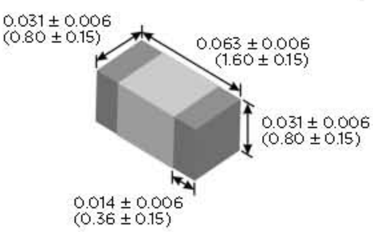


Part Number	Typical Electrical Characteristics: Rated Current (A)	Typical Electrical Characteristics: Nominal Cold DCR (Ω)*	Max Interrupt Ratings: Voltage (V_{DC})	Max Interrupt Ratings: Current (A)
0603SFF050F/32	0.50	0.485	32	50
0603SFF075F/32	0.75	0.254	32	50
0603SFF100F/32	1.00	0.131	32	50
0603SFF150F/32	1.50	0.059	32	35
0603SFF200F/32	2.00	0.044	32	35
0603SFF250F/32	2.50	0.032	32	35
0603SFF300F/32	3.00	0.025	32	35
0603SFF350F/32	3.50	0.024	32	35
0603SFF400F/32	4.00	0.018	32	35
0603SFF500F/32	5.00	0.013	32	35
0603SFF600F/24	6.00	0.010	24	35

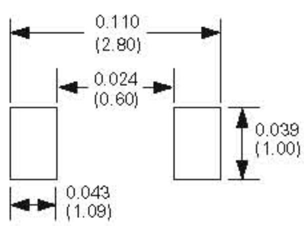
* Measured at ≤ 10% of rated current and 25°C

0603SFF (1608mm) Fast Acting Surface Mount Chip Fuses

Shape and Dimensions Inch (mm)



Recommended Pad Layout Inch (mm)



Part Number	Typical Electrical Characteristics: Rated Current (A)	Typical Electrical Characteristics: Nominal Cold DCR (Ω)*	Typical Electrical Characteristics: Nominal I^2t (A^2sec)†	Max Interrupt Ratings: Voltage (V_{DC})	Max Interrupt Ratings: Current (A)
0603SFS100F/32	1.0	0.200	0.09	32	40
0603SFS150F/32	1.5	0.100	0.18	32	40
0603SFS200F/32	2.0	0.052	0.82	32	40
0603SFS250F/32	2.5	0.041	0.63	32	40
0603SFS300F/32	3.0	0.031	0.87	32	40
0603SFS350F/32	3.5	0.021	1.20	32	40
0603SFS400F/32	4.0	0.017	2.30	32	40
0603SFS450F/32	4.5	0.015	2.70	32	40
0603SFS500F/32	5.0	0.013	3.20	32	40

* Measured at ≤ 10% of rated current and 25°C
† Melting I^2t at 0.001 sec clear time

0603SFS (1608mm) Slow Blow Surface Mount Chip Fuses

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