

# Introduction to Circuit Protection

## Fuseology

### Fuse Facts

The application guidelines and product data in this guide are intended to provide technical information that will help with application design. Since these are only a few of the contributing parameters, application testing is strongly recommended and should be used to verify performance in the circuit/application. In the absence of special requirements, Littelfuse reserves the right to make appropriate changes in design, process, and manufacturing location without notice.

*The purpose of the Fuseology Section is to promote a better understanding of both fuses and common application details. The fuses to be considered are current sensitive devices which are designed as the intentional weak link in the electrical circuit. The function of the fuse is to provide protection of discrete components, or of complete circuits, by reliably melting under current overload conditions. This fuseology section will cover some important facts about fuses, selection considerations, and standards.*

#### FUSE FACTS

The following fuse parameters or application concepts should be well understood in order to properly select a fuse for a given application.

**AMBIENT TEMPERATURE:** Refers to the temperature of the air immediately surrounding the fuse and is not to be confused with “room temperature.” The fuse ambient temperature is appreciably higher in many cases, because it is enclosed (as in a panel mount fuseholder) or mounted near other heat producing components, such as resistors, transformers, etc.

**BREAKING CAPACITY:** See Interrupting Rating.

**CURRENT RATING:** The nominal amperage value of the fuse. It is established by the manufacturer as a value of current which the fuse can carry, based on a controlled set of test conditions (See RERATING).

Catalog Fuse part numbers include series identification and amperage ratings. Refer to the FUSE SELECTION GUIDE section for guidance on making the proper choice.

**RERATING:** For 25°C ambient temperatures, it is recommended that fuses be operated at no more than 75% of the nominal current rating established using the controlled test conditions. These test conditions are part of UL/CSA/ANCE (Mexico) 248-14 “Fuses for Supplementary Overcurrent Protection,” whose primary objective is to specify common test standards necessary for the continued control of manufactured items intended for protection against fire, etc. Some common variations of these standards include: fully enclosed fuseholders, high contact resistances, air movement, transient spikes, and changes in connecting cable size (diameter and length). Fuses are essentially temperature-sensitive devices. Even small variations from the controlled test conditions can greatly affect the predicted life of a fuse when it is loaded to its nominal value, usually expressed as 100% of rating.

The circuit design engineer should clearly understand that the purpose of these controlled test conditions is to enable fuse manufacturers to maintain unified performance standards for their products, and he must account for the variable conditions of his application. To compensate for these variables, the circuit design engineer who is designing for trouble-free, long-life fuse protection in his equipment generally loads his fuse not more than 75% of the nominal rating listed by the manufacturer, keeping in mind that overload and short circuit protection must be adequately provided for.

The fuses under discussion are temperature-sensitive devices whose ratings have been established in a 25°C ambient. The fuse temperature generated by the current passing through the fuse increases or decreases with ambient temperature change.

The ambient temperature chart in the FUSE SELECTION GUIDE section illustrates the effect that ambient temperature has on the nominal current rating of a fuse. Most traditional Slo-Blo® Fuse designs use lower melting temperature materials and are, therefore, more sensitive to ambient temperature changes.

**DIMENSIONS:** Unless otherwise specified, dimensions are in inches.

The fuses in this catalog range in size from the approx. 0402 chip size (.041"L x .020"W x .012"H) up to the 5 AG, also commonly known as a “MIDGET” fuse (13/32" Dia. x 1 1/2" Length). As new products were developed throughout the years, fuse sizes evolved to fill the various electrical circuit protection needs. The first fuses were simple, open-wire devices, followed in the 1890's by Edison's enclosure of thin wire in a lamp base to make the first plug fuse. By 1904, Underwriters Laboratories had established size and rating specifications to meet safety standards. The renewable type fuses and automotive fuses appeared in 1914, and in 1927 Littelfuse started making very low amperage fuses for the budding electronics industry.

The fuse sizes in the chart below began with the early “Automobile Glass” fuses, thus the term “AG”. The numbers were applied chronologically as different manufacturers started making a new size: “3AG,” for example, was the third size placed on the market. Other non-glass fuse sizes and constructions were determined by functional requirements, but they still retained the length or diameter dimensions of the glass fuses. Their designation was modified to AB in place of AG, indicating that the outer tube was constructed from Bakelite, fibre, ceramic, or a similar material other than glass. The largest size fuse shown in the chart is the 5AG, or “MIDGET,” a name adopted from its use by the electrical industry and the National Electrical Code range which normally recognizes fuses of 9/16" x 2" as the smallest standard fuse in use.

FUSE SIZES				
SIZE	DIAMETER (Inches)		LENGTH (Inches)	
1AG	1/4	.250	5/8	.625
2AG	—	.177	—	.588
3AG	1/4	.250	1 1/4	1.25
4AG	9/32	.281	1 1/4	1.25
5AG	13/32	.406	1 1/2	1.50
7AG	1/4	.250	7/8	.875
8AG	1/4	.250	1	1

**TOLERANCES:** The dimensions shown in this catalog are nominal. Unless otherwise specified, tolerances are applied as follows:

- ± .010" for dimensions to 2 decimal places.
- ± .005" for dimensions to 3 decimal places.

The factory should be contacted concerning metric system and fractional tolerances. Tolerances do not apply to lead lengths.

**FUSE CHARACTERISTICS:** The characteristic of a fuse design refers to how rapidly the fuse responds to various current overloads. Fuse characteristics can be classified into three general categories: very fast-acting, fast-acting, or Slo-Blo® Fuse. The distinguishing feature of Slo-Blo® fuses is that these fuses have additional thermal inertia designed to tolerate normal initial or start-up overload pulses.

**FUSE CONSTRUCTION:** Internal construction may vary depending on ampere rating. Fuse photos in this catalog show typical construction of a particular ampere rating within the fuse series.

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## Fuseology

### Fuse Facts

**FUSEHOLDERS:** In many applications, fuses are installed in fuseholders. These fuses and their associated fuseholders are not intended for operation as a “switch” for turning power “on” and “off”.

**INTERRUPTING RATING:** Also known as breaking capacity or short circuit rating, the interrupting rating is the maximum approved current which the fuse can safely interrupt at rated voltage. During a fault or short circuit condition, a fuse may receive an instantaneous overload current many times greater than its normal operating current. Safe operation requires that the fuse remain intact (no explosion or body rupture) and clear the circuit.

Interrupting ratings may vary with fuse design and range from 35 amperes AC for some 250V metric size (5 x 20mm) fuses up to 200,000 amperes AC for the 600V KLK series. Information on other fuse series can be obtained from the factory.

Fuses listed in accordance with UL/CSA/ANCE 248 are required to have an interrupting rating of 10,000 amperes, with some exceptions (See STANDARDS section) which, in many applications, provides a safety factor far in excess of the short circuit currents available.

**NUISANCE OPENING:** Nuisance opening is most often caused by an incomplete analysis of the circuit under consideration. Of all the “Selection Factors” listed in the FUSE SELECTION GUIDE, special attention must be given to items 1, 3, and 6, namely, normal operating current, ambient temperature, and pulses. For example, one prevalent cause of nuisance opening in conventional power supplies is the failure to adequately consider the fuse’s nominal melting I<sup>2</sup>t rating. The fuse cannot be selected solely on the basis of normal operating current and ambient temperature. In this application, the fuse’s nominal melting I<sup>2</sup>t rating must also meet the inrush current requirements created by the input capacitor of the power supply’s smoothing filter. The procedure for converting various waveforms into I<sup>2</sup>t circuit demand is given in the FUSE SELECTION GUIDE. For trouble-free, long-life fuse protection, it is good design practice to select a fuse such that the I<sup>2</sup>t of the waveform is no more than 20% of the nominal melting I<sup>2</sup>t rating of the fuse. Refer to the section on PULSES in the FUSE SELECTION GUIDE.

**RESISTANCE:** The resistance of a fuse is usually an insignificant part of the total circuit resistance. Since the resistance of fractional amperage fuses can be several ohms, this fact should be considered when using them in low-voltage circuits. Actual values can be obtained from the factory. Most fuses are manufactured from materials which have positive temperature coefficients, and, therefore, it is common to refer to cold resistance and hot resistance (voltage drop at rated current), with actual operation being somewhere in between. Cold resistance is the resistance obtained using a measuring current of no more than 10% of the fuse’s nominal rated current. Values shown in this publication for cold resistance are nominal and representative. The factory should be consulted if this parameter is critical to the design analysis. Hot resistance is the resistance calculated from the stabilized voltage drop across the fuse, with current equal to the nominal rated current flowing through it. Resistance data on all Littelfuse products are available on request. Fuses can be supplied to specified controlled resistance tolerances at additional cost.

**SOLDERING RECOMMENDATIONS:** Since most fuse constructions incorporate soldered connections, caution should be used when installing those fuses intended to be soldered in place. The application of excessive heat can reflow the solder within the fuse and change its rating. Fuses are heat-sensitive components similar to semi-conductors, and the use of heat sinks during soldering is often recommended.

**TEST SAMPLING PLAN:** Because compliance with certain specifications requires destructive testing, these tests are selected on a statistical basis for each lot manufactured.

**TIME-CURRENT CURVE:** The graphical presentation of the fusing characteristic, time-current curves are generally average curves which are presented as a design aid but are not generally considered part of the fuse specification. Time-current curves are extremely useful in defining a fuse, since fuses with the same current rating can be represented by considerably different time-current curves. The fuse specification typically will include a life requirement at 100% of rating and maximum opening times at overload points (usually 135% and 200% of rating). A time-current curve represents average data for the design; however, there may be some differences in the values for any one given production lot. Samples should be tested to verify performance, once the fuse has been selected.

**UNDERWRITERS LABORATORIES:** Reference to “Listed by Underwriters Laboratories” signifies that the fuses meet the requirements of UL/CSA/ANCE 248-14 “Fuses for Supplementary Overcurrent Protection”. Some 32 volt fuses (automotive) in this catalog are listed under UL Standard 275. Reference to “Recognized under the Component Program of Underwriters Laboratories” signifies that the item is recognized under the component program of Underwriters Laboratories and application approval is required.

**VOLTAGE RATING:** The voltage rating, as marked on a fuse, indicates that the fuse can be relied upon to safely interrupt its rated short circuit current in a circuit where the voltage is equal to, or less than, its rated voltage. This system of voltage rating is covered by N.E.C. regulations and is a requirement of Underwriters Laboratories as a protection against fire risk. The standard voltage ratings used by fuse manufacturers for most small-dimension and midget fuses are 32, 63, 125, 250 and 600.

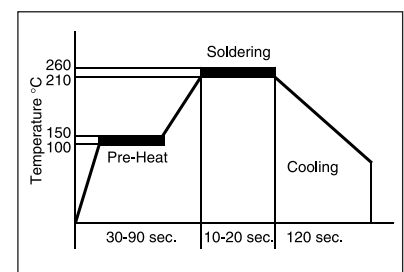
In electronic equipment with relatively low output power supplies, with circuit impedance limiting short circuit currents to values of less than ten times the current rating of the fuse, it is common practice to specify fuses with 125 or 250 volt ratings for secondary circuit protection of 500 volts or higher.

As mentioned previously (See RERATING), fuses are sensitive to changes in current, not voltage, maintaining their “status quo” at any voltage from zero to the maximum rating of the fuse. It is not until the fuse element melts and arcing occurs that the circuit voltage and available power become an issue. The safe interruption of the circuit, as it relates to circuit voltage and available power, is discussed in the section on INTERRUPTING RATING.

To summarize, a fuse may be used at any voltage that is less than its voltage rating without detriment to its fusing characteristics. Please contact the factory for applications at voltages greater than the voltage rating.

#### Lead-Free Soldering Parameters:

- Wave Solder —
- 260°C, 10 seconds max
- Reflow Solder —
- 260°C, 30 seconds max



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### Fuse Facts and Fuse Selection Guide

**DERIVATION OF NOMINAL MELTING I<sup>2</sup>t:** Laboratory tests are conducted on each fuse design to determine the amount of energy required to melt the fusing element. This energy is described as nominal melting I<sup>2</sup>t and is expressed as "Ampere Squared Seconds" (A<sup>2</sup> Sec.). A pulse of current is applied to the fuse, and a time measurement is taken for melting to occur. If melting does not occur within a short duration of about 8 milliseconds (0.008 seconds) or less, the level of pulse current is increased. This test procedure is repeated until melting of the fuse element is confined to within about 8 milliseconds. The purpose of this

procedure is to assure that the heat created has insufficient time to thermally conduct away from the fuse element. That is, all of the heat energy (I<sup>2</sup>t) is used, to cause melting. Once the measurements of current (I) and time (t) are determined, it is a simple matter to calculate melting I<sup>2</sup>t. When the melting phase reaches completion, an electrical arc occurs immediately prior to the "opening" of the fuse element. Clearing I<sup>2</sup>t = Melting I<sup>2</sup>t + arcing I<sup>2</sup>t. The nominal I<sup>2</sup>t values given in this publication pertain to the melting phase portion of the "clearing" or "opening".

### FUSE SELECTION GUIDE

The application guidelines and product data in this guide are intended to provide technical information that will help with application design. Since these are only a few of the contributing parameters, application testing is strongly recommended and should be used to verify performance in the circuit/application.

Many of the factors involved with fuse selection are listed below:

#### Selection Factors

1. Normal operating current
2. Application voltage (AC or DC)
3. Ambient temperature
4. Overload current and length of time in which the fuse must open.
5. Maximum available fault current
6. Pulses, Surge Currents, Inrush Currents, Start-up Currents, and Circuit Transients
7. Physical size limitations, such as length, diameter, or height
8. Agency Approvals required, such as UL, CSA, VDE, METI, MITI or Military
9. Considerations: mounting type/form factor, ease of removal, axial leads, visual indication, etc.
10. Fuseholder features: clips, mounting block, panel mount, p.c. board mount, R.F.I. shielded, etc.

**NORMAL OPERATING CURRENT:** The current rating of a fuse is typically derated 25% for operation at 25°C to avoid nuisance blowing. For example, a fuse with a current rating of 10A is not usually recommended for operation at more than 7.5A in a 25°C ambient. For additional details, see RERATING in the previous section and AMBIENT TEMPERATURE below.

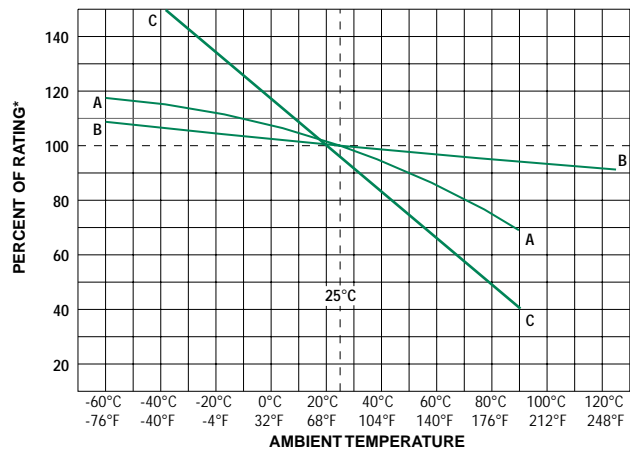
**VOLTAGE:** The voltage rating of the fuse must be equal to, or greater than, the available circuit voltage. For exceptions, see VOLTAGE RATING.

**AMBIENT TEMPERATURE:** The current carrying capacity tests of fuses are performed at 25°C and will be affected by changes in ambient temperature. The higher the ambient temperature, the hotter the fuse will operate, and the shorter its life will be. Conversely, operating at a lower temperature will prolong fuse life. A fuse also runs hotter as the normal operating current approaches or exceeds the rating of the selected fuse. Practical experience indicates fuses at **room temperature** should last indefinitely, if operated at no more than 75% of catalog fuse rating.

### CHART SHOWING EFFECT OF AMBIENT TEMPERATURE ON CURRENT-CARRYING CAPACITY (TYPICAL)

#### KEY TO CHART:

- Curve A: Thin-Film Fuses and 313 Series (.010 to .150A)
- Curve B: FLAT-PAK®, TeleLink®, Nano®, PICO®, Blade Terminal and special purpose and other Leaded and cartridge fuses (except 313.010-.150A)
- Curve C: Resettable PTC's



\*Ambient temperature effects are in addition to the normal rerating, see example.

Example: Given a normal operating current of 2.25 amperes in an application using a 229 series fuse at room temperature, then:

$$\text{Catalog Fuse Rating} = \frac{\text{Normal Operating Current}}{0.75}$$

$$\frac{2.25 \text{ Amperes}}{0.75} \quad \text{or} \quad = 3 \text{ Amp Fuse (at } 25^\circ\text{C)}$$

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## Fuseology

### Fuse Selection Guide

Similarly, if that same fuse were operated at a very high ambient temperature of 80°C, additional derating would be necessary. Curve "B" of the ambient temperature chart shows the maximum operating "Percent of Rating" at 80°C to be 95%, in which case;

$$\begin{aligned} \text{Catalog Fuse Rating} &= \frac{\text{Nominal Operating Current}}{0.75 \times \text{Percent of Rating}} \\ \text{or} \\ \frac{2.25 \text{ Amperes}}{0.75 \times 0.95} &= 3.15 \text{ Amp Fuse (at } 80^\circ\text{C)} \end{aligned}$$

**OVERLOAD CURRENT CONDITION:** The current level for which protection is required. Fault conditions may be specified, either in terms of current or, in terms of both current and maximum time the fault can be tolerated before damage occurs. Time-current curves should be consulted to try to match the fuse characteristic to the circuit needs, while keeping in mind that the curves are based on average data.

**MAXIMUM FAULT CURRENT:** The Interrupting Rating of a fuse must meet or exceed the Maximum Fault Current of the circuit.

**PULSES:** The general term "pulses" is used in this context to describe the broad category of wave shapes referred to as "surge currents", "start-up currents", "inrush currents", and "transients". Electrical pulse conditions can vary considerably from one application to another. Different fuse constructions may not react the same to a given pulse condition. Electrical pulses produce thermal cycling and possible mechanical fatigue that could affect the life of the fuse. Initial or start-up pulses are normal for some applications and require the characteristic of a Slo-Blo® fuse. Slo-Blo® fuses incorporate a thermal delay design to enable them to survive normal start-up pulses and still provide protection against prolonged overloads. The start-up pulse should be defined and then compared to the time-current curve and I<sup>2</sup>t rating for the fuse. Application testing is recommended to establish the ability of the fuse design to withstand the pulse conditions.

Nominal melting I<sup>2</sup>t is a measure of the energy required to melt the fusing element and is expressed as "Ampere Squared Seconds" (A<sup>2</sup> Sec.). This nominal melting I<sup>2</sup>t, and the energy it represents (within a time duration of 8 milliseconds [0.008 second] or less and 1 millisecond [0.001 second] or less for thin film fuses), is a value that is constant for each different fusing element. Because every fuse type and rating, as well as its corresponding part number, has a different fusing element, it is necessary to determine the I<sup>2</sup>t for each. This I<sup>2</sup>t value is a parameter of the fuse itself and is controlled by the element material and the configuration of the fuse element. In addition to selecting fuses on the basis of "Normal Operating Currents", "Rerating", and "Ambient Temperature" as discussed earlier, it is also necessary to apply the I<sup>2</sup>t design approach. This nominal melting I<sup>2</sup>t is not only a constant value for each fuse element design, but it is also independent of temperature and voltage. Most often, the nominal melting I<sup>2</sup>t method of fuse selection is applied to those applications in which the fuse must sustain large current pulses of a short duration. These high-energy currents are common in many applications and are described by a variety of terms, such as "surge current", "start-up current", "inrush current", and other similar circuit "transients" that can be classified in the general category of "pulses." Laboratory tests are conducted on each fuse design to determine its nominal melting I<sup>2</sup>t rating. The values for I<sup>2</sup>t given in this publication are nominal and representative. The factory should be consulted if this parameter is

critical to the design analysis.

The following example should assist in providing a better understanding of the application of I<sup>2</sup>t.

**EXAMPLE:** Select a 125V, very fast-acting PICO®II fuse that is capable of withstanding 100,000 pulses of current (I) of the pulse waveform shown in Figure 1. The normal operating current is 0.75 ampere at an ambient temperature of 25°C.

**Step 1** — Refer to Chart I (page #6) and select the appropriate pulse waveform, which is waveform (E) in this example. Place the applicable value for peak pulse current (i<sub>p</sub>) and time (t) into the corresponding formula for waveshape (E), and calculate the result, as shown:

$$I^2t = \frac{1}{5} (i_p)^2 = I^2t = \frac{1}{5} (ip)^2t$$

$$\frac{1}{5} \times 8^2 \times .004 = 0.0512 \text{ A}^2 \text{ Sec.}$$

This value is referred to as the "Pulse I<sup>2</sup>t".

**Step 2** — Determine the required value of Nominal Melting I<sup>2</sup>t by referring to Chart II (page 6). A figure of 22% is shown in Chart II for 100,000 occurrences of the Pulse I<sup>2</sup>t calculated in Step 1. This Pulse I<sup>2</sup>t is converted to its required value of Nominal Melting I<sup>2</sup>t as follows:

$$\begin{aligned} \text{Nom. Melt } I^2t &= \text{Pulse } I^2t / .22 \\ &= 0.0512 / .22 = 0.2327 \text{ A}^2 \text{ Sec.} \end{aligned}$$

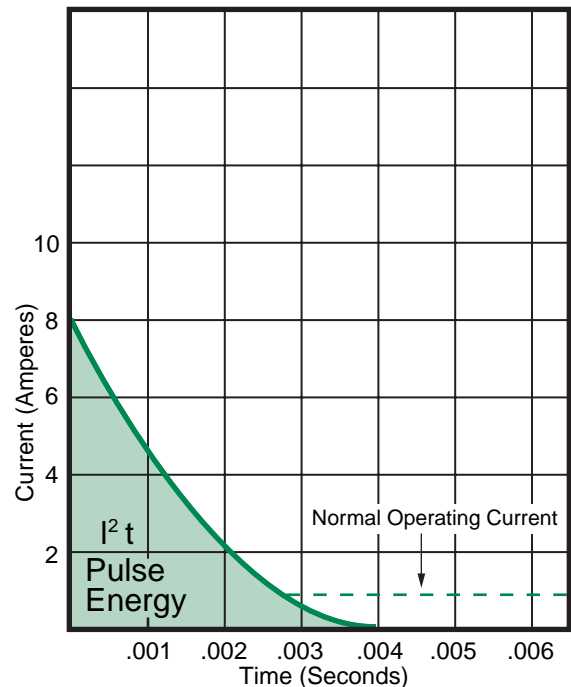
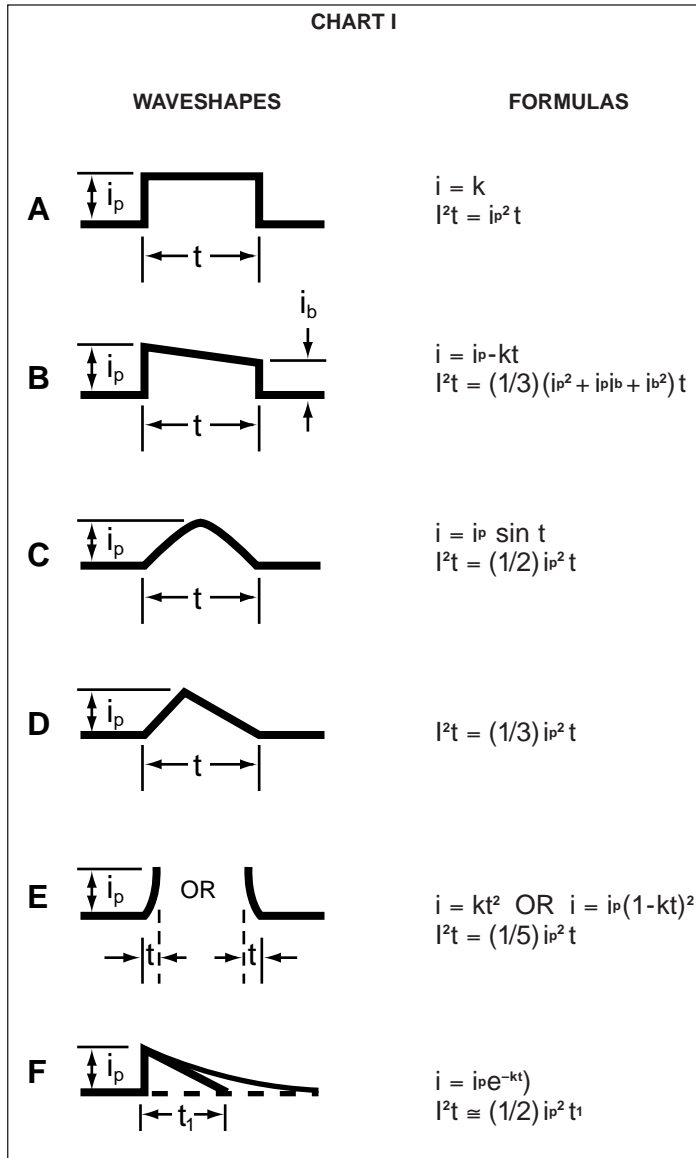


Figure 1

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## Fuseology

### Fuse Selection Guide



Step 3 — Examine the  $I^2t$  rating data for the PICO® II, 125V, very fast-acting fuse. The part number 251001, 1 ampere design is rated at 0.256  $A^2 \text{ Sec.}$ , which is the minimum fuse rating that will accommodate the 0.2327  $A^2 \text{ Sec.}$  value calculated in Step 2. This 1 ampere fuse will also accommodate the specified 0.75 ampere normal operating current, when a 25% derating factor is applied to the 1 ampere rating, as previously described.

**TESTING:** The above factors should be considered in selecting a fuse for a given application. The next step is to verify the selection by requesting samples for testing in the actual circuit. Before evaluating the samples, make sure the fuse is properly mounted with good electrical connections, using adequately sized wires or traces. The testing should include life tests under normal conditions and overload tests under fault conditions, to ensure that the fuse will operate properly in the circuit.



### FUSEHOLDER SELECTION GUIDE

**RERATING:** For 25°C ambient temperatures, it is recommended that fuseholders be operated at no more than 60% of the nominal current rating established using the controlled test conditions specified by Underwriters Laboratories. The primary objective of these UL test conditions is to specify common test standards necessary for the continued control of manufactured items intended for protection against fire, etc. A copper dummy fuse is inserted in the fuseholder by Underwriters Laboratories, and then the current is increased until a certain temperature rise occurs. The majority of the heat is produced by the contact resistance of the fuseholder clips. This value of current is considered to be the rated current of the fuseholder, expressed as 100%

of rating. Some of the more common, everyday applications may differ from these UL test conditions as follows: fully enclosed fuseholders, high contact resistance, air movement, transient spikes, and changes in connecting cable size (diameter and length). Even small variations from the controlled test conditions can greatly affect the ratings of the fuseholder. For this reason, it is recommended that fuseholders be derated by 40% (operated at no more than 60% of the nominal current rating established using the Underwriter Laboratories test conditions, as previously stated).

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## Standards

Littelfuse is at your service to help solve your electrical protection problems. When contacting Littelfuse sales engineers, please have all the requirements of your applications available. Requests for quotes or assistance in designing or selecting special types of circuit protection components for your particular applications are also welcome. In the absence of special requirements, Littelfuse reserves the right to make appropriate changes in design, process, and manufacturing location without prior notice.

Fuse ratings and other performance criteria are evaluated under laboratory conditions and **acceptance criteria**, as defined in one or more of the various fuse standards. It is important to understand these standards so that the fuse can be properly applied to circuit protection applications.

### UL/CSA/ANCE (Mexico) 248-14 FUSES FOR SUPPLEMENTARY OVERCURRENT PROTECTION (600 Volts, Maximum) (Previously UL 198G and CSA C22.2, No. 59)

#### UL LISTED

A UL Listed fuse meets all the requirements of the UL/CSA 248-14 Standard. Following are some of the requirements. UL ampere rating tests are conducted at 100%, 135%, and 200% of rated current. The fuse must carry 100% of its ampere rating and must stabilize at a temperature that does not exceed a 75°C rise.

The fuse must open at 135% of rated current within one hour. It also must open at 200% of rated current within 2 minutes for 0-30 ampere ratings and 4 minutes for 35-60 ampere ratings.

The interrupting rating of a UL Listed fuse is 10,000 amperes AC minimum at 125 volts. Fuses rated at 250 volts may be listed as interrupting 10,000 amperes at 125 volts and, at least, the minimum values shown below at 250 volts.

Ampere Rating of Fuse	Interrupting Rating In Amperes	Voltage Rating
0 to 1	35	250 VAC
1.1 to 3.5	100	250 VAC
3.6 to 10	200	250 VAC
10.1 to 15	750	250 VAC
15.1 to 30	1500	250 VAC

#### Recognized Under the Component Program of Underwriters Laboratories

The Recognized Components Program of UL is different from UL Listing. UL will test a fuse to a specification requested by the manufacturer. The test points can be different from the UL Listed requirements if the fuse has been designed for a specific application. Application approval is required by UL for fuses recognized under the Component Program.


### UL 275 AUTOMOTIVE GLASS TUBE FUSES (32 Volts)

#### UL Listed

UL ampere ratings tests are conducted at 110%, 135%, and 200%. Interrupting rating tests are not required.

#### CSA Certification

CSA Certification in Canada is equivalent to UL Listing in the United States.

 The Component Acceptance Program of CSA is equivalent to the Recognition Program at UL.

#### METI APPROVAL

METI<sup>®</sup> approval in Japan is similar to UL Recognition in the United States. METI<sup>®</sup> has its own design standard and characteristics.



#### MITI APPROVAL

MITI<sup>®</sup> approval in Japan is similar to UL Recognition in the United States. MITI<sup>®</sup> has its own design standard and characteristics.

### INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

Publication 60127, Parts 1, 2, 3, 4, 6

The IEC organization is different from UL and CSA, since IEC only writes specifications and does not certify. UL and CSA write the specifications, and are responsible for testing and certification.

Certification to IEC specifications are given by such organizations as SEMKO (Swedish Institute of Testing and Approvals of Electrical Equipment)  and BSI (British Standards Institute) , as well as UL and CSA.

IEC Publication 60127 defines three breaking capacity levels (interrupting rating). Low breaking capacity fuses must pass a test of 35 amperes or ten times rated current, whichever is greater, while enhanced breaking capacity fuses must pass a test of 150 amperes and high breaking capacity fuses must pass a test of 1500 amperes.

#### 60127 Part 2

Sheet 1 – Type F Quick Acting, High Breaking Capacity

Sheet 2 – Type F Quick Acting, Low Breaking Capacity

Sheet 3 – Type T Time Lag, Low Breaking Capacity

Sheet 4 – Style Fuses 1/4 x 1 1/4

Sheet 5 – Type T Time Lag, High Breaking Capacity

Sheet 6 – Type T Time Lag, Enhanced Breaking Capacity

The letters 'F' and 'T' represent the time-current characteristic of the fast-acting and time delay fuses. One of these letters will be marked on the end cap of the fuse.

### UL/CSA/ANCE (Mexico) 248-14 vs. IEC 60127 Part 2 FUSE OPENING TIMES vs. METI<sup>®</sup> / MITI<sup>®</sup>

Percent of Rating	UL & CSA STD 248-14	IEC TYPE F Sheet 1 (*)	IEC Type F Sheet 2 (*)	IEC Type T Sheet 3 (*)	IEC Type T Sheet 5 (*)	METI/MITI <sup>®</sup>
110	4 Hr. Min.	—	—	—	—	
130	—	—	—	—	—	1Hr. Min.
135	60 Minutes Max.	—	—	—	—	
150	—	60 Minutes Min.	60 Minutes Min.	60 Minutes Min.	60 Minutes Min.	
160	—	—	—	—	—	1 Hr. Max.
200	2 Minutes Max.	—	—	—	—	2 Minutes Max.
210	—	30 Minutes Max.	30 Minutes Max.	2 Minutes Max.	30 Minutes Max.	

(\*) Note: The IEC Specification is only written up to 6.3A (8 and 10A will be added soon), any components above these ratings are not recognized by the IEC (although the fuses may have those opening characteristics).

IEC also has requirements at 275%, 400% and 1000%; however, the chart is used to show that fuses with the same ampere rating made to different specifications are not interchangeable. According to the IEC 60127 Standard, a one ampere-rated fuse can be operated at one ampere. A one ampere-rated fuse made to UL/CSA/ANCE 248-14 should not be operated at more than .75 ampere (25% derated — See RERATING section of FUSEOLOGY).

METI<sup>®</sup> covers only one characteristic i.e. there are no 'delay' definitions on other performance variants.

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## Standards and Packaging Information

### Publication IEC 60127-4 (Universal Modular Fuse-Links [UMF])

This part of IEC 60127 covers both PCB through-hole and surface mount fuses. This standard covers fuses rated 32, 63, 125, and 250 volts. This standard will be accepted by UL/CSA making it the first global fuse standard. This specification uses different fusing gates than IEC 60127-2; the gates used here are 125%, 200%, and 1000%.

The fuses must not open in less than one hour at 125% of rated current and open within two minutes at 200% of rated current. The 1000% overload is used to determine the fuse characteristic. The opening time for each rating is listed below.

Type FF:	Less than 0.001 sec.
Type F:	From 0.001 - 0.01 sec.
Type T:	From 0.01 - 0.1 sec.
Type TT:	From 0.1 - 1.00 sec.

These characteristics correlate to the terminology used in IEC 60127-1.

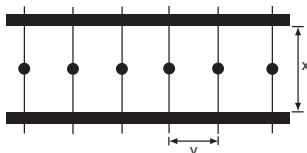
Breaking capacity (interrupting rating) varies based on voltage rating. Parts rated at 32 & 63 volts must pass a test of 35 amperes or ten times rated current, whichever is greater. Parts rated at 125 volts must pass a test of 50 amperes or ten times rated current, whichever is greater. Parts rated at 250 volts are further defined as either low, intermediate or high breaking. The low breaking capacity fuses must pass a test of 100 amperes or ten times rated current, while intermediate breaking capacity fuses must pass a test of 500 amperes and, high breaking capacity fuses must pass a test of 1500 amperes.

### Packaging Suffixes

- R = Taped & reeled fuses
  - A/X = 1 unit per bag
  - V = 5 units per box
  - T = 10 units per box
  - H = 100 units per box
  - U = 500 units per box
  - M = 1000 units per box
  - D = 1500 units per box
  - P = 2000 units per box
  - E = 2500 units per box
  - W = 3000 units per box
  - Y = 4,000 units per box
  - N = 5000 units per box
  - K = 10,000 units per box
- RT1 = Taped & reeled. Spacing (x) = 2.062 inches (52.4 mm)
  - RT2 = Taped & reeled. Spacing (x) = 2.50 inches (63.5 mm)
  - RT3 = Taped & reeled. Spacing (x) = 2.874 inches (73 mm)

Tape and Reel packaging per EIA-296:

- Tape spacing is defined as the width of the tape and reeled fuse (x) as measured from inside tape to inside tape.
- Pitch is defined as the space between two tape and reeled fuses (y) as measured from lead to lead.



### MILITARY/FEDERAL STANDARDS See Table of Contents for Military Product Section.

Fuses and holders approved to the following Military specifications are on the Qualified Products List (QPL) for that specification.

MIL-PRF-15160 and MIL-PRF-23419

These specifications govern the construction and performance of fuses suitable primarily for military electronic applications.

MIL-PRF-19207

This specification governs the construction and performance of fuseholders suitable for military applications.

DSSC Drawing #87108

This drawing governs the construction and performance of .177" x .570" (2AG size) cartridge fuses and axial lead versions suitable for military applications. DSSC #87108 designation is included in the fuse end cap marking.

FEDERAL SPECIFICATION W-F-1814

This specification governs the construction and performance of fuses with high interrupting ratings that are approved for federal applications. Fuses approved to these specifications are on the Federal Qualified Products List.

*Write to the following agencies for additional information on standards, approvals, or copies of the specifications.*

#### Underwriters Laboratories Inc. (UL)

333 Pfingsten Road  
Northbrook, IL 60062

Att: Publications Stock

#### Canadian Standards Association (CSA)

178 Rexdale Boulevard  
Rexdale, Ontario, Canada M9W 1R3

Att: Standard Sales

#### International Electrotechnical Commission (IEC)

3, Rue de Varembe  
1211 Geneva 20  
Switzerland

Att: Sales Department

#### Naval Publications and Military Standards Form Center (for Military and Federal Standards)

5801 Tabor Avenue  
Philadelphia, PA 19120

Att: Commanding Officer

#### Defense Supply Center Columbus (DSCC)

3990 East Broad Street  
Columbus, OH 43216-5000

#### Ministry of Economy Trade and Industry (METI)

Kasumigaseki  
Chi-Youda-Ku  
Tokyo 100, Japan

# Introduction to Circuit Protection

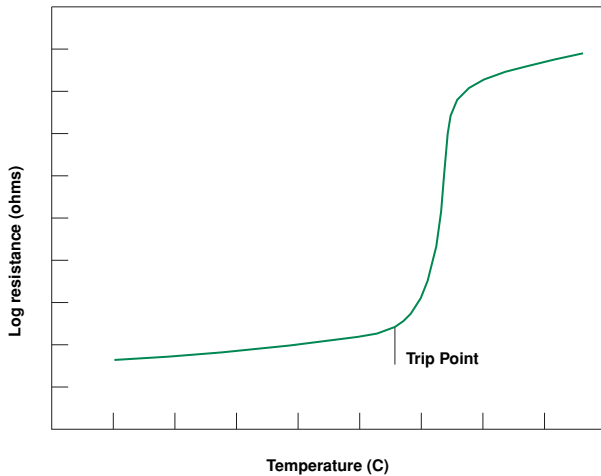
## Fuseology

### PTC Facts

Overcurrent circuit protection can be accomplished with the use of either a traditional fuse or the more recently developed resettable PTC. Both devices function by reacting to the heat generated by the excessive current flow in the circuit. The fuse melts open, interrupting the current flow, and the PTC changes from low resistance to high resistance to limit current flow. Understanding the differences in performance between the two types of devices will make the best circuit protection choice easier.

The most obvious difference is that the PTC is *resettable*. The general procedure for resetting after an overload has occurred is to remove power and allow the device to cool down. There are several other operating characteristics that differentiate the two types of products. The terminology used for PTCs is often similar but not the same as for fuses. Two parameters that fall into this category are leakage current and interrupting rating.

**LEAKAGE CURRENT:** The PTC is said to have “tripped” when it has transitioned from the low resistance state to the high resistance state due to an overload.



Protection is accomplished by limiting the current flow to some low *leakage* level. Leakage current can range from less than a hundred milliamps at rated voltage up to a few hundred milliamps at lower voltages. The fuse on the other hand completely interrupts the current flow and this open circuit results in no leakage current when subjected to an overload.

**INTERRUPTING RATING:** The PTC is rated for a maximum short circuit current at rated voltage. This fault current level is the maximum current that the device can withstand keeping in mind that the PTC will not actually interrupt the current flow (see LEAKAGE CURRENT above). A typical PTC short circuit rating is 40A. Fuses do in fact interrupt the current flow in response to the overload and the range of interrupting ratings vary from tens of amperes up to 10,000 amperes at rated voltage.

The circuit parameters may dictate the component choice based on typical device rating differences.

**OPERATING VOLTAGE RATING:** General use PTCs are not rated above 60V while fuses are rated up to 600V.

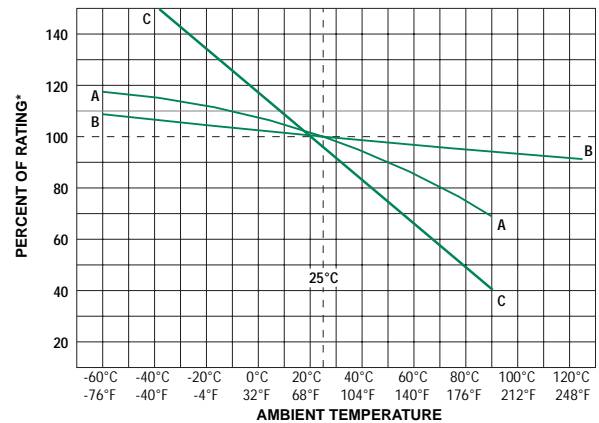
**CURRENT RATING:** The operating current rating for PTCs can be up to 11A while the maximum level for fuses can exceed 20A.

**TEMPERATURE RATING:** The useful upper limit for a PTC is generally 85°C while the maximum operating temperature for fuses is 125°C.

The following temperature derating curves that compare PTCs to fuses illustrate that more derating is required for a PTC at a given temperature.

Additional operating characteristics can be reviewed by the circuit designer in making the decision to choose a PTC or a fuse for overcurrent protection.

**Key to chart:** Curve A: Thin-Film Fuses and 313 Series (.010 to .150A)  
Curve B: FLAT-PAK®, TeleLink®, Nano®, PICO®, Blade Terminal and special purpose and other Leaded and cartridge fuses (except 313.010-.150A)  
Curve C: Resettable PTCs



• Ambient temperature effects are in addition to the normal derating.

**AGENCY APPROVALS:** PTCs are Recognized under the Component Program of Underwriters Laboratories to UL Standard 1434 for Thermistors. The devices have also been certified under the CSA Component Acceptance Program. Approvals for fuses include Recognition under the Component Program of Underwriters Laboratories and the CSA Component Acceptance Program. In addition, many fuses are available with full “Listing” in accordance with the new Supplementary Fuse Standard UL/CSA/ANCE (Mexico) 248-14.

**RESISTANCE:** Reviewing product specifications indicates that similarly rated PTCs have about twice (sometimes more) the resistance of fuses.

**TIME-CURRENT CHARACTERISTIC:** Comparing the time-current curves of PTCs to time-current curves of fuses show that the speed of response for a PTC is similar to the time delay of a Slo-Blo® fuse.

**SUMMARY:** Many of the issues discussed become a matter of preference, but there is an important area of application where the use of resettable PTCs is becoming a requirement. Much of the design work for personal computers and peripheral devices is strongly influenced by *Microsoft and Intel System Design Guide* which states that “Using a fuse that must be replaced each time an overcurrent condition occurs is unacceptable.” And the *Plug and Play SCSI (Small Computer Systems Interface) Specification* for this large market includes a statement that “... must provide a self-resetting device to limit the maximum amount of current sourced”.

The PTC / fuse discussion provides some insight as to when PTCs may be the appropriate choice for providing overcurrent circuit protection. A selection guide worksheet appears on the following page as an aid in choosing the best circuit protection component.



# Introduction to Circuit Protection

## Fuseology

# Overcurrent Selection Guide Worksheet

### 1. Define the circuit operating parameters (Complete the following form).

Normal operating current in amperes: \_\_\_\_\_

Normal operating voltage in volts: \_\_\_\_\_

Maximum interrupt current: \_\_\_\_\_

Ambient Temperature: \_\_\_\_\_

Typical overload current: \_\_\_\_\_

Required opening time at specified overload: \_\_\_\_\_

Transient pulses expected (Quarterly): \_\_\_\_\_

Resettable or one-time: \_\_\_\_\_

Agency Approvals: \_\_\_\_\_

Mounting type/form factor: \_\_\_\_\_

Typical resistance (in circuit): \_\_\_\_\_

### 2. Select the proper circuit protection component.

### 3. Determine the opening time at fault.

Consult the Time-Current (T-C) Curve to determine if the selected part will operate within the constraints of your application. If the device opens too soon, the application may experience nuisance operation. If the device does not open soon enough, the overcurrent may damage downstream components. To determine the opening time for the chosen device, locate the overload current on the X-axis of the appropriate T-C Curve and follow its line up to its intersection with the curve. At this point read the time tested on the Y-axis. This is the average opening time for that device. If your overload current falls to the right of the curve the device will open. If the overload current is to the left of the curve, the device will not operate.

### 4. Verify ambient operating parameters.

Ensure that the application voltage is less than or equal to the device's rated voltage and that the operating temperature limits are within those specified by the device.

### 5. Verify the device's dimensions.

Using the information from the Designer's Guide page, compare the maximum dimensions of the device to the space available in the application.

### 6. Test the selected product in an actual application.

### Overcurrent Selection Guide:

	Surface Mount PTC	30V PTC Leaded	60V PTC Leaded	0402 SMF	0603 SMF	1206 SMF	Nano <sup>®</sup> Telelink SMF Fuse	PICO <sup>®</sup> II Fuse	0402,0603,1206 TFF	3.6 x10mm	TR5 <sup>®</sup> /TE5 <sup>®</sup> Fuses	2AGs	5x20 mm	3AGs/3ABs	Midgets
Lead-Free Available		N/A	N/A							N/A					N/A
Operating Current Range	0.200-2.6A	0.900 - 9A	0.100 - 3.75A	0.250 - 2A	0.250-5A	0.125 - 7A	0.062 - 15A	0.062 - 15A	0.250-7A	0.100-10A	0.40 - 10A	0.100 - 10A	0.032-15A	0.010 - 35A	0.100 - 30A
Maximum Voltage (*)	15V	30V	60V	24V	32V	125V	250V	250V	24-125V	250V	125-250V	250V	250V	250V	600V
Maximum Interrupting Rating (**)	40A	40A	40A	35A	50A	50A	50A	50A	35-59A	35-63A	25-100A	10,000A	10,000A	10,000A	200,000A
Temperature Range	-40°C to 85°C	-40°C to 85°C	-40°C to 85°C	-55°C to 90°C	-55°C to 90°C	-55°C to 90°C	-55°C to 125°C	-55°C to 90°C	-55°C to 125°C	-55 to +125°	-40 to 85°C	-55°C to 125°C	-55°C to 125°C	-55°C to 125°C	-55°C to 125°C
Thermal Rerating	High	High	High	Medium	Medium	Medium	Low	Low	Medium	Low	Low	Low	Low	Low	Low
Opening time at 200% of Amp Rating	Slow	Slow	Slow	Fast	Fast	Fast to Medium	Fast to Medium	Fast to Medium	Fast to Medium	Fast to Medium	Fast to Slow	Fast to Medium	Fast to Slow	Fast to Slow	Fast to Slow
Transient Withstand	Low	Low	Low	Low	Low	Low to Medium	Low to Medium	Low to Medium	Low to Medium	Low to Medium	Low to Medium	Low to High	Low to High	Low to High	Low to High
Resistance	Medium	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Agency Approvals	UL, CSA, TUV	UL, CSA, TUV	UL, CSA, TUV	UL, CSA	UL, CSA	UL, CSA	UMF, UL, CSA, MITI	UL, CSA, MITI	UL, CSA, VDE, CCC	UL, CSA, VDE, CCC	UL, VDE Senko, METI, MITI, CCC, CSA	UL, CSA, MITI	CSA, BSI, VDE, MITI, SEMKO, UL	UL, CSA, MITI	UL, CSA
Operational Uses	Multiple	Multiple	Multiple	One Time	One Time	One Time	One Time	One Time	One Time	One Time	One Time	One Time	One Time	One Time	One Time
Mounting/Form Factor	Surface Mount	Leaded	Leaded	Surface Mount	Surface Mount	Surface Mount	Surface Mount	Leaded	Surface Mount	Leaded	Leaded	Leaded or Cartridge	Leaded or Cartridge	Leaded or Cartridge	Cartridge

(\*) Maximum operating voltage in the series, parts may be used at voltages equal to or less than this value.  
 (\*\*) Maximum interrupting rating at specified voltage which may be less than maximum operating voltage.  
 (\*\*\*) Opening time is in relation to other forms of protection. A fast device will typically operate within three seconds at 200% of rated current.  
 Denotes Lead-Free Product according to Littelfuse standards. Contact factory for availability.  
 Denotes Lead-Free product according to RoHS specification. Contact factory for availability.