Littelfuse®

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Fuseology
Design Guide

A guide to selecting the right fuse for your application

Fuseology
Design Guide
Fuse Characteristics, Terms, and Consideration Factors

About This Guide

Fuses are current-sensitive devices that provide reliable protection for systems, components, or circuits by melting under current overload conditions. Choosing the right fuse for your application can be an overwhelming, time-consuming process, even for a seasoned electronics design engineer. This user-friendly Fuseology Design Guide makes the fuse selection process quick and easy, helping you optimize the reliability and performance of the application.

Littelfuse: Everywhere, Every Day

Founded in 1927, Littelfuse has become the world's most respected circuit protection brand, with well-established and growing platforms in power control and sensing technologies. Today, we are a global company, offering a diverse and extensive product portfolio—fuses, semiconductors, polymers, ceramics, relays, sensors, and more—serving the electronics, transportation, and industrial markets. Each product is manufactured to exacting quality standards and backed by an unwavering commitment to technical support and customer service.

Our history of innovation, combined with our customer-first culture, drives us to collaborate with you to develop safer, more reliable products that are energy efficient and compliant with global regulations. We will partner with you to solve complex problems wherever electrical energy is used, bringing design, engineering, and technical expertise to deliver business results.

Why Choose Littelfuse

Complementing our wide portfolio of circuit protection products is a global network of design and technical support expertise. We offer decades of design experience to help you address application challenges and achieve regulatory compliance.

Your Single Source

Littelfuse offers an extensive circuit protection product line. We design forward-thinking, application-specific solutions to provide assurance that your most demanding requirements will be met. Our goal is to provide the most complete range of options so that you will not have to compromise.

Testing Support

Littelfuse can help ensure that your products will withstand most common threats repeatedly and will fail safely under extreme circumstances. We can serve as an independent source to provide assistance as you design by offering lab testing capabilities. With more than 15 locations worldwide, Littelfuse labs are equipped to provide testing that includes overcurrent, overvoltage, Electrostatic Discharge (ESD), temperature, failure analysis, material analysis, and application performance.

Application Knowledge

For over 95 years, Littelfuse has maintained a focus on circuit protection, and we will continue to adapt as technologies evolve. Engineers and circuit designers around the world have come to rely on Littelfuse products and application knowledge to support their designs.

Global Support

Littelfuse stays close to customers. With manufacturing, lab, and design facilities located around the globe, application knowledge and technical support are locally available. Also, we offer a network of regional customer support offices and hundreds of independent authorized distributor contacts to assist you. Visit Littelfuse.com/contact-us to find local support near you.

Standards Compliance Expertise

Most Littelfuse products comply with a wide range of applicable industry and government guidelines as well as our own rigorous quality and reliability criteria. We continually look forward and adapt to changing requirements so that our products will comply with industry-specific national and international standards and regulations, such as CCC, CSA, IEC, IEEE, ISO, ITU, METI (Ministry of Economy, Trade and Industry), RoHS (Reduction of Hazardous Substances), Telcordia, TIA, and many more.

Operational Excellence

With our global manufacturing footprint, Littelfuse is firmly committed to manufacturing quality products at a competitive price. We build quality into our products and services, aiming for zero defects in everything we do, thereby reducing cost and increasing your total satisfaction. We strive to exceed your expectations every day.

Quality Assurance

Our global manufacturing facilities abide by strict quality assurance requirements and hold the following quality management system registrations:

- ISO 9001
- ISO 14001
- IATF 16949

Fuse Characteristics, Terms, and Consideration Factors

The purpose of this introductory section is to promote a better understanding of both fuses and common application details within circuit design.

The fuses to be considered are current-sensitive devices designed to serve as the intentional weak links in the electrical circuit. Their function is to provide protection of discrete components, or of complete circuits, by reliably melting under overcurrent conditions. This section will cover some important facts about fuses, selection considerations, and standards.

The application guidelines and product data in this guide are intended to provide technical information that will help with application design. The fuse parameters and application concepts presented should be well understood in order to properly select a fuse for a given application.

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.

Littelfuse reserves the right to make changes in product design, processes, manufacturing location, and information without notice. For current Littelfuse product information, visit our website at Littelfuse.com.

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.

Current Rating

The nominal amperage value of the fuse. It is established by the manufacturer as a value of current that the fuse can carry based on a controlled set of test conditions (see Rerating section)

Catalog fuse part numbers include series identification and amperage ratings. Refer to the Fuse Selection Checklist section for guidance on making the proper choice.

Rerating

For 25 ºC 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 248-14 "Fuses for Supplementary Overcurrent Protection," whose primary objective is to specify common test conditions necessary for the continued control of manufactured items intended for protection against fire, shock, etc. Some common variations of these conditions 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 must account for the variable conditions of the application. To compensate for these variables, the circuit design engineer who is designing for trouble-free, long-life fuse protection in the equipment generally loads the 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 temperature rerating curves in the Fuse Selection Checklist section illustrate 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

The fuses in this catalog range in size from the approximately 0402 chip size (.041"L×.020"W×.012"H) up to the 5 AG (13/32" diameter.×11/2" 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 1890s 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. 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 cartridge fuse sizes in following chart 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, fiber, ceramic, or a similar material other than glass.

Common Cartridge Fuse Sizes

Size	Diameter		Length	
	Inches	mm	Inches	mm
1AG	0.250	6.35	0.625	15.88
2AG	0.177	4.50	0.588	14.94
3AG	0.250	6.35	1.250	31.75
4AG	0.281	7.14	1.250	31.75
5AG	0.406	10.32	1.500	38.10
7AG	0.250	6.35	0.875	22.23
8AG	0.250	6.35	1.000	25.40

Common Surface Mount Fuse Sizes

Size	Diameter		Length	
	Inches	mm	Inches	mm
0402	0.04	1.02	0.02	0.51
0603	0.06	1.52	0.03	0.76
0805	0.08	2.03	0.05	1.27
1206	0.12	3.05	0.06	1.52
1210	0.12	3.05	0.10	2.54
2410	0.24	6.10	0.10	2.54

Dimensions provided are for reference only.
Consult product data sheet for specific dimensions and tolerances.

Fuse Characteristics

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

Fuse Construction

Internal construction may vary, depending on form factor and Amperage rating.

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 that 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 can range from 35 A for some 250 V_{AC} metric-size (5x20mm) fuses up to 200,000 A for the 600 V_{AC} KLK series. Information on other fuse series can be obtained from Littelfuse.com.

Fuses listed in accordance with UL/CSA/ANCE 248 are required to have an interrupting rating of 10,000 A at 125 V_{AC}, with some exceptions (See Standards and Certifications section), which, in many applications, provides a safety factor far in excess of the short circuit currents available.

Nuisance Opening

Nuisance opening is a term used to describe undesired opening of a fuse in an application. This is most often the result of a fuse being selected without a complete analysis of the circuit under consideration.

Of all the "selection factors" listed in the Fuse Selection Checklist, 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^2t 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^2t 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^2t circuit demand is provided in the Fuse Selection Checklist. it is good design practice to select a fuse such that the I^2t of the waveform is no more than 20% of the nominal melting I^2t rating of the fuse. Refer to the section on pulses in the Fuse Selection Checklist.

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 by contacting Littelfuse.

Most fuses are manufactured from materials that 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.

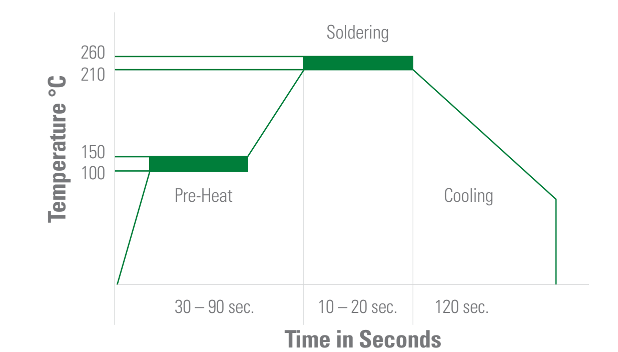
Cold resistance is the resistance obtained using a measuring current of no more than 10% of the fuse's nominal rated current. Values shown in this publication for cold resistance are nominal and representative. Littelfuse should be consulted if this parameter is critical to the application.

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 internal soldered connections, caution should be used when installing fuses intended to be soldered in place. The application of excessive heat can reflow the solder within the fuse and change its rating.

Typical Solder Profile



Lead-Free Soldering Parameters (most instances):
Wave Solder—260° C, 10 seconds max
Reflow Solder—260° C, 30 seconds max

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

A graphical presentation of the fusing characteristic, time-current curves are generally average curves that 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 depending on fuse standard characteristics). A time-current curve represents average data for the design; however, there may be some differences in the values for any given production lot. Samples should be tested to verify performance, once the fuse has been selected.

UL Fuses

Reference to "Listed by UL" signifies that the fuses meet the requirements of the UL/CSA/ANCE 248 series of standards. Some 32 V fuses (automotive) are listed under UL 275. Reference to "Recognized under the Component Program of UL" signifies that the item is recognized under the component program of UL and application approval is required.

Voltage Rating

The voltage rating 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.

The standard voltage ratings used by fuse manufacturers for most small-dimension fuses are 32, 63, 125, 250, and 600 volts.

As mentioned previously (see Rerating section), fuses are sensitive to changes in current, not voltage, maintaining their "status quo" at any voltage up 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. Contact Littelfuse for applications at voltages greater than the voltage rating.

Derivation of Nominal Melting I^2t

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^2t and is expressed as "ampere squared seconds" (A^2 s).

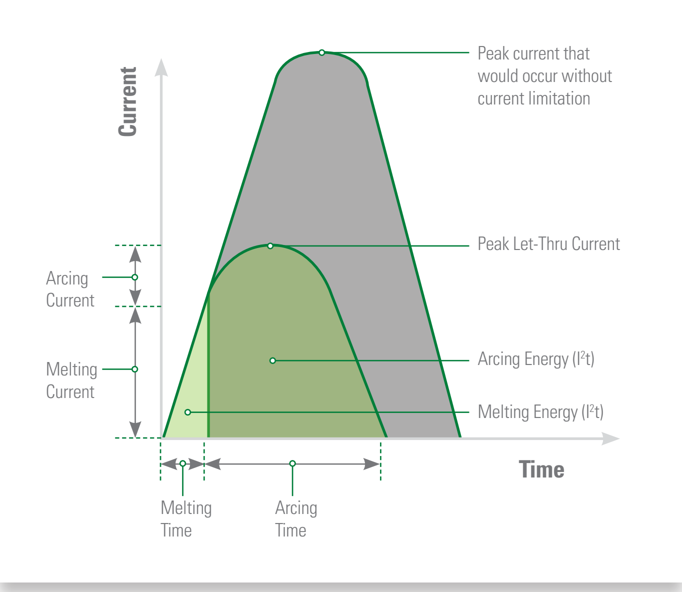
A pulse of current is applied to the fuse, and a time measurement is taken for melting to occur. If melting does not occur within a short duration of about 8 milliseconds (0.008 seconds) or less (or 1 millisecond [0.001 seconds] or less for thin-film fuses), the level of pulse current is increased. This test procedure is repeated until melting of the fuse element is confined to within about 8 milliseconds (or 1 millisecond for thin-film fuses).

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^2t) 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^2t. When the melting phase reaches completion, an electrical arc occurs immediately prior to the "opening" of the fuse element.

Clearing I^2t = Melting I^2t + Arcing I^2t

The nominal I^2t values given in this publication pertain to the melting phase portion of the "clearing" or "opening." Alternatively, the time can be measured at 10 times the rated current, and the I^2t value is calculated as described above.

Current-Limiting Effect of Fuses



Fuse Selection Checklist

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.

Selection Factors

Many of the factors involved with fuse selection are listed below. For additional assistance with choosing fuses appropriate to your requirements, contact your Littelfuse products representative.

1. Normal Operating Current

The current rating of a fuse is typically derated 25% for operation at 25 ºC to avoid nuisance opening. For example, a fuse with a current rating of 10 A is not usually recommended for operation at more than 7.5 A in a 25 ºC ambient. For additional details, see Rerating in the previous section and Ambient Temperature below.

2. Application Voltage

The voltage rating of the fuse must be equal to or greater than the available circuit voltage. For exceptions, see Voltage Rating.

3. Ambient Temperature

The current-carrying capacity tests of fuses are performed at 25 ºC 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. Conversely, operating at a lower temperature will prolong fuse life. A fuse also runs hotter as the normal operating current approaches or exceeds the current rating of the selected fuse. Practical experience indicates fuses at room temperature should last indefinitely if operated at no more than 75% of nominal current rating.

Ambient temperature effects are in addition to the normal rerating. Example: Given a normal operating current of 1.5 A in an application using a traditional Slo-Blo® fuse at room temperature, then:

$$\textbf{Fuse Nominal Current Rating} = \frac{\textbf{Normal Operating Current}}{\textbf{0.75}}$$

- or -

$$\frac{\textbf{1.5 amperes}}{\textbf{0.75}} = \textbf{2.0 A Fuse (at 25 °C)}$$

Similarly, if that same fuse were operated at a very high ambient temperature of 75 °C, additional derating would be necessary. Curve A (traditional Slo-Blo® fuse) of that ambient temperature chart shows the maximum operating "Percent of Rating" at 75 °C to be 80%, in which case:

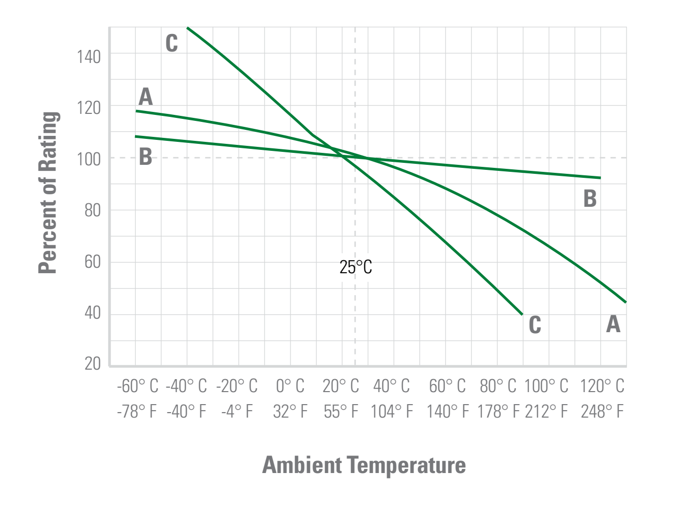
$$\textbf{Fuse Nominal Current Rating} = \frac{\textbf{Normal Operating Current}}{\textbf{0.75 x Percent of Rating}}$$

- or -

$$\frac{\textbf{1.5 amperes}}{\textbf{0.75 x 0.80}} = \textbf{2.5 A Fuse (at 75 °C)}$$

The **Temperature Rerating Curves** chart shows typical ambient temperature effects on the current-carrying capacity of Littelfuse products. For specific rerating information, consult the product data sheet at Littelfuse.com or contact a Littelfuse representative.

Temperature Rerating Curves



Curve A: Thin-Film Fuses and 313 Series (.010 to .150 A)

Curve B: FLAT-PAK®, TeleLink®, Nano²®, PICO®, Blade Terminal, and other leaded and cartridge fuses

Curve C: PolySwitch PPTC

4. 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 (TCC) 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.

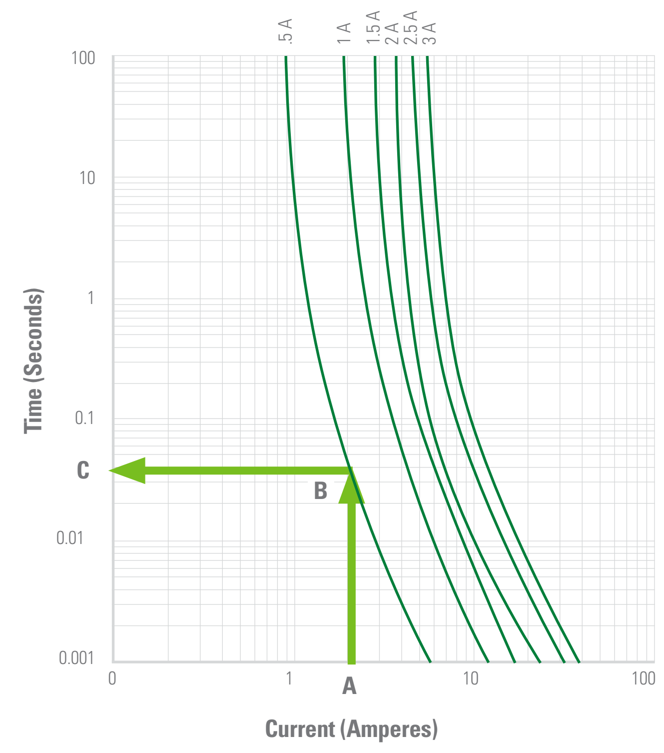
The TCC is a graphical representation, or performance plot, of the fuse's virtual pre-arcing (melting) time at any given prospective (overload) current. It is generated based on standard test conditions and at an ambient temperature range of 20 °C to 25 °C.

A TCC represents the inverse time-current relation characteristic of fuses, illustrating how the pre-arcing (melting) time of a fuse decreases with the increase in prospective (overload) current. A TCC is used to determine a fuse's melting time for a given (overload) current and to select the proper fuse rating for an application.

The x-axis of a TCC represents the current in amperes. The y-axis denotes the virtual pre-arcing (melting) time for the fuse. This is the time span from initiation of an overcurrent condition to when the instant arcing begins inside the fuse. Each curve represents a particular fuse rating within a family or series of fuses.

To determine the melting time for a fuse, start by locating the (overload) current on the x-axis (reference point A) as shown in the Time/Current Curve Example graph. Extend a line from point A upward until it intersects the fuse TC curve at point B. Then move to the left to identify the corresponding value on the y-axis (referenced as point C), which represents the fuse's pre-arcing (melting) time.

Time/Current Curve Example



5. Maximum Fault Current

The interrupting rating of a fuse must meet or exceed the maximum fault current of the circuit.

6. 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^2t rating for the fuse. Application testing is recommended to establish the ability of the fuse design to withstand the pulse conditions.

Nominal melting I^2t is a measure of the energy required to melt the fusing element and is expressed as ampere squared seconds (A^2 s). This nominal melting I^2t, 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^2t for each. This I^2t 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^2t design approach.

This nominal melting I^2t 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^2t 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 critical to the design analysis.

The following example should provide a better understanding of the application of I^2t.

Example:
Select a 125 V, very fast-acting PICO^{2}® fuse that is capable of withstanding 100,000 pulses of current (I) of the pulse waveform shown in the **Common Pulse Waveforms** figure.

The normal operating current is 0.75 A at an ambient temperature of 25 °C.

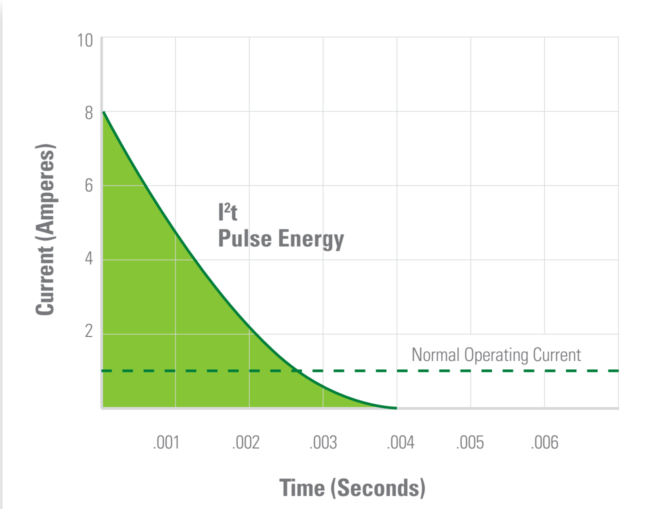
Step 1–Refer to the Pulse energy model (I^2t) and select the appropriate pulse waveform, which is waveform (E) in this example. Place the applicable value for peak pulse current (i_p) and time (t) into the corresponding formula for waveshape (E), and calculate the result, as shown:

$$I^2t = (1/5)\, i_p^2\, t$$

$$= (1/5)\times 8^2 \times 0.004 = 0.0512\ A^2\ s$$

This value is referred to as the "pulse I^2t."

Common Pulse Waveforms

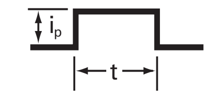
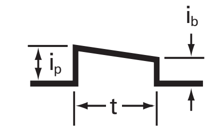
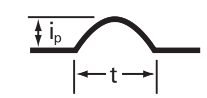
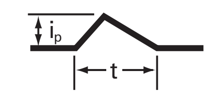
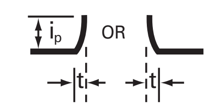
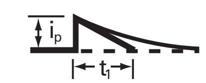


Step 2–Determine the required value of Nominal Melting I^2t by referring to the Pulse Cycle Withstand Chart. A value of 22% is shown for 100,000 occurrences of the Pulse I^2t calculated in Step 1. This Pulse I^2t is converted to its required value of Nominal Melting I^2t as follows:

Nom. Melt I^2t = Pulse I^2t/0.22

$0.0512/0.22 = 0.2327\ A^2$ Sec.

Pulse Energy Model (I^2t)

	Waveshapes	Formulas
A		$i = k$ $I^2t = i_p^2\, t$
B		$i = i_p - kt$ $I^2t = (1/3)(i_p^2 + i_p i_b + i_b^2)\, t$
C		$i = i_p \sin t$ $I^2t = (1/2)\, i_p^2\, t$
D		$I^2t = (1/3)\, i_p^2\, t$
E		$i = kt^2$ OR $i = i_p(1-kt)^2$ $I^2t = (1/5)\, i_p^2\, t$
F		$i = i_p e^{-kt}$ $I^2t \cong (1/2)\, i_p^2\, t^1$

Step 3–Examine the I^2t rating data for the PICO^{2}®, 125 V, very fast-acting fuse. The part number 251001, 1-ampere design is rated at 0.256 A^2 Sec., which is the minimum fuse rating that will accommodate the 0.2327 A^2 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.

7. Physical Size Limitations

Refer to the product dimensions presented in current Littelfuse product datasheets for specific information.

8. Agency Approvals

For background information about common standards, consult the Standards and Certifications section of this guide. For specific agency approval information for each Littelfuse product, refer to the product datasheets, which can be found on Littelfuse.com. As agency approvals and standards may change, rely on the information presented on Littelfuse.com as current information.

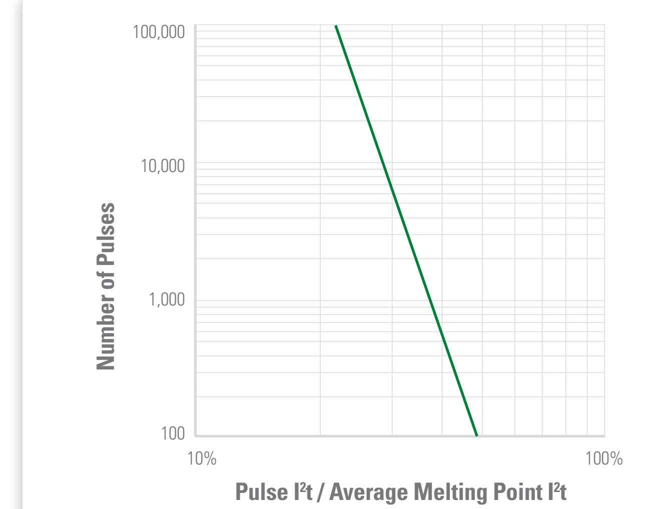
9. Fuse Features

Consult the specific product features presented on our website at Littelfuse.com. For additional information and support, contact your Littelfuse product representative.

10. Fuseholder Rerating

For information about the range of Littelfuse fuseholders and specific features and characteristics, consult with a Littelfuse products representative or visit Littelfuse.com.

Pulse Cycle Withstand Capability



100,000 Pulses	Pulse I^2t = 22% of Nominal Melting I^2t
10,000 Pulses	Pulse I^2t = 29% of Nominal Melting I^2t
1,000 Pulses	Pulse I^2t = 38% of Nominal Melting I^2t
100 Pulses	Pulse I^2t = 48% of Nominal Melting I^2t

Note: Adequate time (10 seconds) must exist between pulse events to allow heat from the previous event to dissipate.

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 and shock hazard. 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).

11. Testing

The factors presented here 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.

Standards and Certifications

Littelfuse partners with third-party Certification Bodies (CBs) and Nationally Recognized Testing Laboratories (NRTLs) to offer the market safe and reliable products that will perform as intended and operate in a safe manner. Many end-product standards require fuses that comply with industry safety and performance standards, and a large number of our fuses have obtained such compliance. The resultant certification by third-party CBs and NRTLs are readily available and are easily accessible on Littelfuse.com.

Depending on the end-market, there are different standards that fuses must conform to and various certification schemes they may achieve. It is important to understand the differences between the standards and the different certification schemes that fuses adhere to.

The table below lists the most widely used fuse standards along with possible certification schemes they meet:

Fuse Certification Schemes

End Market	Standards	Possible Certification Scheme
North America (Canada, USA, and Mexico)	CSA C22.2 No. 248 .1 UL 248-1 NMX-J009/248/1-ANCE CSA C22.2 No. 248.14 UL 248-14 NMX-J-009/248/14-2000-ANCE	CSA Component Acceptance CSA Certification UL Listing UL Recognition
Europe	EN 60127 Series	TUV Approval VDE Approval SEMKO/ Intertek Approval BSI Approval
Japan	J60127 Series or Appendix 3 of METI	DENAN Conformity Assessment
China	GB/T 9364 Series	CCC Certification CQC Certification
South Korea	K60127 Series	KC Safety Certificate
International	IEC 60127 Series	IEC CB Scheme

It is worth noting that fuses in this document are referred to as "Supplemental Fuses" in the North American market (i.e., CSA/ANCE/UL 248 series), while they are referred to as "Miniature Fuse-links" in other markets (International, Europe, China, etc.).

North America

For Canada, the US, and Mexico, the trinational standard CSA/ANCE/UL 248 series is used to assess compliance. This series consists of a base set of general requirements (CSA/ANCE/UL 248-1) as well as specific fuse-type requirements (CSA/ANCE/UL 248-2, -3…-18). For supplemental fuses (regardless of fuse size or shape), CSA/ANCE/UL 248-1 and -14 are used to verify conformity. CSA/ANCE/UL 248-14 covers fuses that have nominal current ratings of less than 60 A. Littelfuse utilizes UL Solutions and CSA Group to obtain North American certification, and both NRTLs offer two different certification schemes:

UL Listing/CSA Certification

A UL Listed/CSA Certified fuse meets all the requirements of the standards without any deviations. For example, the standard requires 135% and 200% overload gates, and therefore a fuse must meet these gates for it to be a UL Listed/CSA Certified fuse.

A UL Listed/CSA Certified fuse must meet the following criteria:

- **Current-Carrying Capacity:** the fuse shall carry 100% of its rated current (referred to as non-fusing current, Inf) until temperature stabilization, and the fuse may not open.
- **Verification of Temperature Rise:** in room ambient temperature, a fuse shall carry 100% of its rated current until temperature stabilization. The measured temperature of the fuse contacts cannot exceed 75 °C.
- **Verification of Overload Operation:** 135% (60 minutes maximum clearing time) and 200 % (maximum clearing time of 2 minutes for 0-30 A fuses and 4 minutes for 31-60 A.
- **Verification of Operation at Rated Voltage:** the interrupting rating must be 10,000 A at 125 V_{AC}. Fuses might have a dual rating of 10,000 A at 125 V_{AC} and a lower interrupting rating at 250 V_{AC} as found in the table below:

Minimum IR for Dual-Rated Fuses

Nominal Current Rating (A)	Minimum Interrupting Rating (A)
0–1	35
1.1–3.5	100
3.6–10	200
10.1–15	750
15.1–30	1500

UL Recognition/CSA Component Acceptance

A UL Recognized/CSA Component fuse also meets the requirements of the standards but with slight parametrical deviations. In general, these programs allow the NRTLs to verify a manufacturer's specifications, and they give fuse manufacturers great flexibility to design fuses that are specific for end-product applications. For example, if an end-product application required an overload gate of 210% along with a breaking capacity of 130 A, then the fuse will be verified by the NRTL to meet this specific overload gate and breaking capacity.

International

The International Electrotechnical Commission (IEC) is an international standards organization that prepares and publishes standards for the electrical and electronics industry. They are also responsible for various conformity assessment schemes, such as the IECEE (CB Scheme), IECEx, IECQ, and IECRE. The IEC standards appliable to supplemental (miniature) fuses (fuse-links) are under the IEC 60127 series.

The IEC 60127 series of standards is divided into parts, as shown in the following table:

IEC 60127 Parts

Standard	Name	Types of Fuses
IEC 60127-1	Definitions for miniature fuses and general requirements for miniature fuse-links	Applicable to all that fall within the IEC 60127 series
IEC 60127-2	Cartridge fuse-links	5x20mm, 6.3x10mm cartridge fuses
IEC 60127-3	Sub-miniature fuse-links	TR/TE and PICO fuses
IEC 60127-4	Universal modular fuse-links (UMF)	Through-hole and surface mount fuses
IEC 60127-7	Miniature fuse-links for special applications	All

As shown in the preceding table, IEC 60127-1 contains the general requirements that are applicable to all fuses covered in the subsequent parts. Furthermore, subsequent parts contain Standard Sheets (SS) that give specific requirements for applicable fuses. This standard series covers fuses with nominal current ratings up to 10 A, except for IEC 60127-7, which covers fuses with nominal current ratings up to 20 A.

Fuses that comply with the IEC 60127 series of standards meet the following tests:

- **Fuse-Link Temperature:** a step-test* where an initial current (as found in the SS) is applied for 15 minutes and then increased by 10% for another 15 minutes until the fuse opens. The maximum temperature rise shall meet the requirement in the subsequent parts, as shown in the following table:

IEC 60127 Maximum Temperature Rise

Standard	SS	Max. Temp. Rise
IEC 60127-2	All	150° C on terminations
IEC 60127-3	1, 2	150° C on terminations
	3, 4	135° C on plastic bodies
IEC 60127-4	1	75° C for 6.3 A and below 95° C for above 6.3 A
	2	95° C
IEC 60127-7	1	Method I–150° C for terminations and 135° C for plastic bodies Method II–95° C for terminations

Note: IEC 60127-7 allows two methods: Method I is a step-test and Method II is similar to CSA/ANCE/UL 248-14.
Note: IEC 60127-4, the temperature is measured during the final 5 minutes of the endurance test at 1.25 in.

- **Time/Current Characteristics (a.k.a. Overload Gates):** IEC 60127 series assigns time/current (T/C) terms to differentiate the time duration for a fuse to open under a specified overload condition:

IEC 60127 Time/Current Terms

Standard	SS	T/C Term
IEC 60127-2	1, 2, 4, 7, 9	Quick-acting
	3, 5, 6, 8, 10	Time-lag
IEC 60127-3	1, 2, 3	Quick-acting
	4	Time-lag
IEC 60127-4	1, 2	Very quick acting Quick acting Time-lag Long Time-lag
IEC 60127-7	1	None as it is per manufacturer specification

For example, comparing the 1000% overload gate of an IEC 60127-2 SS 1 (quick-acting) vs IEC 60127-2 SS 5 (time-lag), the clearing time is 0.02 s versus 0.15 s, respectively. It is clear that the SS 1 fuse will clear the overload much quicker than the SS 5 fuse.

The overload gates depend on the subsequent IEC 60127 parts, as shown in the following table:

IEC 60127 Overload Gates

Standard	SS	% of Nominal Current Rating
IEC 60127-2	All	210, 275, 400, and 1000
IEC 60127-3	All	210, 275, 400, and 1000
IEC 60127-4	All	125, 200, 1000
IEC 60127-7	All	200/210, 275, 400, 1000

Note: IEC 60127-7, 275% and 400% are optional

To determine the actual time duration, consult the IEC 60127 standards or the fuse datasheets.

- Breaking Capacity: IEC 60127 series also assigns terms for breaking capacity. These are shown in the following table:

IEC 60127 Breaking Capacity Terms

Standard	SS	Breaking Capacity
IEC 60127-2	2, 3, 4	Low
	6, 7, 8	Enhanced
	1, 5, 9 ,10	High
IEC 60127-3	1, 2, 3, 4	Low
IEC 60127-4	1, 2	Low
		Intermediate
		High
IEC 60127-7	1	None as it is per manufacturer specification

The actual breaking capacity amperage depends on the subsequent IEC 60127 parts and SS, as shown in the following table:

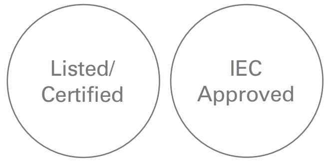
IEC 60127 Breaking Capacity Amperage

Standard	SS	Breaking Capacity
IEC 60127-2	2, 3, 4	35 A or 10xIn
	6	150 A
	7, 8	200 A
	1, 5, 9 ,10	1500 A
IEC 60127-3	1, 2	50 A
	3, 4	35 A or 10xIn
IEC 60127-4	1, 2	100 A, 500 A, 1500 A
IEC 60127-7	All	None as it is per manufacturer specification

- **Endurance Test:** a 100-cycle test where a test current is applied for 1 hour and then off for 15 minutes. This is then followed by 1 hour of another current where voltage drop and power dissipation are measured.

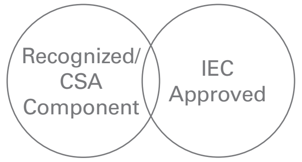
North American Fuses vs IEC Fuse-links

It is important to note that a UL Listed/CSA Certified fuse cannot meet the requirements of the IEC 60127 series. This is mainly due to the endurance test requirement of the IEC 60127 series. For example, the Endurance Test for IEC 60127-2 SS 1 requires that the fuse cannot open at 150% of In*, while UL Listed/CSA Certified fuses must open within 1 hour of 135% of In*.



***Note:** In is the nominal current rating of the fuse

However, since Recognized/CSA Component fuses can meet manufacturer specifications, they can be both UL Recognized/CSA Component and meet IEC 60127 series standards.



Europe

Fuses intended for the European market must comply with the applicable European directives and their safety objectives. The two main directives they must comply with the Low Voltage Directive (LVD) and the Restriction of Hazardous Substances (RoHS) Directive. Compliance with the LVD enables the manufacturer to apply the CE mark to fuses as a self-declaration that the products meet applicable European directives. The safety objectives of the LVD are presumed to be addressed if a fuse meets the harmonized standards of the EN 60127 series. The EN 60127 series is based on the IEC 60127 series (see the International section above) with National Differences. Compliance with the LVD does not require certification from a Certification Body, but many of our fuses do have third-party certification to the EN 60127 series of standards. This certification is primarily done to account for end-product standards requiring fuses to be compliant with their basic component standard.

Many Certification Bodies can issue certification to the EN 60127 series, as they all use the same set of standards. Littelfuse primarily obtains certifications for the European market from TUV Rheinland, VDE, BSI, or Semko/Intertek.

As a result of Brexit (the United Kingdom's withdrawal from the European Union) in 2020, the United Kingdom adopted a similar product compliance approach as the European Union. Fuses for the UK market must comply with the Electrical Equipment (Safety) Regulations (similar to LVD) and Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations (similar to RoHS). Fuses meeting the applicable requirements for the UK market are affixed with the UKCA mark.

Japan

The Japanese Ministry of Economy, Trade and Industry (METI) released the Electrical Appliance and Materials Safety Act (DENAN Law) to regulate electrical appliances and materials to prevent potential hazards. The law allows fuses to either comply with the requirements of the J60127 series standards (IEC 60127–based standards) or Appendix 3 of the DENAN Law.

The J60127 series is almost identical to the IEC 60127 series, while Appendix 3 requirements are similar to those of CSA/ANCE/UL 248-1 and -14 standards. For example, Appendix 3 requires overload gates of 135% and 200% of nominal current rating.

There are many different certification organizations that provide compliance to the Japanese market, since the same set of standards is applied. Littelfuse utilizes UL Solutions and Japan Electrical Safety and Environment Technology Laboratories (JET) for Japanese market certifications.

China

The Chinese market also based its national fuse standards on the IEC 60127 series standards. The following table shows the correlation between the two sets of standards:

Chinese Standards Comparison to IEC Standards

Chinese Standards	IEC Standards
GB/T 9364.1	IEC 60127-1
GB/T 9364.2	IEC 60127-2
GB/T 9364.3	IEC 60127-3
GB/T 9364.4	IEC 60127-4
GB/T 9364.7	IEC 60127-7

If a fuse meets the requirements of the GB/T standard, then the Chinese Compulsory Certification (CCC) mark is used. A voluntary CQC mark can also be used for fuses if certification is needed.

Littelfuse utilizes China Quality Certification Center to obtain the necessary Chinese certifications.

South Korea

The K60127 series of standards is the adopted national standard in South Korea. They are IEC-based standards and follow the same requirements. Fuses suitable for the South Korean market are marked with the KC mark (see marks below).

Littelfuse obtains South Korean certification from Korea Testing Laboratory.

Fuseholders

Certification of fuseholders is also market specific. In North America, CSA//ANCE/UL 4248-1 is the standard that fuseholders must comply with, while the rest of the world uses IEC 60127-6 (and various National Differences).

Marks

The following table displays the certification schemes and programs that apply to Littelfuse products and the corresponding marks:

Certification Marks

Certification Scheme/Program	Mark
UL Listed for the US Market	
UL Listed for the US and Canada Market	
Recognized for the US Market	
Recognized for the US and Canada Market	
CSA Certified for the Canada Market	
CSA Component Acceptance for the Canada Market	
TUV Rheindland for the European Market	
VDE Component for the European Market	
VDE for the European Market	
BSI for the UK and European Market	
Semko/Intertek for the European Market	
Japan Market	
China Market—Compulsory	
China Market—Voluntary	

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About Littelfuse

Littelfuse is a trusted partner to engineers worldwide who seek our technical expertise to accurately conduct and analyze test results. Our global vision, team, and leadership collectively provide the strategic foundation to deliver innovations that help bolster businesses and align with global megatrends.

Littelfuse offers leading technologies in circuit protection, power control, and sensing. We continue to expand our broad and diverse portfolio of products into adjacent markets, including power semiconductors, heavy-duty switches, and magnetic, optical, electromechanical, and temperature sensors, as well as other products that provide safe control and distribution of electrical power.

Littelfuse offers a wide variety of product technologies.

Overcurrent Protection
- Fuses
- Resettable Positive Temperature Coefficient (PPTC) Devices

Overvoltage Suppression
- Gas Discharge Tubes (GDTs)
- TVS Diode Arrays
- PLED Series Open LED Protectors
- SIDACtor® Protection Thyristors
- PulseGuard® ESD Suppressors
- Switching Thyristors
- TVS Diodes
- Varistors
- Power Control
- TRIAC Thyristors

Power Semiconductors
- Bipolar Devices
- IGBTs
- MOSFETs
- Switching Thyristors
- Silicon Carbide Technology
- Power Semiconductors and ICs
- Discrete and Module Solutions
- Bare Die Devices
- Power Control
- TRIAC Thyristors
- Fully Engineered Subsystems

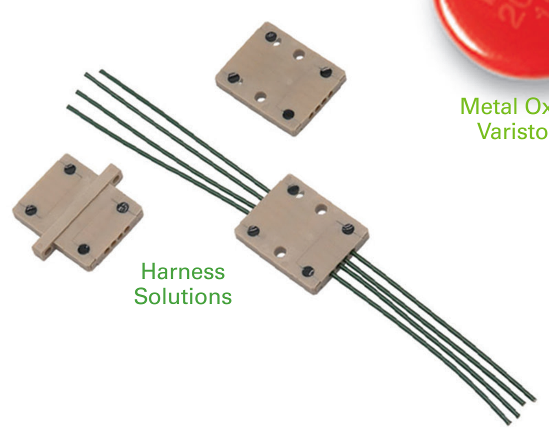
Integrated Circuits and Solid-State Relays
- High-Voltage ICs
- Solid-State Relays
- Gate Drivers

Magnetic Sensing
- Reed Switches
- Reed Sensors
- Reed Relays
- Hall Effect Sensors
- Magnetic Actuators

Temperature Sensing
- Thermistors
- RTDs
- Digital Temperature Indicators

Electromechanical Switches
- Tactile Switches
- Pushbutton Switches
- Keyswitch Switches
- Snap-Acting Switches
- Slide Switches
- Dip Switches
- Detect Switches
- Navigation Switches
- Toggle Switches
- Rocker Switches
- Switchlock Switches
- Rotary Switches

High Reliability Connectors
- Micro-D Connectors
- D-Sub Connectors
- Wire to Wire connectors
- Harness Solutions

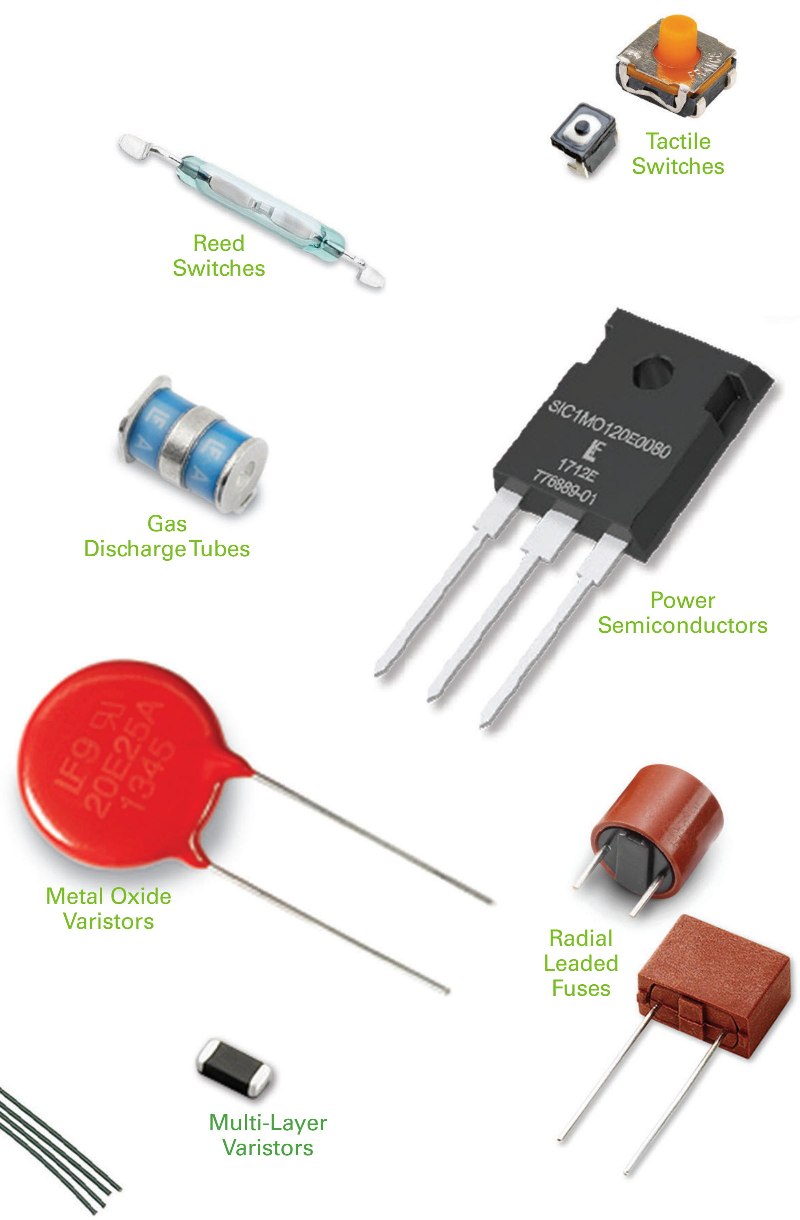


Global Footprint

At Littelfuse, our mission is to develop innovative circuit protection, power control, and sensing solutions that meet our customers' unique needs. This customer-focused philosophy has helped us become the top circuit protection brand in the world.

Our industry-leading product portfolio includes reliable circuit protection, power control, and sensing products that are designed for a variety of markets and applications. We have assembled unparalleled expertise and developed a global footprint that puts our facilities close to our customers and target markets. As our global manufacturing and R&D teams objectively recommend the best circuit protection, power control, or sensing solution for each customer application, they form partnerships that will lead to the development of the next generation of advanced products.

Littelfuse provides:
- Application Expertise
- Global Support
- Operational Excellence
- Technology Innovation
- Collaboration
- Customer Focus



Additional Resources

Circuit Protection Products Selection Guide
This guide provides a summary of key circuit protection consideration factors, descriptions of the technologies Littelfuse offers, and product selection tables. It is designed to help you quickly find a protection solution appropriate to your application.
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Sensing Products Selection Guide
This guide provides an overview of magnetic and temperature-sensing technologies, key consideration factors, descriptions of technologies Littelfuse offers, and product selection tables to help you quickly find the sensing solution appropriate for your application.
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Power Semiconductor Selection Guide
This selection guide offers a comprehensive look at the breadth and depth of the IXYS: A Littelfuse Technology power semiconductor and control IC portfolio.
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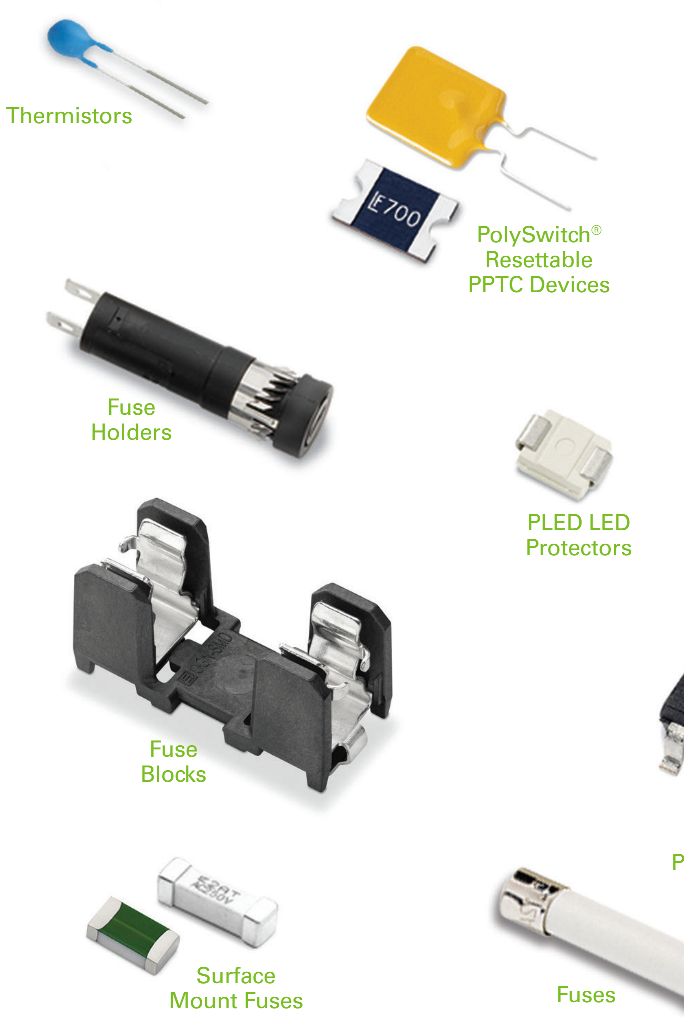

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Littelfuse engineers are a phone call away to help identify potential issues and provide product recommendations to solve problems.

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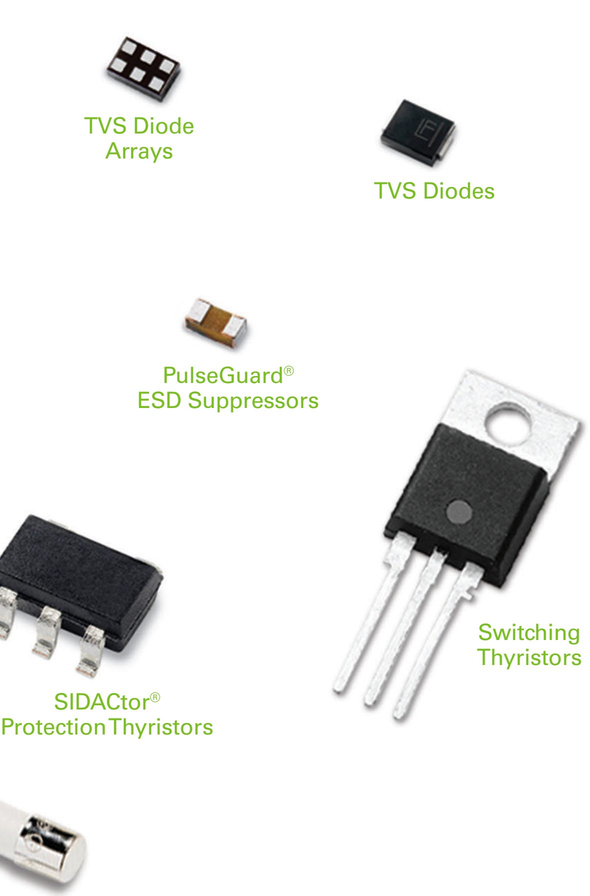
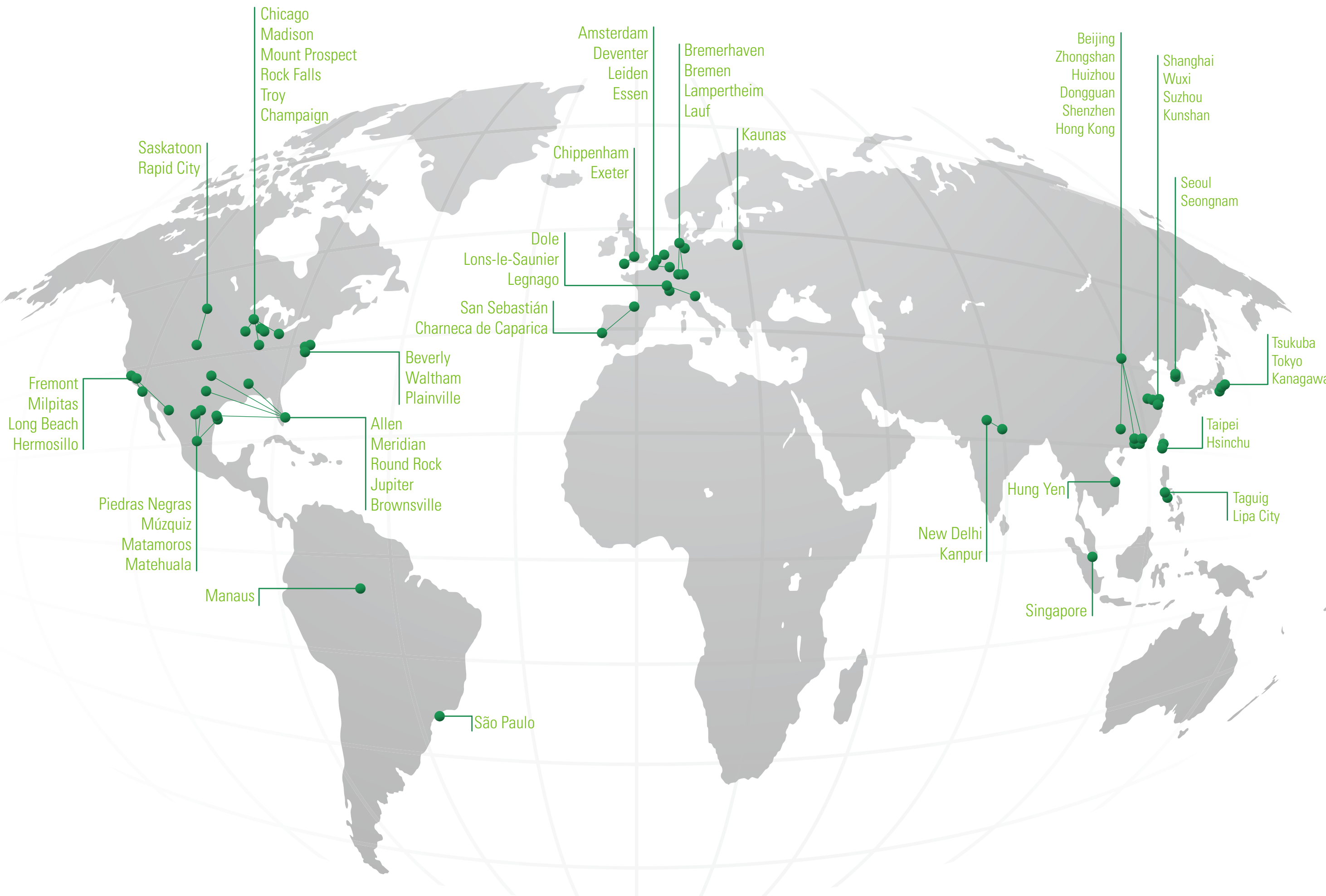


LOCAL RESOURCES FOR A **GLOBAL** MARKET



Littelfuse products are certified to many standards around the world. To check certifications on specific products, refer to the product datasheet on Littelfuse.com.

Littelfuse

Expertise Applied | Answers Delivered