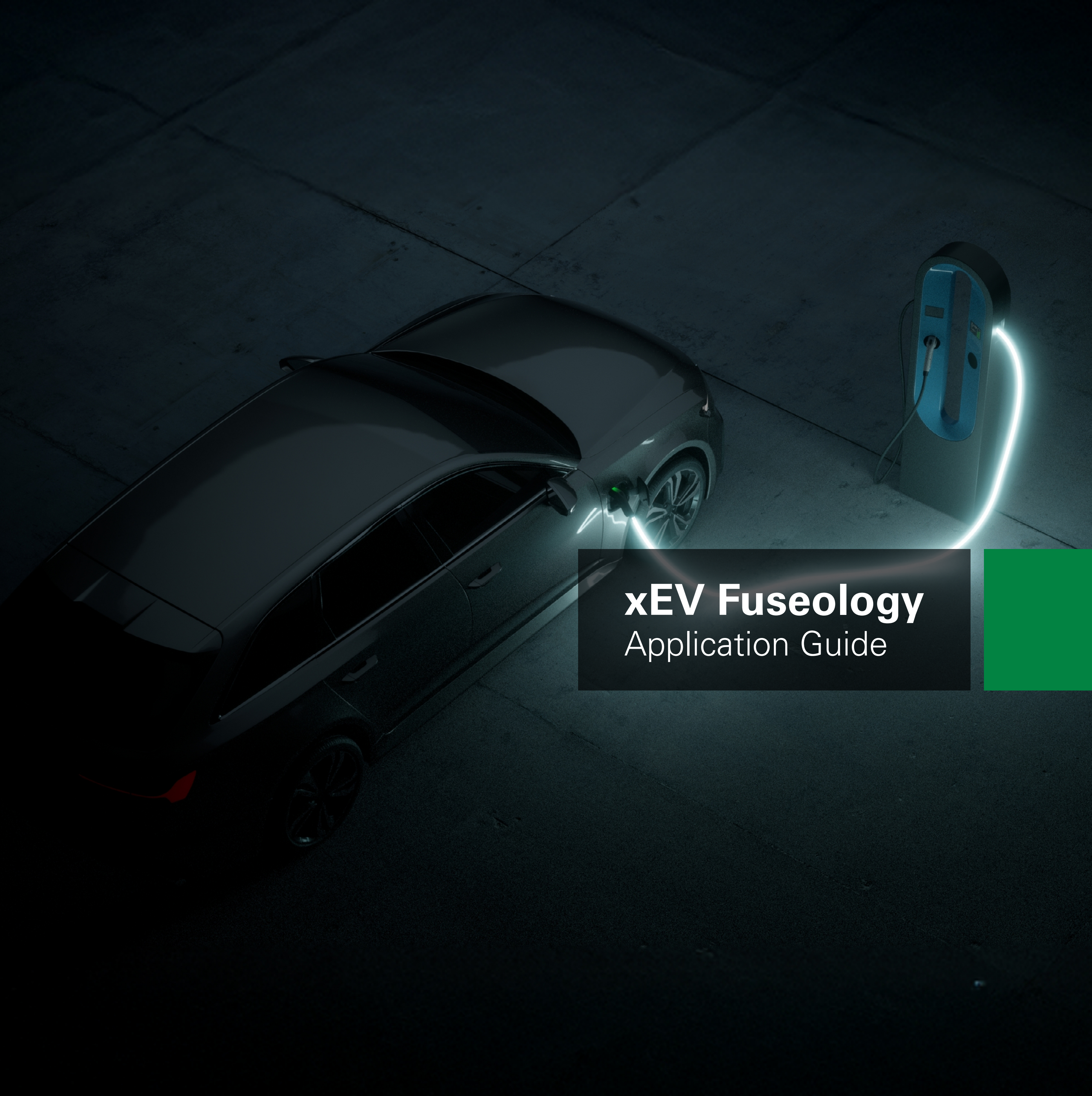
Expertise Applied | Answers Delivered



xEV Fuseology
Application Guide

www.littelfuse.com

Contents

1. Introduction

From it’s very foundation, Littelfuse has been a leader in the protection of automotive electrical systems. From glass tube fuses that protected the automobiles of yesteryear, to the modern blade style plug in fuses that we pioneered, we have been around to provide an innovative edge to the industry. As the automotive world evolves to higher voltage hybrid and purely electric vehicles, Littelfuse is dedicated to producing the products and services necessary to create a safe environment for consumers.

1.1 About This Guide

This guide has been created to broaden awareness for the sizing characteristics and usage of high voltage fuses. By itself, it is not intended to be a single point of reference for the deployment of circuit protection. For formal guidance, we strongly recommend reaching out to our global team of application engineers that are ready to serve you. They possess the knowledge and tools to assist with your application, or can offer customized training sessions for your team on our extensive portfolio.

1.1.1 Applications in EVs

In general, fuses are used to protect circuit components from the electrothermal damage caused by over current conditions. Circuits onboard vehicles contain a power source (such as a battery or onboard charger), the conductors necessary for power distribution, the devices required to operate vehicle systems, and often times active circuit disconnects (such as contactors or pyroswitches). Littelfuse has offerings to protect both AC and DC circuits that can be reliably coordinated with any combination of the above devices.

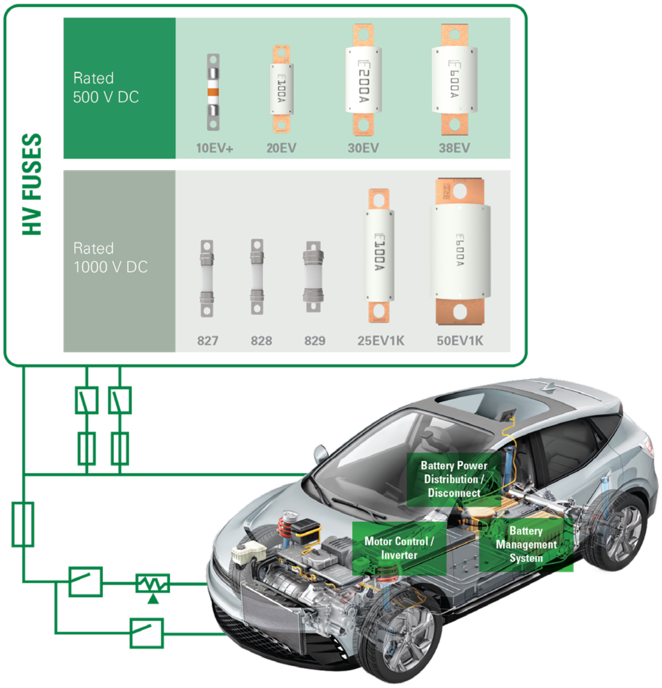


Figure 1: Littelfuse customized automotive electronics solutions.

1.2 Fuse Construction

High voltage automotive fuses come in a variety of styles and terminations. More information on these can be found in section 1.2.2 below. A similar set of components can be found in all high voltage fuses: namely a conductive element and terminations, arc quenching filler, and a collection of housing components. These include a round tube often referred to as a body, and some form of end cap to complete the enclosure and secure the sand filler.

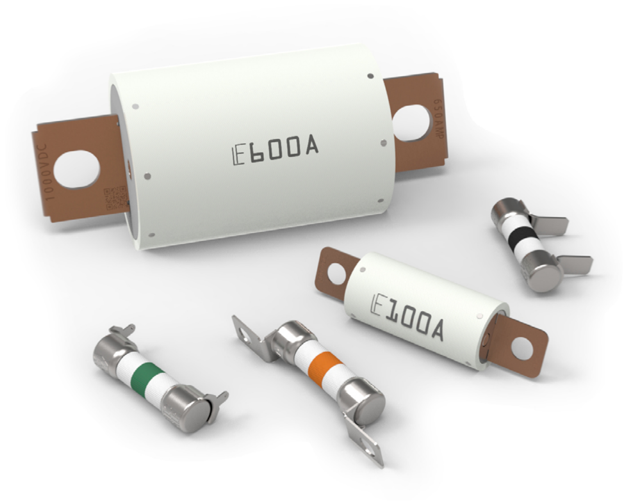


Figure 2 : Littelfuse automotive solutions for EVs.

1.2.1 Automotive vs Industrial Fuses

Littelfuse high voltage automotive fuses are designed from the ground up to meet the stringent automotive requirements. Industrial fuses, though offering the same voltage and current requirements, are designed to standards that do not guarentee their safe or reliable operation onboard vehicles. We do not recommend the useage of industrial fuses in automotive applications.

1.2.2 Fuse Styles

Our fuse offerings tend to be split into two categories dependent on their rated current level. Lower current fuses tend to have a cartridge as their standard package. These fuses then have a variety of terminations attached to their caps, providing a platform for many options to suit your needs. Common choices for terminations are PCB mounts, bolt down terminals, or inline barrels. Higher current fuses tend to have blades extending from the part, suitable for bolting to conductors. Our portfolio of offerings allows us to create custom terminations, or to provide a multitude of terminal plating options to suit your applications needs.

1.2.3 General Size Guidelines

Changes in rated current or rated voltage require alterations to the package size to maintain thermal characteristics, as well as the fuse's arc quenching ability. When designing systems, it is important to keep in mind that higher rated current fuses will have larger diameters than lower ratings. As voltage increases, additional length is needed for arc suppression.

1.3 Fuse Operation

Similar to their low voltage counterparts, high voltage fuses contain an element with restrictions (called bridges) stamped in to create weak points. As the voltage increases, multiple sets of bridges are stamped to create a series of weak points along the element surface.

Fusible elements are specially designed to carry a specified amount of current continuously without opening. This is referred to as the rated current of the fuse. When electric current flows through these element bridges or restrictions, heat is generated. While there is a balance in heat transfer (where the heat generated equals the heat dissipated) the fuse element(s) continue to carry the current as intended.

When there is an imbalance in heat transfer due to overcurrent conditions, such as an overload or short-circuit occurrence, the amount of heat generated is greater than the heat dissipated. This causes a significant rise in temperature at the fusible element's bridges.

When this rise in temperature reaches the melting point of the fusible element (1,984°F / 1,085°C for copper or 1,763°F / 962°C for silver), the element bridges start to melt and break, resulting in an interruption of current flow through the fuse to the circuit.

Between the broken halves, electric arcs form, driven by the applied energy from the vehicle battery or other source of potential. These arcs result in extreme temperatures and pressures inside the assembly. High voltage fuses are designed to contain this event through the materials chosen for the fuse assembly, as well as a quartz silica sand filler. The filler cools the arc and absorbs energy by undergoing a phase change. In broader terms, the heat from the electric arc pushes the sand to it's melting point. When enough energy has been absorbed to overcome the arc, and it has been extinguished, the liquid sand returns to it's solid form, but this time in a different condition: as fulgerite. This fulgerite contains the coalesced filler, metal particulate from the fuse element, elements from the air around the fuse, and materials from the housing walls.

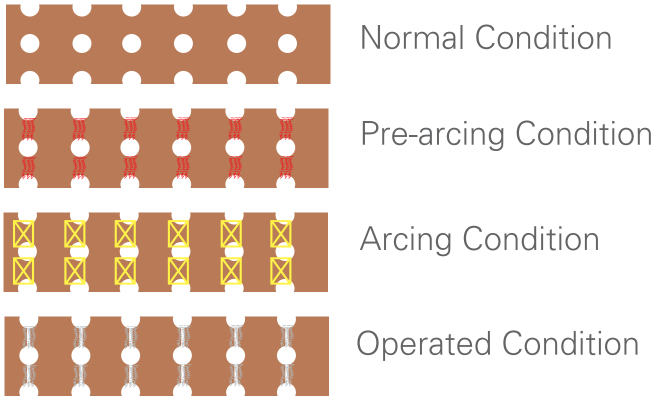


Figure 3: Changes to a fuse element during its operation.

2. Overcurrent Protection Fundamentals

An overcurrent is any current which exceeds the ampere rating of wiring, equipment, or devices under conditions of use. The term "***overcurrent***" includes both overloads and short circuits.

2.1 Overloads

An overload is an overcurrent that is confined to normal current paths. An overload occurs when the current exceeds the value for which the wires or equipment are rated. This can happen when too many devices are connected to the circuit, or when a device connected to the circuit malfunctions in a way that causes it to draw higher than normal current. Overloads are usually in the range of one to six times normal current. Sustained overloads eventually overheat circuit components. Therefore, fuses are designed to open circuits experiencing sustained overloads before damage occurs.

2.2 Short Circuits

A short circuit occurs when electrical current flows outside of its normal path. It occurs when an accident or malfunction creates an unintended path for the electricity to flow from the electrical source (battery or alternator) to ground. This shorter, more direct path to ground bypasses the resistance normally offered by the wiring and devices connected to the circuit. With virtually no resistance left to limit current flow, the current very quickly increases to destructive values. Under such a condition, the generated heat can burn insulation and severely damage equipment unless the circuit is opened by a fuse.

3. Fuse Performance Characteristics

Since overcurrent protection is crucial to safe electrical system operation, fuse selection and application should be carefully considered. When selecting fuses, the following parameters should be evaluated.

3.1 Voltage Rating

The voltage rating, as marked on a fuse, indicates the maximum AC or DC voltage of the circuit for which the fuse is designed to operate safely in the event of an overcurrent. Therefore, the fuse's voltage rating must equal or exceed the available circuit voltage where the fuse will be installed. In situations where the system voltage exceeds the fuse's voltage rating, fuse damage my occur. This situation can exceed the physical abilities of the fuse, which may lead to arcing and sparking until the voltage source is shut off.

3.2 Rated Current

The current rating which is typically printed on the fuse is mainly used to identify the product performance related to the load and overload calculation. Fuse ratings are based on steady state characterization in a laboratory environment. This testing employs standard test fixtures, conductors, and connecting terminals to understand the operational limits of the devices under test. To find the right fuse ratings under given ambient temperature and load conditions, it is mandatory to use the parameters in the successive sections.

3.3 Safe Current Operating Range

Paying close attention to the safe operating range is essential to the reliable operation of high voltage fuses. Massive amounts of heat and pressure are generated during arcing events, these products are designed with the operational limits in sections 3.3.1 and 3.3.2 in mind.

3.3.1 Minimum Breaking Capacity

On the lower end of a high voltage fuse link's operating range is it's minimum breaking capacity. This value is the lowest percentage of it's rated current, or absolute lowest overload current that it is rated to safely open under. Sustained loads between the rated current and this value may cause irrepairable damage to the fuse link. Clean opening of the product is not guarenteed due to the extended thermal load on the part, followed by the high temperatures and pressures of the electric arc. In this region, it is necessary to have an alternative device such as a contactor, pyro or other active switch present. Fuses are often be described by two terms: Full or Parital Range. These terms describe the magnitude of their minimum breaking capacity. Fuses that are made to open under any overload condition and often tested down to 135% of rated current are considered full range, whereas fuses designed to safely operate at 2x I_{RATED} (or potentially even higher) are considered partial range.

3.3.2 Interrupt Rating

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

3.4 Fuse Operating Energy

The operating energy of fuses is described with the term I^2t. This is an expression of the available thermal energy resulting from current flow. Regarding fuses, the term is usually expressed as melting, arcing, and total clearing I^2t. The units for I^2t are expressed in ampere-squared-seconds [A^2s].

3.4.1 Melt I2t

The Melt I^2t is the thermal energy required to melt a specific fuse element. Such values are recorded typically during ***"Interrupt Rating"*** tests and represent average values.

3.4.2 Arc I^2t

The Arc I^2t is the thermal energy passed by a fuse during the arcing time. The magnitude of arcing I^2t is a function of the available voltage and stored energy in the circuit.

3.4.3 Total I^2t

The Total I^2t is th thermal energy through the fuse from overcurrent inception until current is completely interrupted. Total clearing I^2t = (melting I^2t) + (arcing I^2t). I^2t has two important applications to fuse selection. The first is pulse cycle withstand capability and the second is selective coordination. See sections 4.2.3 and 4.3 below for more information.

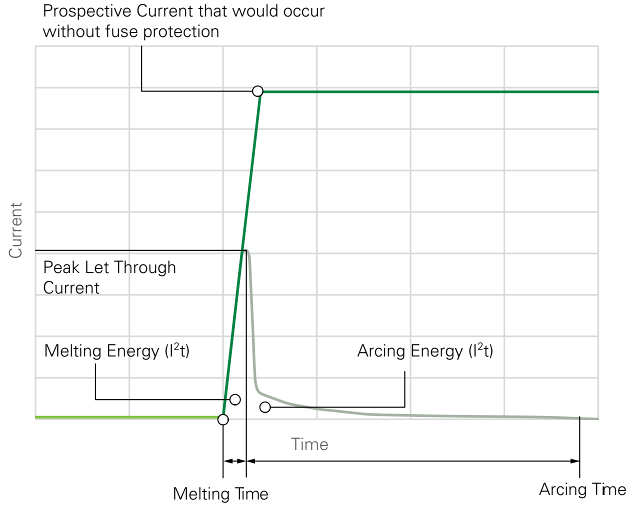


Figure 4: Changes to a fuse element during its operation.

3.5 Time-Current Characteristics

A fuse's time-current characteristics determine how fast it responds to prospective overcurrents. All fuses have inverse time-current characteristics, with opening times decreasing as overcurrent magnitude increases. Time-current characteristics are presented graphically on a logarithmic scale. The times included are for melt only – no arc time is factored into them.

On most high current faults, the fuse tends to limit the magnitude of the situation. For this reason, the current is listed and often referred to as "Prospective Current", or the current that the circuit would see without the fuse present (See Figure 4). Additional resources can be used to determine the peak let through current. Please reach out to our Applications Engineering team for more information.

Time-current curves display the ***average melting*** times and can be referenced as a design aid. They are not considered as part of the fuse specifications. Figure 5 below emphasizes the impact of cold resistance range on TC Curves. Creating a curve that would match every possible fuse resistance would make the curve ineffective. Time Current Curves are typically generated from validation test data, using standard test fixtures, conductors, and connecting terminals in an ambient environment.

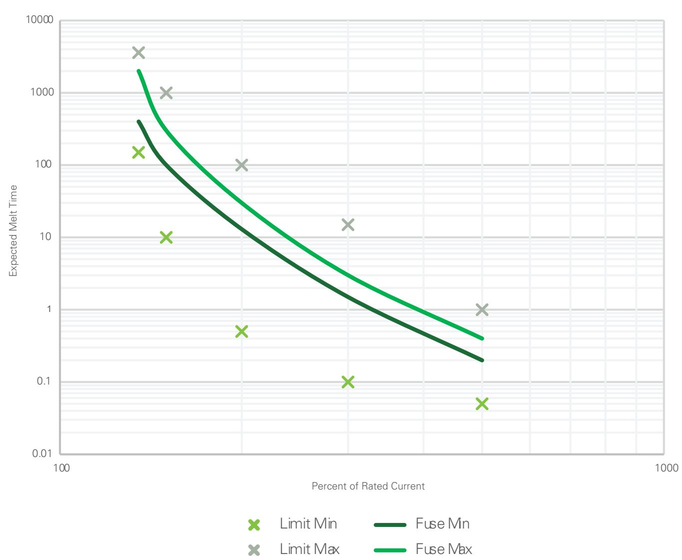


Figure 5: Time Current Characteristic shift based on fuse cold resistance values.

Opening times may shift in real-world applications when the heating situation is different from the standard test conditions. Reducing the cross-section of conductors, lugs, and/or using lower-conductivity materials will augment heat generation in the system, and cause faster blow times. Increases in ambient temperatures will have a similar effect, as seen in Figure 5. Decreased ambients will have the opposite effect, lengthening the time for the fuse to melt. As current magnitude approaches the interrupt rating, the effects of the ambient temperature on fuse melting times decrease. In other words, the fuse enters an adiabatic region when subjected to high current faults. In this area of the TC Curve, the fuse element melts so quickly that outside factors have minimal effects.

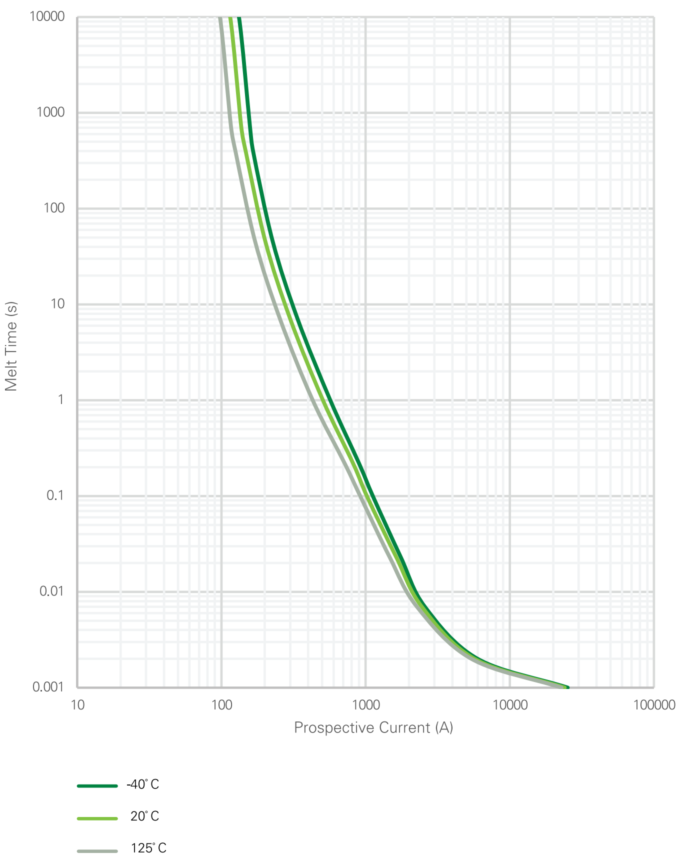


Figure 6: Time Current Characteristic shift based on different ambient temperatures.

The following section describes some examples on how to read the time current curves.

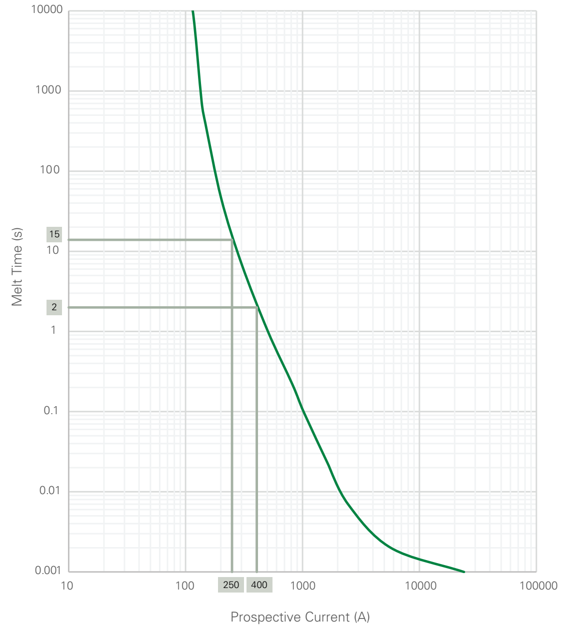


Figure 7: Time Current Characteristic Graph of a 125A Fuse.

Figure 7 displays the Time-Current Curve for a 125A fuse rating, with two outlined overload conditions. Here it can be determined that an overload of **400A** will melt the fuse in about **2** seconds, while an overload of **250A** on the same fuse would take about **15** seconds to blow.

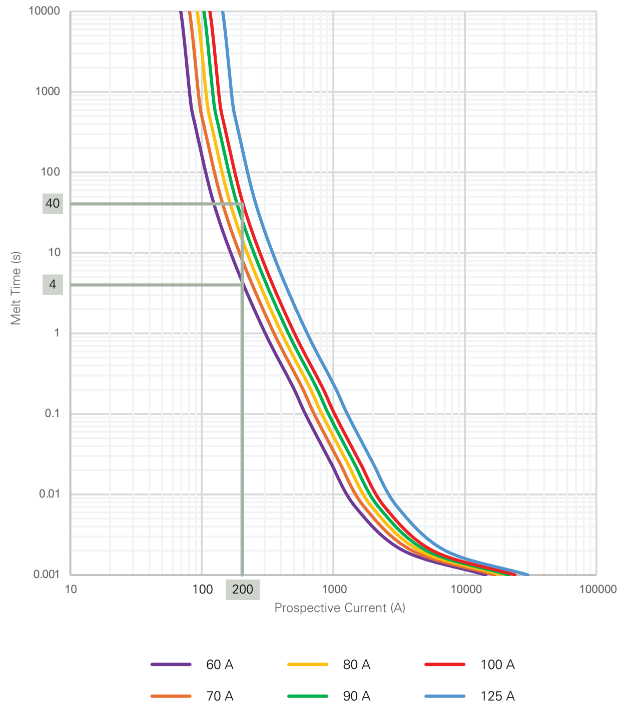


Figure 8: Time Current Characteristic Graphs of a fuse series.

Time-current curves are also used to compare fuses of the same series but of different current ratings. Suppose it was desired to compare the opening times of 60A and 100A fuses at an overload of **200A**. From the curves in Figure 8, one can see that a **60A** fuse opens in about **4** seconds, whereas the **100A** fuse does not open until about **40** seconds subjected to the same magnitude of current.

Note that some TC Curves may contain a dotted region at the top of the curves. This feature clearly displays the melt times below the minimum breaking capacity for accurate coordination with other components. Safe opening is not guaranteed in this region. (See section 3.3.1 above)

Depending on the fuse family and use application, recommended opening time gates are listed in accordance with ISO 8820 or AECQ.

% of Rating	Opening Time Min. / Max. (s)
110	14 400 / -
200	1 / 300
300	0.2 / 30
500	0.05 /1

Figure 9: Example of opening gates related to % of rating.

A special gate, which is defined as a "lifetime" test has to be proven under a specified percentage of rated current. Here the fuse needs to last with a minimum hold time of 14,400s . Lifetime gates can be different based on fuse types and fuse ratings. For high voltage fuse links, typically gates are between 75% and 110% of rated current.

4. Fuse Application Considerations

Selecting the correct fuse to properly interact with your system can be a very challenging subject. This section will provide clarity as it relates to the fuse performing in it's environment, via a variety of common parameters .

4.1 Thermal Factors

Being thermal devices, any alterations to the thermal situation the fuse is being placed in will have an influence on it's ability to reliability carry current. This includes not only the temperatures directly surrounding the fuse, but also it's propensity to dissipate heat to it's surroundings.

4.1.1 Conductor Sizing

Fuses are sized in a lab environment with a standard set of conductors and fixtures. Alterations to this layout require adjustments to the fuse's rating based on the conditions below:

4.1.1.1 Cross Sectional Size Considerations

Using larger or smaller conductors than recommended can influence the fuse's ability to maintain its thermal properties. Larger conductors allow for more heat to be removed from the fuse assembly. This can be beneficial to the lifetime of the fuse, but at low overloads can increase opening times. Using smaller conductors can increase the operational temperature of the fuse, negatively influencing lifetime, and decreasing operating times. Littelfuse recommends reaching out to us with more information on your application. Using your specifics, we can run simulations that can make accurate changes to fuse performance.

4.1.1.2 Cooled Busbars

Cooled busbars can be an effective solution to maintaining lower temperatures on smaller conductors. However, they can also sway the fuse's lifetime and opening performance depending on the conductor temperature. It is very important to factor in any changes that may take place to the thermal conditions. Please contact us for recommendations when using cooled busbars.

4.1.1.3 Asymmetric Loading

While not uncommon to have different conductors on either side of the product, it can complicate the operation of the high voltage fuse. With arcing taking place within the assembly, it is very important to have equal opening distances inside the housing for the arc to propagate through. If too extreme, asymmetric loading can impact the initial melt point of the fuse, potentially resulting in less element distance to consume, and subsequently arcing outside of the constraints. Care must be taken to maintain thermal consideration when attaching fuses to conductors of differing sizes. Please contact us for assistance with your asymmetric loading cases.

4.1.2 Environmental Conditions

The thermal properties of the fuse environment also influence it's performance. The factors that influence the operation are most commonly:

4.1.2.1 Ambient Temperature

Fuse ratings are established by a steady state characterization in a laboratory environment. Changes to the ambient temperaure surrounding the fuse directly influences the thermal parameters of the product. For your use we provide rerating curves that have been created with similar characterization in increased ambients. These explicitly contain the maximum allowable steady state current at the given temperature. Failure to respect the maximum current could push the fuse into a thermal runaway condition, resulting in irrepairable damage, or a nuissance opening.

At Littelfuse, our goal is to provide our customers with the most reliable products. For this reason, we use a standard derating factor for our products of 20-25% of the fuse rating, depending on our design criteria. This derating factor applies to all ambient temperature levels in our posted tables. By recommending lower steady state currents, we are able to provide reliable performance to the end user, while still protecting against overcurrents.

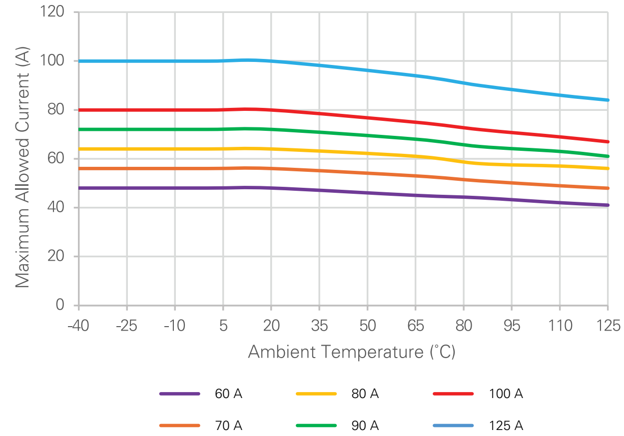


Figure 10: Rerating curve.

Ambient temperatures can also affect the box or fixture that the fuse is bolted to. If the mismatch in coefficients of thermal expansion is too great, the contacts the fuse is bolted to can induce large stresses onto the fuse that will negatively effect it's lifetime. In the most extreme cases, the forces can unintentionally corrupt the fuse in the circuit.

4.1.2.2 Altitude

Increased altitudes influence the density of air surrounding fuses. This directly has an impact on the fuse's thermal properties. A general industry practice is to factor in a 0.5% de-rating in maximum allowable current for every 100m above 2000m mean sea level. This factor should be added on top of any ambient derating.

Example

What is the altitude correction factor to be used for installation applied at 3500m above sea level?

Application Altitude (h): 3500m

Altitude Correction Factor Formula:
$\mathbf{F_{AL}}$ = (1-((h-2000)/100)*0.005)
$\mathbf{F_{AL}}$ = (1-((3500-2000)/100)*0.005)
$\mathbf{F_{AL}}$ = (1-(0.075))
$\mathbf{F_{AL}}$ = 0.925
Altitude Correction Factor $\mathbf{F_{AL}}$ = 0.925

4.1.2.3 Fuse Surroundings

Space constraints can drive the design of the areas directly around the fuse. Items with close proximity can modify the thermal properties of the product. Proximity to other devices that generate heat or insulators that negatively influence the fuse's thermal stability can cause the product to be derated. Examples of this are other fuses close by, or form fitting boxes that don't allow for air exchange (convection) around the fuse.

4.2 Current Profile Consequences

As we addressed in Section 1.3 above, electrical energy is converted into thermal energy in the bridges of the fuse element. This current generating heat is what allows the fuse to operate, but also causes thermal expansion of the element. This expansion needs to be controlled to allow for maximum reliability throughout the lifetime of the product.

4.2.1 Cycling

As the current cycles on and off in the circuit, the bridges within the fuse are expanding and contracting to match the changes in heat generated in the restrictions. After enough cycles, the fuse begins to age, cracking from the physical stresses put onto the element. In terms of reliability, the effect can be managed by applying appropriate profiles, and minimizing the operational temperature rise of the fuse. Contact us for more assistance with understanding your cycling needs. For additional information on our capability and reliability, please see section 5.0.

4.2.2 Inrush

Inrush current peaks are often higher than the nominal fuse rating, and therefore dangerous for the fuse lifetime. For such applications that feature these peaks, it is necessary to understand the energy applied to the fuse. The energy applied must be less than that of the melt I2t (see section 3.4.1) or damage to the fuse can occur. Similar to current cycling, the rapid heating and cooling of the element bridges can negatively influence the reliability of the product. Please contact us for more assistance with understanding the balance between reliability and protection.

4.2.3 Pulse Withstand

Electrical pulses produce thermal cycling, which leads to the possiblility of mechanical fatigue that is deterimental to the fuse (Reference section 4.2.1). For this reason, it is important to know the pulse cycle withstand capability of the fuse. This is defined as the number of pulses of a given I^2t value that can be withstood by the fuse without opening. The assumption is that sufficient time is given for the fuse to cool down between pulses.

4.3 Coordinating with Other Components

High voltage fuses are designed to be sacrificial elements within circuits to prevent dangerous current flows. The section below will shine light on coordinating fuses with the components in the circuit which they are tasked with protecting.

4.3.1 System

Protecting onboard devices and wires can be simple when the appropriate information is available. When looking at the wires and their datasheet, it is important to know the temperature level of the wire, as well as the ampacity of the conductor cross section. Both of these should be provided, as one is typically a function of the other. Select the appropriate fuse rating based on this ampacity. When coordinating with other devices, compare the total I^2t of the fuse with that of the device needing protection. Reach out to our global teams for more assistance with system level coordination. See sections 4.3.2 and 4.3.3 below for more information on coordinating with Fuses and Contactors.

4.3.2 Fuses

Referred to as selective coordination, aligning the levels of fuses to create a reliable system is a common practice. In a selectively coordinated system, only the fuse immediately on the load side of an overcurrent opens. Upstream fuses remain closed and undamaged. All other equipment remains in service, which simplifies locating overloaded equipment or short circuits. In Figure 11, if a short circuit arises behind fuse #3, fuse #3 should open and fuses #1 and #2 should stay closed and undamaged. The condition necessary to assure this result is that the minimum melting I^2t of the supply side and intermediatry fuses (fuses #1 and #2) must be significantly greater than the total clearing I^2t of the load side fuse (fuse #3). Selection of the higher level components must be done such that the operational differential is large enough that there is no chance of melt degradation to the higher level components. This condition results in the lowest level fuse opening before the highest level fuse begins to melt. Minimum melting and total clearing I^2t data are given by request.

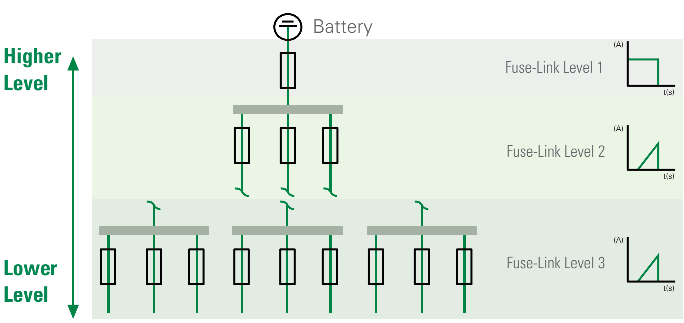


Figure 11: Selective Coordination for fuses in seriesI^2t – Time Curve.

4.3.3 Contactors

Contactors are an integral part of active circuit protection in high voltage architecture. High voltage fuses can be the perfect companion to them by providing passive protection against high current faults. Littelfuse is dedicated to assisting with contactor pairing, please reach out to us with your product specifics so we can help you to analyze suitable pairings.

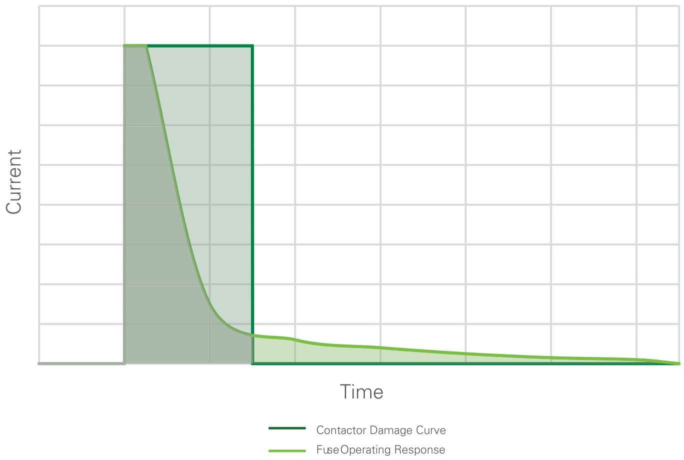


Figure 12: Contactor Coodination

The most important aspect to our inspection is the applicable contactor's damage curve. The damage curve is important because it is the value that we compare against to allow for the fuse to be the weakest link in the circuit. With proper coordination, the circuit response upon a fault will mimic the example in Figure 12. In this example, the fuse element melts prior to the damage threshold of the contactor, quickly cutting current levels down, and preventing a thermal meltdown of the contactor. Though the tail of the fuse opening time extends beyond that of the contactor's damage curve, the amount of thermal energy through the contactor has been severely limited, preventing further damage. Figure 13 below displays comparisons for the amount of thermal energy (I^2t) needed to open the fuse and catastrophically damage the contactor.

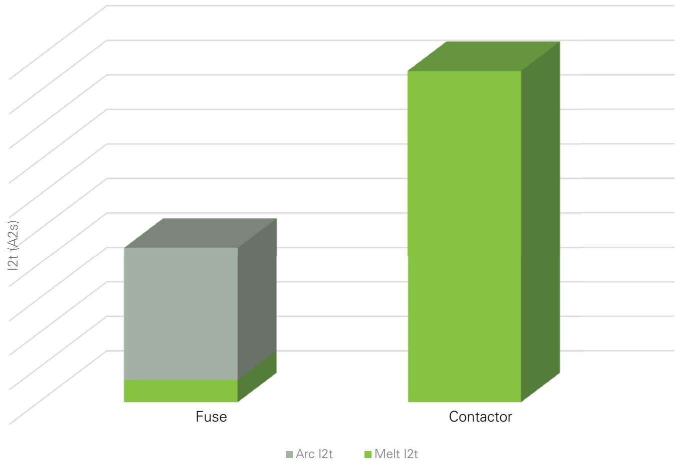


Figure 13: Contactor Coordination Energy.

4.4 Parallel Fuses

In some applications, it might be necessary to use fuses connected in parallel for space requirements. In this situation, the main objective is to increase the current carrying capability without increasing the assembly height.

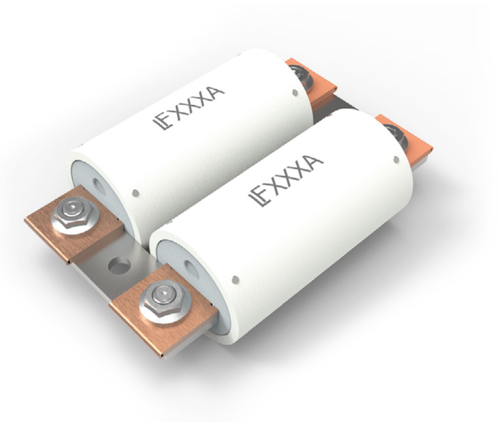


Figure 14: : Parallel Connection of 2 high voltage fuses

This case requires that some basic rules are satisfied:

- Fuses should be as closely matched in resistance as possible, and always be the same fuse ratings.
- The max interrupting current and max voltage is equal to that of an individual fuse. They are NOT equal to the sum of the two fuses.
- The melt I^2t will increase by the square of the number of fuses in the parallel connection. For example, if two fuses with a melt I^2t of 10,000A^2s are used in parallel, the effective melt I^2t will be 10,000A^2s x 2^2 = 40,000A^2s

5. Reliability

At Littelfuse, our goal is to create the most dependable products to serve our customers. Doing so allows us to provide years of reliable service, both in avoiding nuissance openings, as well as maintain safe openings if an overcurrent does occur. There are certain parameters that can affect the reliable use of the product, fortunately we have resources available to assist in quickly making predictions.

5.1 Parameters Affecting Reliability

Temperature is the largest driver to the reliabilty of the product. Efforts made to minimize the operational temperature of the fuse will have positive influences on the product. These can include minimizing the ambient temperature, limiting the current through the fuse, or increasing wire sizes.

5.2 Simulation and Reliability

To better serve our customers, we are continually expanding our reliability capabilities by testing/ stressing our components and recording parameters that allow us to correlate with simulation. This gives us the ability to provide reliability estimates using customer inputs in a timely manner. Please see section 6.2 below for more information on our simulation capability.

6. Littelfuse Resources

6.1 Application Engineering Team

Littelfuse has much more information and additional resources available to provide application support. A worldwide network of qualified technical FAEs/ ADEs is available to assist with the fuse selection process. Littelfuse can also provide customized training sessions that include relevant product data, simulation reports, and application testing.

6.2 Simulation

Outside of our reliability capability, we also possess the expertise to do thermal rise and time current simulations for your application. Taking your profiles and environments, we can quickly generate answers to your thermal questions and make recommendations accordingly. Please see the examples below.

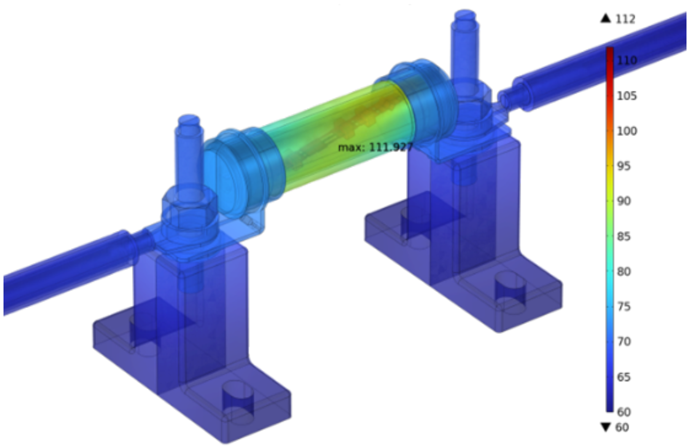


Figure 15: Temperature Distribution.

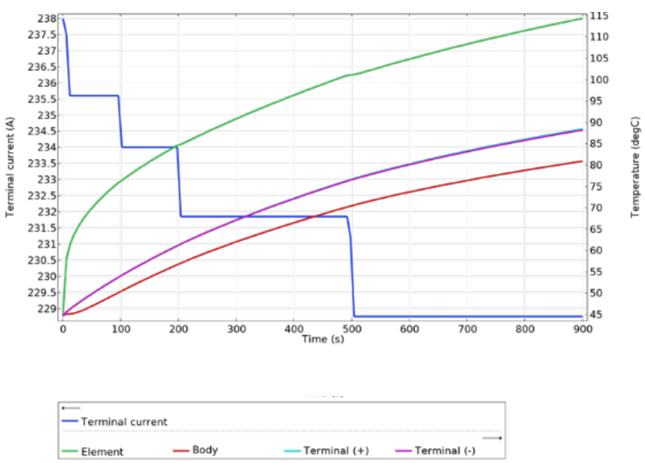


Figure 16: Time Current Curve.

6.3 Test Capabilities

On top of great engineering and quality support, Littelfuse has exceptional test capabilities for high voltage products. Testing of high-voltage fuses is a highly specialized activity, and is typically difficult to perform with commercially available test equipment.

Littelfuse posesses the expertise and ability for analyzing high voltage circuit protection in our global collection of labs. We do this through a variety of different technologies, including:

- DC Power Supplies
- Generator/Reactor/Transformer systems (AC or rectified DC testing)
- Battery Power Sources
- Capacitor Banks

Besides these overload capabilities, Littelfuse boasts a wide range of test resources for thoroughly evaluating our components, such as:

- Mechanical Vibration and Shock
- Steady State and Current Cycling Operation
- Thermal Shock
- Temperature and Humidity Cycling with Damp Heat
- Mechanical Pull Force Testing
- Material Lab capabilities
- Salt Spray Testing
- Harmful Gas Testing
- Chemical Resistance Testing
- Dielectric Strength

7. Additional Product Offerings

Please visit Littelfuse.com to see our full selection of product offerings. A short description of some applicable products can be seen below.

7.1 LV Fuse Portfolio

Littelfuse has a deep legacy in our offerings of low voltage fuses. They are the perfect compliment to protect circuits onboard vehicles that don't require the same high potentials.

7.2 Current Sensing

The superb companion to your active and passive circuit protection is our line of high quality current sensors.

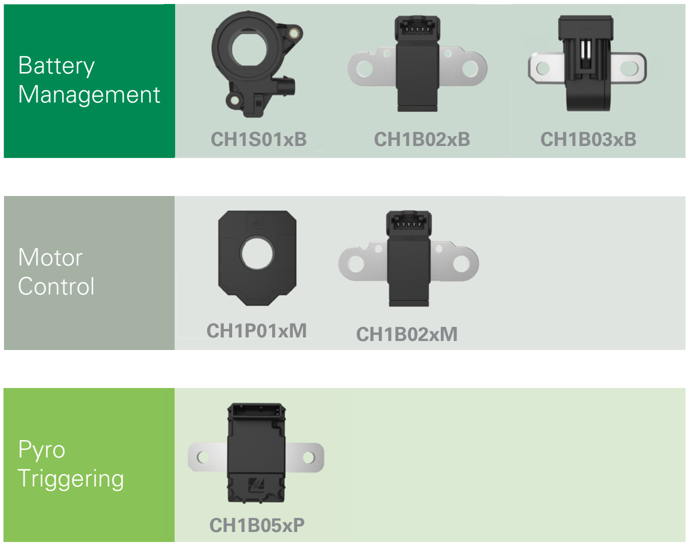
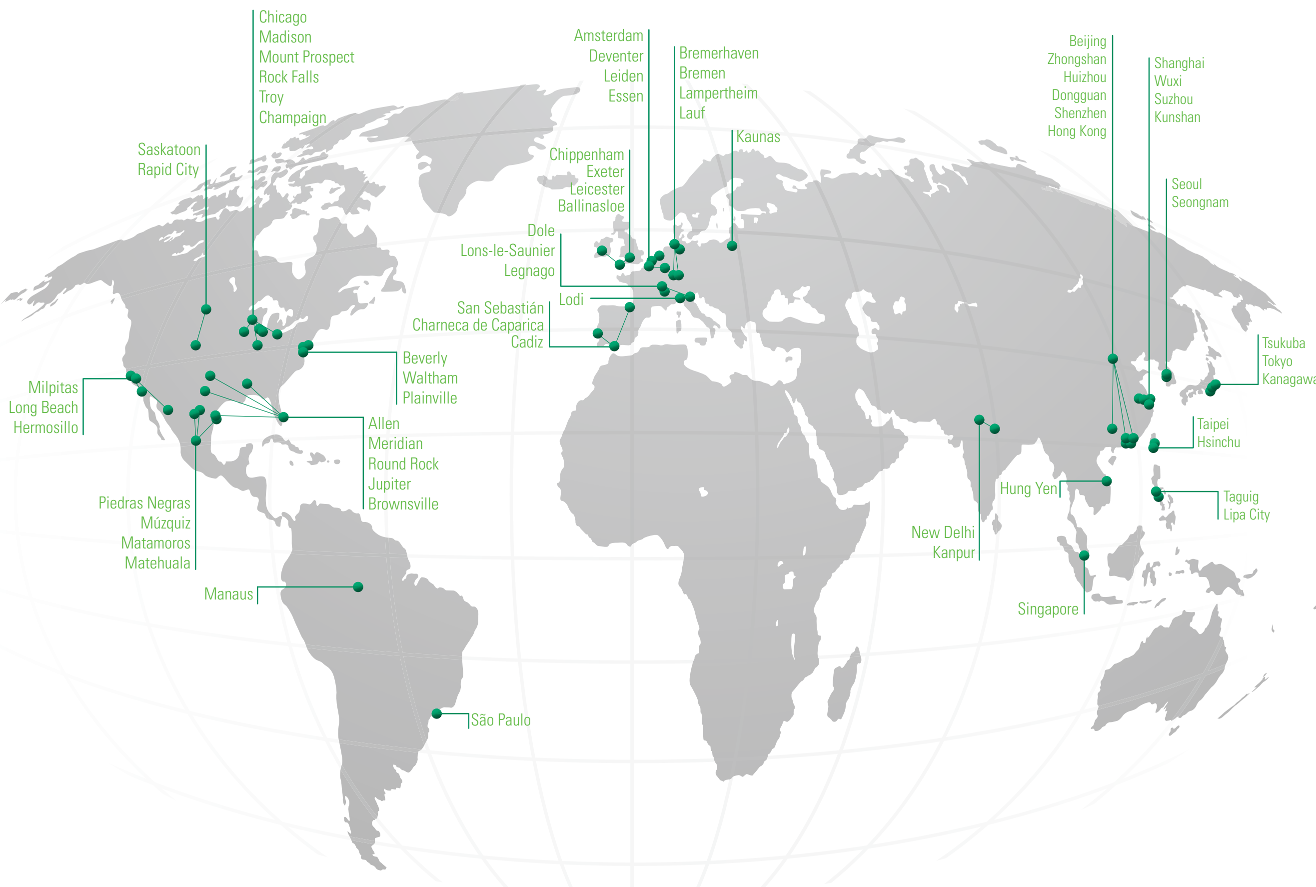


Figure 17: Littelfuse variety of current sensors for battery management and motor control systems.

8. Conclusion

The High Voltage automotive market is changing very quickly. Requests for higher fuse performances related to voltages, breaking capacities, and longer lifetime expectations are very common amongst the industry. Littefuse is present, continuously improving and expanding our new high voltage product portfolios. At Littelfuse, we are dedicated to ensuring robust and reliable solutions for all potential market applications.

LOCAL RESOURCES FOR A GLOBAL MARKET



Specifications descriptions and illustrative material in this literature are as accurate as known at the time of publication, but are subject to changes without notice. Visit www.littelfuse.com for most up-to-date technical information.