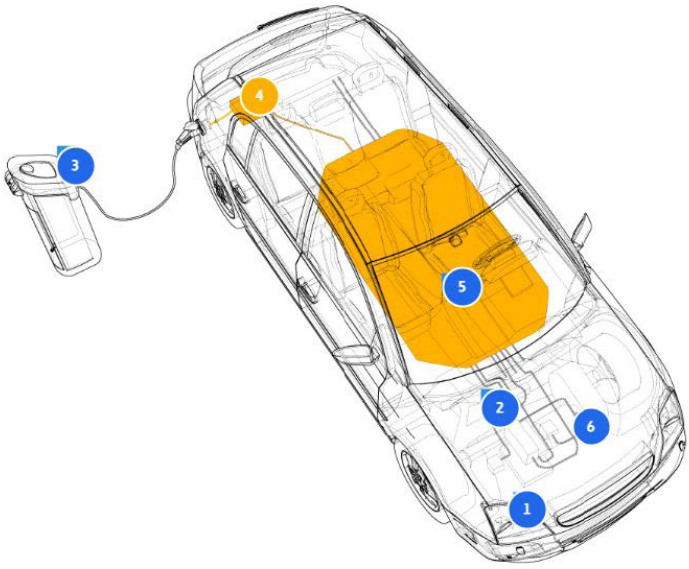


EV fuse selection guide



Introduction

As the automotive industry advances towards electrification, ensuring the safety and reliability of EV systems is crucial. The purpose of this document is to provide detailed application guidelines for selecting and properly sizing the current and voltage ratings of electric vehicle (EV) fuses used in automotive applications. This document outlines the key factors and considerations involved in choosing the appropriate EV fuses, with a focus on adequately sizing the fuse based on the ambient temperature and current load profiles of the end application.

Global fuse standards related to EV

Multiple global standards exist related to EV fuses. Eaton designs and tests its EV fuses according to a combination of the standards below depending on the fuse rating and mounting conditions:

- AEC-Q200
- JASO D622 – Japan
- ISO 8820

Key challenges:

Traditional fuses are designed for industrial purposes and are not suitable for the harsh environment of a vehicle or the expected operating life requirements. Industrial fuse standards do not account for these challenges in their test criteria, hence the need for automotive specific standards which test for:

- Thermal shock
- Mechanical shock and vibration
- High inrush withstand capability
- Cyclic loading and thermal fatigue
- Sustained high and low temperature operation

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EV fuse applications

The high voltage battery pack within an electric vehicle can pose a serious safety risk due to the high voltage and available fault current. The system should be protected by installing downstream circuit protection that is sized appropriately to protect each load.

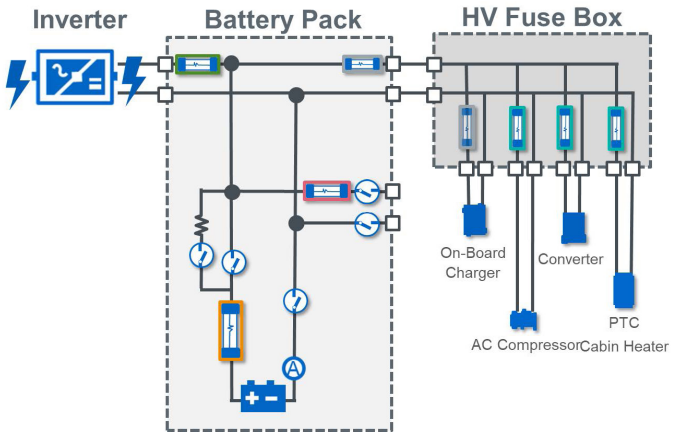


Figure 1: Example system configuration with a battery pack and HV power distribution fuse box

1. Battery pack:

- Contains the BMS (battery management system) responsible for monitoring the health of the system, state of charge, temperature, etc.
- Traction motor / inverter circuit protection
- Fast charging circuit protection

2. Power Distribution Unit (HV fuse box):

- On board charger
- Auxiliary circuit protection: A/C, DC/DC, pumps, PTC / heater, etc.

Basic sizing requirements

1. Determine the rated voltage:

- The voltage rating of the fuse should exceed the maximum system voltage which is determined by the voltage of the battery at its maximum state of charge
- If the fuse has separate AC and DC voltage ratings, then the corresponding voltage rating should be chosen based on the application

2. Determine the nominal rated current (In):

- The nominal rated current is calculated according to the maximum permissible continuous load current and the application specific correction (derating) factors
- Apply the appropriate derating factors explained below according to the application specific requirements

3. Determine the physical size and mounting configuration:

- Bolt down terminals for mating with bus bars or wire connectors
- PCB thru-hole terminals for mounting on PCB

Calculating nominal rated current In

In is the nominal rated current of the fuse. This is the rated current listed on the fuse label and datasheet. In is calculated based on a derating calculation intended to ensure that the actual RMS steady-state load current passing through the fuse should be equal to or lower than the maximum permissible load current Ib. Overload and cyclic loading are not accounted for in this In calculation and must be considered separately in subsequent steps.

Ib = In x Kt x Ke x Kv x Kf x Ka x Kx
Convert to: In≥ Ib / (Kt x Ke x Kv x Kf x Ka x Kx)

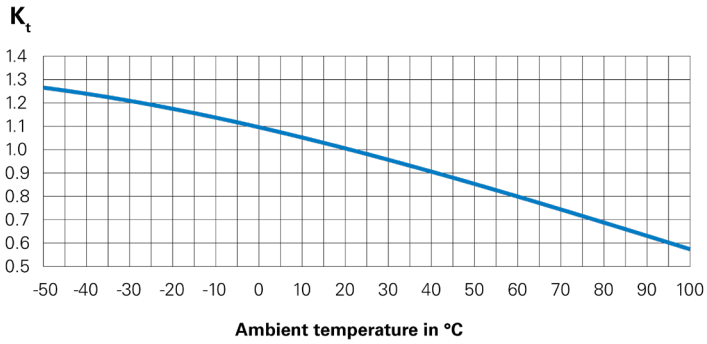
Where:
In: Current rating of fuse
Ib: Maximum permissible continuous load current*
Kt: Ambient temperature correction factor
Ke: Thermal connection factor
Kv: Cooling air correction factor
Kf: Frequency correction factor
Ka: High altitude correction factor
Kx: enclose space correction factor

*Note: For any periods of 10 minutes duration or more, the RMS value of the load current should not exceed this.

Determining the ambient temperature correction factor

Kt: Ambient temperature correction factor

EV fuses are derated for ambient temperatures above +20 °C to account for the elevated ambient temperature's impact on the fuse's ability to dissipate heat by convection. Kt should be chosen based on the maximum ambient operating temperature of the application.

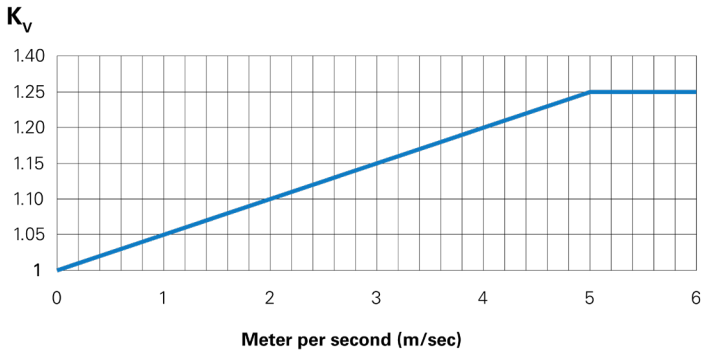


Example of an ambient temperature re-rating curve
Note: Refer to specific datasheet

Determining the cooling air correction factor

Kv: Cooling air correction factor

The curve on the next page shows the influence of forced air cooling on the fuse. Kt is equal to 1 for sealed enclosures and enclosures without active cooling.

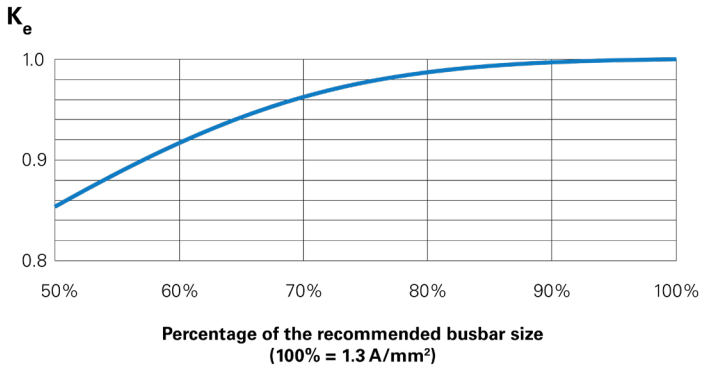


Note: Must be air speed surrounding the fuse, not speed out of the fan.

Determining the thermal correction factor

Ke: Thermal connection factor

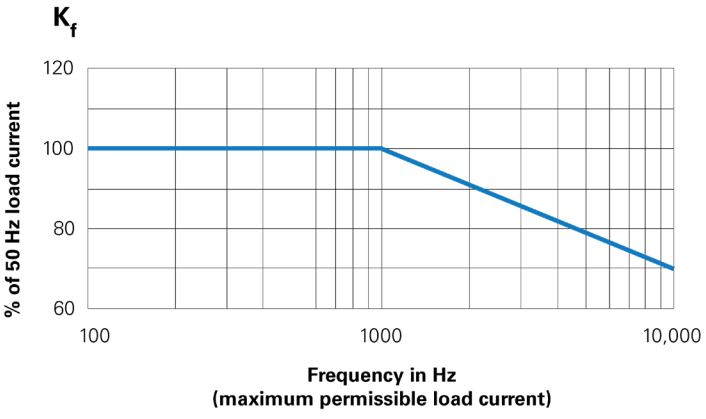
Busbar and wire size are important factors to consider when sizing EV fuses, as they help conduct heat away from the fuse allowing it to operate cooler. The nominal busbar or wire current density on which the fuses are mounted should be 1.3 A / mm² (based on IEC 60269 Part 4 which defines a range from 1.0 A to 1.6 A / mm²). If the busbar carries a current density greater than this, then the fuse should be derated.



Determining the frequency correction factor

Kf: Frequency correction factor

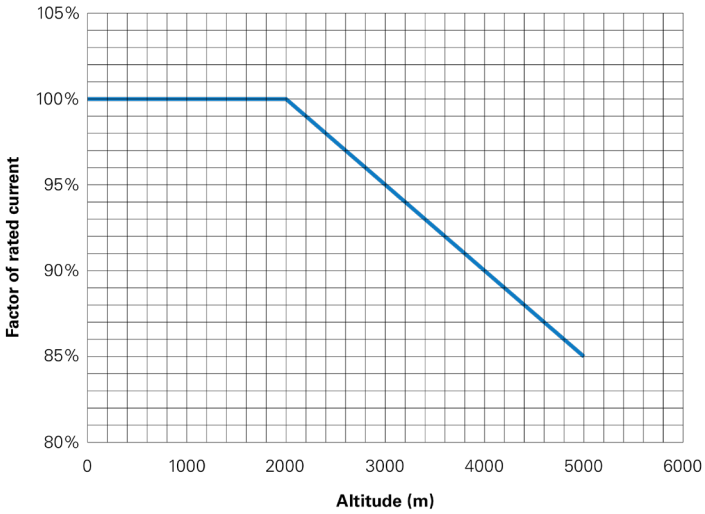
Not applicable for DC current.



Determining the high-altitude correction factor

Ka: High altitude correction factor

When fuses are used at high altitudes, the atmosphere's lower density reduces the cooling effect on the fuse. An altitude correction factor (Ka) should be applied to the fuse's continuous rating when used above 2000 m.



Determining the enclosure correction factor

Kx: Enclosure correction factor

In automotive applications, the fuse is often mounted in a small enclosure with no ventilation. For these conditions a correction factor of 0.8 is applied to ensure the fuse does not run too hot.

Example: Calculating nominal current rating In

An EV fuse is required to protect an EV auxiliary load such as a PTC heater. The continuous current load profile is determined to be 30 A. The maximum ambient air temperature is defined as +60 °C and the fuse is mounted in a small enclosure with no ventilation. It is decided that the cabling used to connect the fuse will be 15 mm². It is also specified that the vehicle needs to function up to 2500 m above sea level.

Insertion of the derating factors into the nominal current rating equation and solving for In:

$In \geq Ib/(Kt \times Ke \times Kv \times Kf \times Ka \times Kx)$, $In \geq 1.89\ Ib$

Derating factors based on the example application:

Ib: the continuous current is specified as 30 A (for applications with variable current, use RMS current)
Kt: the maximum ambient temperature is specified as +60 °C, thus Kt = 0.8
Ke: in this example with 30 A current and 20 mm² wire diameter, the current density is 1.5 A / mm². The recommended wire diameter based on our 1.3 A / mm² guideline is 28.7 mm² (30 A ÷ 1.3 A / mm²) therefore the 15 mm² wire diameter in the example is 52% of the recommended size, and we define Ke = 0.85
Kv: no air cooling specified, Kv = 1.0
Kf: DC current, Kf = 1.0

Ka: maximum altitude is specified as 2500 m, in which case Ka = 0.97
Kx: considering the fuse being installed in a closed and small space, we would like to apply an additional de-rating factor Kx = 0.8

Finally we get In ≥1.89 Ib, which means that the fuse rating should be greater than 1.89 x 30 A = 57 A. We then round up to the nearest available fuse rating, that being 60 A in this example.

Optimizing the selection

Variable loads with non-continuous load profiles may require additional derating to buffer against thermal fatigue due to irregular current profiles. In such cases an additional derating factor of 0.8 should be applied for cyclic loading.

Sustained overloads greater than 80% of the fuse rating for longer than 1 second should be avoided. If such overloads cannot be avoided then additional derating may be necessary to prevent the fuse from blowing prematurely due to thermal fatigue.

For help or technical assistance with these more complicated load profiles please contact Eaton application engineering: **ELXtech@eaton.com**.

Additional considerations

After making the initial fuse rating selection, there are other considerations that need to be addressed to ensure the fuse is sized appropriately to adequately protect the rest of the system:

Check for coordination with downstream components. Determine the available fault current and check that the fuse will blow in time to prevent damage downstream. Examples of downstream components which may need to coordinate with the fuse: cables, headers, connectors, relays, contactors, etc.

Make sure the fuse can protect against all intended fault currents. Many EV fuses provide short circuit protection only and are specified with a minimum breaking capacity. The minimum breaking capacity is the lowest current that the fuse will reliably protect against. Overload faults below the fuse's minimum breaking capacity will not be protected by the fuse and may require another protection mechanism.

Consider choosing a fuse size which has higher available ratings in the same package size to give yourself flexibility if you need to increase the fuse rating in the future. This can be a benefit later if the fuse rating needs to be increased, since doing so will be possible without having to change the physical package.

System level and vehicle level qualification is always recommended and should be performed as a means to validate system reliability and proper design implementation.

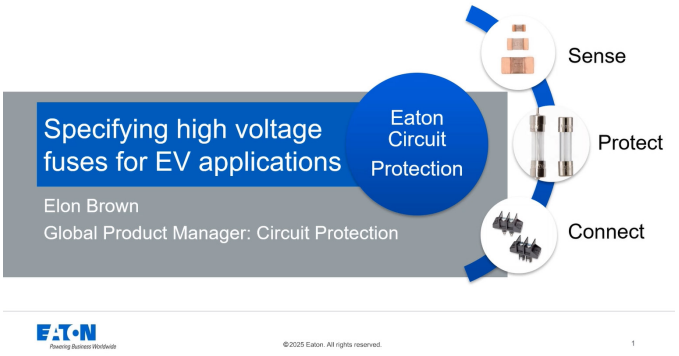


Figure 2: The webinar session titled "Specifying high voltage fuses for EV applications", held on May, 2025. Click to access.



Figure 3: Eaton's wide range of xEV fuses for demanding applications.

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Printed in USA
Publication No. ELX1527 BU-ELX22423
June 2025

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