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# Powertrain

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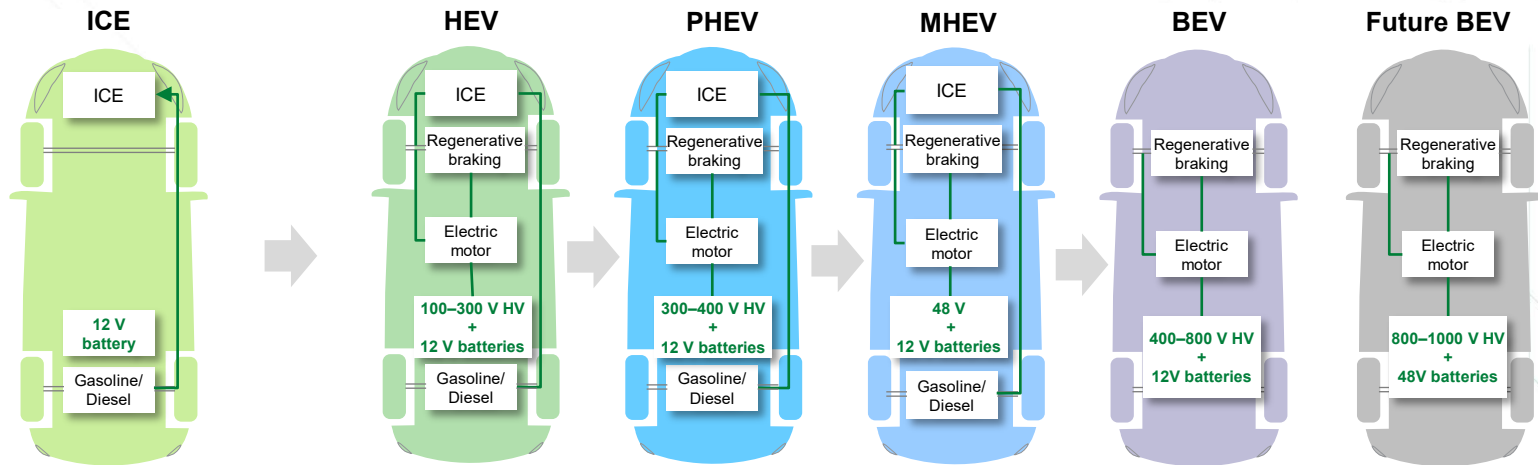


Passenger Vehicle

*Users must independently evaluate the suitability of, and test each product selected for their own specific applications. It is the user's sole responsibility to determine fitness or use of a particular system based on their own performance criteria, conditions, specific application, compatibility with other parts, and environmental conditions. Users must independently provide appropriate design and operating safeguards to minimize any risks associated with their applications and products. Littelfuse products are not designed for, and may not be used in, all applications. Read complete Disclaimer Notice at [littelfuse.com/disclaimer-electronics](https://www.littelfuse.com/disclaimer-electronics).*

# Evolution of EV powertrain and electrical systems

*Decarbonizing mobility through scalable electrification*



## Technical advancements

### 1980s

- Mechanical to ECU control
- Onboard diagnostics and electronic throttle control
- 12 V lead acid battery systems

### 1990s

- Introduction of EFI & catalytic converters
- Introduction to HEVs and NiMH batteries in late 90s
- Early Integration of electric motor assist
- Foundation of electrified powertrains

### 2000s

- Hybrid powertrains matures
- Emergence of PHEV/early BEV in late 2000s
- Inverter, DC–DC convertor became critical
- Advance ECU + CAN Bus became industry standard

### 2010s

- Rise of PHEVs/BEV
- HV 400 Li-ion batteries become standard
- 48 V, 12 VDC, etc. mild hybrid systems
- Advancement in inverter, OBC, DC-DC convertor
- Domain/zonal control; CAN + Ethernet

### 2020s

- Shift to pure BEVs and scalable EV Platforms
- Adoption of 800 V systems
- Continued addition of 48 VDC Li-ion batteries to cars
- Shift to zonal architecture + central compute

### Future

- Modular, scalable powertrains; in-wheel motors
- Hydrogen fuel cells for fleets
- 48 V Li-ion + 800V–1000 V traction, solid-state batteries
- Central compute, software-defined, AI-based energy, and safety control

# Driving the future: EV market trends and projections

*Government regulations, environmental concerns, and performance drive shift to EVs*

## Market trends

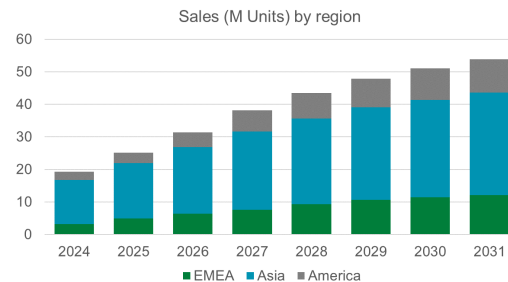
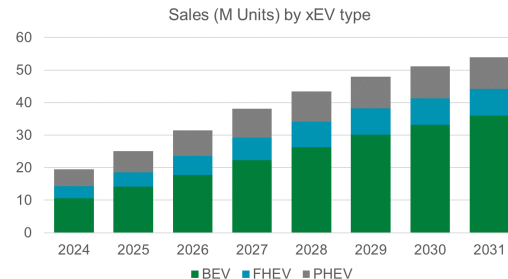
While global sales of passenger cars contracted in 2025, electric vehicles experienced double-digit growth rates. Global EV sales are expected to top 50 million units by 2030, crossing the 50% market share threshold versus traditional ICE engines.

To support the growing number of EVs, there will likely be a substantial increase in the installation of public and private charging stations. Governments and private companies are expected to invest heavily in fast-charging networks.

Continuous improvements in battery technology has led to increased energy density, faster charging times, and longer driving ranges. Innovations in solid-state batteries, wireless charging, and vehicle-to-grid technology are enhancing the overall appeal and functionality of EVs.

Policies continue to support electric vehicle deployment and are evolving to a more holistic policy portfolio. Environmental and sustainability objectives drive electric vehicle policy support at all governance levels.

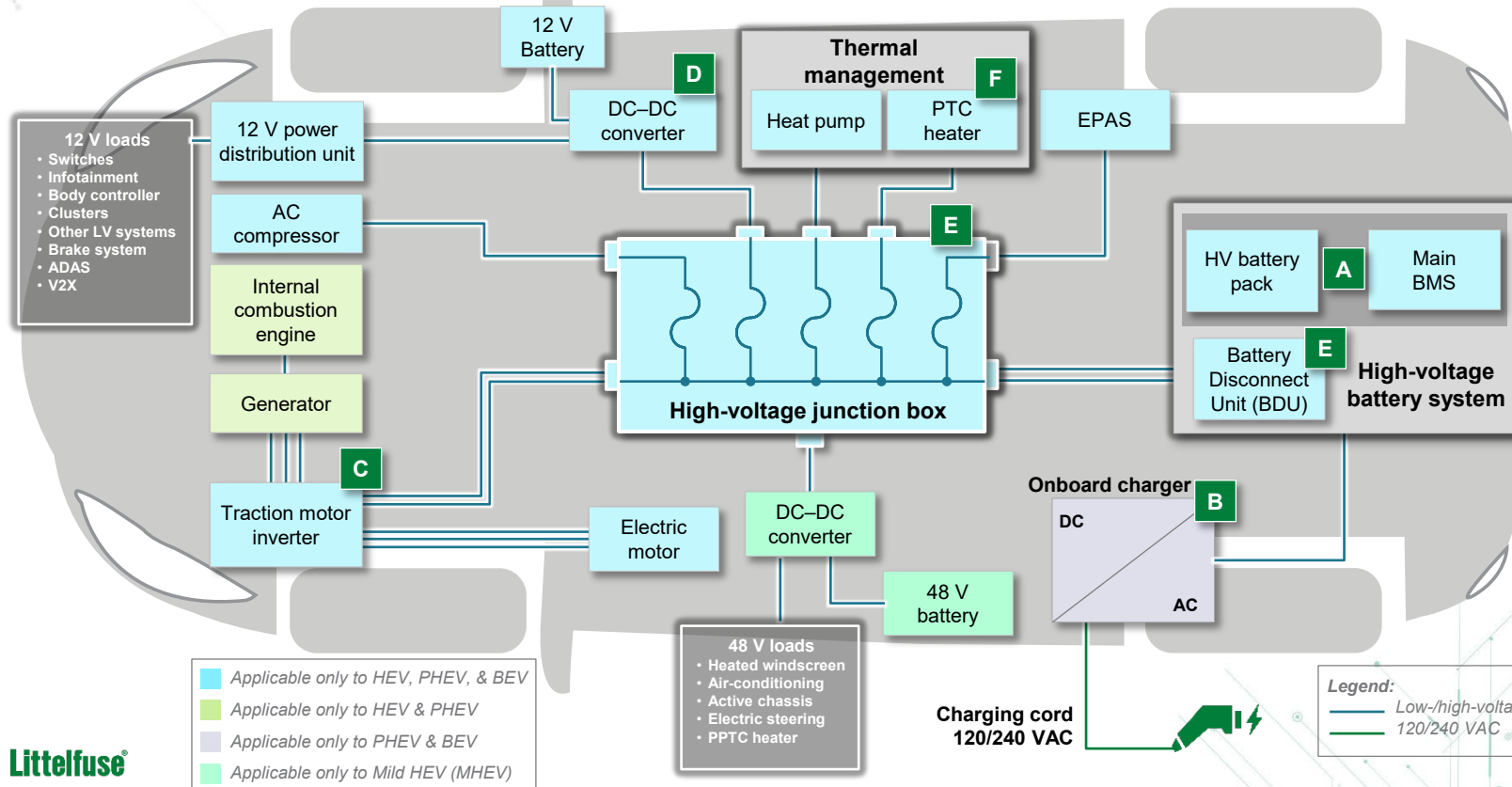
## Sales (M Units) by xEV type and region



Source: Littelfuse Estimates

# Unified powertrain architecture:

12V & HV powering hybrids & BEVs; 48V exclusive to MHEVs, emerging in BEVs alongside 12V



# Littelfuse solutions for powertrain

*Ensuring safety, efficiency, and reliability across the powertrain*

A

## HV Battery Systems

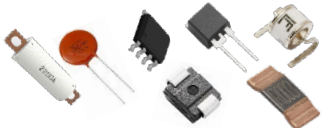
Fuse, TVS Diode, Gate Driver, Diode Array, TTape™, Switch



B

## Onboard Charger

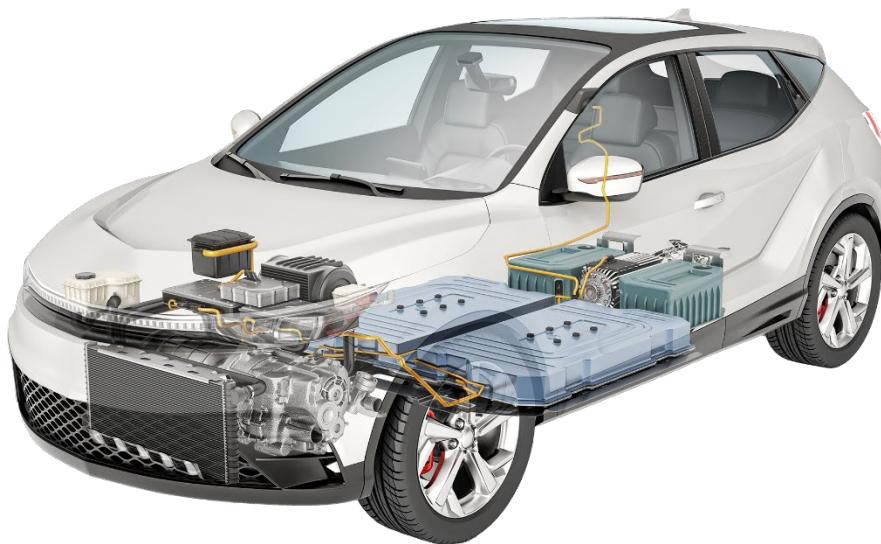
Fuse, MOV, Gate Driver, GDT, SIDAcTcr®, TVS Diode, Shunt Resistor



C

## Traction Motor Inverter

Fuse, TVS Diode, Diode Array, Current Sensor, Gate Driver, Thermal Protector



D

## DC-DC Converter

Fuse, TVS Diode, Diode Array, Gate Driver, Shunt Resistor



E

## BDU/HV Junction Box

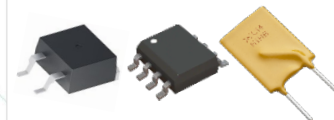
Contactor, IGBT, Current Sensor, High Voltage Fuse, TVS Diode



F

## Thermal Management

IGBT, Gate Driver, PTC Heaters





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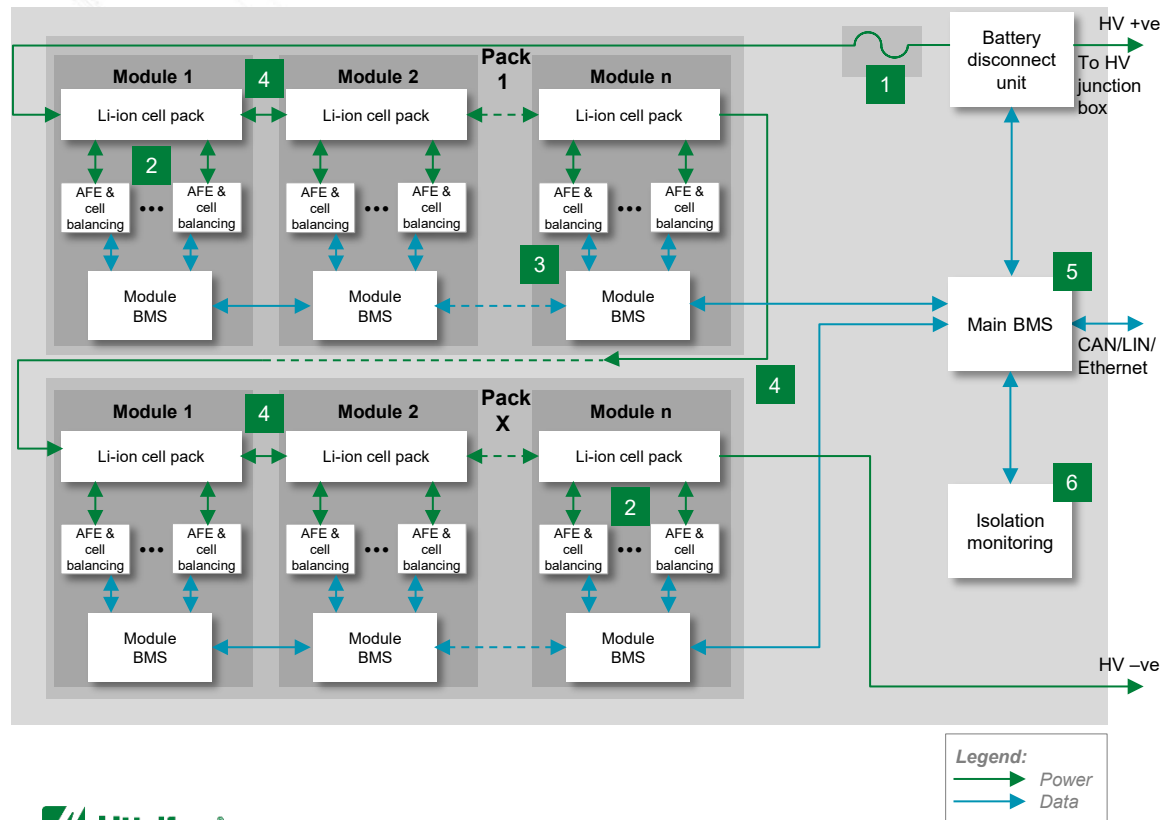
## High-voltage Battery System





Click the product series in the table below for more info

# High-voltage battery system block diagram



	Technology	Product Series
1	High-voltage Fuse	<a href="#">30EV1K</a> , <a href="#">25EV1K</a>
	TTape™ Platform	<a href="#">TTP</a>
	SMD Fuse	<a href="#">437A</a> , <a href="#">483A</a> , <a href="#">438A</a>
	OR	<a href="#">521</a>
	In-Line Fuse	<a href="#">TPSMA6L/SD05</a>
2	TVS Diode	<a href="#">TPSMA6L/SD05</a>
	TVS Diode Array	<a href="#">AQ05C/AQ1205/AQ12C</a>
	TVS Diode	<a href="#">TPSMC</a> , <a href="#">TPSMD</a> , <a href="#">TPSMB/TPSMB-L</a> , <a href="#">TP5.0SMDJ</a> , <a href="#">SZSMF6L</a>
3	Fuse (Optional)	<a href="#">501A</a> , <a href="#">881</a> , <a href="#">871</a>
	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a>
4	TVS Diode Array	<a href="#">AQ24COM-02</a> , <a href="#">AQ24COM-01</a>
	Fuse	<a href="#">885</a>
	TVS Diode	<a href="#">TPSMB</a> , <a href="#">TPSMC</a>
5	TVS Diode	<a href="#">TPSMB</a>

# Potential Littelfuse products for high-voltage battery system



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	High-Voltage Fuse	Main fuse design to protect BMS system from short circuit, wiring failure, etc.	<a href="#">30EV1K</a> , <a href="#">25EV1K</a>	Provides safety protection in high-voltage environments; full range fuse	Bolt-down form factor; high breaking capacity; ISO 8820 qualified
2	TTape™ Platform	Overtemperature monitoring of many cells or large area with single MCU input	<a href="#">TTP</a>	Helps the MCU to wake from sleep mode at overtemperature events; <1 s response for temperature monitoring; extremely thin device suitable for conformal installation	Simple integration with existing BMS solutions complementing NTCs; no calibration or temperature look-up tables needed; pressure-sensitive adhesive for simple and quick installation
	SMD or In-Line Fuse	Protects cells and BMS components from overcurrent	<a href="#">437A</a> , <a href="#">483A</a> , <a href="#">438A</a> , <a href="#">521</a> (In-Line Fuse)	Excellent temperature stability and performance reliability; ceramic substrate ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device
	TVS Diode	Cell monitor IC sense line input overvoltage protection	<a href="#">TPSMA6L</a> / <a href="#">SD05</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
3	TVS Diode	Transient voltage suppression	<a href="#">AQ05C/AQ1205/AQ12C</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
4	TVS Diode	Protects battery from fast, high voltage transients	<a href="#">TPSMC</a> , <a href="#">TPSMD</a> , <a href="#">TPSMB/TPSMB-L</a> , <a href="#">TP5.0SMDJ</a> , <a href="#">SZSMF6L</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
	Fuse (Optional)	Protects battery packs or module-to-module from high fault currents due to external shorts	<a href="#">501A</a> , <a href="#">881</a> , <a href="#">871</a>	Excellent temperature stability and performance reliability; compact design; ceramic substrate ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device



# Potential Littelfuse products for high-voltage battery system



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
5	Gate Driver	Controls the switching MOSFETs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times lower than 10 ns	Tight tolerance; small form factor; fast thermal response
	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	<a href="#">AQ24COM-02</a> , <a href="#">AQ24COM-01</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low-leakage current and clamping voltage
	SMD Fuse	Protects cells and BMS components from overcurrent	<a href="#">885</a>	High-voltage SMD form-factor enables compact design; ceramic body ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device
	TVS Diode	Transient voltage suppression	<a href="#">TPSMB</a> , <a href="#">TPSMC</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
6	TVS Diode	Protects Solid State Relays from voltage transients	<a href="#">TPSMB</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges



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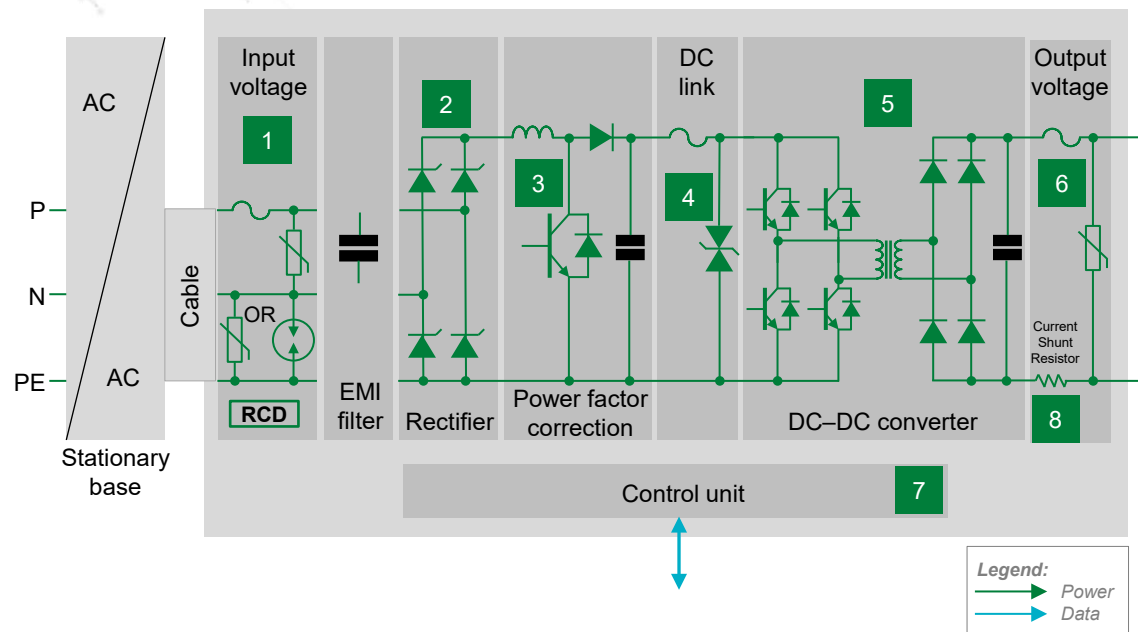
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## Onboard Charger



Click the product series in the table below for more info

# Onboard charger block diagram



	Technology	Product series
1	Fuse	<a href="#">526</a> , <a href="#">527</a> , <a href="#">10EV</a> , <a href="#">20EV</a>
	MOV	<a href="#">AUMOV</a> , <a href="#">SM10</a>
	GDT	<a href="#">CG2</a> , <a href="#">CG3</a>
	SIDACtor®	<a href="#">Pxxx0FNL</a> , <a href="#">Pxxx0S3N-A</a> (6 kV / 3 kA), <a href="#">Pxxx0S3G-A</a> (4 kV / 2 kA)
	Residual Current Monitor	CF3P03xC*
2	Thyristor	<a href="#">S8016xA</a>
3	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>
4	TVS Diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZSMF6L</a>
5	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a>
	TVS Diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a> , <a href="#">SZSMF6L</a>
	TVS Diode Array	<a href="#">AQ4022</a>
6	Fuse	<a href="#">526</a> , <a href="#">527</a> , <a href="#">10EV</a> , <a href="#">20EV</a> , <a href="#">30EV1K</a> , <a href="#">25EV1K</a> , <a href="#">828</a> , <a href="#">38EV</a>
	MOV	<a href="#">AUMOV</a> , <a href="#">SM10</a>
7	TVS Diode Array	<a href="#">AQ24COM-02</a>
8	Current Shunt Resistor	<a href="#">SSA</a>

\* Contact Littelfuse Sales for more details



Click the product series in the table below for more info

# Benefits of Littelfuse products in an onboard charger

	Technology	Function in application	Product series	Benefits	Features
1	Fuse	Short circuit protection; overload circuit protection	<a href="#">526</a> , <a href="#">527</a> , <a href="#">10EV</a> , <a href="#">20EV</a>	Provides safety protection in high-voltage environments; full range fuse	AEC-Q200 qualified, high voltage; ceramic body ensures compatibility with high-temperature environment
	MOV	Protects from lightning and system transient surges	<a href="#">AUMOV</a> , <a href="#">SM10</a>	Clamps transient surge to ensure reliable performance of the circuitry	Wide range of surge current ratings; disk sizes and lead options; surface mount available
	GDT	Ensures electrical isolation between line, neutral, and ground	<a href="#">CG2</a> , <a href="#">CG3</a>	Provides safety to the system with high-resistance isolation	Rugged, high-surge current based on ceramic tube design; low-leakage current
	SIDACtor®	Lightning and system transient surges	<a href="#">Pxxx0FNL</a> , <a href="#">Pxxx0S3N-A</a> (6 kV / 3 kA), <a href="#">Pxxx0S3G-A</a> (4 kV / 2 kA)	Used in combination with MOV; provides lower clamping voltage for sensitive circuitry	Surface mount form factor; semiconductor-based design does not wear out; used in combination with MOV; provides lower clamping voltage for sensitive circuitry
	Residual Current Monitor	Residual current detection	CF3P03xC*	Personal protection against AC and DC leakage currents according to IEC 62752/UL 2231	Modular design, thereby enabling customized configuration for PCBs
2	Thyristor	Rectification	<a href="#">S8016xA</a>	Reduces the in-rush current during rectification that can damage expensive DC link capacitor	Compact TO-220 and surface mount TO-263 form factors, $V_{DRM}$ of 800 V, IT or 16 A <sub>(RMS)</sub>
3	Gate Driver	Controls the switching IGBTs and SiC MOSFETs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10ns	Tight tolerance; small form factor; fast thermal response
4	TVS Diode	Active clamping	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZSMF6L</a>	Clamps the transient that is created when the MOSFET device switches; ensures reliability	Small form factor DO214-AA package; low clamping voltage; products are available with voltage ratings from 150 V~650 V. For more information on "Active Clamp", see <a href="#">here</a>
5	Gate Driver	Controls the switching of IGBTs and SiC MOSFETs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10ns	Tight tolerance; small form factor; fast thermal response
	TVS Diode	Active clamping	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a> , <a href="#">SZSMF6L</a>	Clamps the transient that is created when the MOSFET device switches; ensures reliability	Small form factor DO214-AA package; low clamping voltage; products are available with voltage ratings from 150 V~650 V. For more information on "Active Clamp", see <a href="#">here</a>
	TVS Diode Array	ESD protection of the gate input	<a href="#">AQ4022</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low leakage current and clamping voltage



# Benefits of Littelfuse products in an onboard charger

	Technology	Function in application	Product series	Benefits	Features
6	Fuse	Short circuit protection; overload circuit protection	<a href="#">526</a> , <a href="#">527</a> , <a href="#">10EV</a> , <a href="#">20EV</a> , <a href="#">30EV1K</a> , <a href="#">25EV1K</a> , <a href="#">828</a> , <a href="#">38EV</a>	Provides safety protection in high-voltage environments; full range fuse	AEC-Q200 and ISO 8820 qualified; high voltage; high breaking capacity; bolt-down form factor available; ceramic body ensures compatibility with high-temperature environment
	MOV	Transient voltage suppression	<a href="#">AUMOV</a> , <a href="#">SM10</a>	Clamps transient surge to ensure reliable performance of the circuitry	Wide range of surge current ratings; disk sizes and lead options; surface mount available
7	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	<a href="#">AQ24COM-02</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low leakage current and clamping voltage
8	Current Shunt Resistor	Measures the overall output current	<a href="#">SSA</a>	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Isolated from HV network; no additional power loss due to shunt resistor



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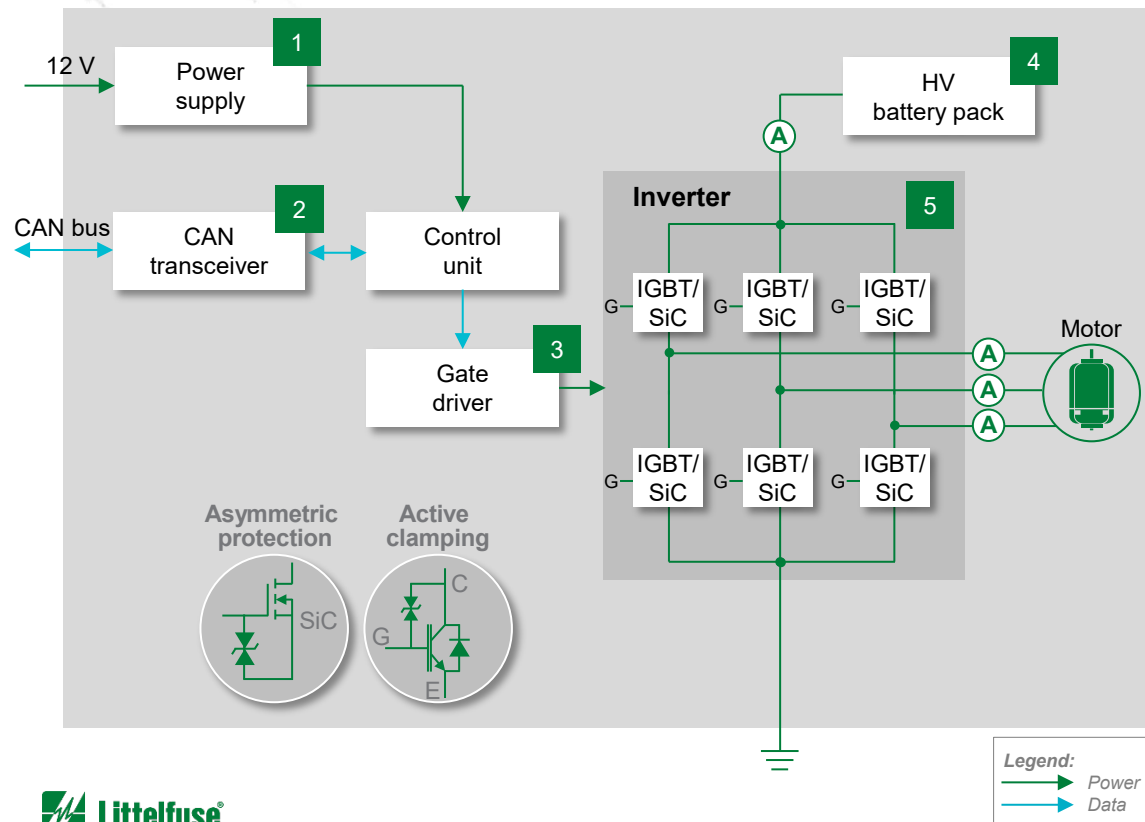
## Traction Motor Inverter





Click the product series in the table below for more info

# Traction motor inverter block diagram



	Technology	Product series
<b>1</b>	TVS Diode	<a href="#">TPSMB</a> , <a href="#">TPSMA6L</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZ1SMA</a> , <a href="#">SZSMF4L</a> , <a href="#">SZSMF6L</a>
	SMD Fuse	<a href="#">501A</a>
<b>2</b>	TVS Diode Array	<a href="#">AQ24COM-02</a>
<b>3</b>	TVS Diode Array	<a href="#">AQ4022</a>
	TVS Diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a> , <a href="#">SZSMF6L</a>
	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>
<b>4</b>	Fuse	<a href="#">526</a> , <a href="#">828</a> , <a href="#">30EV1K</a> , <a href="#">25EV1K</a> , <a href="#">823A</a>
<b>5</b>	TVS Diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a>
	Current Sensor	<a href="#">CH1B02xM</a> , <a href="#">CH1P01xM</a> , <a href="#">CH3S01xM*</a>
	Thermal Protection	<a href="#">HCRTP-mini</a>

\* Contact Littelfuse Sales for more details

# Benefits of Littelfuse products in a traction motor inverter



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	TVS Diode	Transient voltage suppression	<a href="#">TPSMB</a> , <a href="#">TPSMA6L</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZ1SMA</a> , <a href="#">SZSMF4L</a> , <a href="#">SZSMF6L</a>	Excellent clamping capability; meets automotive industry standards; fast response time; compact design	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
	SMD Fuse	Short circuit protection; overload circuit protection	<a href="#">501A</a>	Excellent temperature stability and performance reliability; compact design; ceramic substrate ensures compatibility with high-temperature environment	Tested as per new AEC-Q specification; fast response to fault current; surface mount device
2	TVS Diode Array	Protect CAN bus from ESD, EFT, and voltage transient	<a href="#">AQ24COM-02</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO10605; low leakage current and clamping voltage
3	TVS Diode Array	ESD protection of the gate input	<a href="#">AQ4022</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low leakage current and clamping voltage
	TVS Diode	Active clamping and gate driver protection	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a> , <a href="#">SZSMF6L</a>	Excellent clamping capability; meets automotive industry standards; fast response time; compact design	Small form factor DO214-AA package; low clamping voltage; products are available with voltage ratings from 150 V~650 V. For more information on 'Active Clamp', see <a href="#">here</a>
	Gate Driver	Controls the switching IGBTs and SiC MOSFETs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10 ns	Tight tolerance; small form factor; fast thermal response
4	Fuse	Short circuit protection	<a href="#">526</a> , <a href="#">828</a> , <a href="#">30EV1K</a> , <a href="#">25EV1K</a> , <a href="#">823A</a>	Provides safety protection from short circuit conditions	High voltage; ceramic body ensures compatibility with high-temperature environment
5	TVS Diode	Active clamping for IGBT; gate protect for SiC MOSFET	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TPSMBASY</a>	Clamps the transient that is created when the MOSFET device switches; ensures reliability	Clamps the transient that is created when the MOSFET switches; ensures reliability; asymmetric diodes to protect the gate of SiC transistors. For more information on 'Active Clamp', see <a href="#">here</a>
	Current Sensor	Measures current on each phase of the inverter/motor and/or the DC link current	<a href="#">CH1B02xM</a> , <a href="#">CH1P01xM</a> , <a href="#">CH3S01xM*</a>	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Up to 2000 A with analog or CAN output; functional safety ratings from ASIL QM to ASIL C available
	Thermal Protection	Thermal protection for MOSFETs	<a href="#">HCRTP-mini</a>	Responds to over-temperature conditions caused by catastrophic failure of the MOSFET device	Responds to over-temperature conditions caused by catastrophic failure of the MOSFET device

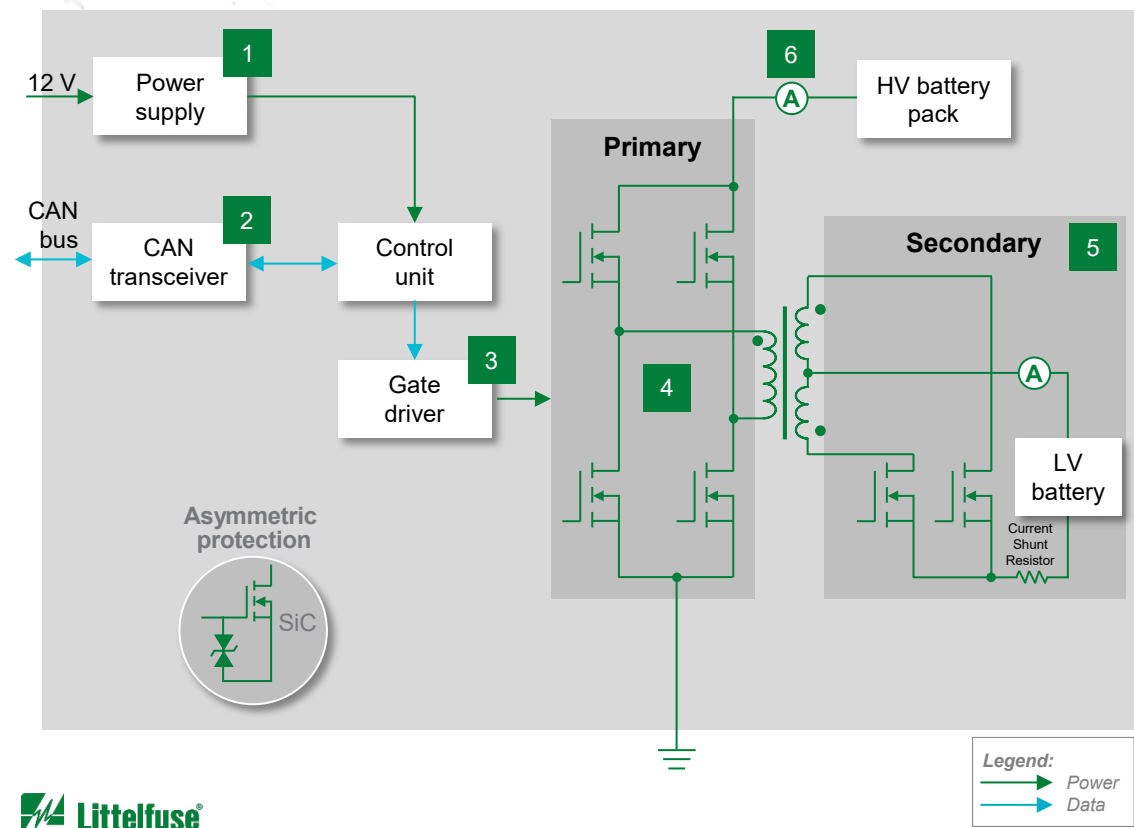


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DC-DC Converter

# DC-DC converter block diagram



	Technology	Product series
1	TVS Diode	<a href="#">TPSMB</a> , <a href="#">TPSMA6L</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZ1SMA</a> , <a href="#">SZSMF4L</a>
	Fuse	<a href="#">441A</a>
2	TVS Diode Array	<a href="#">AQ24COM-02</a>
3	TVS Diode Array	<a href="#">AQ4022</a>
	TVS Diode	<a href="#">TPSMF4L</a> , <a href="#">TPSMBASY</a>
4	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>
	TVS Diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TP5.0SMDJ</a> , <a href="#">TPSMBASY</a>
5	Thermal Protection	<a href="#">HCRTP-mini</a>
	TVS Diode	<a href="#">TPSMD</a> , <a href="#">TP5.0SMDJ</a>
6	Current Shunt Resistor	<a href="#">SSA</a>
	Current Sensor	<a href="#">CH1B02xM</a> , <a href="#">CH1P01xM</a>



Click the product series in the table below for more info

# Benefits of Littelfuse products in a DC–DC converter

	Technology	Function in application	Product series	Benefits	Features
1	TVS Diode	Transient voltage suppression	<a href="#">TPSMB</a> , <a href="#">TPSMA6L</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">SZ1SMA</a> , <a href="#">SZSMF4L</a>	Excellent clamping capability; meets automotive industry standards; fast response time; compact design	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
	Fuse	Short circuit and overload circuit protection	<a href="#">441A</a>	Excellent temperature stability and performance reliability; ceramic substrate ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device
2	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	<a href="#">AQ24COM-02</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low leakage current and clamping voltage
3	TVS Diode Array	ESD protection of the gate input	<a href="#">AQ4022</a>	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low leakage current and clamping voltage
	TVS Diode	Transient voltage suppression	<a href="#">TPSMF4L</a> , <a href="#">TPSMBASY</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
	Gate Driver	Controls the switching Si/SiC MOSFETs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a> , <a href="#">IX4351NEAU</a> , <a href="#">IX4352NEAU</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10 ns	Tight tolerance; small form factor; fast thermal response



# Benefits of Littelfuse products in a DC–DC converter

	Technology	Function in application	Product series	Benefits	Features
4	TVS Diode	Active clamping for IGBT; gate protect for SiC MOSFET	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a> , <a href="#">TP5.0SMDJ</a> , <a href="#">TPSMBASY</a>	Clamps the transient that is created when the MOSFET device switches, thereby ensuring reliability	Clamps the transient that is created when the MOSFET device switches; ensures reliability; asymmetric diodes to protect the gate of SiC transistors. For more information on "Active Clamp", see <a href="#">here</a>
5	Thermal Protection	Thermal protection for MOSFETs	<a href="#">HCRTF-mini</a>	Responds to over-temperature conditions caused by catastrophic failure of the MOSFET device	Surface mountable form factor; compatible with standard reflow process; breaks current flow during overtemperature condition
	TVS Diode	Transient voltage suppression	<a href="#">TPSMD</a> , <a href="#">TP5.0SMDJ</a>	Excellent clamping capability; meets automotive industry standards; fast response time	Small form factor DO214-AA package; low clamping voltage
	Current Shunt Resistor	Measures the overall output current	<a href="#">SSA</a>	Small size; high voltage	Multiple case sizes: 2512, 3921, and 5931; resistance range 0.2 mΩ–4 mΩ; power up to 15 W; tolerance down to ±1.0%; TCR down to ±50 ppm/°C
6	Current Sensor	Measures current on each phase of the inverter/motor and/or the DC link current	<a href="#">CH1B02xM</a> , <a href="#">CH1P01xM</a>	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Up to 2000 A with analog or CAN output; functional safety ratings from ASIL QM to ASIL C available





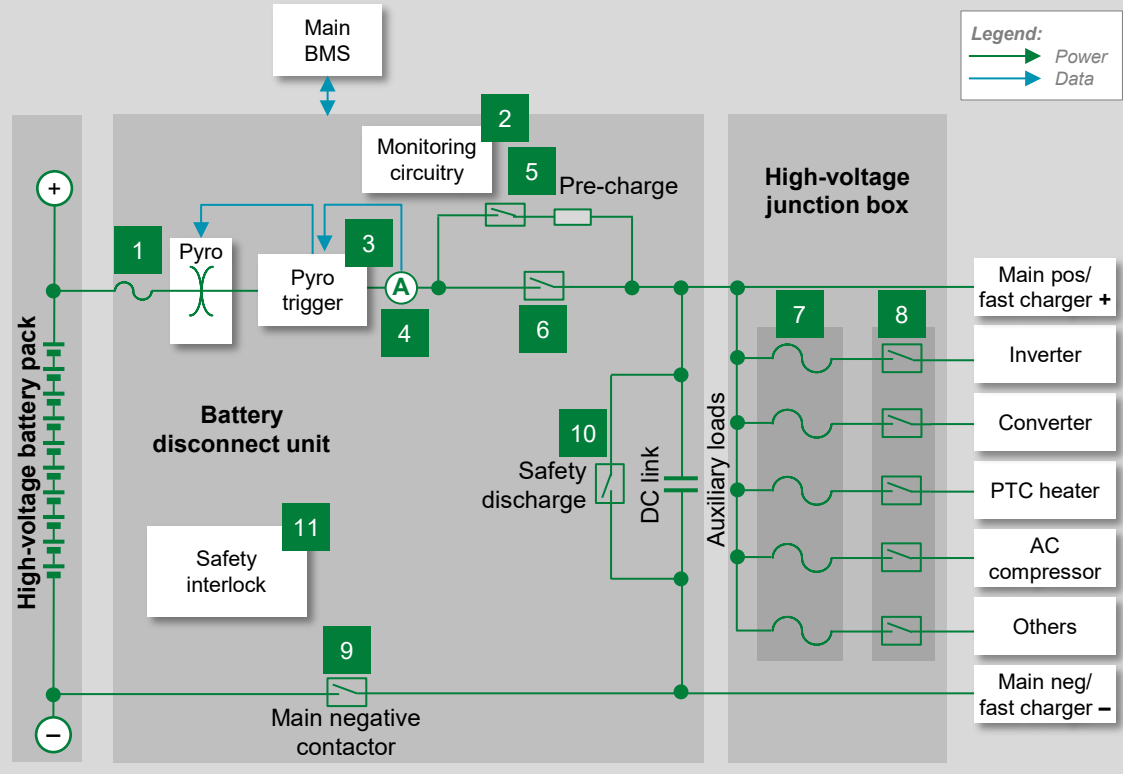
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Battery Disconnect Unit (BDU)/  
High-voltage Junction Box

# Battery Disconnect Unit (BDU)/ HV junction box block diagram

 Click the product series in the table below for more info



	Technology	Product series
1	High-Voltage Fuse	<a href="#">30EV1K, 25EV1K, 828, 38EV</a>
2	Fuse	<a href="#">823A</a>
3	Pyro Trigger	<a href="#">CH1B05xP</a>
4	Current Sensor	<a href="#">CH1S01xB, CH1B02xB</a>
5	High-Voltage DC Contactor <b>OR</b> IGBT*	<a href="#">DCNHR</a> IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV
	TVS Diode	<a href="#">TP5.0SMDJ</a>
6	High-Voltage DC Contactor	<a href="#">DCNHR</a>
	TVS Diode	<a href="#">TP5.0SMDJ</a>
7	Auxiliary Fuse	<a href="#">10EV, 20EV, 30EV1K, 25EV1K, 828, 526</a>
8	High-Voltage DC Contactor	<a href="#">DCNHR</a>
9	High-Voltage DC Contactor	<a href="#">DCNHR</a>
10	Discrete Thyristor <b>OR</b> IGBT*	<a href="#">SJxx40xxA</a> IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV
	Switch	<a href="#">SSW</a>

# Benefits of Littelfuse products in the Battery Disconnect Unit (BDU)/HV junction box



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	High-Voltage Fuse	Short circuit and overload circuit protection	<a href="#">30EV1K</a> , <a href="#">25EV1K</a> , <a href="#">828</a> , <a href="#">38EV</a>	Provides safety protection in high-voltage environments; full range fuse; can protect the entire pack's voltage and short circuit current	Bolt down form factor; high breaking capacity; ISO 8820 qualified
2	Fuse	Short circuit protection	<a href="#">823A</a>	Avoid nuisance opening due to high inrush and surge current inherent in the system; suitable for harsh automotive environments; high voltage protection while saving PC board space	AEC-Q200 qualified; high I <sup>2</sup> t; rated for 1000 Vdc with Interrupting rating of 100 A; compact body size of 5x20 mm; operating temperature from -40 °C to 125 °C; Pb-free, RoHS compliant, and Halogen-free
3	Pyro Trigger	Trigger the pyro-fuse in case of overcurrent	<a href="#">CH1B05xP</a>	Fast and reliable circuit protection solution; customizable trigger labels; active protection solution; low power consumption; compact lightweight design	Very fast overcurrent detection, triggering, and interruption (cut-off time <1 ms), which significantly reduces peak current; additional input for activation of trigger using external signal; variants with accurate current measurement available
4	Current Sensor	Measure the overall current in the system	<a href="#">CH1S01xB</a> , <a href="#">CH1B02xB</a>	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Up to 2000 A with analog or CAN output; functional safety ratings from ASIL QM to ASIL C available
5	High-Voltage DC Contactor	Protects main contactors from excess inrush current; a pre-charge contactor is used together with a pre-charge resistor to charge the capacitors of the power inverter typically to a level of 90%–98% of the battery voltage	<a href="#">DCNHR</a>	Allows a low-voltage signal to switch the contacts for a high-voltage signal	Wide amperage rating 30 A–100 A; gas-filled contact chamber and magnetic blowouts for arc suppression; available direct switched auxiliary circuit for status indication
	OR IGBT	Controls the power delivered to the PTC heating element	IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV	Tailored for an 800 V BEV electric vehicle; optimized for low conduction losses; short-circuit rated; HV SMD packages to enhance clearance and creepage distances	Automotive qualified IGBT; higher breakdown voltage BV <sub>CES</sub> (1300 V); wider range of currents IC (5 A to 85 A at 110 °C); surface mount discrete packages include TO-263HV, TO-268HV, and the through-hole TO-247
	TVS Diode	Transient voltage suppression	<a href="#">TP5.0SMDJ</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges

# Benefits of Littelfuse products in the Battery Disconnect Unit (BDU)/HV junction box



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
6	High-Voltage DC Contactor	The main contactors connect and disconnect the traction battery from the entire electric drivetrain in the vehicle	<a href="#">DCNHR</a>	Allows a low-voltage signal to switch the contacts for a high-voltage signal	Wide amperage rating; gas-filled contact chamber and magnetic blowouts for arc suppression; integrated coil economizer included in many models; available direct switched auxiliary circuit for status indication
	TVS Diode	Transient voltage suppression	<a href="#">TP5.0SMDJ</a>	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
7	Auxiliary Fuse	Short circuit protection; overload circuit protection	<a href="#">10EV, 20EV, 30EV1K, 25EV1K, 828, 526</a>	Provides safety protection in high-voltage environments, full range fuse; can protect the entire pack's voltage and short circuit current	High voltage; ceramic body ensures compatibility with high-temperature environment
8	High-Voltage DC Contactor	Controls other electrical loads in the vehicle operated by the HV battery (for example, electric heater, blower, AC compressor, power steering pump, etc.)	<a href="#">DCNHR</a>	Allows a low-voltage signal to switch the contacts for a high-voltage signal	Wide amperage rating; gas-filled contact chamber and magnetic blowouts for arc suppression; integrated coil economizer included in many models; available direct switched auxiliary circuit for status indication
9	High-Voltage DC Contactor	The main contactors connect and disconnect the traction battery from the entire electric drivetrain in the vehicle	<a href="#">DCNHR</a>	Allows a low-voltage signal to switch the contacts for a high-voltage signal	Wide amperage rating; gas-filled contact chamber and magnetic blowouts for arc suppression; integrated coil economizer included in many models; available direct switched auxiliary circuit for status indication
10	Discrete Thyristor	Fast discharge of the DC link for safety reason	<a href="#">S.Jxx40xxA</a>	High surge capability; offers low gate current trigger levels of 15 mA or 40 mA at approximately 1.5 V	High-temperature Thyristor with low gate current; available in a TO-220AB and surface mount TO-263 form factors; AEC-Q101 qualified
	<b>OR</b>  IGBT	Controls the power delivered to the PTC heating element	IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV	Tailored for 800 V BEV electric vehicles; optimized for low conduction losses; short-circuit rated; HV SMD packages to enhance clearance and creepage distances	Automotive qualified IGBT; higher breakdown voltage BV <sub>CES</sub> (1300 V); wider range of currents IC (5 A to 85 A at 110 °C); surface mount discrete packages include TO-263HV, TO-268HV, and the through-hole TO-247
11	Switch	Lid disconnection; detects an opening of the battery distribution unit	<a href="#">SSW</a>	Surface mount terminations; IP67	Products suitable for automotive applications; designed for ASIL-related applications



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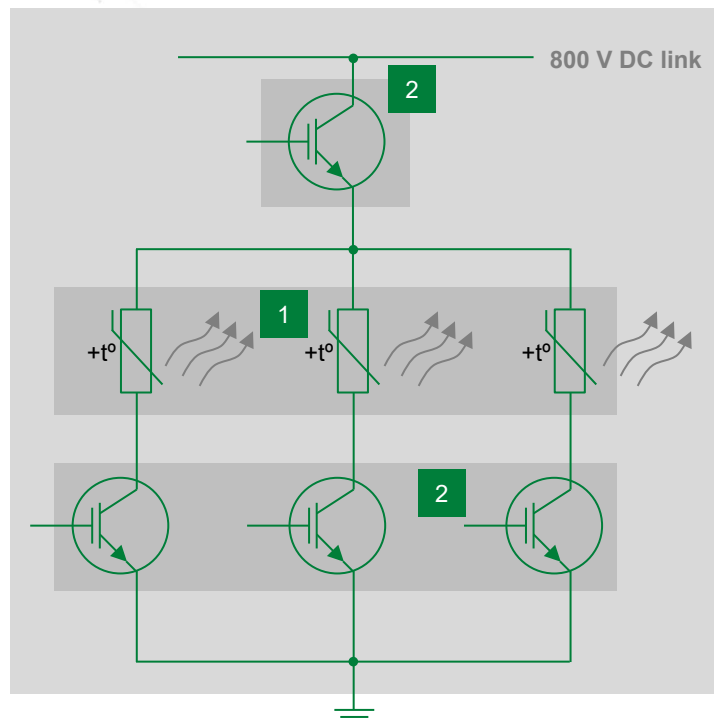
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## Thermal Management System with a PTC Heater for Battery Heating

# Thermal management system with a PTC Heater for battery heating



Click the product series in  
the table below for more info



	Technology	Product series
1	PTC Heater*	<a href="#">Custom</a>
2	IGBT*	IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV
	Gate Driver	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a>

\* Contact Littelfuse Sales for more details



# Benefits of Littelfuse products in a thermal management system



Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	PTC Heater*	Provide a safe source of heat for all kind of applications, such as battery heating, HV coolant heater, auxiliary air heater, camera /ADAS heater, etc.	<a href="#">Custom</a>	Self limiting; self regulating; no need for external control components; available in wide format (even A3 sheet size) and shape is fully customizable (by simply punching with the die tool); available in flexible and semi-rigid structure; possibility to coat the surface for increased robustness from chemical aggression	Wide power supply range: from 3 V to 1000 V; self-limiting temperature: from +35 °C up to more than +200 °C; power density: from 0.1 W/cm <sup>2</sup> to 150 W/cm <sup>2</sup> ; thickness: <0.4 mm (low voltage) and <1.3 mm (high voltage); suitable for clamping, welding, and soldering
2	IGBT*	Controls the power delivered to the PTC heating element	IXVA15N130A5AHV, IXVA30N130A5AHV, IXVT55N130A5AHV, IXVT85N130A5AHV	Tailored for 800 V BEV electric vehicles; optimized for low-conduction losses; short-circuit rated; HV SMD packages to enhance clearance and creepage distances	Automotive qualified IGBT; higher breakdown voltage BV <sub>CES</sub> (1300 V); wider range of currents IC (5 A to 85 A at 110 °C); surface mount discrete packages include TO-263HV, TO-268HV, and the through-hole TO-247
	Gate Driver	Controls the switching IGBTs	<a href="#">IXD_6xxSI</a> , <a href="#">IX4340NE</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10 ns	Tight tolerance; small form factor; fast thermal response

\* Contact Littelfuse Sales for more details.

# Select standards for automotive applications

Standard	Title	General scope	Littelfuse technology	Region
ISO 7637-2	Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only	Specifies test methods and procedures to ensure compatibility with conducted electrical transients of equipment installed on passenger cars and commercial vehicles fitted with 12 V or 24 V electrical systems. It describes bench tests for both the injection and measurement of transients. It is applicable to all types of road vehicles, independent of the propulsion system (For example, spark ignition, or diesel engine, and electric motor).	TVS Diode	Global
ISO 16750-2	Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2: Electrical loads	This standard applies to electric and electronic systems/components for road vehicles. It describes the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on/in the road vehicle.	TVS Diode	Global
ISO 10605:2008	Road vehicles – Test methods for electrical disturbances from electrostatic discharge	This standard specifies the electrostatic discharge (ESD) test methods necessary to evaluate electronic modules intended for vehicle use. It includes the following sources of ESD: in assembly, by service staff, and by vehicle occupants.	Diode Array PulseGuard® (AXGD) Multilayer Varistor	Global

# Additional information can be found at [Littelfuse.com](https://www.littelfuse.com)

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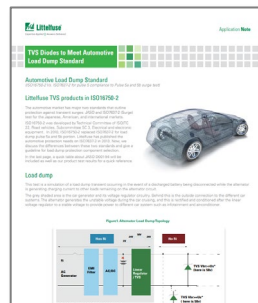


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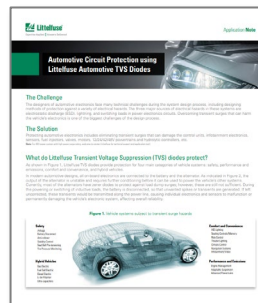
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