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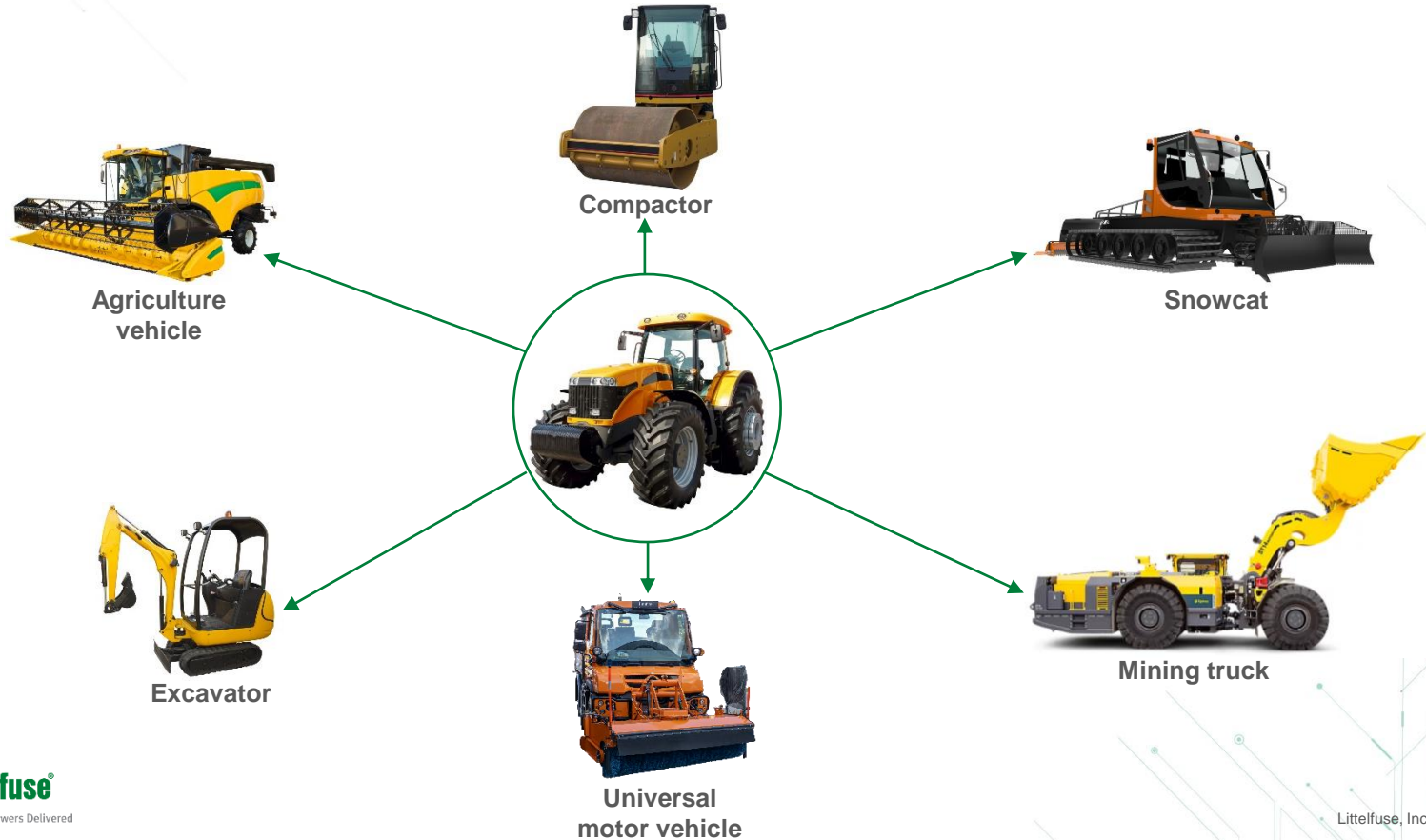
Off-highway Electric Vehicle Solutions



Transportation

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Off-highway electric vehicles share similar architecture



Off-highway electric vehicle market trends and drivers

Market trends and drivers

The off-highway electric vehicle market size was estimated at USD 5.48 billion in 2019 and is expected to grow at a CAGR of 21.2% from 2020 to 2027.

Pursuing electrification of off-highway vehicles promises less fuel consumption and long-term cost savings because of less maintenance.

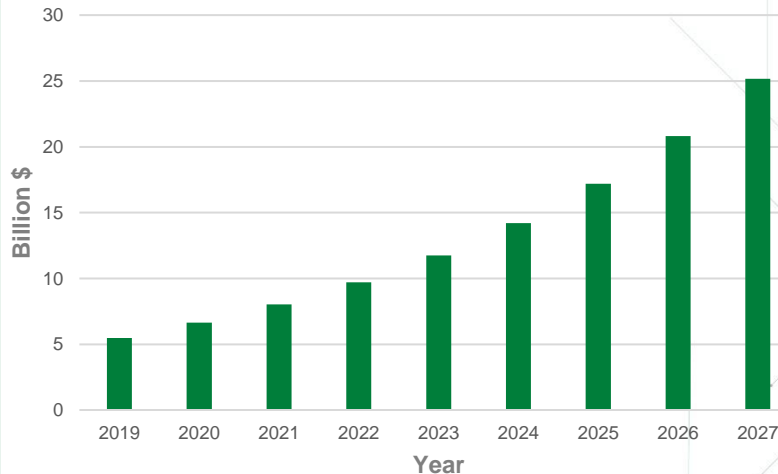
Aggressive steps toward minimizing emissions and ventilation costs in underground mining, stringent emission regulations by government agencies, and increase in infrastructure spending by various governments are some of the reasons driving the demand for off-road electric vehicles.

The off-highway electric construction vehicle segment accounted for the largest revenue share of around 38.2% in 2019. The agricultural segment is projected to grow at a CAGR of 22.3% from 2020 to 2027.

The North America region accounted for the largest revenue share of 42.7% for the market in 2019. The Asia Pacific region is projected to expand at the highest CAGR of 34.4% from 2020 to 2027.

Rapid growth at ~21.2% CAGR

Off-highway Electric Vehicle Market



Source: [Grand View Research, MarketsandMarkets](#)

Littelfuse solutions for off-highway electric vehicles

1 Onboard charger

- Fuse
- MOV + SIDACTor®
- GDT
- IGBT
- Si/SiC MOSFET
- Gate Driver
- TVS Diode
- TVS Diode Array

2 Battery + BMS*

- Fuse
- TVS Diode
- TVS Diode Array
- Contactor relay
- NTC

3 12 V Battery + PDU**

- High-current Fuse
- Fuse Box
- DC Power Distribution Module
- Battery Disconnect Switch



4 DC/DC Converter

- TVS Diode
- TVS Diode Array
- Si/SiC MOSFET
- Gate Driver
- Diode

5 Traction motor inverter

- Fuse
- TVS Diode
- TVS Diode Array
- IGBT
- IGBT Module
- Gate Driver

6 Junction Box

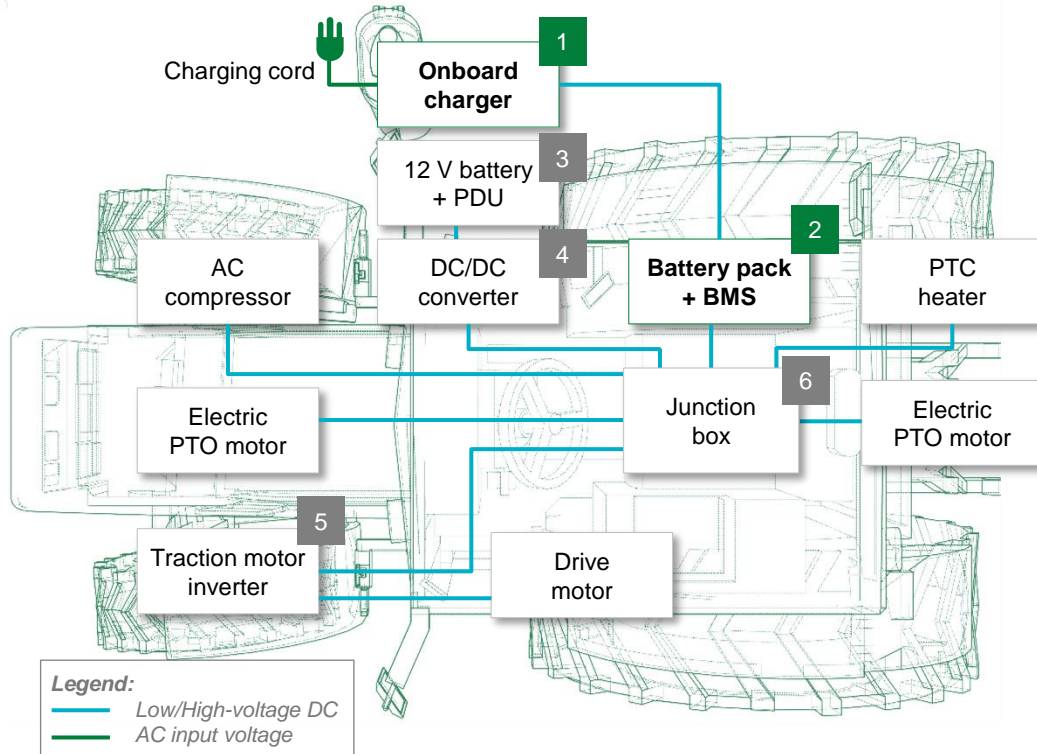
- Fuse
- HVDC† Contactor Relay
- Power Distribution Module

* BMS: Battery Management System

** PDU: Power Distribution Unit

† HVDC: High Voltage Direct Current

Off-highway electric vehicle powertrain architecture



Legend:
— Low/High-voltage DC
— AC input voltage

BMS: Battery Management System
 PDU: Power Distribution Unit
 PTO: Power Take-off
 PTC: Positive Temperature Coefficient

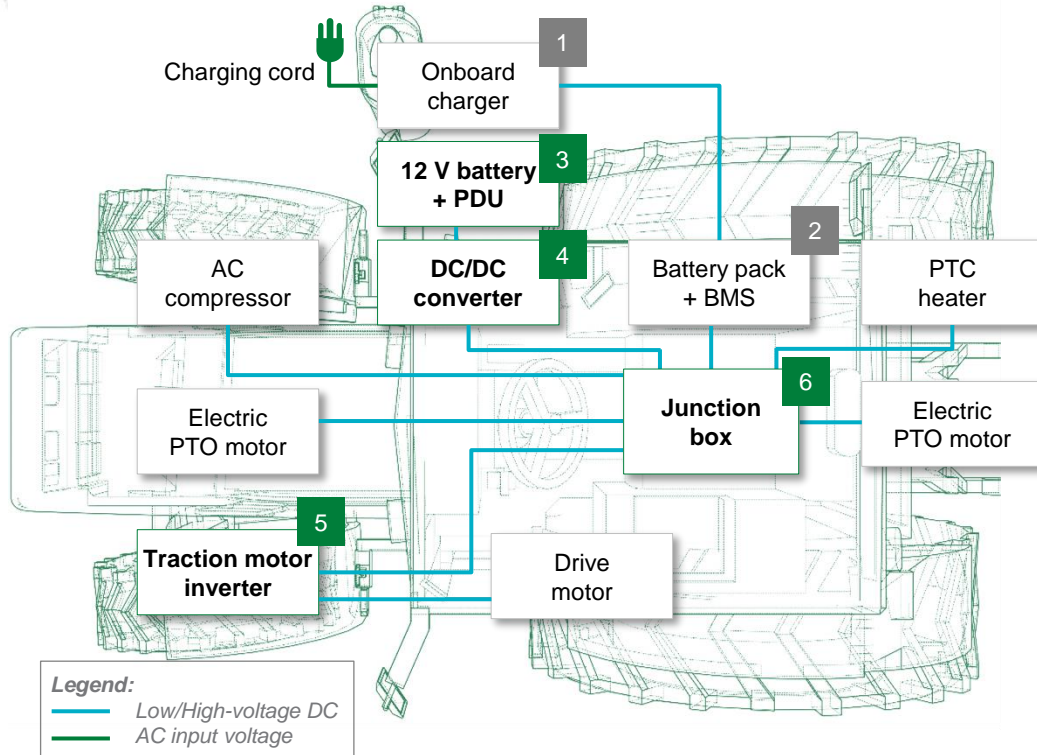
	Technology	Product series
1	AC Fuse	LC HEV 50A , HC10EV*,
	DC Fuse	526*, 527*, HC10EV* Mega®70 V , MIDI 70V
	MOV	AUMOV
	SIDACTor®	Pxxx0FNL
	GDT	CG2 , CG3
	TVS Diode	TPSMB , TPSMC , SZ1SMC , SZ1SMB
	TVS Diode Array	AQ24CANA
	Gate Driver	IXD 6xxSI , IX442X IX4340NE , IX4351NE
	Si MOSFET or SiC MOSFET	X Class , X2 Class LSIC1MOxx
	IGBT	Planar , Trench
2	DC Fuse or Specialty Power Fuse	SHEV , HC20EV , HC10EV* CNNE , JLLS
	SMD Fuse	438A , 441A ,
	TVS Diode	TPSMB , TPSMC , SZ1SMC , SZ1SMB
	TVS Diode Array	AQ24CANA
	HVDC Contactor Relays	DCNEV , DCNLEV
	NTC	KC , LC , Custom Assembly

* Please contact Littelfuse associates for details

Features and benefits of Littelfuse products

	Technology	Function in application	Series	Benefits	Features
1	AC Fuse	AC input protection from short circuit and overload condition	LC HEV 50A , HC10EV*	Provides safety protection in high-voltage environments; full range fuse	Bolt down form factor; high breaking capacity; qualified to ISO 8820 standard
	DC Fuse	DC output protection from short circuit and overload condition	526*, 527*, HC10EV* Mega®70 V , MIDI 70V	Guarantees safe interruption at any voltage; ideal for battery protection	Automotive bolt-down fuse; high interrupt rating; operating temperature -40 °C to 125 °C; low open-state resistance
	MOV+ SIDACTor®	Protection from lightning and system transient surges	AUMOV	Provides lower clamping voltage; ensures the reliable performance; no wear out	Wide range of surge current ratings, disk sizes, and lead options
	GDT	Ensures electrical isolation between L-N-G	CG2 , CG3	Safety to the system with high isolation	Compact design; semiconductor-based solution
	TVS Diode	Protects semiconductor products from transients	TPSMB , TPSMC , SZ1SMC , SZ1SMB	Enables compact design; improves system reliability	Rugged, low leakage current
	TVS Diode Array	Protects CAN Bus from ESD, EFT, and voltage transient	AQ24CANA	Ensures reliability of the equipment without performance degradation	600 W peak pulse power capability; excellent clamping capability; small footprint
	Gate Driver	Efficient switching of MOSFETs and IGBTs	IXD_6xxSI , IX442X IX4340NE IX4351NE	Ultra-fast turn-on and turn-off of MOSFET; extremely robust device	AEC-Q101 qualified; meets ESD protection levels specified under safety standard; low leakage current and clamping voltage
	Si MOSFET or SIC MOSFET	Switches the charge/discharge cycles based on controller feedback	X Class , X2 Class LSIC1MOxx	Minimizes switching losses; ultra-fast switching speeds; eliminates the need for separate supply	1.5 A to 30 A peak source/sink drive current; wide operating voltage range; -40 °C to +125 °C; low propagation delay times
	IGBT		Planar , Trench	High efficiency; high power density; easy to mount	Internal charge pump regulator for selectable negative gate drive bias; protection features (UVLO detection and thermal shutdown)
2	DC Fuse or Specialty Fuse	Short circuit protection and overload circuit protection	SHEV , HC20EV , HC10EV*	Provides safety protection in high-voltage environments; quicker reaction time	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Q_g ; dv/dt ruggedness
	SMD Fuse		CNNE , JLLS	Hard-switching capability; high power density; low gate drive requirements	Low V_{CESAT} , low E_{on}/E_{off} ; high surge current capability; positive thermal coefficient of V_{CESAT} ; short circuit capability
	TVS Diode	Protects from large current transients in hot-swap application	438A , 441A	Excellent temperature stability and performance reliability; compact design	Low V_{CESAT} , low E_{on}/E_{off} ; high surge current capability; positive thermal coefficient of V_{CESAT} ; short circuit capability
	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	TPSMB , TPSMC , SZ1SMC , SZ1SMB	Lowest qualification effort; ensures system reliability	Tested to new AECQ specifications; fast response to fault current; surface mount device
	HVDC Contactor Relays	Connect disconnected battery from main circuitry	AQ24CANA	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection and in-vehicle transient surge requirement as defined under IEC and ISO safety standards; excellent clamping capability
	NTC	Temperature monitoring of battery pack during charging and discharging cycles	DCNEV , DCNLEV	Allows a low-voltage signal to switch the contacts for a high-voltage signal	AEC-Q101 qualified; meets ESD protection levels specified under safety standards; low leakage current and clamping voltage
			KC , LC , Custom Assembly	Provides accurate temperature reading to enable safe device operation	Wide range of capabilities—can switch from tens of amperes to thousands of amperes, and tens of volts to thousands of volts

Off-highway electric vehicle powertrain architecture



Legend:
— Low/High-voltage DC
— AC input voltage

BMS: Battery Management System
 PDU: Power Distribution Unit
 PTO: Power Take-off
 PTC: Positive Temperature Coefficient

	Technology	Product series
3	Ignition Switch	95060
	High-current Fuse	ZCase
	Fuse Block	FHZ
	TVS Diode	SLD8S
	DC Power Distribution Module	HWB60, HWB18
4	Manual Battery Disconnect Switches	08010100, 08099100
	TVS Diode Array	AQ24CANA
	TVS Diode	TPSMB, SZ1SMB, SZP6SMB
	Gate Driver	IXD 6xxSI, IX4340NE, IX4351NE X Class, X2 Class, LSIC1MOxx
	Si/SiC MOSFET	X Class, X2 Class, LSIC1MOxx
	Diode	DSEP, LSIC2SD, DHG
	5	TVS Diode Array
TVS Diode		TPSMB
Gate Driver		IXD 6xxSI, IX4340NE, IX4351NE
Discrete IGBT (1200 V, 150 A)		Trench XPT™, Planar
IGBT Module (1200 V, 450 A)		MIXA450PF1200TSF
6	DC output Fuse	526*, 527*, HC10EV* Mega®70 V, MIDI 70V
	HVDC Contactor Relays	DCNEV, DCNLEV
	Power Distribution Module	MDB5

* Please contact Littelfuse associates for details

Features and benefits of Littelfuse products

	Technology	Function in application	Series	Benefits	Features
3	Ignition Switch	Activates the main electrical systems for the vehicle	95060	Stands up to mechanical shock and vibration and will not corrode or rust; integrated Deutsch-type socket makes electrical connection quick and easy	Available in broad voltage range up to 48 V; made of rugged engineering grade plastic; UL tested
	High-current Fuse	Overcurrent protection for the wire harness	ZCase	Compact design when compared to a traditional solution; integration of the pre-fuse function into the main junction box	Wide rating range up to 600 A; voltage rating: 32 VDC; small footprint
	Fuse Block	Fuse holder designed for primary high current power distribution, usually paired with a ZCASE shunt for the input	FHZ	Improved flexibility of design; wide variety of configurations possible; protects fuses from dust and debris	Mega range fuses (40–600 A) can be used in any location; flexible bussing and configurable stud sizes; corrosion-resistant coatings
	TVS Diode	Load dump protection	SLD8S	Optimizes board space; lowest qualification effort; ensures system reliability	AEC-Q101 qualified; small footprint; meets IEC standards for ESD protection and ISO for in-vehicle transient surges
	DC Power Distribution Module	Hard-wired 12 V power distribution module protects and distributes current throughout an application	HWPB60 , HWPB18	Allows the user to customize their own circuitry; easy to mount; multiple PDMs can be dovetailed together to expand circuit protection capacity	Uses MINI (280 style) circuit protection component; features multiple cavities creating a high-density fuse module; compact footprint
	Manual Battery Disconnect Switches	Cuts off the connection between a battery and accessories that can drain it	08010100 , 08099100	Lowers the chances of the battery malfunctioning and protects it against electrical fires and theft	Current rating 100–500 A; handle and contacts are designed with a unique 360° C operation for activating the switch ON/OFF; waterproof and dustproof
4	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	AQ24CANA	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under safety standards; low leakage current and clamping voltage
	TVS Diode	Gate driver protection	TPSMB , SZ1SMB , SZP6SMB	Lowest qualification effort; ensures system reliability	AEC-Q101 qualified; meets ESD protection and in-vehicle transient surge requirement as defined under IEC and ISO safety standards; excellent clamping capability
	Gate Driver	Controls the switching MOSFETs	IXD_6xxSI , IX4340NE	Ultra-fast turn-on and turn-off of MOSFET; extremely robust device	1.5A to 30A Peak Source/Sink Drive Current; wide operating voltage range; -40°C to +125°C; low propagation delay times
			IX4351NE	Minimizes switching losses; ultra-fast switching speeds; eliminates the need for separate supply	Internal charge pump regulator for selectable negative gate drive bias; protection features (UVLO detection and thermal shutdown)
	Si MOSFET or SiC MOSFET	High-frequency switching and rectification	X Class , X2 Class , LSIC1MOxx	High efficiency; high power density; easy to mount	AEC-Q101 qualified SMPD packages; low on-resistance R _{DS(ON)} and gate charge Q _g
Diode	DSEP , LSIC2SD , DHG		Reduces switching losses; increases efficiency	High surge capability; negligible I _{RR} ; T _J 175 °C	



Click on the product series in the table below for more info

Features and benefits of Littelfuse products

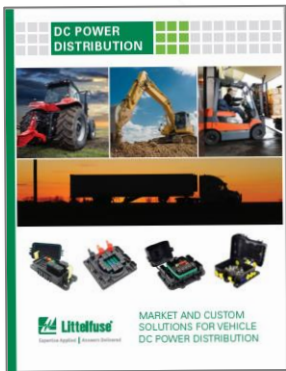
	Technology	Function in application	Series	Benefits	Features
5	TVS Diode Array	Protects CAN bus from ESD, EFT and voltage transient	AQ24CANA	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under safety standards; low leakage current & clamping voltage
	TVS Diode (Active clamping)	Activates clamping	TPSMB	Excellent clamping capability; meets automotive standards; fast response time	AEC-Q101 qualified; meets ESD protection and in-vehicle transient surge requirement as defined under IEC and ISO safety standards; excellent clamping capability
	Gate Driver	Controls the switching of IGBTs	IXD_6xxSI , IX4340NE	Ultra-fast turn-on and turn-off of MOSFET; extremely robust device	1.5 A to 30 A Peak Source/Sink Drive Current; wide operating voltage range; -40 °C to +125 °C; low propagation delay times
			IX4351NE	Minimizes switching losses; ultra-fast switching speeds; eliminates the need for separate supply	Internal charge pump regulator for selectable negative gate drive bias; protection features (UVLO detection and thermal shutdown)
	Discrete IGBT (1200 V, 150 A)	Switches applications	Trench XPT™ , Planar	Hard-switching capability; high power density; low gate drive requirements	Low V_{CESAT} ; low E_{on}/E_{off} ; high surge current capability; positive thermal coefficient of V_{CESAT} ; short circuit capability
IGBT Module (1200 V, 450 A)	MIXA450PF1200TSF		Short circuit rated for 10 μ sec; low gate charge; low EMI and competitive low $V_{CE(SAT)}$	Rugged XPT design with thin wafer technology	
6	DC output Fuse	Short circuit protection and overload circuit protection	526* , 527* , HC10EV* , Mega®70 V , MIDI 70V	Provides safety protection in high-voltage environments; quicker reaction time	Bolt down form factor; fast-acting; high breaking capacity; qualified to ISO 8820 standard
	HVDC Contactor Relays	Protects the electrical loads operated through the battery	DCNEV , DCNLEV	Allows a low-voltage signal to switch the contacts for a high voltage signal	Wide range of capabilities – can switch from tens of amperes to thousands of amperes, and tens of volts to thousands of volts
	Power Distribution Module	Main power distribution module protects and distributes current throughout an application	MDB5	Robust solution for high corrosion environments	Capability to handle fuse ratings from 23–500 A and voltages up to 70 V; full range of fuses for applications from 12 V–48 V+; user choice of sealing options

* Please contact Littelfuse associates for details.

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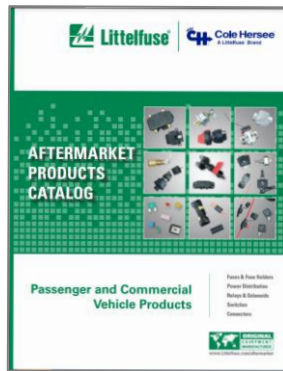
DC Power Distribution
Selection Guide



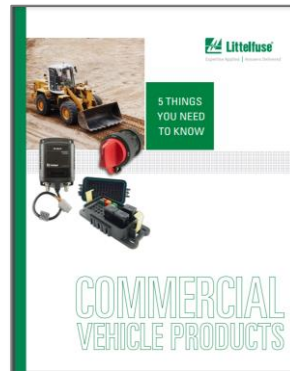
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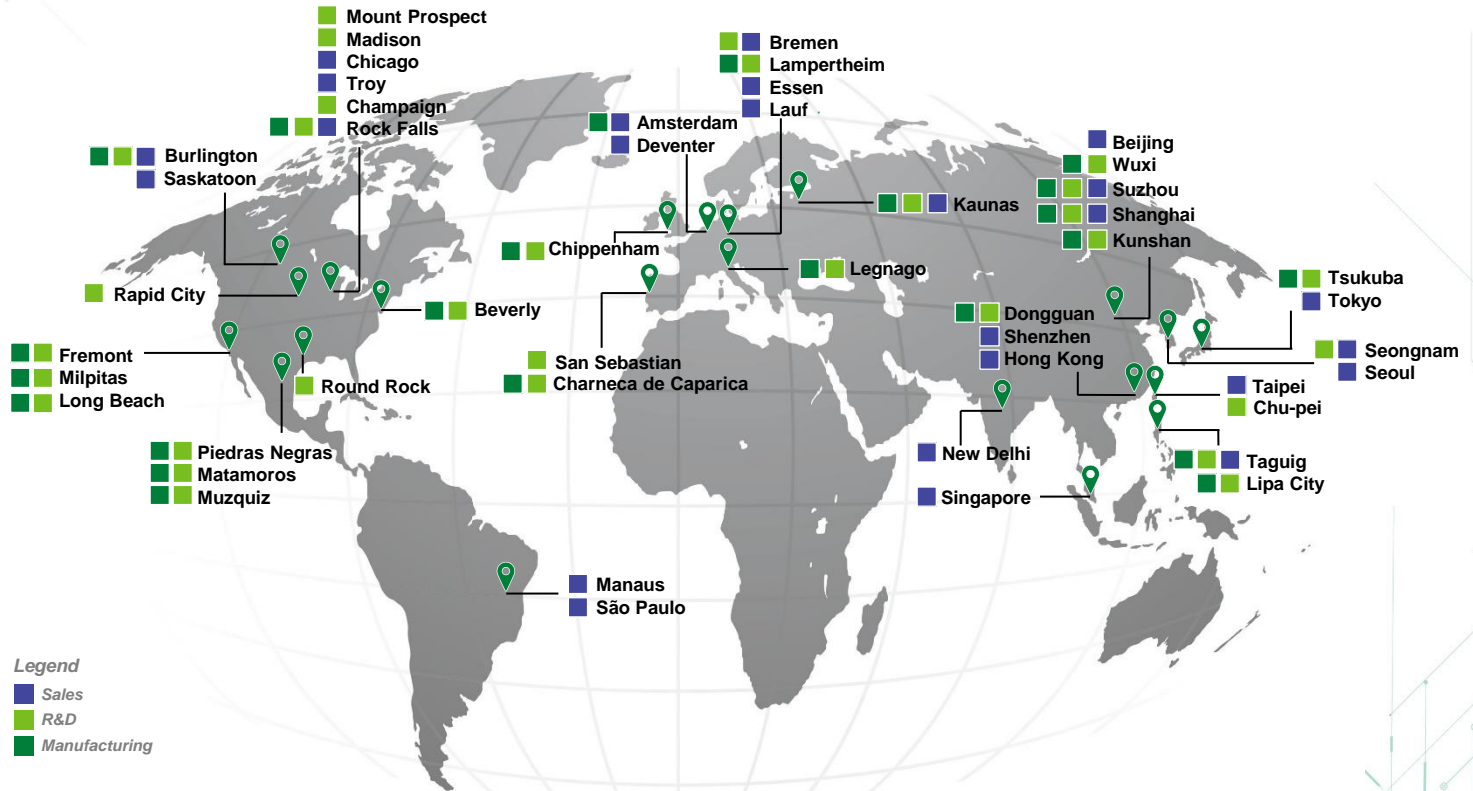
Relays
Brochure



Power Semiconductor
Selection Guide



Local resources supporting our global customers



Legend

- Sales
- R&D
- Manufacturing

Partner for tomorrow's electronic systems

BROAD PRODUCT PORTFOLIO

An industrial technology manufacturing company empowering a sustainable, connected, and safer world

APPLICATION EXPERTISE

Our engineers partner directly with customers to help speed up product design and meet their unique needs

GLOBAL CUSTOMER SERVICE

Our global customer service team is with you to anticipate your needs and ensure a seamless experience

COMPLIANCE AND REGULATORY EXPERTISE

We help customers in the design process to account for requirements set by global regulatory authorities

TESTING CAPABILITIES

We help customers get products to market faster. We offer certification testing to global regulatory standards

GLOBAL MANUFACTURING

High-volume manufacturing that is committed to the highest quality standards



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