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Off-highway Electric Vehicle Solutions

Transportation

REV0624

Off-highway electric vehicles share similar architecture

Agricultural vehicle

Digging excavator

Universal motor vehicle

Mining truck

Compactor

Snowcat

Wheel loader (bulldozer)

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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.

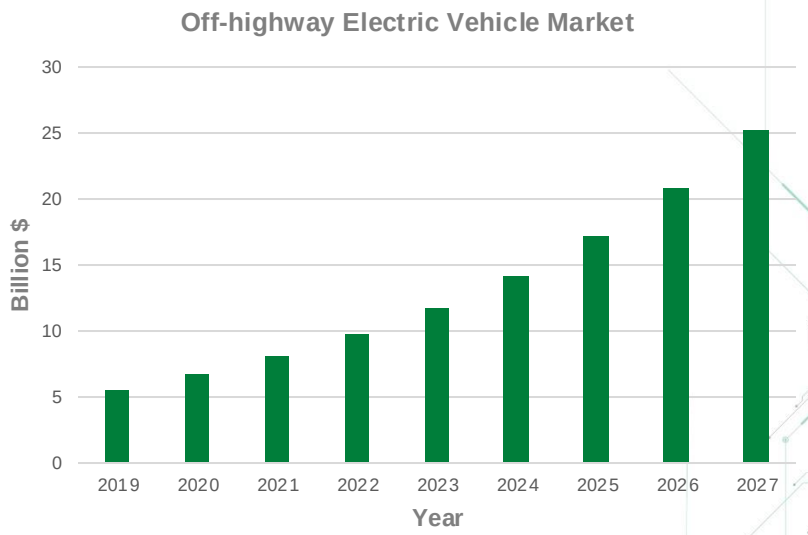
Pursuing electrification of off-highway vehicles promises less fuel consumption and long-term cost savings because of less maintenance.

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



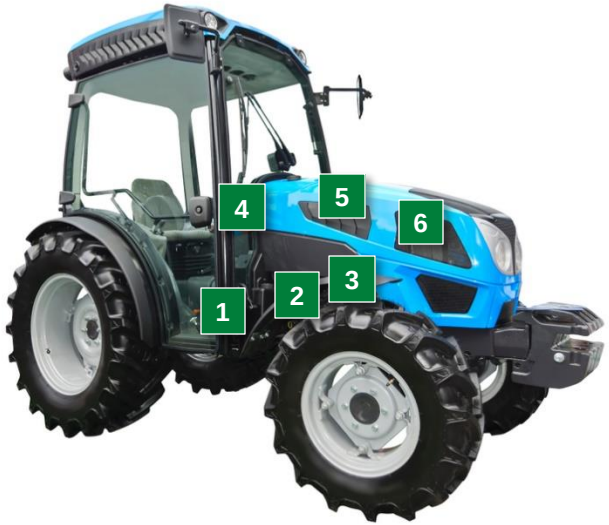
Source: Grand View Research, MarketsandMarkets

Littelfuse solutions for off-highway electric vehicles

1 Onboard charger
Fuse, MOV, SIDACtor®, GDT, TVS Diode, TVS Diode Array, MOSFET, Gate Driver

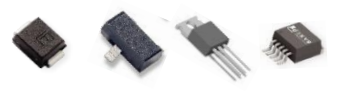
2 Battery + BMS*
Fuse, TVS Diode, TVS Diode Array, NTC, HVDC Contactor Relays, TTape™ Platform

3 12 V Battery + PDU**
Fuse, Switches, Power Distribution Modules, Battery Disconnect Switches,

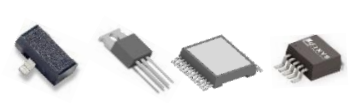


** BMS: Battery Management System*
*** PDU: Power Distribution Unit*
† HVDC: High Voltage Direct Current

4 DC / DC Converter
TVS Diode, TVS Diode Array, MOSFET, Gate Driver, Diode



5 Traction motor inverter
TVS Diode, TVS Diode Array, IGBT, Gate Driver



6 Junction Box
Fuse, Power Distribution Modules, HVDC† Contactor Relays

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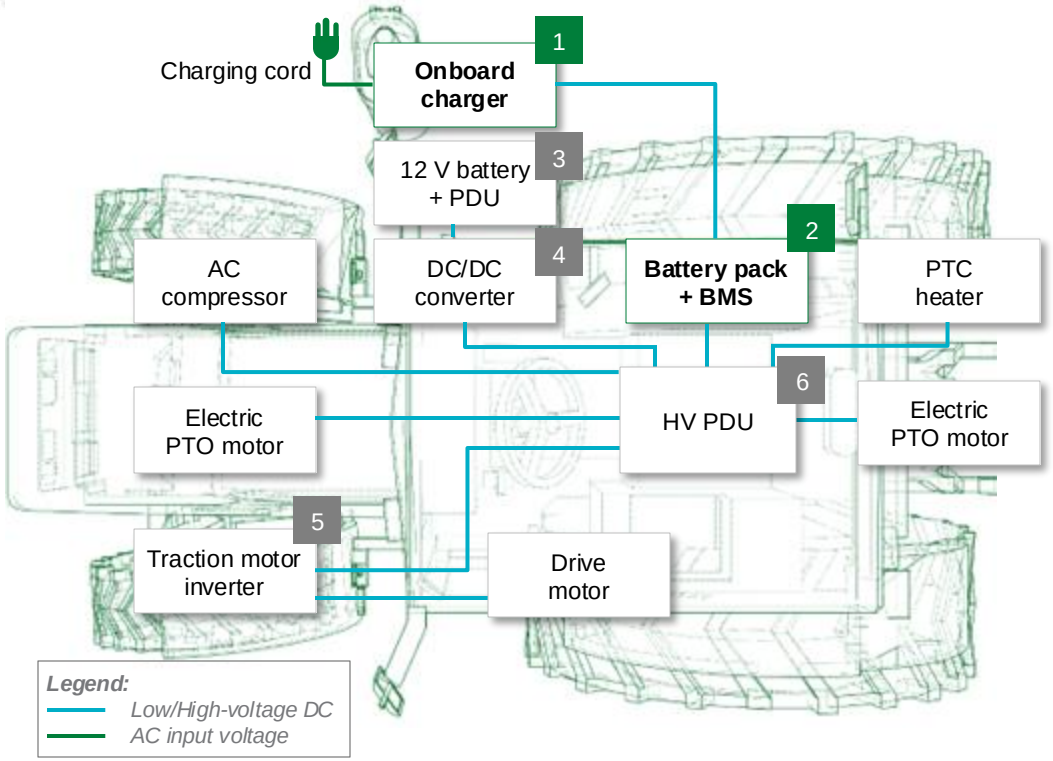
Click the product series in the table below for more info

Off-highway electric vehicle powertrain architecture



	Technology	Product series
1	AC Fuse	LC HEV 50A, LC10EV,
	DC Fuse	526, 527, LC10EV 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, LC10EV
		Mega®70 V, MIDI 70V
	SMD Fuse	438A, 441A,
	TVS Diode	TPSMB, TPSMC, SZ1SMC, SZ1SMB
	TVS Diode Array	AQ24CANA
	HVDC Contactor Relays	DCNLR, DCNHR, DCNEVT, DCNHS
	NTC	KC, LC, Custom Assembly
	TTape™ Platform	TTP

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

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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
1	AC Fuse	AC input protection from short circuit and overload condition	LC HEV 50A, LC10EV,	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, LC10EV 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 ºC to 125 ºC; low on-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
			Pxxx0FNL		Compact design; semiconductor-based solution
	GDT	Ensures electrical isolation between L-N-G	CG2, CG3	Safety to the system with high isolation	Rugged, low leakage current
	TVS Diode	Protects semiconductor products from transients	TPSMB, TPSMC, SZ1SMC, SZ1SMB	Enables compact design; improves system reliability	600 W peak pulse power capability; excellent clamping capability; small footprint
	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 standard; low leakage current and clamping voltage
	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	1.5 A to 30 A peak source / sink drive current; wide operating voltage range; -40 °C to +125 °C; low propagation delay times
			X Class, X2 Class	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	Switches the charge/discharge cycles based on controller feedback	LSIC1MOxx	High efficiency; high power density; easy to mount	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	IGBT		Planar, Trench	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

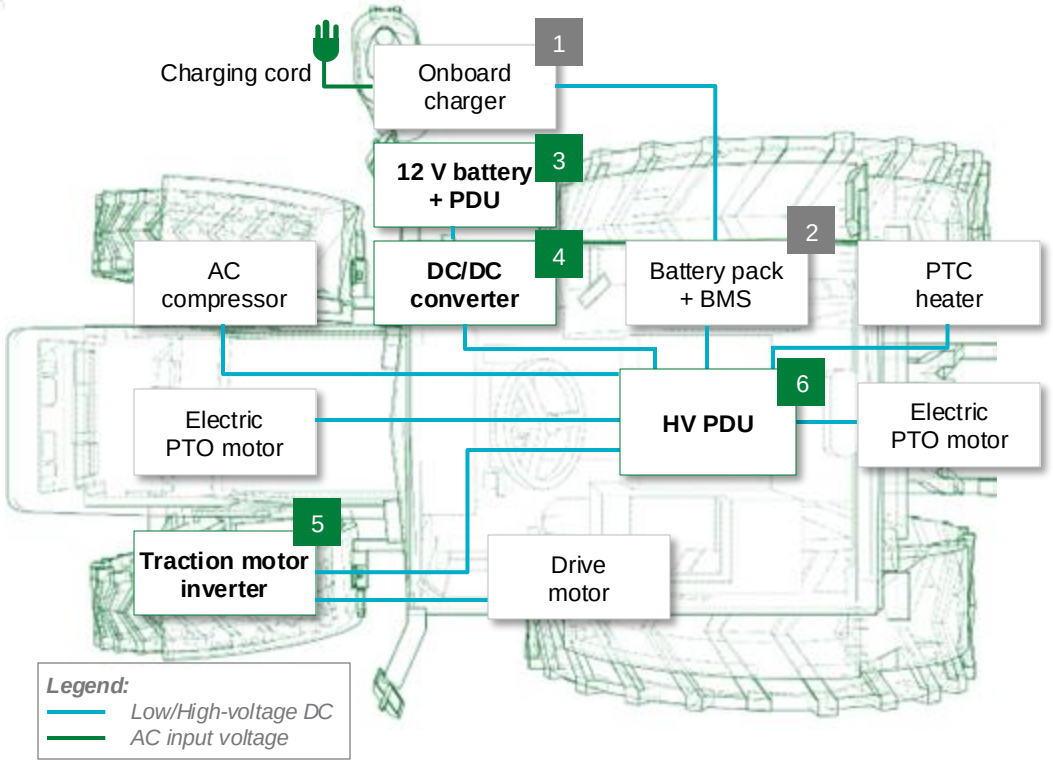
Click on the product series in the table below for more info

Features and benefits of Littelfuse products

	Technology	Function in application	Series	Benefits	Features
2	DC Fuse or Specialty Fuse	Short circuit protection and overload circuit protection	SHEV, HC20EV, LC10EV	Provides safety protection in high-voltage environments; quicker reaction time	Bolt down form factor; fast-acting; high breaking capacity; qualified to ISO 8820 standard
			Mega®70 V, MIDI 70V		High interrupt ratings; compact size
	SMD Fuse	Sense line protection	438A, 441A	Excellent temperature stability and performance reliability; compact design	Tested to new AECQ specifications; fast response to fault current; surface mount device
	TVS Diode	Protects from large current transients in hot-swap application	TPSMB, TPSMC, SZ1SMC, SZ1SMB	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
	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
	HVDC Contactor Relays	Connect disconnected battery from main circuitry	DCNLR, DCNHR, DCNEVT, DCNHS	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
	NTC	Temperature monitoring of battery pack during charging and discharging cycles	KC, LC, Custom Assembly	Provides accurate temperature reading to enable safe device operation	Custom solutions; small form factor; fast thermal response
	TTape™ Platform	Overtemperature monitoring of many cells or large area with single MCU input	TTP	Helps the MCU to wake from sleep mode at overtemperature events; <1s 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

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

Off-highway electric vehicle powertrain architecture



	Technology	Product series
3	Ignition Switch	95060
	Switches (Rocker, Pushbutton, Key switch)	DSR, V-Series, VM-Series, K12S, APB, AP, PNP
	High-current Fuse	Zcase, Mega, Midi
	Fuse Block	FHZ, MDB, MDB5
	TVS Diode	SLD8S
	DC Power Distribution Module	HWB60, HWB18, MiniFlec
	Manual Battery Disconnect Switches	08010100, 08099100, TR
4	TVS Diode Array	AQ24CANA
	TVS Diode	TPSMB, SZ1SMB, SZP6SMB
	Gate Driver	IXD_6xxSI, IX4340NE, IX4351NE
	Si MOSFET SiC MOSFET	X Class, X2 Class, LSIC1MOxx
	Diode	DSEP, LSIC2SD, DHG
5	TVS Diode Array	AQ24CANA
	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, 828, LC10EV Mega®70 V, MIDI 70V
	HVDC Contactor Relays	DCNLR, DCNHR, DCNEVT, DCNHS
	Power Distribution Module	MDB5

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

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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
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
	Switches (Rocker, Pushbutton, Key switch)	For various in cabinet functional control (joystick. cabin controls, lights/fans/etc.)	DSR, V-Series, VM-Series	reliable, high-quality and high-performance switches; protects against harsh environment dust, liquid; suitable for high amp, industrial applications	Wide range of switches; IP65 or IP6; custom design capabilities
	High-current Fuse	Overcurrent protection for the wire harness	Zcase, Mega, Midi	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, MDB, MDB5	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	HWB60, HWB18, MiniFlec	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
	Battery Disconnect Switches	Cuts off the connection between a battery and accessories that can drain it	08010100, 08099100, TR	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 Qg
	Diode		DSEP, LSIC2SD, DHG	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C

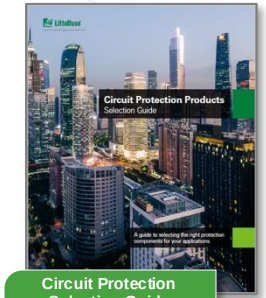
Click on the product series in the table below for more info

Features and benefits of Littelfuse products

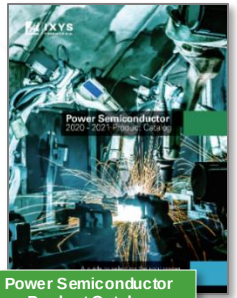
	Technology	Function in application	Series	Benefits	Features
5	TVS Diode Array	Protects CAN bus from ESD, EFT and voltage transient	AQ24CANA	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under safety standards; low leakage current and 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 Eon / Eoff; 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 µsec; 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, 828, LC10EV 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	DCNLR, DCNHR, DCNEVT, DCNHS	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

Additional information can be found at Littelfuse.com

Explore the world of Littelfuse products and applications with ecatalogs (ecatalogs.littelfuse.com)

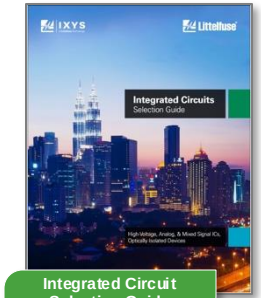


Circuit Protection Selection Guide



Power Semiconductor Product Catalog

Sensing Products Selection Guide

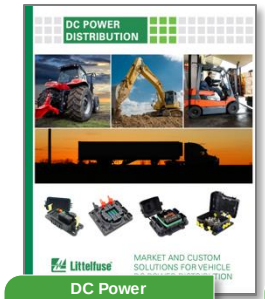


Integrated Circuit Selection Guide

C&K Switches Selection Guide

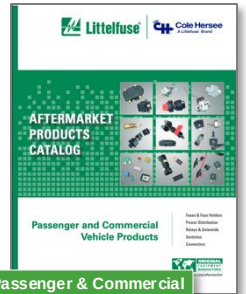
C&K Sensors Selection Guide

Click on images for more information



DC Power Distribution Guide

Automotive Power Relays Selection Guide



Passenger & Commercial Vehicle Guide

Scan the code to learn more!

High Voltage DC Contactor Relays

C&K Switch Solutions

Transportation Product Catalog

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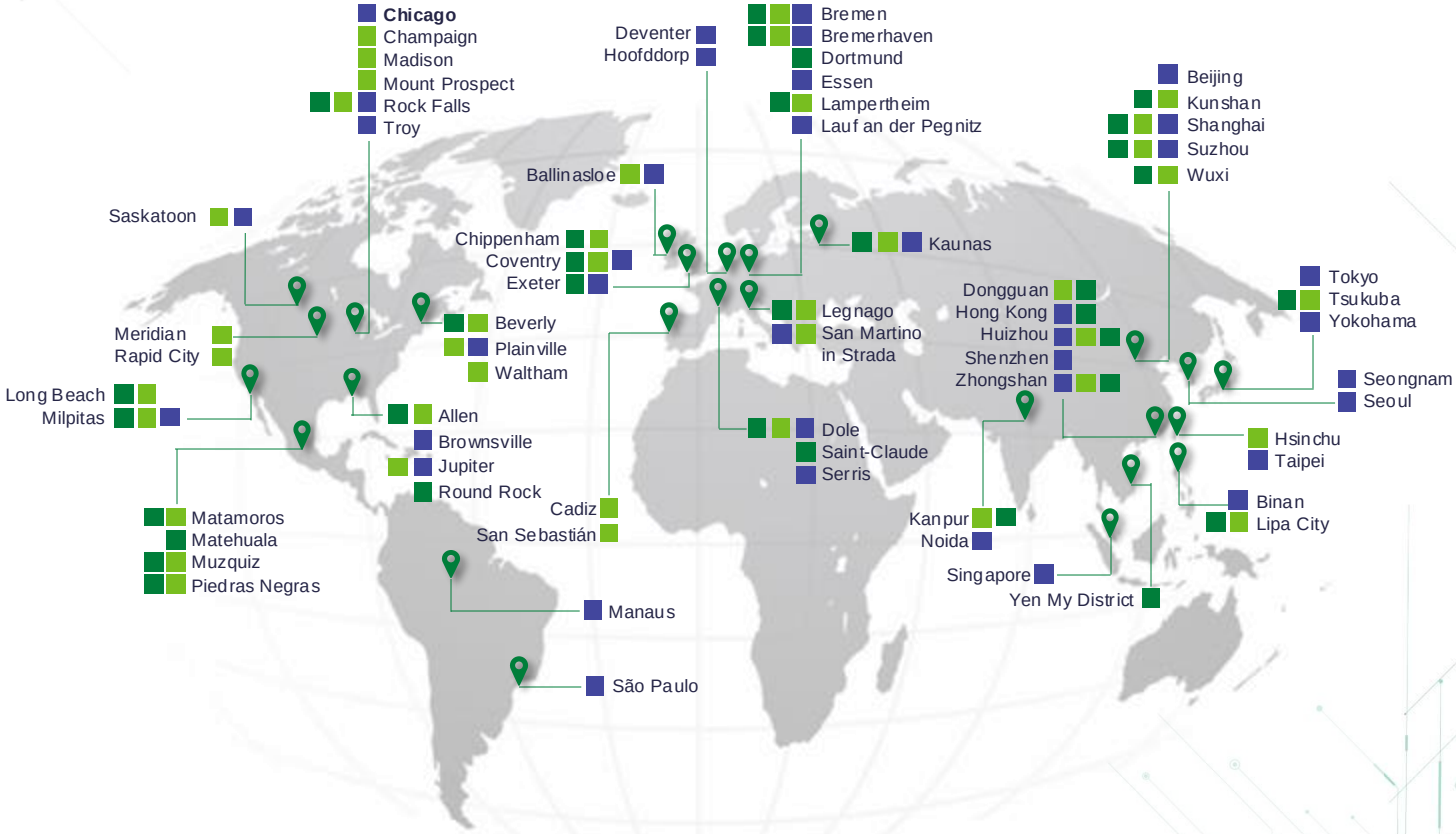
Local resources supporting our global customers



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Partner for tomorrow’s electronic systems

Broad Product Portfolio

We are an industrial technology manufacturing company empowering a sustainable, connected, and safer world.

Testing Capabilities

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

Application Expertise

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

Compliance and Regulatory

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