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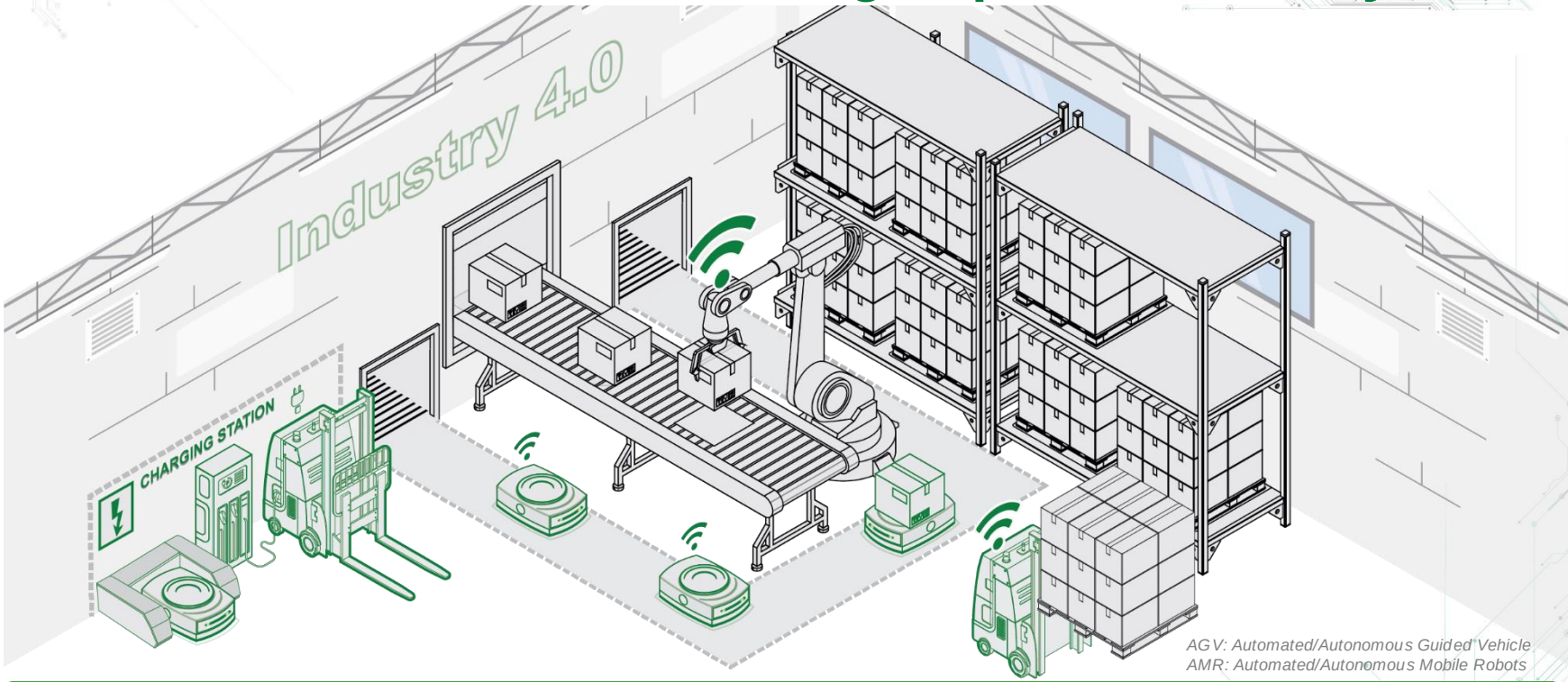
Material Handling Charging Solutions

EV Infrastructure

REV0723

Material handling electric vehicles such as AGVs, AMRs, and forklifts are an integral part of Industry 4.0



AGV: Automated/Autonomous Guided Vehicle
AMR: Automated/Autonomous Mobile Robots

Littelfuse offers solutions for a vehicle's entire electrical system (including charging) that help distribute, protect, and control vehicle power

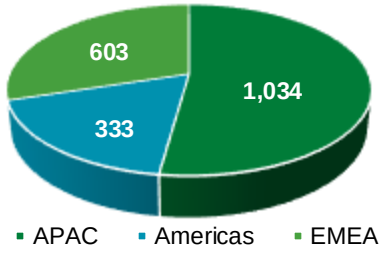
Material handling equipment such as AGVs, AMRs, and electric drive train are an integral part of Industry 4.0

Market trends and drivers

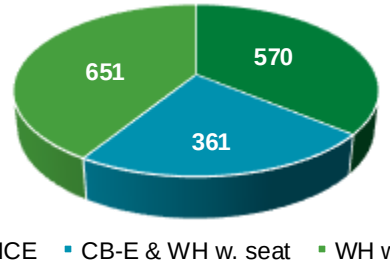
- **Regulatory requirements on exhaust gases get stricter**
  - Replacement of internal combustion engine by electric forklift
    - Introduction of high-power Li-Ion batteries
    - Increase in charging power
    - More outdoor use of chargers
- **Demand for higher performance and reduced TCO**
  - Replacement of lead-acid by Li-Ion batteries
    - Increase of energy content, power density, and efficiency
    - Reduce space for charging infrastructure
- **Driverless operation – driving and charging**
  - Wireless charging
  - Robot-assisted charging
- **Worldwide total units delivered:**
  ~1.97 million trucks (+24.6 % vs. 2021)
- **Total revenue of Top 10 manufactures:**
  ~ 40.7 billion EUR (+13.7 % vs. 2021)

Rapid growth in material handling

Worldwide deliveries in k units during 2020/2021



Segmentation in k units during 2020/2021



Source: World Industrial Truck Statistics (WITS) 2020/2021, dhf-Intralogistik-10-2022.pdf

Acronyms:
AGV: Automated Guided Vehicle
AMR: Automated Mobile Robot

CB: Counterbalance
WH: Warehouse
ICE: Internal Combustion Engine

Recommended Littelfuse solutions for material handling equipment (AGVs, AMRs, & electric forklifts)

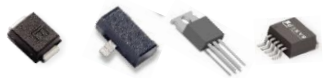
1 Charging station
Fuse, MOV, Rectifier Bridge, Diode, Si/SiC MOSFET, Gate Driver

2 Onboard charger
Fuse, MOV, SIDACtor®, GDT, TVS Diode, TVS Diode Array, Si/SiC MOSFET, Gate Driver

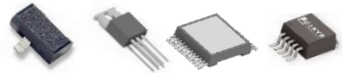
3 Battery + BMS*
Fuse, TVS Diode, TVS Diode Array, NTC, DC Contactor Relays

4 12 V Battery + PDU**
Fuse, Switches, Power Distribution Unit, Battery Disconnect Switches,

5 DC-DC Converter
TVS Diode, TVS Diode Array, MOSFET, Gate Driver, Diode



6 Drive train motor inverter
TVS Diode, TVS Diode Array, MOSFET/IGBT, Gate Driver



7 Junction box
Fuse, Power Distribution Unit, HVDC† Contactor Relays

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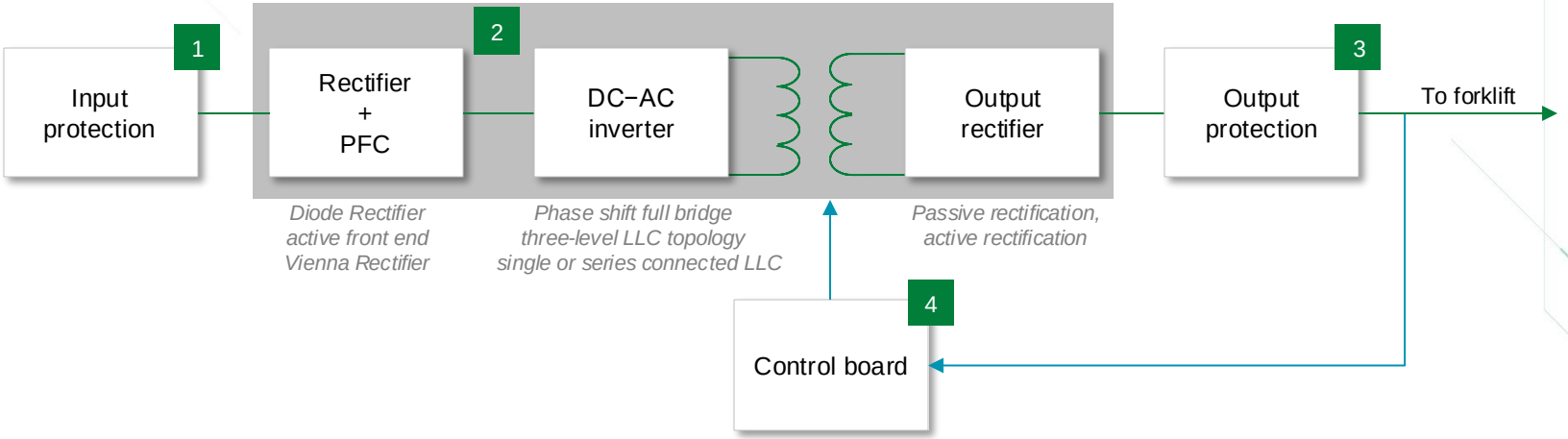
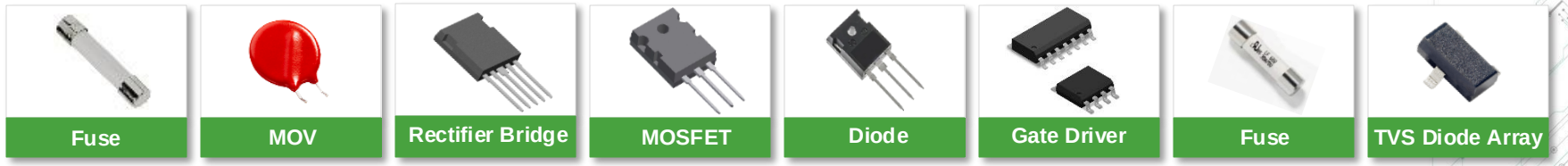
** BMS: Battery Management System*
*** PDU: Power Distribution Unit*
† HVDC: High Voltage Direct Current

Material handling charging equipment overview





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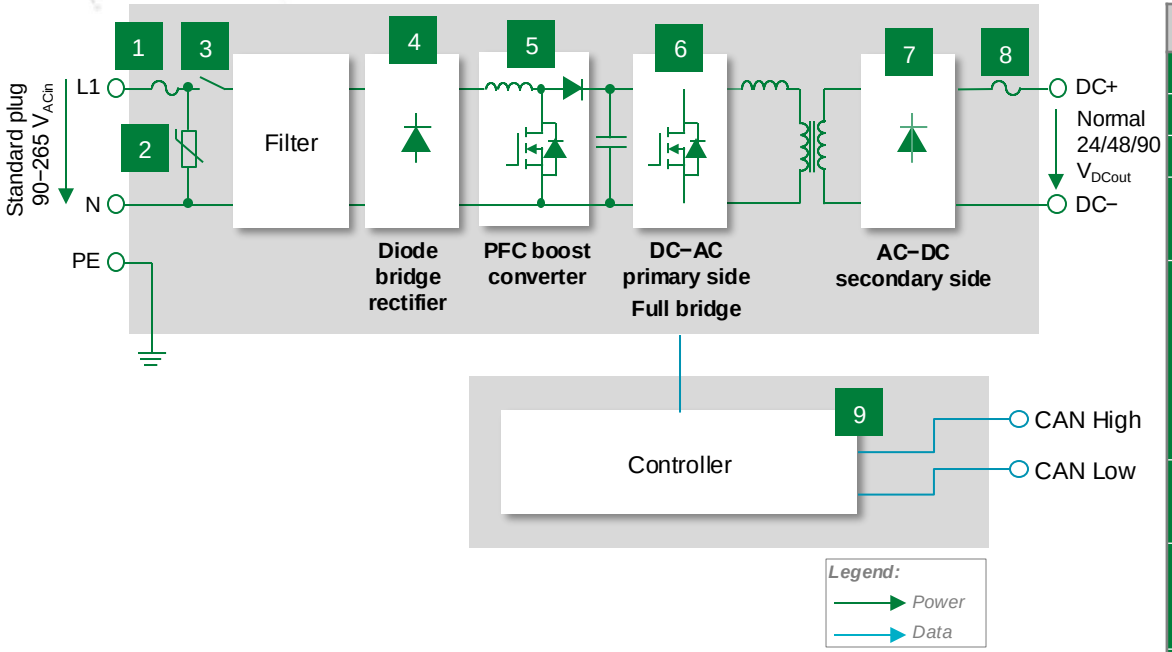
Click the product series in the table below for more info

Single-phase forklift charger



	Technology	Series
1	Fuse	606, 505, 607
2	MOV	TMOV, Xtreme, UltraMOV
3	AC Relay	SC01*
4	Rectifier Bridge	FBO40-12N
	Rectifier Bridge + Boost	vum33-06ph
5	MOSFET	X2-Class
	Power MOSFET with HiPerDyn™ FRED	MXB40Q600DPHFC*
	Si/SiC Schottky Diode	LSIC2SD, DHG, DSEI, DSEPxx
	Gate Driver	IX4340, IXD60x
6	Gate Driver	IX4340, IXD60x
	Si MOSFET	X2-Class
7	Fast Diode (Passive Rectification)	DSEK 60, DPG, DSEPxx
	Si MOSFET (Active Rectification)	X4-Class
8	Fuse	Mega-120, midi-70, CNN, CNNE
9	TVS Diode Array	AQ24CANA

** Contact Littelfuse Sales for details.*

Click the product series in the table below for more info

Littelfuse products for single-phase forklift chargers

	Technology	Function in application	Product series	Benefits	Features
1	Fuse	Primary overcurrent protection of EV equipment	606, 505, 607	Enables robust yet compact design; reduces customer qualification time by complying with third-party safety standards such as UL/IEC	Rated voltage @ 500 VAC; 10−63 A rating available; small footprint
2	MOV	Protects from power fluctuations or surges	TMOV, Xtreme, UltraMOV	Reduces customer qualification time by complying with third-party safety standards, such as UL/IEC	High energy absorption capability: 40–530 J (2 ms); integrated thermal protection
3	AC Relay	Safety cutoff on the grid (power network) to prevent abnormal current supply	SC01*	PCB mount capable; higher flexibility for designers; compact design	Low heat generation and low coil power consumption; performance to meet regulatory UL/IEC compliance
4	Rectifier Bridge	Converts AC voltage to DC voltage	FBO40-12N	Very low current leakage and forward voltage drop; improved thermal behavior	1200 V single-phase standard rectifier bridge in i4-Pac; isolation voltage 3000 V~;
	Rectifier Bridge + Boost		vum33-06ph	Three functions in one package; output power up to 8 kW; no external isolation	Integrated MOSFET with FRED diode in single package; isolation voltage ~3600 V; low $R_{DS(on)}$
5	MOSFET	High-frequency switching	X2-Class	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	Power MOSFET with HiPerDyn™ FRED	Integrated switching for PFC (power factor correction)	MXB40Q600DPHFC*	High power density; reduces component count; PCB space savings	Integrated MOSFET with FRED diode in single package
	Si/SiC Schottky Diode	High-frequency switching and rectification	LSIC2SD, DHG, DSEI, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
	Gate Driver	Efficient switching of MOSFETs	IX4340, IXD60x	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

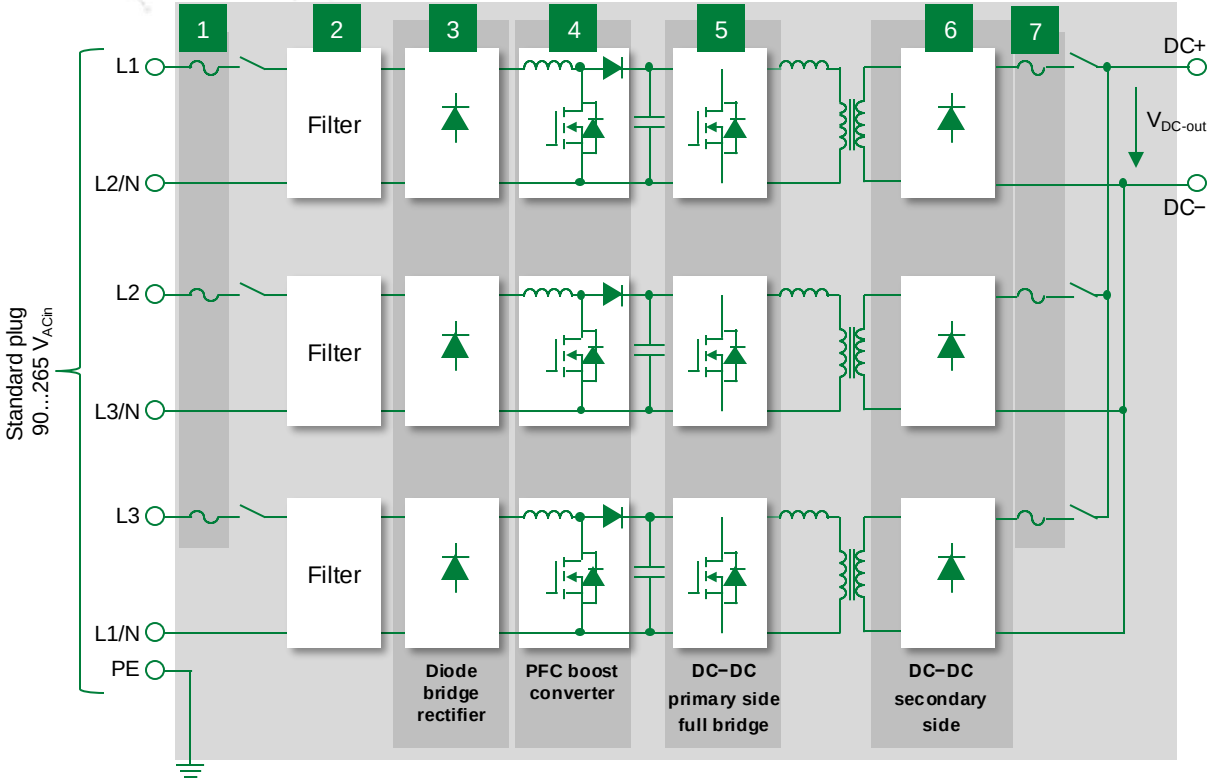
Click the product series in the table below for more info

Littelfuse products for single-phase forklift chargers

	Technology	Function in application	Product series	Benefits	Features
6	Si MOSFET	Primary side of the DC−DC converter	IX4340, IXD60x	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	Gate Driver	Efficient switching of MOSFETs	X2-Class	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
7	Fast Diode	Secondary side output passive rectification of DC-DC converter	DSEK 60, DPG, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
	Si MOSFET	Secondary side output active rectification of DC−DC converter	X4-Class	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
8	Fuse	Prevent reverse current from the forklift battery pack to the charging equipment in case of short circuit at the output of the charger	Mega-120, midi-70, CNN, CNNE	Provides safety protection in high-voltage environments; quicker reaction time	Bolt down form factor; fast-acting; high breaking capacity
9	TVS Diode Array	Protects CAN bus from ESD, EFT, and voltage transience	AQ24CANA	Ensures reliability of equipment without performance degradation	Meets ESD protection levels specified under IEC 61000-4-2; ISO 10605; low leakage current and clamping voltage

Modular approach with single-phase chargers with active PFC

Click the product series in the table below for more info



	Technology	Series
1	Fuse	606, 505, 607
2	MOV	TMOV, Xtreme, UltraMOV
3	Rectifier Bridge	FBO40-12N
	Rectifier Bridge + Boost	vum33-06ph
4	MOSFET	X2-Class
	Power MOSFET with HiPerDyn™ FRED	MXB40Q600DPHFC*
	Si/SiC Schottky Diode	LSIC2SD, DHG, DSEI, DSEPxx
	Gate Driver	IX4340, IXD60x
5	Gate Driver	IX4340, IXD60x
	Si MOSFET	X2-Class
6	Fast Diode (Passive Rectification)	DSEK 60, DPG, DSEPxx
	Si MOSFET (Active Rectification)	X4-Class
7	Fuse	Mega-120, midi-70, CNN, CNNE

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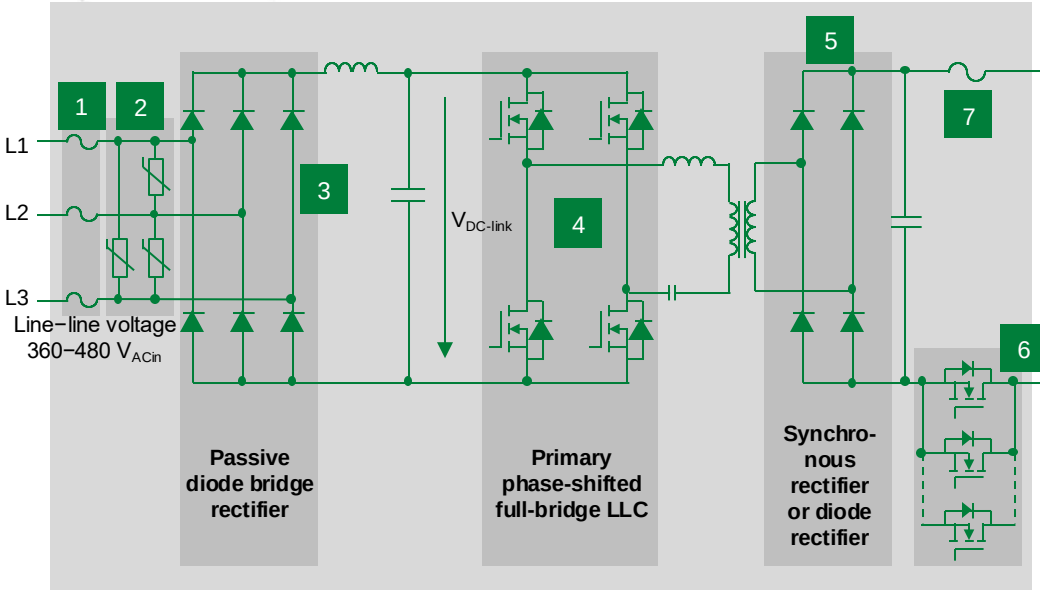
Littelfuse products for modular chargers with active PFC

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	Fuse	Protects and isolates subunit in case of short circuit	606, 505, 607	Enables robust yet compact design; reduces customer qualification time by complying with third-party safety standards such as UL/IEC	Rated voltage @ 500 VAC; 10−63 A rating available; small footprint
2	MOV	Protects from temporary overvoltage event and transient surges; meets requirements for common mode protection	TMOV, Xtreme, UltraMOV	Reduces customer qualification time by complying with third-party safety standards, such as UL/IEC	High energy absorption capability: 40–530 J (2 ms); integrated thermal protection
3	Rectifier Bridge	Input rectification	FBO40-12N	Very low current leakage and forward voltage drop; improved thermal behavior	1200 V single-phase standard rectifier bridge in i4-Pac
	Rectifier Bridge + Boost		vum33-06ph	High power density; reduces component count; PCB space savings	Integrated MOSFET with FRED diode in single package
4	MOSFET	Primary side of the DC−DC converter	X2-Class	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	Power MOSFET with HiPerDyn™ FRED	Integrated switching for PFC (power factor correction)	MXB40Q600DPHFC*	High power density; reduces component count; PCB space savings	Integrated MOSFET with FRED diode in single package
	Si/SiC Schottky Diode	High-frequency switching and rectification	LSIC2SD, DHG, DSEI, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
	Gate Driver	Efficient switching of MOSFETs and IGBTs	IX4340, IXD60x	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
5	Gate Driver	Efficient switching of MOSFETs and IGBTs	IX4340, IXD60x	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
	Si MOSFET	Primary side of the DC−DC converter	X2-Class	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
6	Fast Diode	Secondary side output passive rectification of DC−DC converter	DSEK 60, DPG, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
	Si MOSFET	Secondary side output active rectification of DC−DC converter	X4-Class	High power density; easy to mount; board space saving	Low on-resistance $R_{DS(ON)}$ and gate charge Q; dv/dt ruggedness; avalanche capability
7	Fuse	Short circuit protection and overload circuit protection	Mega-120, midi-70, CNN, CNNE	Provides safety protection in high-voltage environments; quicker reaction time	Bolt down form factor; fast-acting; high breaking capacity

Industrial state-of-the-art three-phase charger without active PFC

Click the product series in the table below for more info



	Technology	Series
1	Fuse	606, 505, 607
2	MOV	TMOV, Xtreme
3	Diode	FUO, GUO
4	HV Si MOSFET	Polar™
	SiC MOSFET	LSIC, SMPD
	IGBT	XPT
	Gate Driver	IX4340, IXD60x
5	Diode	DHG, DSEI, DSEPxx
6	Si MOSFET	X4-Class, MMIX
7	Fuse	JLLN, TLS, Mega-120, midi-70, CNN, CNNE

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Littelfuse products for three-phase charger without active PFC

Click the product series in the table below for more info

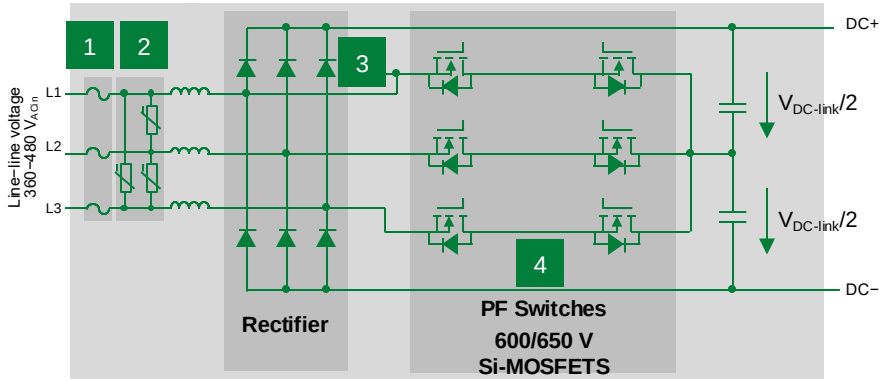
	Technology	Function in application	Series	Benefits	Features
1	Fuse	Primary overcurrent protection of EV equipment	606, 505, 607	Enables robust yet compact design; reduces customer qualification time by complying with third-party safety standards such as UL/IEC	Rated voltage @ 500 VAC; 10−63 A rating available; small footprint
2	MOV	Protects from power fluctuations or surges	TMOV, Xtreme	Reduces customer qualification time by complying with third-party safety standards, such as UL/IEC	High energy absorption capability: 40–530 J (2 ms); integrated thermal protection
3	Diode	Three-phase rectifier bridge for input rectification	FUO, GUO	Easy to mount with one screw; space and weight savings	Low forward voltage drop; planar passivated chips; industry standard packages
4	HV Si MOSFET	Primary side of the DC−DC converter	Polar™	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	SiC MOSFET		LSIC	Optimized for high-frequency applications	Ultra-low output capacitance and on-resistance
			SMPD	Board space savings; offers more design flexibility	Ultra-low and compact package profile; low package inductance; excellent thermal capability; high power cycling capability
	IGBT		XPT	Higher efficiency; elimination of multiple series-connected devices; increased reliability of power systems	Thin wafer XPT™ technology; low on-state voltages $V_{CE(sat)}$; co-packed fast recovery diodes; positive temperature coefficient of $V_{CE(sat)}$; industry standard packages
	Gate Driver	Controls the switching MOSFETs	IX4340, IXD60x	Quick turn-on and turn-off of MOSFETs/IGBTs; eliminates the need for separate supply	9 A peak current; low propagation delay time; low output impedance
5	Diode	Secondary side output rectification of DC−DC converter	DHG, DSEI, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
6	Si MOSFET	DC−DC converter	X4-Class, MMIX	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
7	Fuse	Short circuit protection and overload circuit protection	JLLN, TLS, Mega-120, midi-70, CNN, CNNE	Provides safety protection in high-voltage environments; quicker reaction time	Bolt down form factor; fast-acting; high breaking capacity

Forklift truck charging

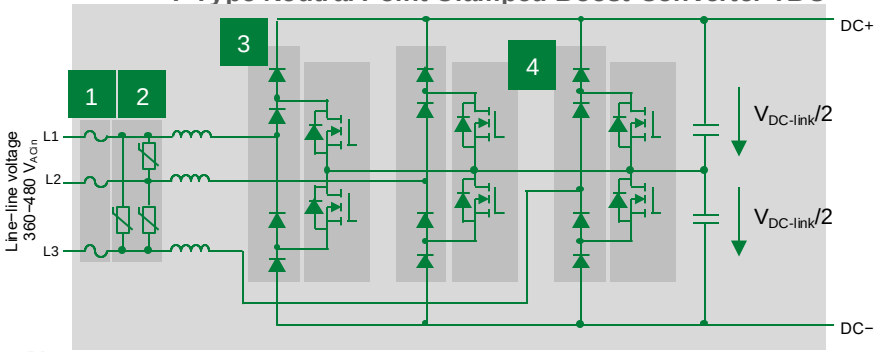
Input rectification and Power Factor Control (PFC)

Click the product series in the table below for more info

T-Type Neutral Point Clamped Boost Converter (Vienna Rectifier)



T-Type Neutral Point Clamped Boost Converter TBC



	Technology	Series
1	Fuse	606, 505, 607
2	MOV	TMOV, Xtreme,
3	Diode	LSIC2SD, DHG, DSEI, DSEPxx
4	Si MOSFET	X2-Class

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Click the product series in the table below for more info

Littelfuse products for forklift charging

	Technology	Function in application	Product series	Benefits	Features
1	Fuse	Overcurrent protection of auxiliary power supply	606, 505, 607	Enables robust yet compact design; reduces customer qualification time by complying with third-party safety standards such as UL/IEC	Rated voltage @ 500 VAC; 10−63 A rating available; small footprint
2	MOV	Protects from transient spikes or surges	TMOV, Xtreme,	Reduces customer qualification time by complying with third-party safety standards, such as UL/IEC	High energy absorption capability: 40–530 J (2 ms); integrated thermal protection
3	Diode	Part of vienna rectifier	LSIC2SD, DHG, DSEI, DSEPxx	Reduces losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C
4	Si MOSFET	Active rectification	X2-Class	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness

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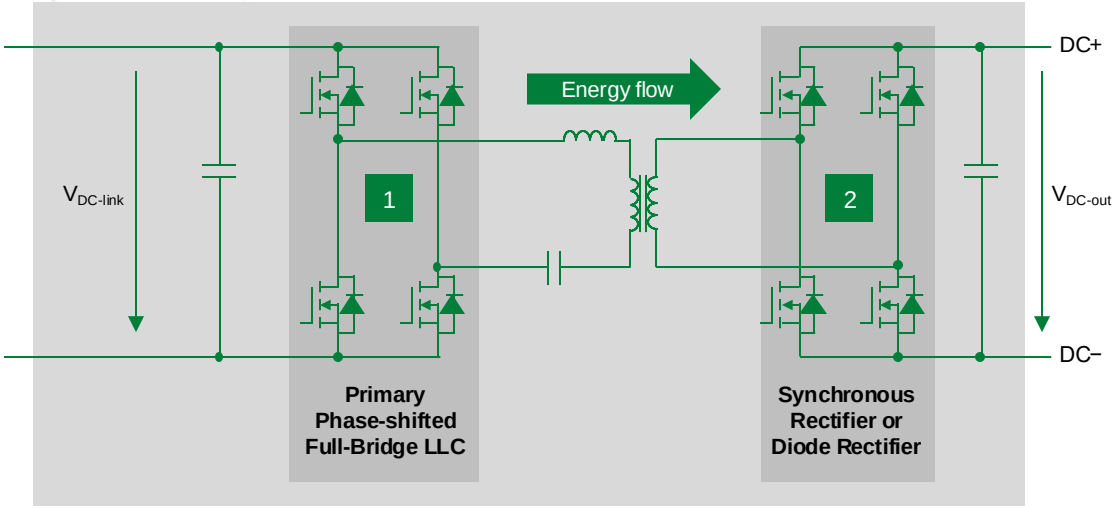
DC–DC stage with active rectification for higher efficiency

Click the product series in the table below for more info



	Technology	Series
1	SiC MOSFET	LSIC SMPD
2	Si MOSFET	X4-Class, Trench Gen 1, 2, 3
	Si Diode	DSEK 60, DPG, DSEPxx

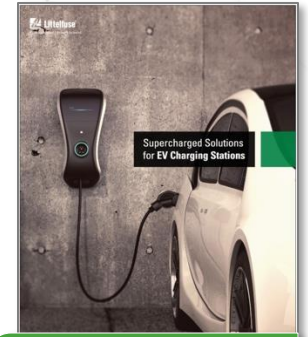
Littelfuse products for unidirectional charging DC–DC stage

Click the product series in the table below for more info

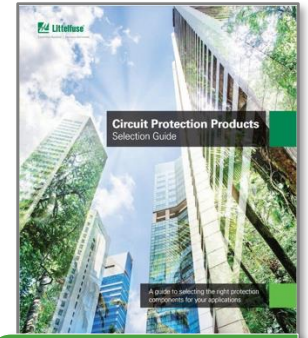
	Technology	Function in application	Product series	Benefits	Features
1	SiC MOSFET	Active rectification on primary side DC–DC converter	LSIC	Optimized for high-frequency applications	Ultra-low output capacitance and on-resistance
			SMPD	Board space savings; offers more design flexibility	Ultra-low and compact package profile; low package inductance; excellent thermal capability; high-power cycling capability
2	Si MOSFET (Active rectification)	Secondary side output active rectification of DC–DC converter	X4-Class, Trench Gen 1, 2, 3	Optimized for high-frequency applications	Ultra-low on-resistance $R_{DS(ON)}$ and gate charge Qg; dv/dt ruggedness
	Si Diode (Passive rectification)	Secondary side output passive rectification of DC–DC converter	DSEK 60, DPG, DSEPxx	Reduces switching losses; increases efficiency	High surge capability; negligible I_{RR}; Tj 175 °C

Additional information can be found on Littelfuse.com

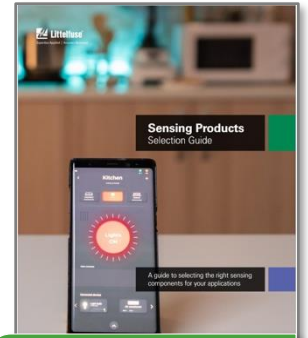
Explore the world of Littelfuse with the electronics eCatalogs (ecatalogs.littelfuse.com)



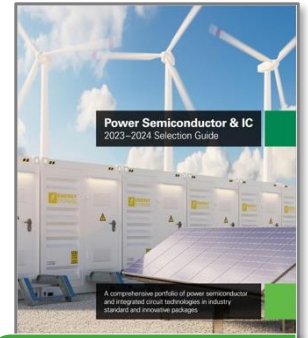
EV Charging Brochure



Circuit Protection Selection Guide



Sensor Selection Guide

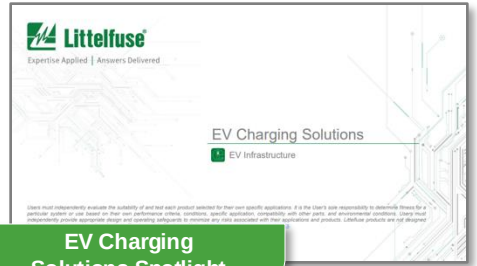


Power Semiconductor Catalog

C&K Automotive Switch Flyer

Click on images for more information

Integrated Circuit Selection Guide



EV Charging Solutions Spotlight

Two-/Three-Wheeler Solutions Spotlight

Local resources supporting our global customers

Legend

- *Sales*
- *R&D*
- *Manufacturing*

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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

Application expertise

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

Global customer service

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

Compliance & 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 and offer certification testing to global regulatory standards

Global manufacturing

We offer high-quality manufacturing that is committed to the highest quality standards

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