



Expertise Applied | Answers Delivered

Residential Energy Storage with Hybrid Inverters



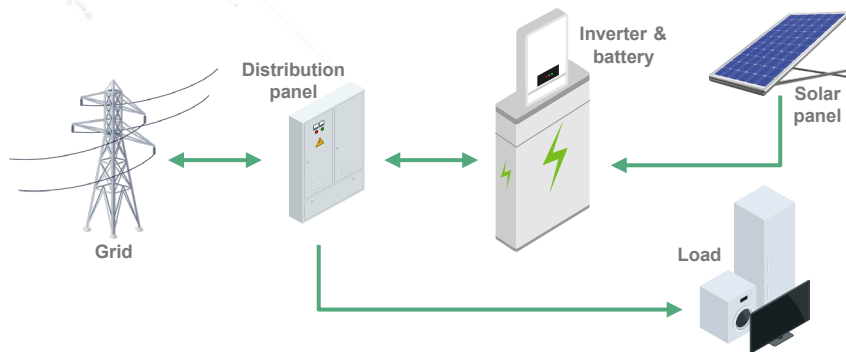
Renewable Energy



Energy Storage

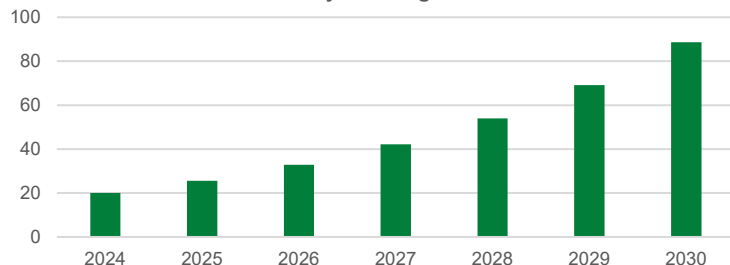
Users must independently evaluate the suitability of, and test each product selected for their own specific applications. It is the user's sole responsibility to determine fitness or use of a particular system based on their own performance criteria, conditions, specific application, compatibility with 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).

Market for residential energy storage with hybrid inverters



Residential energy storage forecast

Projected GigaWatt



Source: Littelfuse estimations, [Volta Foundation](#)

Market trends and drivers

Gains in popularity are primarily driven by battery costs, government policy incentives, and a massive uptick in investments in BESS technology and projects.

Systems that support smart monitoring, load shifting, and grid interaction have been the subject of growing demand. Residential energy storage is increasingly integrated into Virtual power plants (VPPs), enabling homeowners to contribute to grid stability and benefit from participation in the energy market.

Leading battery and solar manufacturers are expanding into residential energy storage, accelerating innovation and driving competitive pricing.

Hybrid inverters, which integrate PV and battery control into one unit, are becoming more popular than traditional dual-inverter systems. They simplify installation, reduce equipment footprint, improve efficiency, and lower overall system costs.

Combining energy storage and power conversion into a single system simplifies wiring and installation but also introduces challenges such as inrush current, fault isolation, and thermal stress. Littelfuse solutions help address these issues and enhance overall system safety and reliability.

Recommended Littelfuse solutions for residential battery energy storage

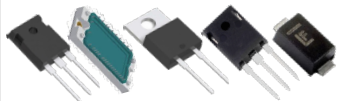
Input protection

Fuse, MOV,
GDT, NTC



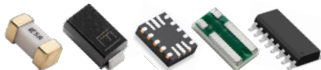
Power conversion

MOSFET, IGBT, Rectifier Diode, SiC
Schottky Diode, TVS Diode, Gate Driver



Auxiliary power

Fuse, TVS Diode, eFuse,
CSR, Gate Driver



AC line protection

Fuse, GDT, MOV + SIDACtor®



Communication & user

interface: TVS Diode Array,
PolySwitch® Device, Switch



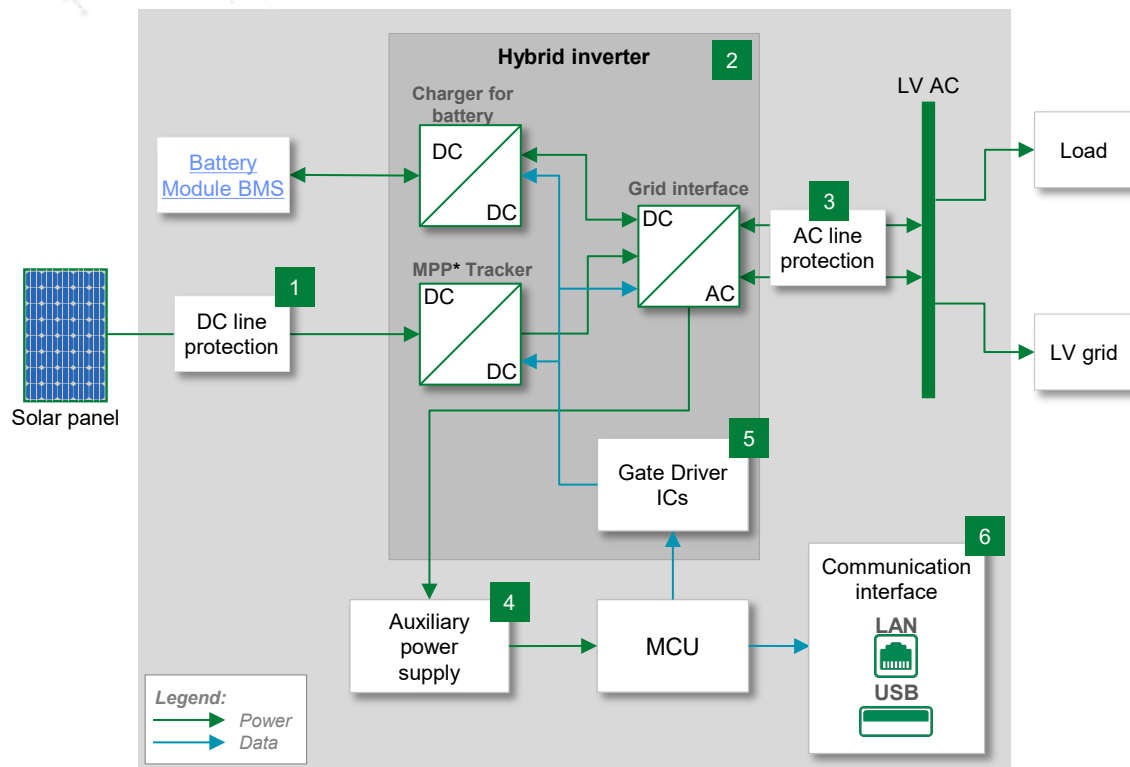
Acronyms:

MOV: Metal-oxide Varistor
GDT: Gas Discharge Tube
NTC: Negative Temperature Coefficient
IGBT: Insulated-Gate Bipolar Transistor
SiC: Silicon Carbide
TVS: Transient Voltage Suppression
CSR: Current Sensing Resistor



Click the product series in the table below for more info

Residential energy storage with hybrid inverters



* MPP: Maximum power point

	Technology	Product series
1	MOV	LST, LA
	MOSFET	N-Channel Trench Gate
2	Silicon Carbide	SiC MOSFET
	IGBT	XPT
	Rectifier Diode	D40
	Si Fast Recovery Diode	HiperFRED Extreme Fast
	TVS Diode	SMFA
3	MOV + SIDACtor® Protection Thyristor	UltraMOV + Pxxx0ME
	GDT	CG3/CG4
	Fuse	Class J, KLKD
4	Fuse	448
	TVS Diode	SACB, SMAJ
	Protection IC (eFuse)	LS2406ERQ23
	Current Sensing Resistor	L4CA/C
5	Gate Driver	IX4352
6	TVS Diode Array	SP712, SM712
	PolySwitch® Device	1206L
	Switch	KSC, ATP16



Click the product series in the table below for more info

Littelfuse solutions in residential energy storage

	Technology	Function in application	Product series	Benefits	Features
1	MOV	Protects from lighting surges on PV lines	LST, LA	Thermally protected MOV (LST); high surge capability; long life-cycle capability	Wide voltage range up to 1000 V; radial or disk type; UL recognized
2	MOSFET	Switching or power control	N-Channel Trench Gate	135–1000 V, $R_{DS(on)}$ as low as 1.99 mOhm; high current ratings; standard SMT THT and unique packages	Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design
	SiC MOSFET	High-efficiency power switching	SiC MOSFET	Fast switching, low R_{on} , wide bandgap MOSFETs	Improved efficiency; higher switching frequency to downsize passive components (Discrete and SMPD)
	IGBT	High-power switching	XPT	Positive temperature coefficient for on-state voltage facilitates paralleling; low gate current requirements	Simplified mounting, lower R_{thJ-H} and higher integration versus standard discrete (Discrete and SMPD)
	Rectifier Diode	Provides bypass protection	D40	Advanced Planar design; wide current and voltage range with unique package types	Superior commutation robustness and high surge current capability
	Si Fast Recovery Diode	Boost diode	HiperFRED Extreme Fast	Comprehensive portfolio cover P_i , A_v , H_e doped diffusion; wide current and voltage range with unique package types	The FRED Low Vf series offers improved forward voltage characteristics and breakdown voltages up to 1200V.
	TVS Diode	Protects semiconductor switches from voltage transient	SMFA	Improves system reliability by clamping the voltage at safe levels during transients	SOD-123FL low-profile package: maximum height of 1.08 mm, Low inductance, excellent clamping capability, Low dynamic resistance
3	MOV + SIDActor® Protection Thyristor	Protects the AC line from voltage transients and lighting surges	UltraMOV + Pxxx0ME	Lower clamp voltage ~912 V at 3 kA 8/20 μ s surge current; minimize leakage current	Combining a SIDActor® and MOV in series offers superior surge protection and extends the life of downstream components—while also reducing overall system cost
	GDT	Provides line-to-ground protection from voltage transients and lightning	CG3/CG4	Small form-factor allows for compact system design; enables product to comply with IEC/UL standards	High energy absorption capability; small form-factor; low leakage current
	Fuse	Overcurrent protection for AC connection	Class J, KLKD	Reduces damage to equipment caused by short circuit currents; compact design	Extremely current-limiting; small footprint; 200 kA interrupting rating



Click the product series in the table below for more info

Littelfuse solutions in residential energy storage

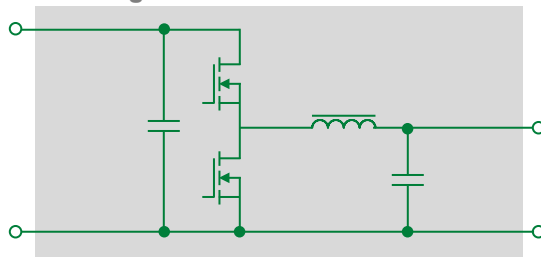
	Technology	Function in application	Product series	Benefits	Features
4	Fuse	Auxiliary power over-current protection	448	Reduces damage to equipment; compact design	Fast acting; SMD fuse with small footprint; low temperature derating
	TVS Diode	Protects power units from voltage transients	SACB , SMAJ	Improves system reliability by clamping voltage at safe levels during transients	Excellent clamping capability
	Protection IC (eFuse)	Provides protection from overload, short circuit, input voltage surge, over-temperature, excessive inrush current, and reverse current	LS2406ERQ23	Integrated alternative to discrete components that offers several functions in a single package	Wide operation voltage range from 3 V to 24 V; low profile 16 leads QFN 2.5 mm x 3.2 mm package
	Current Sensing Resistor	Part of current measurement circuitry	L4CA/C	Cost-effective solution compared to competing technologies; compact size	Resistance range down to 0.5 mΩ; separate voltage-sensing terminals
5	Gate Driver	Drive Si/SiC MOSFETs (both Discrete and SMPD)	IX4352	Most robust Gate Driver on the market; has the highest voltage and current	Allows for more voltage margin; enables easy paralleling of the MOSFETs; SiC driver with integrated charge pump (IX4352)
6	TVS Diode Array	ESD protection; surge protection for communication ports	SP712 , SM712	High ESD performance in small packages	Low capacitance of 1 to 0.2 pF (TYP) per I/O
	PolySwitch® Device	Resettable overcurrent protection for data line connections	1206L	Saves board space; promotes robust operations	Low internal resistance; highest current-holding capability among competitors; the smallest SMD package
	Switch	Switch for function controlling, resetting, etc.	KSC , ATP16	Available in a wide range of operating forces; rugged sealing and resistant to corrosion; very long operating life	Ultra-low current consumption; operating life of up to 1 million cycles (KSC); lightweight switches are IP67 rated (ATP16)

Power supplies topologies:

Charger ~ 400 V voltage battery

 Click the product series in the table below for more info

Charger: Bidirectional buck/boost



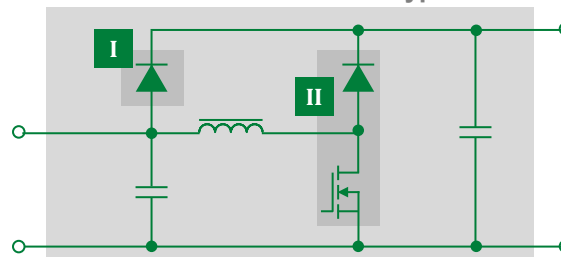
	Technology	Function in application	Product series	Benefits	Features
	TVS Diode (Protection)	Protects semiconductors; is applied between gate and source	SMF, SMFA	200 W peak pulse power capability; excellent clamping capability; low profile	Improves system reliability by clamping voltage at safe levels during transients
	Si MOSFET Discrete	Semiconductor switch	N-Channel Ultra Junction	135–1000 V, $R_{DS(on)}$ as low as 1.99 mOhm; high current ratings; standard SMT THT and unique packages	Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design
	Si SMPD		SMPD Packages- MOSFETs	Pick-and-place compatible; built in isolation; multichip design blocks	Simplified mounting; lower R_{thJA} and higher integration versus standard discrete packages
	SiC MOSFET Discrete & SMPD		Silicon Carbide	Fast switching; low R_{on} ; wide-bandgap MOSFETs	Improved efficiency; higher switching frequency to downsize passive components
	High-side/Low-side Drivers & Half-bridge Drivers	Drive Si/SiC MOSFETs (both Discrete and SMPD)	Gate Driver ICs	Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable, cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics	Allows for more voltage margin and facilitates MOSFET paralleling of the MOSFETs; eases implementation and reduces number of components; offers improved alternatives and facilitates the supply chain



Click the product series in the table below for more info

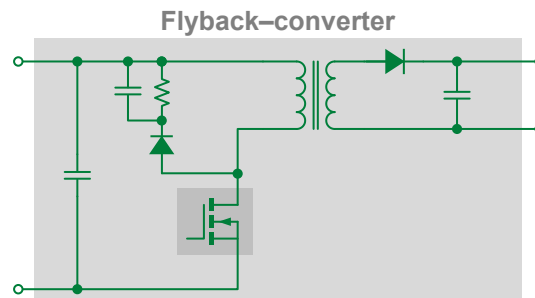
Power supplies topologies: MPP tracker

Unidirectional boost + bypass



	Technology	Function in application	Product series	Benefits	Features
I	Rectifier Diode	Bypass protection	Rectifier	Advanced planar design; wide current and voltage range with unique package types	Best-in-class commutation robustness and high surge current capability
	Si Fast Recovery Diode	Boost diode	Fast Recovery	Comprehensive portfolio cover P_r , A_v , H_g doped diffusion; wide current and voltage range with unique package types	Unique recovery behavior for extensive application needs
	SiC Schottky Diode		Schottky (SiC)	Fast-switching wide-bandgap material; zero recovery	Increases application power density and improves efficiency
	Si MOSFET Discrete	Semiconductor switch	N-Channel Ultra Junction	135–1000 V; high current ratings; one of the best-in-class F_{OM} $R_{DS(on)}$ Q_g ; standard SMT THT and unique packages	Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design
	Si SMPD	Semiconductor switch and boost diode	SMPD Packages-MOSFETs	Pick-and-place compatible; built-in isolation; multichip design blocks	Simplified mounting; lower R_{thJA} and higher integration versus standard discrete package
	SiC MOSFET Discrete	Semiconductor switch	Silicon Carbide	Fast switching; low R_{on} ; wide-bandgap MOSFETs	Improved efficiency; higher switching frequency to downsize passive components
	Low-side Drivers	Drive Si/SiC MOSFETs (both Discrete and SMPD)	Gate Driver ICs	Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable and cost-efficient solutions in industry-standard pinouts and with enhanced voltage & thermal characteristics	Allows for greater voltage margin and easier paralleling of MOSFETs; eases implementation and reduces number of components; offers improved alternatives; facilitates the supply chain
	TVS Diode (Protections)	Protects semiconductors; applied between gate and source	SMF, SMFA	Peak pulse power capability of 200 W; excellent clamping capability; low profile	Improves system reliability by clamping voltage at safe levels during transients
	Rectifier Diode	Bypass protection	Rectifier	Advanced planar design; wide current and voltage range with unique package types	Superior commutation robustness and high surge current capability

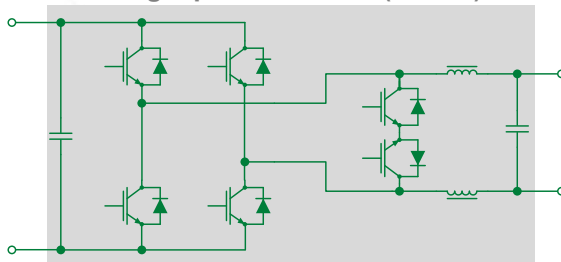
Power supplies topologies: Auxiliary power supply



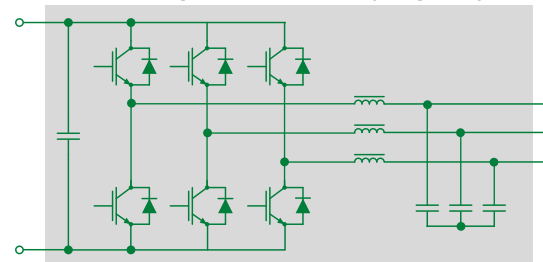
	Technology	Function in application	Product series	Benefits	Features
	SiC MOSFET Discrete	Semiconductor switch	Silicon Carbide	Fast switching; low R_{on} , 1700 V SiC MOSFETs	Improved efficiency; 1700 V V_{bk} allows single-switch flyback topology for high-voltage DC bus
	OR HV Si MOSFET Discrete		N-Channel Standard	Up to 4.7 k; standard SMT THT and unique packages	Simplifies design, improves reliability, and saves PCB space
	Low-Side Drivers	Drive Si/SiC MOSFETs	Gate Driver ICs	Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable, cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics	Allows for greater voltage margin and the easy paralleling of MOSFETs; eases implementation and reduces number of components; offers improved alternatives, thereby facilitating the supply chain
	TVS Diode (Protections)	Protects semiconductors; applied between gate and source	SMF , SMFA	Protects semiconductor switches from voltage transients	Peak pulse power capability of 200 W; excellent clamping capability; low profile

Power supplies topologies: Grid interface

Single-phase inverter (HERIC)



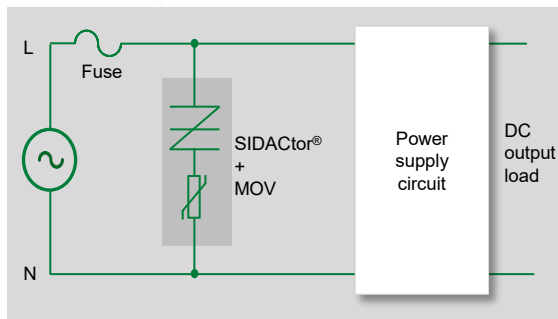
Three-phase inverter (Sixpack)



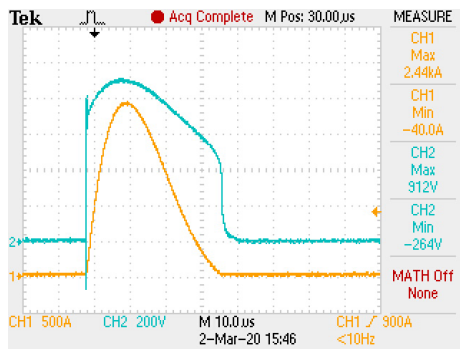
	Technology	Function in application	Product series	Benefits	Features
	SiC MOSFET Discrete and SMPD	Semiconductor switch	Silicon Carbide	Fast switching; low R_{on} ; wide-bandgap MOSFETs	Improved efficiency; higher switching frequency to downsize passive components
	IGBT Discrete		XPT	Pick-and-place compatible; built in isolation; multichip design blocks	Simplified mounting; lower R_{thJA} and higher integration versus standard discrete
	High-Side/Low-Side Drivers and Half-Bridge Drivers	Drive Si/SiC MOSFETs (both Discrete and SMPD)	Gate Driver ICs	Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable and cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics	Allows for greater voltage margin and easier paralleling of MOSFETs; eases the implementation and reduces the number of components; offers improved alternatives to facilitate the supply chain
	TVS Diode (Protections)	Protects semiconductors; is applied between gate and source	SMF , SMFA	Peak pulse power capability of 200 W; excellent clamping capability; low profile	Improves system reliability by clamping voltage at safe levels during transients

SIDACTor® Protection Thyristor + MOV in series protect AC power lines solution

SIDACTor® Protection Thyristor + MOV



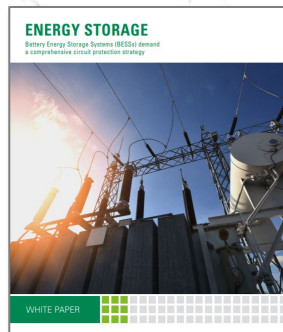
3kA 8/20 with P3500FNL + V14E230P



- **How it works:** SIDACTor® Protection Thyristor triggers first to clamp voltage; then, MOV absorbs surge energy.
- **Dual protection:** Low clamping and high energy-absorption in one solution.
- **Higher reliability:** Protects sensitive inverter circuits and extends system life.
- **Cost savings:** Enables smaller MOVs and reduces component stress.
- **Example P3500FNL+V14E230P:** Lower clamp voltage of ~912 V at 3 kA 8/20 µs surge current compared to single solutions featuring 350 V MOV.

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

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



Energy Storage
Whitepaper



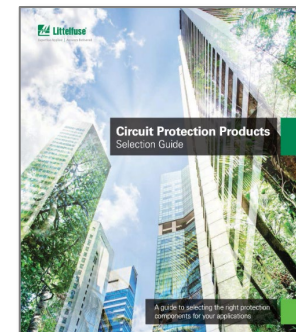
SPDs in
PV Systems



Industrial Fuses
Catalog



Power Semiconductor
Selection Guide

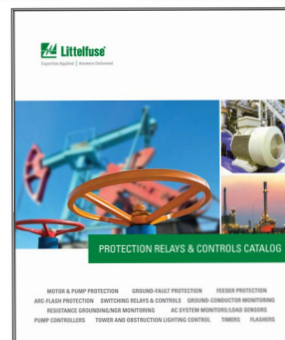


Circuit Protection
Selection Guide

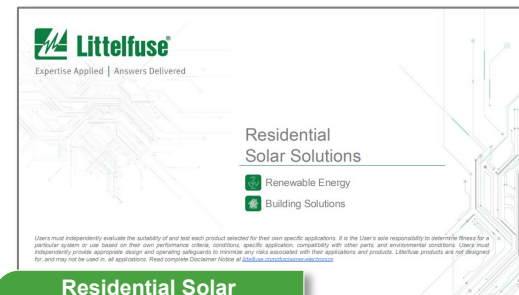
Click
on the images
for more
information



Solar Protection
White Paper



Power Relay &
Control Catalog



Residential Solar
Solutions Spotlight



Scan me!

Local resources supporting our global customers



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 & Regulatory

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

Global Customer Service

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

Global Manufacturing

We support high volume manufacturing that is committed to the highest quality standards.



This document is provided by Littelfuse, Inc. ("Littelfuse") for informational and guideline purposes only. Littelfuse assumes no liability for errors or omissions in this document or for any of the information contained herein. Information is provided on an "as is" and "with all faults" basis for evaluation purposes only. Applications described are for illustrative purposes only, and Littelfuse makes no representation that such applications will be suitable for the customer's specific use without further testing or modification. Littelfuse disclaims all warranties, whether express, implied, or statutory, including but not limited to the implied warranties of merchantability and fitness for a particular purpose and non-infringement. It is the customer's sole responsibility to determine suitability for a particular system or use based on their own performance criteria, conditions, specific application, compatibility with other components, and environmental conditions. Customers must independently provide appropriate design and operating safeguards to minimize any risks associated with their applications and products. Read complete Disclaimer Notice at: www.littelfuse.com/disclaimer-electronics.



Expertise Applied | Answers Delivered

Littelfuse.com