High Performance Power Module Solutions

高性能電源管理暨創新功率元件研討會
台北 • 2019/10/8

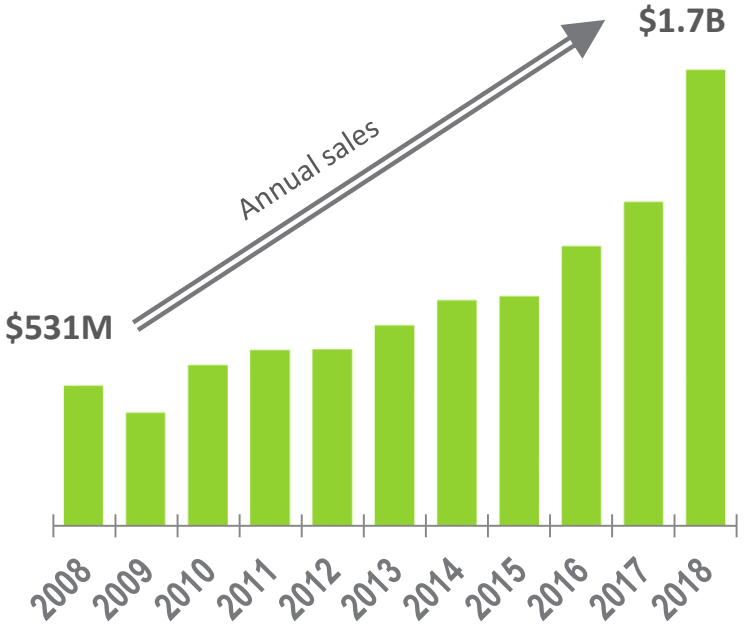
Littelfuse®
Expertise Applied | Answers Delivered

Agenda

- About Littelfuse
- Critical Device in Power Switch
  - Silicon Base Switch Device(MOSFET)
  - Silicon Carbide Device(MOSFET/ SBD)
  - Advanced Package Technology for Critical Power Devices→ SMPD
- Circuit/Power protection
  - Off-board charger, DC/DC converter, On board charger
  - BMS protection
  - Product portfolio
  - Bike computers
- ESD/EOS protection
- Conclusions

Littelfuse: over 90 years of serving global customers

- Founded in 1927
- Preferred brand in circuit protection, with growing platform in power control & sensing.
- Enhance safety, reliability and performance of our customers' systems that use electrical energy
- Global sales in over 150 countries, manufacturing & engineering in over 50 countries
- $1.7 billion of annual sales in 2018
- 12,000+ dedicated and innovative employees
- Headquartered in Chicago, IL, USA



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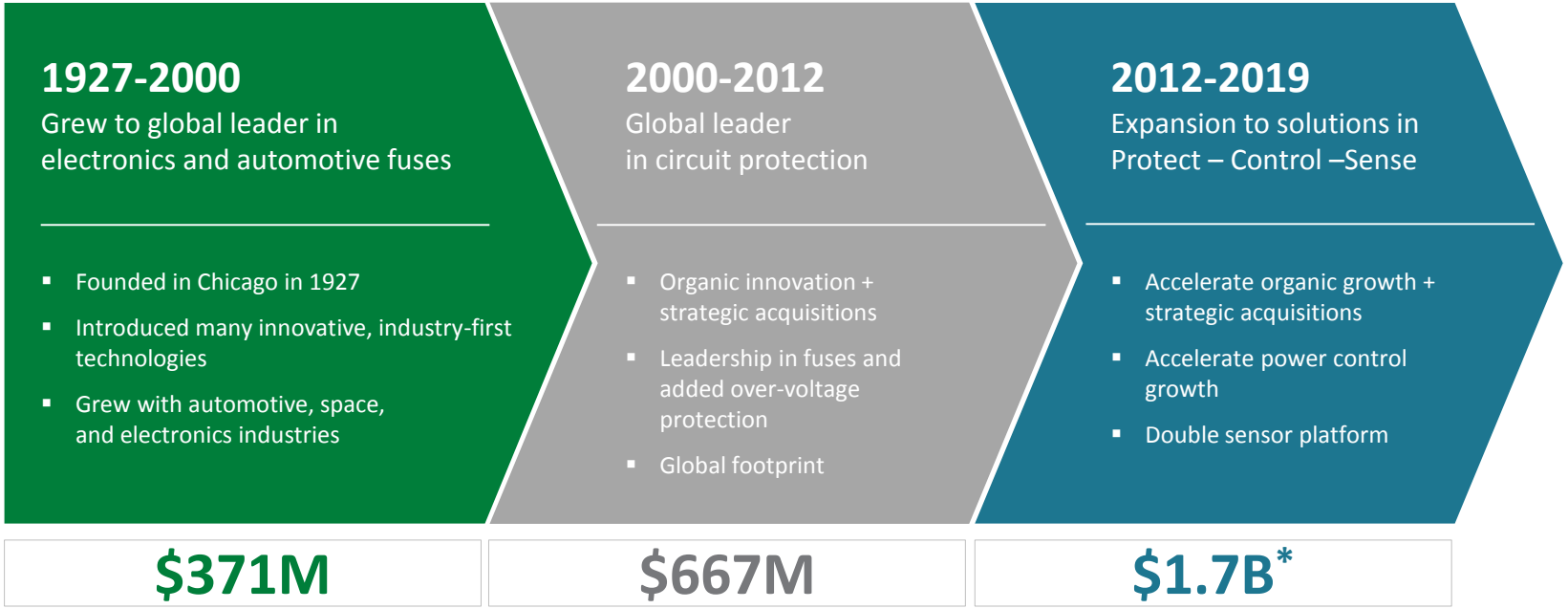
Track record of technology and product innovation



** 2018 Revenue*

Technology strength accelerated through acquisitions

Protect
Control
Sense

2013 – Hamlin, Inc
Products: Sensors
Markets: Automotive, Appliances, Building Automation, Industrial

2015 – Sigmar SRL
Products: Sensors
Markets: Automotive & Commercial Vehicles

2016 – Menber's S.p.A.
Products: Battery Switches, Trailer Connectors
Markets: Commercial Vehicles

2017 – U.S. Sensor Corporation
Products: Temperature Sensors & Assemblies
Markets: Appliances, Building Automation, HVAC

2018 – Monolith Semiconductor, Inc.
Products: Silicon Carbide Power Semiconductors
Markets: Power Electronics

2012 - ACCEL AB
Products: Sensors, Switches
Markets: Automotive

2014 – SymCom, Inc.
Products: Overload Relays, Pump Controllers, Time Delay Relays
Markets: Industrial

2016 – Circuit Protection Business of TE Connectivity Ltd.
Products: Resettable PPTC Fuses
Markets: Automotive, Battery, Industrial, Mobile Computing, Telecommunications

2016 – Select Product Portfolio of ON Semiconductor
Products: IGBTs, Switching Thyristors, TVS Diodes
Markets: Automotive, General Electronics

2018 – IXYS Corporation
Products: Power semiconductors
Markets: Industrial, Automotive, Datacenter & Cloud Infrastructure

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Protection: helping make products safer & reduce TCO

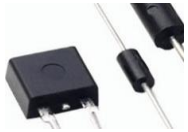

Fuses

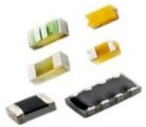

Polymeric PTCs


GDTs


LED Protection


MOV/MLV


Thyristors


Polymer ESD


Surge Protection Module


TVS Diode/Diode Arrays

- Broadest protection technology portfolio with many industry-first solutions.
- Independent testing capabilities to for compliance with industry and national standards including: UL, IEC, ITU, AEC-Q, and others.
- Application knowledge to help our customers address functional requirements and regulatory compliance.

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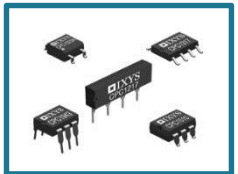
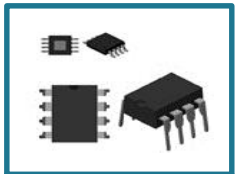
TCO: Total Cost of Ownership
PPTC: Polymeric Positive Temperature Coefficient
ESD: Electrostatic Discharge
TVS: Transient Voltage Suppression

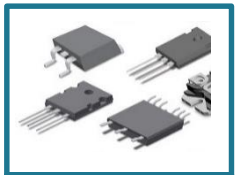
MOV: Metal Oxide Varistors
MLV: Multi-Layer Varistors
GDT: Gas Discharge Tubes

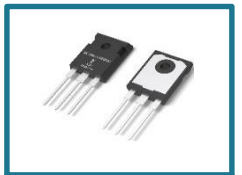
Control: broad power semiconductors offering


Solid State Relays

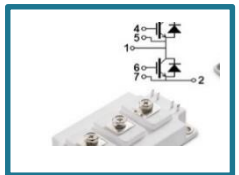

Gate Drivers

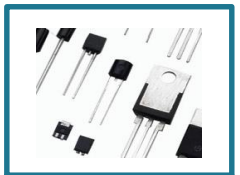

Ignition IGBT

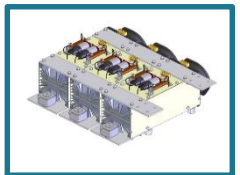

IGBT Discrete


MOSFET
SiC/Discrete


SiC/Si:
Schottky,FRED


Power Modules


Power Thyristor


High Power
(Stacks, Disc)

- Leading Silicon and SiC technologies spanning a wide range of power needs.
- Broad offering of components & modules packaging options: standard and application-specific.
- Customer-centric focus: design, test, and application engineering support

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IGBT: Insulated-gate Bipolar Transistor
SSR: Solid State Relays

FRED: Fast Recovery Epitaxial Diodes
SiC: Silicon Carbide

Sensing: standard and customized solutions


Reed Switch


Hall effect sensors


Custom sensor Magnetic


NTCs


RTDs


Custom sensor Temperature


Digital Temperature Indicators setP™


RTP Mini


Thermal Breaker

- Comprehensive range of temperature and magnetic sensing technologies; portfolio of standard and custom products.
- Recognized for highly reliable sensing solutions for use in automotive, appliance, industrial, and other applications.
- Custom sensor design support: deep applications know-how, and magnetitic & mechanical modeling.

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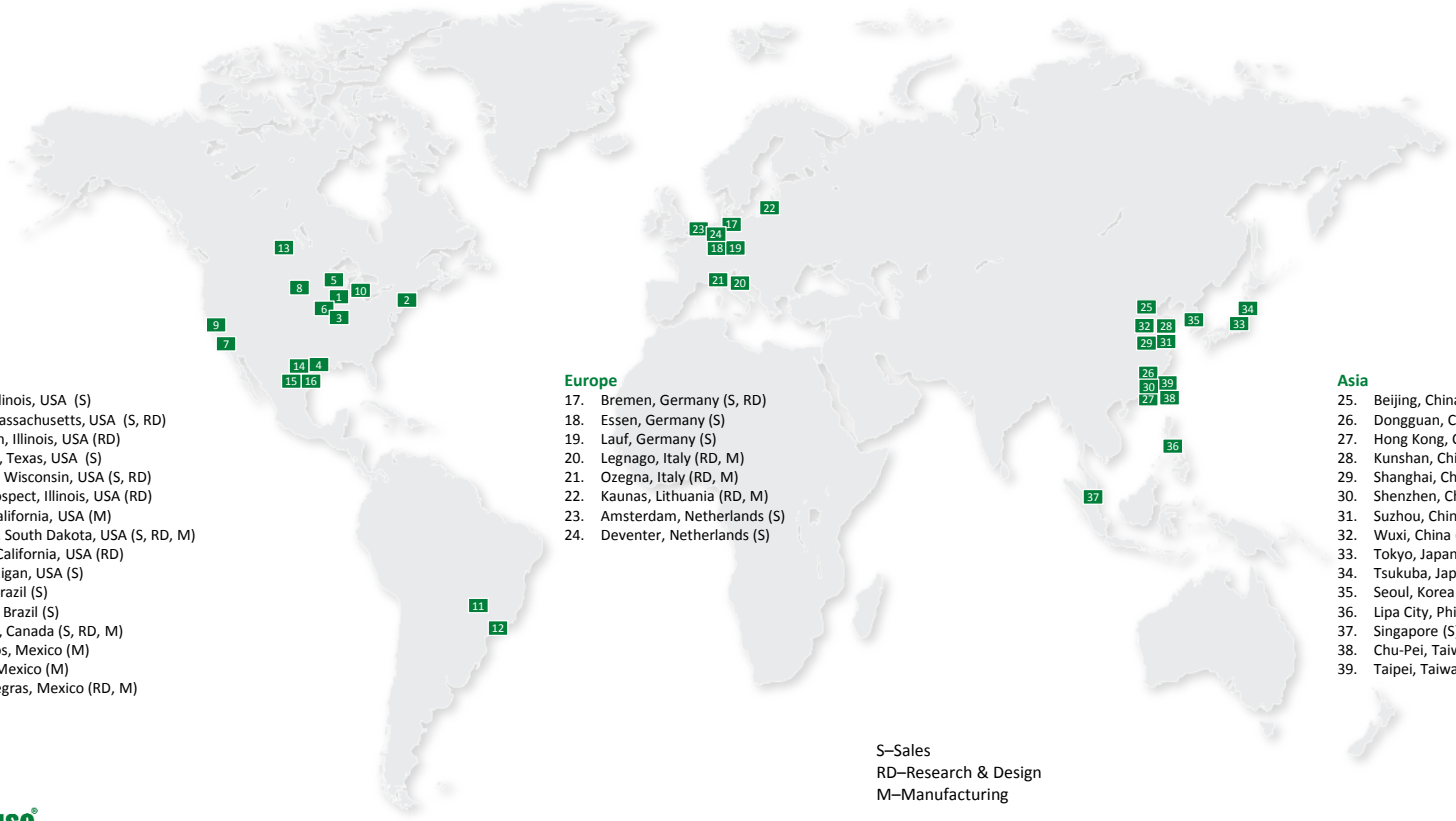
NTC: Negative Temperature Coefficient
RTD: Resistance Temperature Detector

PTC: Positive Temperature Coefficient
RTP: Reflowable Thermal Protection

Global Footprint – R&D, Manufacturing & Support



Americas

1. Chicago, Illinois, USA (S)
2. Boston, Massachusetts, USA (S, RD)
3. Champaign, Illinois, USA (RD)
4. Eagle Pass, Texas, USA (S)
5. Lake Mills, Wisconsin, USA (S, RD)
6. Mount Prospect, Illinois, USA (RD)
7. Orange, California, USA (M)
8. Rapid City, South Dakota, USA (S, RD, M)
9. Fremont, California, USA (RD)
10. Troy, Michigan, USA (S)
11. Manaus, Brazil (S)
12. São Paulo, Brazil (S)
13. Saskatoon, Canada (S, RD, M)
14. Matamoros, Mexico (M)
15. Muzquiz, Mexico (M)
16. Piedras Negras, Mexico (RD, M)

Europe

17. Bremen, Germany (S, RD)
18. Essen, Germany (S)
19. Lauf, Germany (S)
20. Legnago, Italy (RD, M)
21. Ozegna, Italy (RD, M)
22. Kaunas, Lithuania (RD, M)
23. Amsterdam, Netherlands (S)
24. Deventer, Netherlands (S)

Asia

25. Beijing, China (S)
26. Dongguan, China (RD, M)
27. Hong Kong, China (S)
28. Kunshan, China (S, M)
29. Shanghai, China (S, RD, M)
30. Shenzhen, China (S)
31. Suzhou, China (S, RD, M)
32. Wuxi, China (RD, M)
33. Tokyo, Japan (S)
34. Tsukuba, Japan (RD, M)
35. Seoul, Korea (S)
36. Lipa City, Philippines (RD, M)
37. Singapore (S)
38. Chu-Pei, Taiwan (RD)
39. Taipei, Taiwan (S)

S–Sales
RD–Research & Design
M–Manufacturing

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Critical Device in Power Switch

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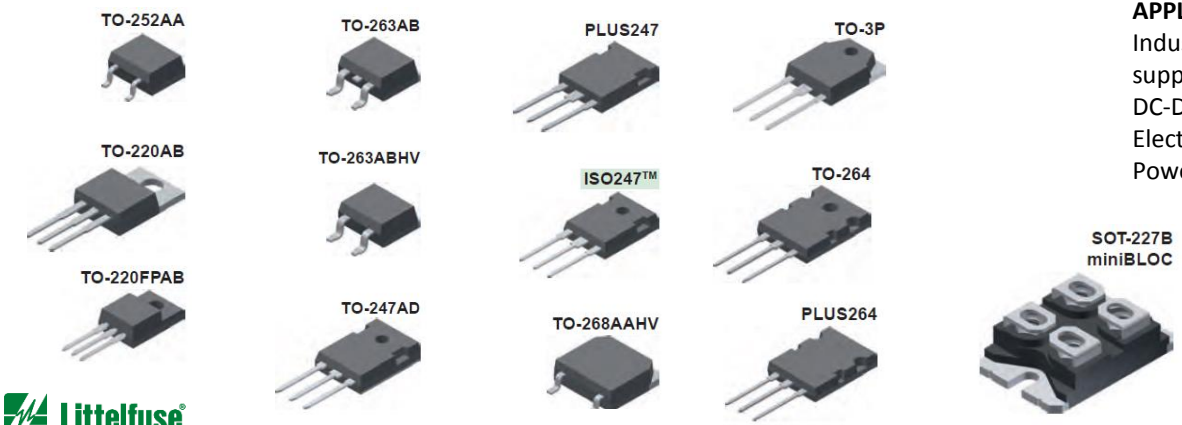
Ultra Junction MOSFET(X)

IXYS X-Class 850V - 1000V Power MOSFETs with HiPerFET™

IXYS X-Class 850V-1000V Power MOSFETs with HiPerFET™ with fast body diodes are rugged devices that display the lowest on-state resistances in the industry. This enables a very high power density in high-voltage power conversion applications. Developed using the charge compensation principle and proprietary process technology, these devices exhibit low gate charges and superior dv/dt performance. In addition, thanks to the fast soft-recovery body diode, these ultra-junction MOSFETs help reduce switching losses and Electromagnetic Interference (EMI).



FEATURES

Ultra low on-resistance RDS(ON) and gate charge Qgs
Avalanche-rated
Low package inductance
High power density
High efficiency
Fast body diode
International standard packages
dv/dt ruggedness
Easy to mount
Space savings

APPLICATIONS

Industrial switch-mode and resonant-mode power supplies
DC-DC converters
Electric vehicle battery chargers
Power Factor Correction (PFC) circuits

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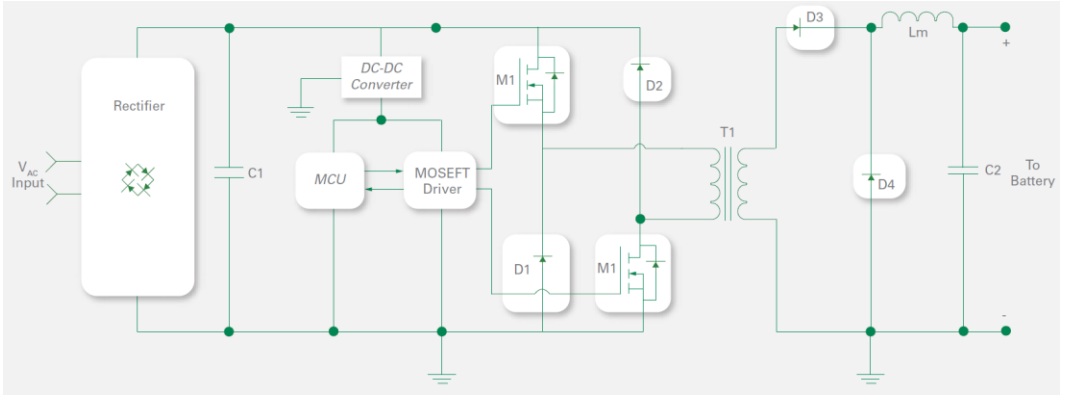
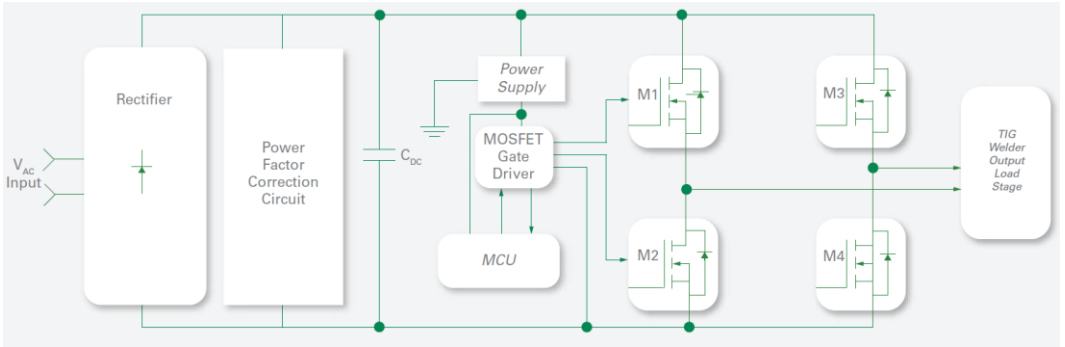
Typical Circuit for X-series MOSFET(1/2)

The battery charger circuit that utilizes a half-bridge asymmetrical forward converter topology. Commonly implemented on the primary side of 220VAC offline switch-mode power supplies, it consists of a primary rectifier, MOSFET gate driver, and half-bridge asymmetrical forward converter. Two 1000V Ultra Junction X-Class devices, **IXFX52N100X** (M1, M2), form the forward converter stage, enabling a highly efficient and reliable power conversion.



Demonstrates a generic high-current Tungsten Inert Gas (TIG) welding inverter. It is comprised of a rectification stage, power factor correction (PFC) circuit, micro controller, gate drivers, and power inverter. An AC input (185VAC-265VAC) is converted into a DC signal through rectification; it then goes through the PFC where its distorted current is reshaped to be in phase with the input voltage. It next enters the full-bridge inverter, made up of four 1000V X-Class MOSFETs (IXFN70N100X: M1, M2, M3, M4), to be converted back to an AC signal (typically ranging from 30kHz to 50kHz) and applied to the load. The IX2120, a 1200V half bridge gate driver, can be used to drive the MOSFETs.



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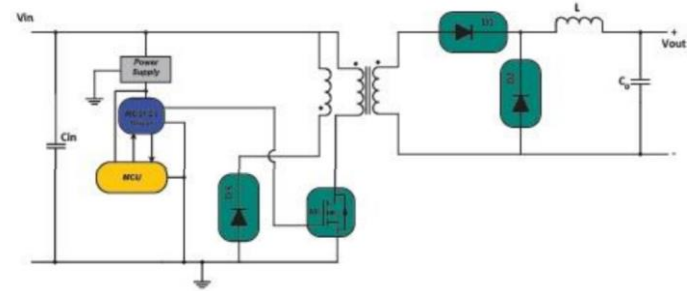
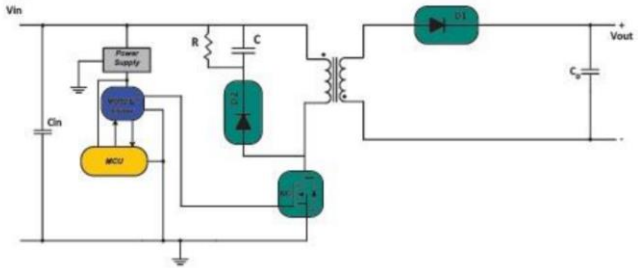
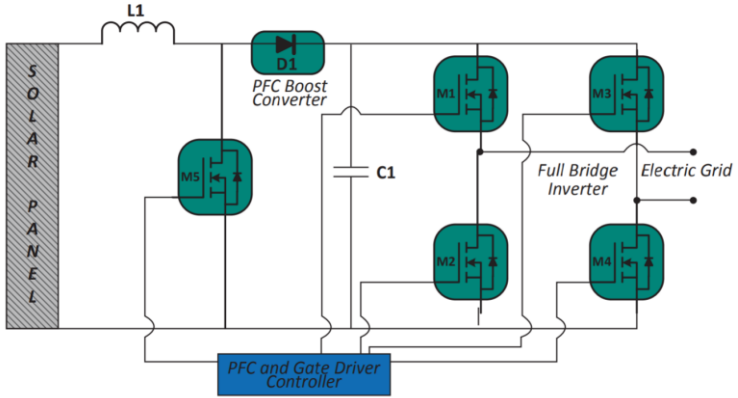
Typical Circuit for X-series MOSFET(2/2)

Single transistor forward converter



Flyback converter

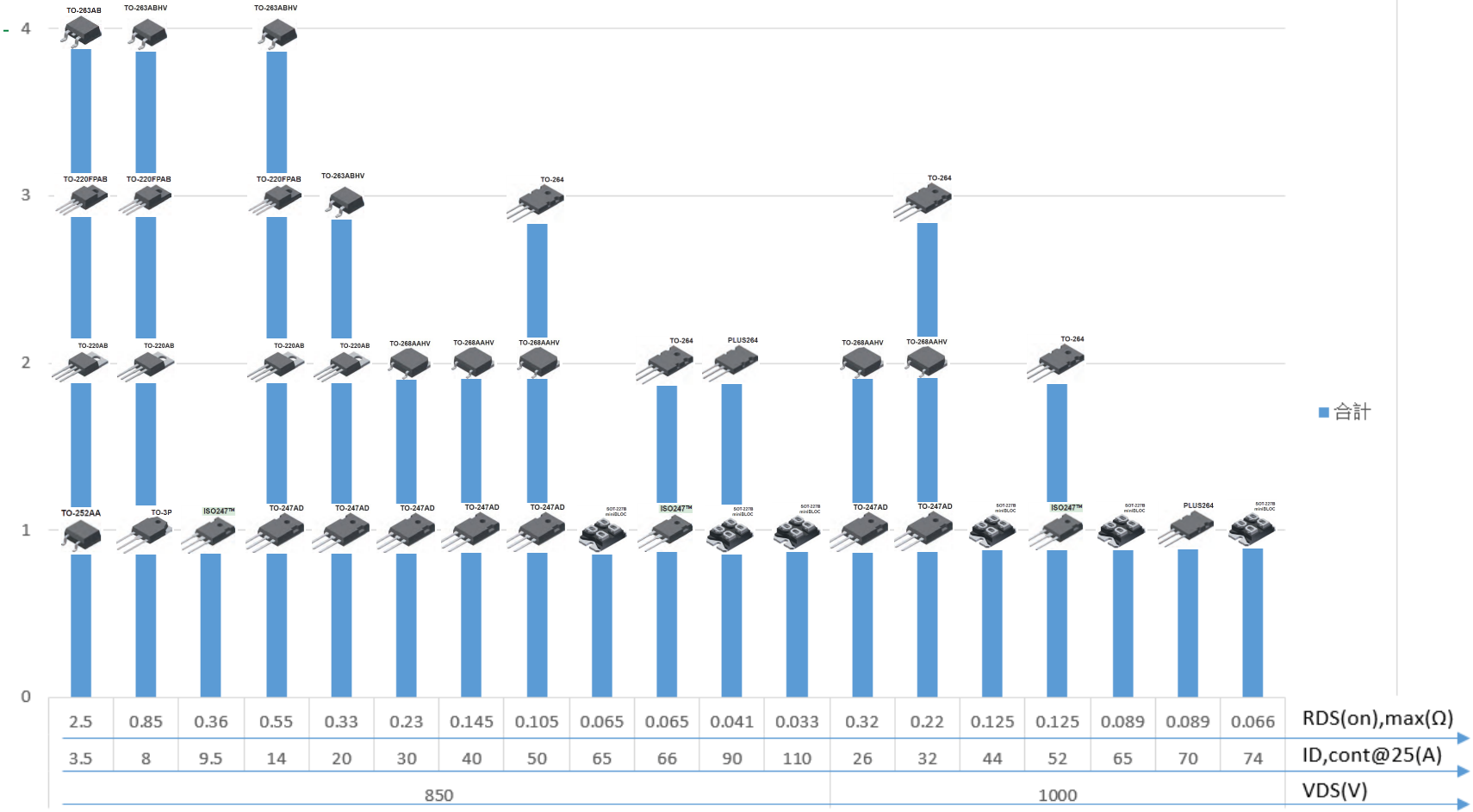




Solar inverter

計數 - Package Type

Package type for each X1 rating



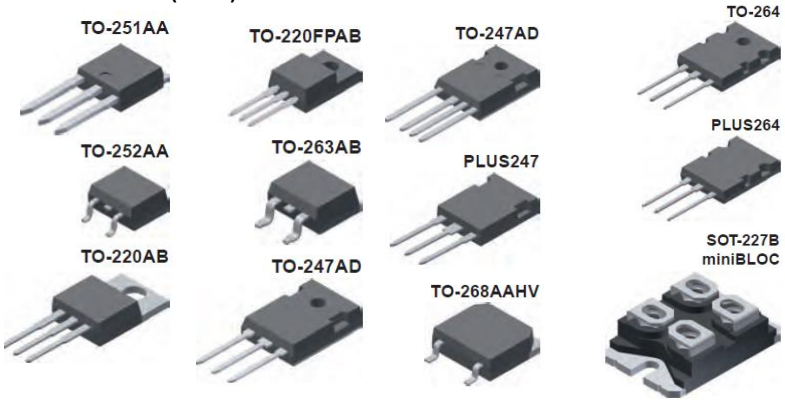
2.5	0.85	0.36	0.55	0.33	0.23	0.145	0.105	0.065	0.065	0.041	0.033	0.32	0.22	0.125	0.125	0.089	0.089	0.066	RDS(on),max(Ω)
3.5	8	9.5	14	20	30	40	50	65	66	90	110	26	32	44	52	65	70	74	ID,cont@25(A)
850												1000							VDS(V)

Ultra Junction MOSFET(X2)

IXYS X2-Class 650V-700V Power MOSFETs with HiPerFET™

IXYS X2-Class 650V-700V Power MOSFETs with HiPerFET™ are designed for high-efficiency and high-speed power switching applications. The Ultra-Junction X2-Class MOSFETs offer low gate charge and excellent ruggedness with a fast intrinsic diode. These MOSFETs are available in many standard industrial packages including isolated types. Typical applications are switch-mode and resonant-mode power supplies, DC-DC converters, PFC circuits, AC and DC motor drives and robotics and servo controls.

The X2-class MOSFETs feature low ON-state resistance, low gate charge, and superior dv/dt performance. These MOSFETs are developed using the charge compensation principle and proprietary process technology. The X2-class MOSFETs come with fast soft-recovery body diode that reduces the switching losses and Electro-Magnetic Interference (EMI).



FEATURES

Ultra low on-resistance $R_{DS(ON)}$ and gate charge Q_g
Fast body diode
dv/dt ruggedness
High efficiency
High power density
Avalanche-rated
Low package inductance
International standard packages
Easy to mount
Space savings

APPLICATIONS

Industrial switched-mode and resonant mode power supplies
Electric vehicle battery chargers
AC and DC motor drives
DC-DC converters
Renewable-energy inverters
Power Factor Correction (PFC) circuits
Robotics and servo control

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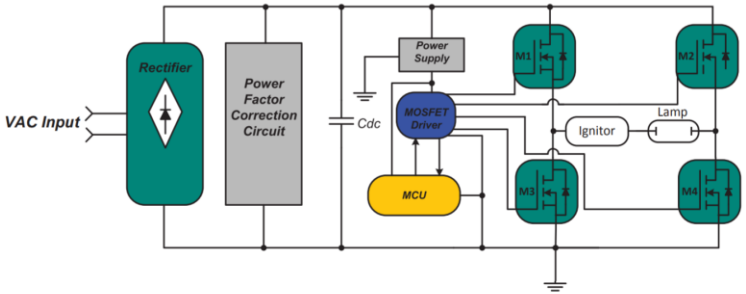
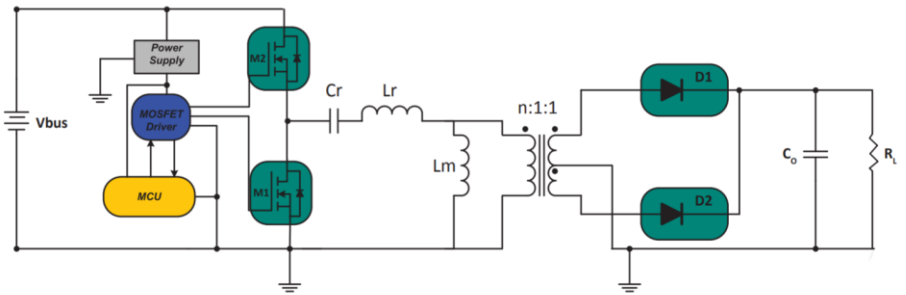
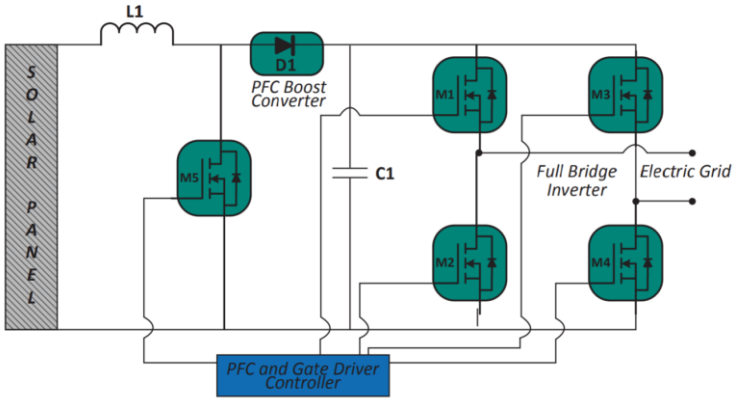
Typical Circuit for X2-series MOSFET(1/2)



High Intensity Discharge (HID) lamp ballast

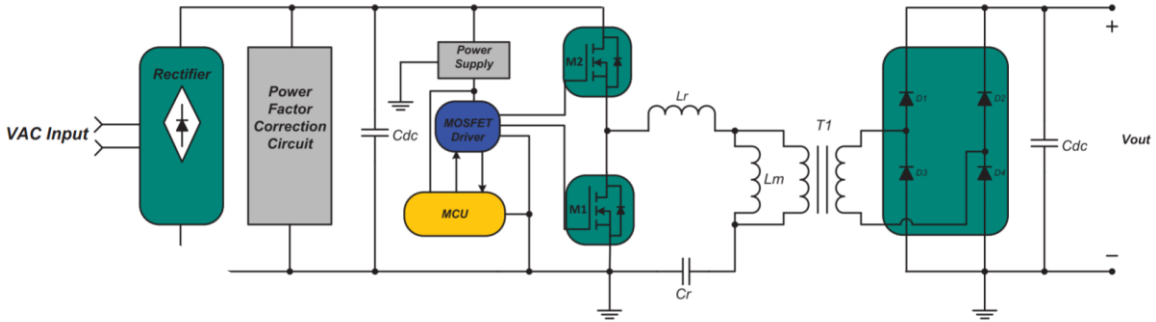


LLC resonant half-bridge converter

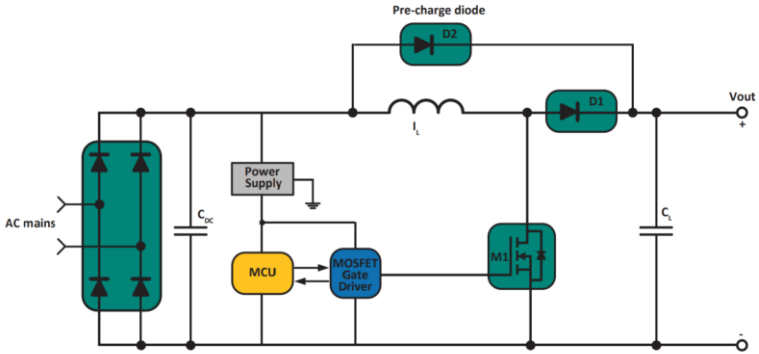


Solar inverter

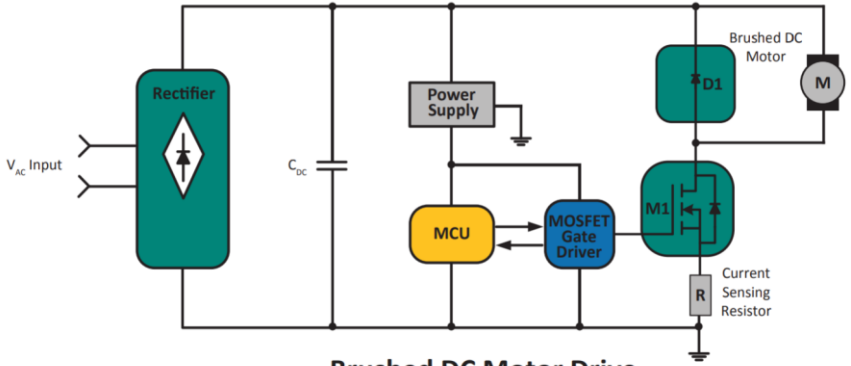
Typical Circuit for X2-series MOSFET(2/2)



SMPS - Half-Bridge Resonant-Mode Converter



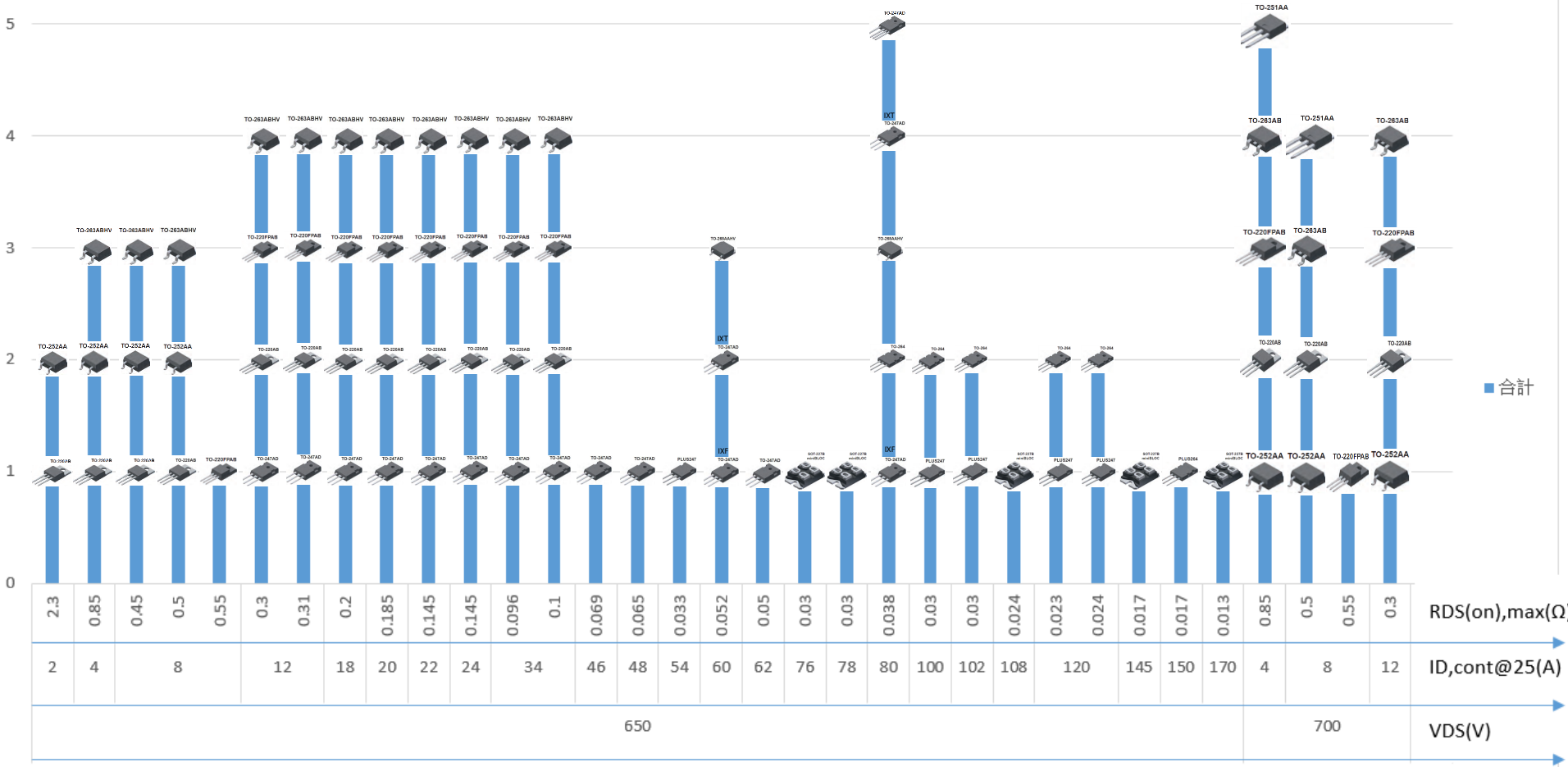
Power Factor Correction (PFC) circuit



Brushed DC Motor Drive

計數 - Package Type

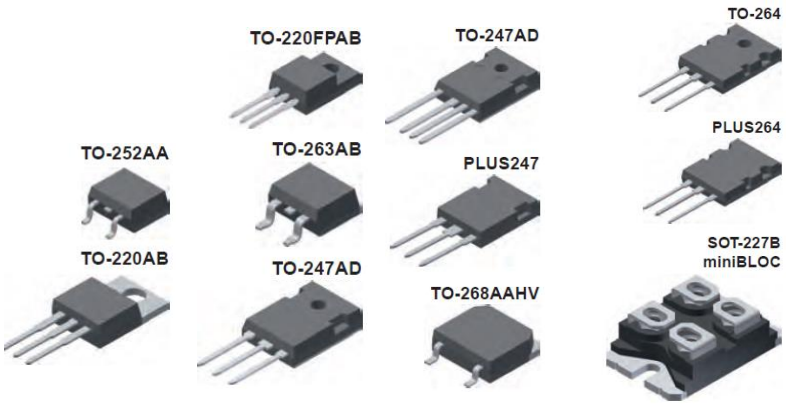
Package type for each X2 rating



Ultra Junction MOSFET(X3)

IXYS X3-Class 200V-300V Power MOSFETs with HiPerFET™

IXYS X3-Class 200V-300V Power MOSFETs with HiPerFET™ are avalanche-rated fast intrinsic diodes with N-channel enhancement mode. These MOSFETs feature low $R_{DS(ON)}$, low gate charge (Q_G), and high-power density. IXYS X3-Class 200V-300V Power MOSFETs with HiPerFET™ remove leftover energies during high-speed switching to avoid device failure. Typical applications include DC-to-DC converters, power supplies, robotics, servo controls, and battery chargers for light electric vehicles.



FEATURES

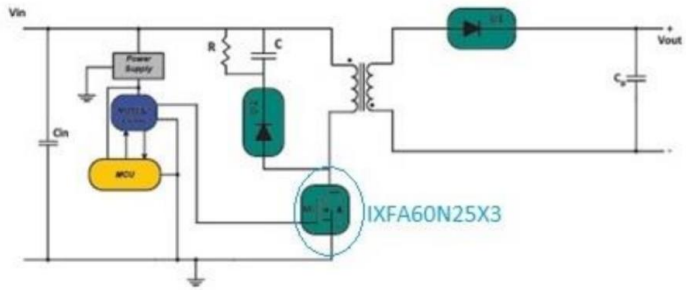
High-power density
Easy to mount
Low $R_{DS(ON)}$ and Q_G
-55° C to 150° C temperature range
$20V_{gs}$ and $2.5V_{gs(th)}$
Avalanche capability
dv/dt ruggedness
Si technology
Low package inductance
Fast soft recovery body diode
International standard packages

APPLICATIONS

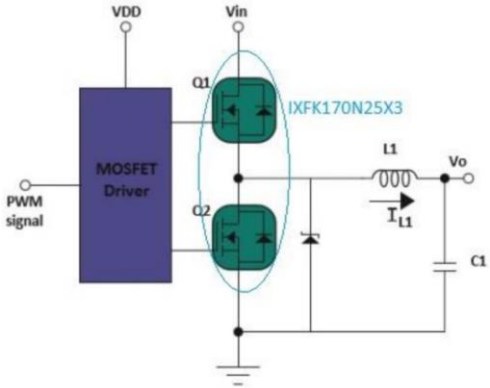
Battery chargers for light electric vehicles
Synchronous rectification in switching
Power supplies
Motor control
DC-DC converters
Uninterruptible power supplies
Electric forklifts
Class-D audio amplifiers
Telecom systems
Robotics and servo controls

Typical Circuit for X3-series MOSFET

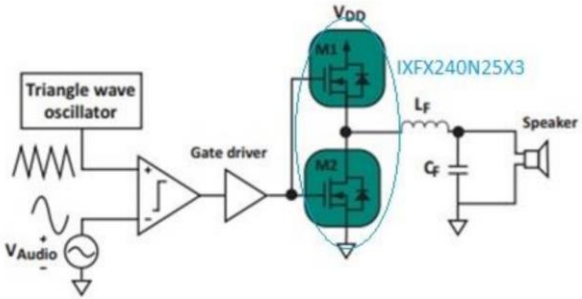
Flyback converter for telecom power supplies



Synchronous rectification in a buck converter

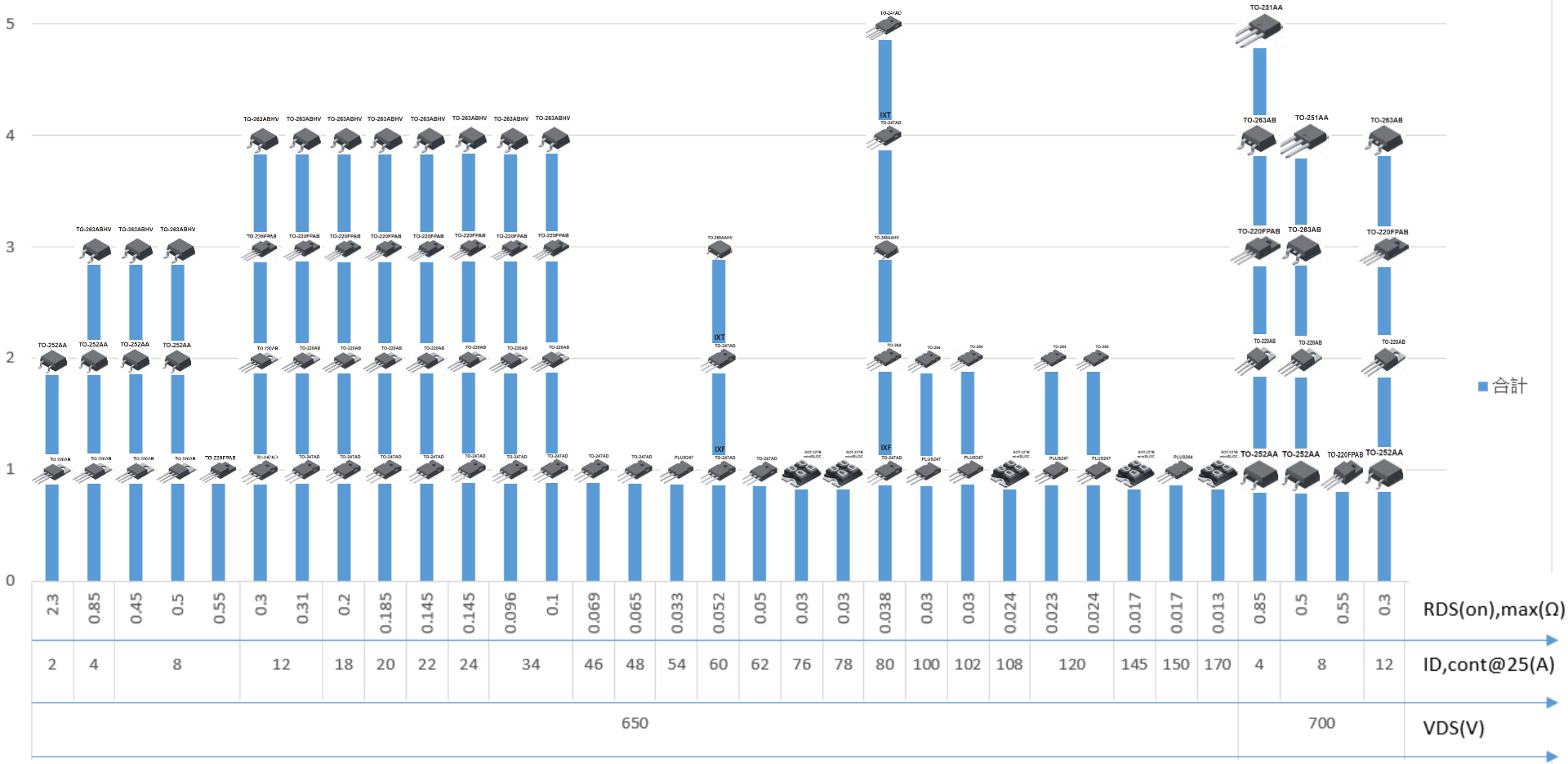


Half-bridge Class-D audio amplifier

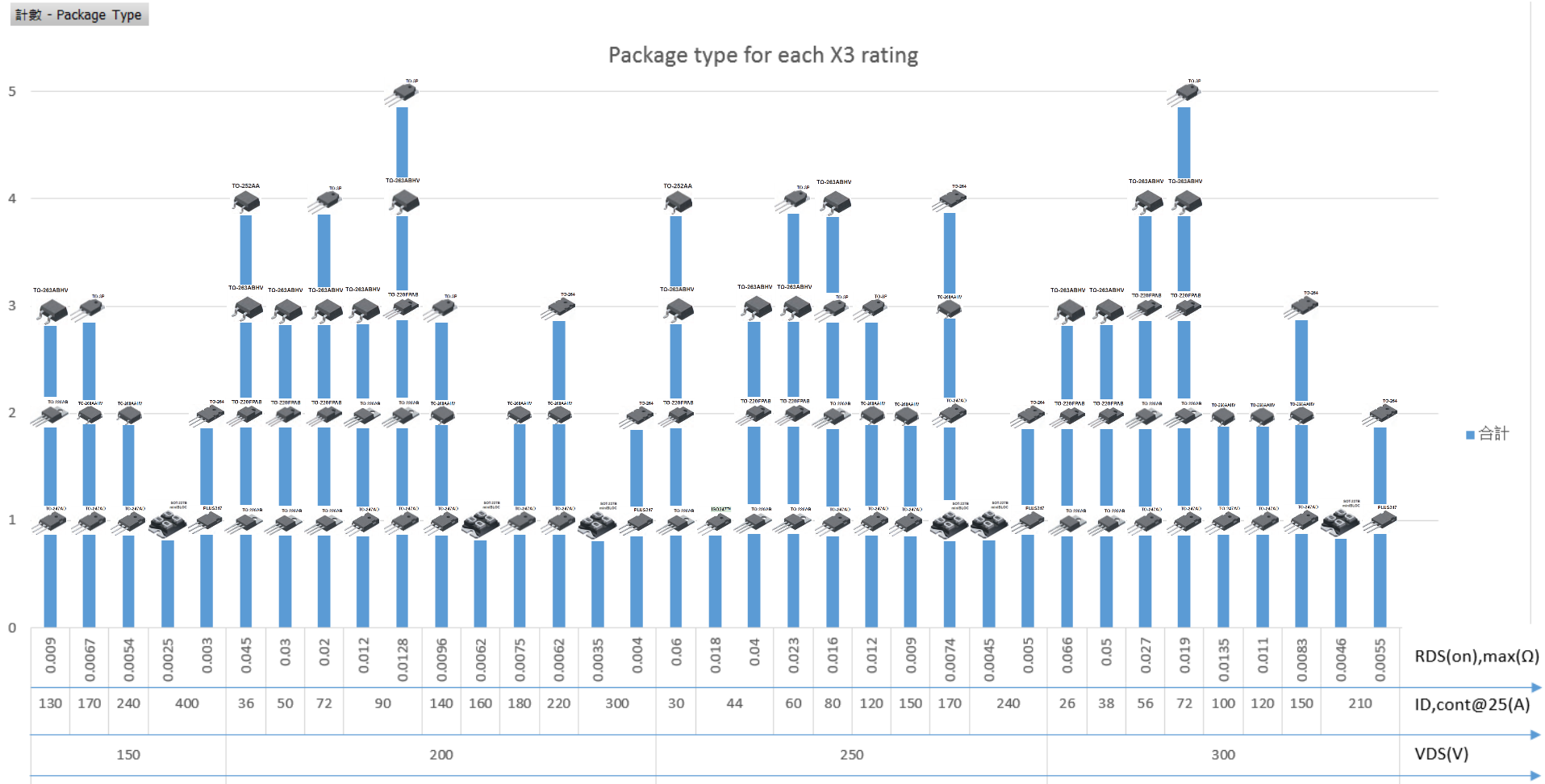


計數 - Package Type

Package type for each X2 rating



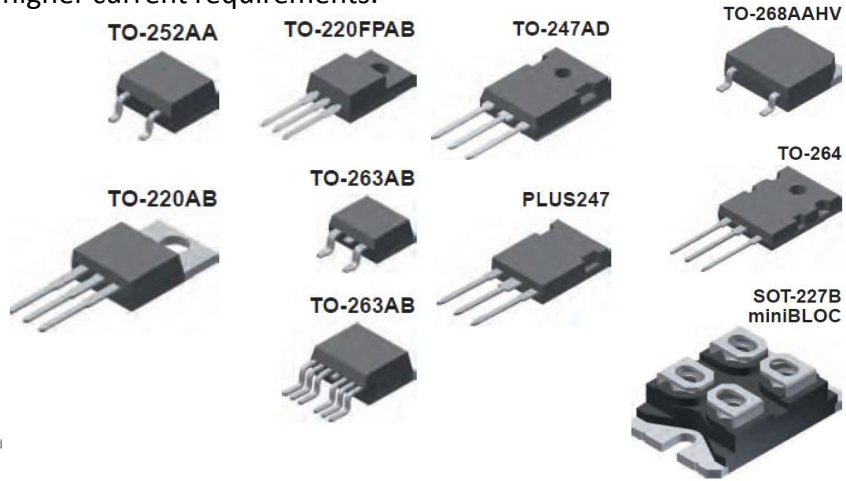
計數 - Package Type



Ultra Junction MOSFET(X4)

IXYS X4-Class 135V-150V Power MOSFETs

IXYS X4-Class 135V-150V Power MOSFETs are developed using a charge compensation principle and proprietary process technology. This technology results in Power MOSFETs with significantly reduced resistance $R_{DS(on)}$ and gate charge Q_g. A low on-state resistance reduces the conduction losses; it also lowers the energy stored in the output capacitance, minimizing the switching losses. A low gate charge results in higher efficiency at light loads as well as lower gate drive requirements. These MOSFETs are also avalanche rated and exhibit a superior dv/dt performance. Due to the positive temperature coefficient of their on-state resistance, these MOSFETs can be operated in parallel to meet higher current requirements.



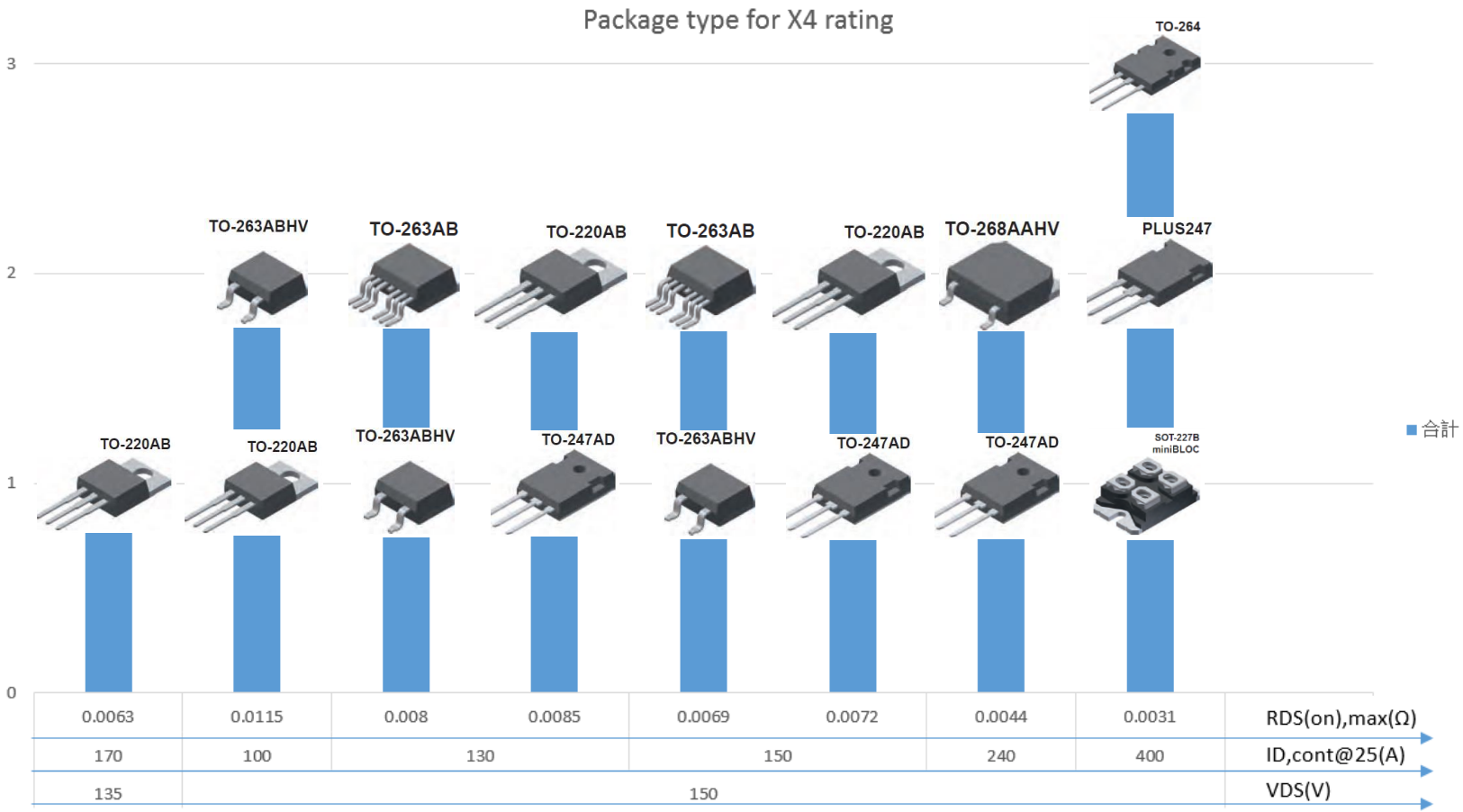
FEATURES

High-power density
Easy to mount
Low $R_{DS(ON)}$ and Q_G
-55° C to 150° C temperature range
$20V_{gs}$ and $2.5V_{gs(th)}$
Avalanche capability
dv/dt ruggedness
Si technology
Low package inductance
Fast soft recovery body diode
International standard packages

APPLICATIONS

Battery chargers for light electric vehicles
Synchronous rectification in switching
Power supplies
Motor control
DC-DC converters
Uninterruptible power supplies
Electric forklifts
Class-D audio amplifiers
Telecom systems
Robotics and servo controls

計數 - Package Type



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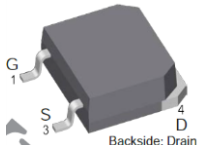
Expertise Applied | Answers Delivered

SiC MOSFET Standard Package Portfolio

In production

In qualification.



	RDSON (mΩ)	TO247-3L	TO247-4L	TO263-7L (D2PAK)	TO268-2L (D3PAK)
1200V	160	LSIC1MO120E0160	LSIC1MO120G0160 Engr. Sample available	LSIC1MO120T160 Engr. Sample available	
	120	LSIC1MO120E0120	LSIC1MO120G0120 Engr. Sample available	LSIC1MO120T120 Engr. Sample available	
	80	LSIC1MO120E0080	LSIC1MO120G0080 Engr. Sample available	LSIC1MO120T080 Engr. Sample available	
	40	LSIC1MO120E0040 Engr. Sample available	LSIC1MO120G0040 Engr. Sample available		
	25	LSIC1MO120E0025 Engr. Sample available	LSIC1MO120G0025 Engr. Sample Q4 19		
1700V	750	LSIC1MO170E1000		LSIC1MO170T0750 Engr. Sample Q3 19	LSIC1MO170H0750 Engr. Sample available

- TO247-3L : Most common
- TO247-4L : With Kelvin connection
- TO263-7L : Surface mount with Kelvin connection
- TO268-2L : High creepage
- Other R_{DSON} and voltages being developed
- Bare die available on request.
- Competitive performance and price with best-in-class delivery in market
- Samples available for evaluation

Littelfuse Power Semiconductors

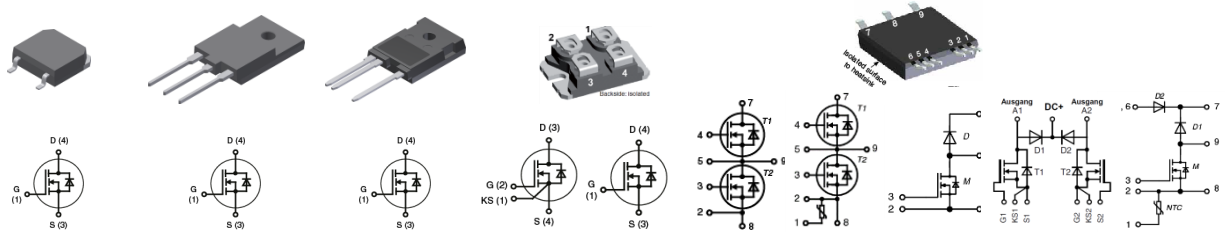
SiC MOSFET Advanced Package Portfolio

In production

In development

Planned

Idea



	RDSON (mΩ)	TO268HV (D3 HV)	T03-PFP	TO247 HV	SOT227 (MiniBloc)	SMPD (phase leg)	SMPD (boost)
900 V	10 mΩ	MCB110I900TZ			IXFN130N90SK* Sample Available	MCB110P90TLB #	
1200 V	80 mΩ	MCB25I1200TZ			IXFN27N120SK* Sample Available	MCB20P1200LB	MKH17RP650DCGLB [1,2]
						MCB25P1200TLB #	MCL25R1200LB
							MCL25RP1200LB [1]
	40 mΩ	MCB40I1200TZ			IXFN50N120SiC	MCB30P1200LB Sample Available	MCB30RL1200TLB [3]
					IXFN50N120SK*	MCB45P1200TLB #	
	25 mΩ	MCB60I1200TZ			IXFN70N120SK*	MCB40P1200LB Sample Available	MCB60R1200TLB
						MCB60P1200TLB #	
	12 mΩ				IXFN140N120SK*		
1700 V	750 mΩ	LSIC1MO170H0750	MCL3I1700QN	MCL4I1700HV			
	80 mΩ						
	45 mΩ	MCB45I1700TZ			IXFN45N170SK*	MCB35P1700TLB #	MCB35R1700LB
	25 mΩ				IXFN90N170SK* Sample Available		

* Kelvin Source
\# Improved Rth & NTC
[1] Dual Boost
[2] CoolMOS + SiC Boost
[3] Boost + Bypass + NTC

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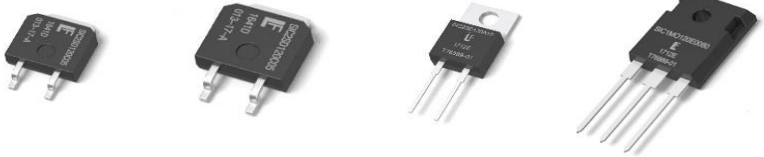
SiC Diode Standard Package Portfolio

In production

In development



		TO252-2L (DPAK)	TO263-2L (D2PAK)	TO220-2L	TO247-3L (Dual Package)
650V AEC-Q101 Qualified (In Production)	6A	LSIC2SD065C06A	LSIC2SD065D06A	LSIC2SD065A06A	
	8A	LSIC2SD065C08A	LSIC2SD065D08A	LSIC2SD065A08A	
	10A	LSIC2SD065C10A	LSIC2SD065D10A	LSIC2SD065A10A	
	12A				LSIC2SD065E12CCA
	16A	LSIC2SD065C16A	LSIC2SD065D16A	LSIC2SD065A16A	LSIC2SD065E16CCA
	20A	LSIC2SD065C20A	LSIC2SD065D20A	LSIC2SD065A20A	LSIC2SD065E20CCA
	32A				LSIC2SD065E32CCA
	40A				LSIC2SD065E40CCA
1200V (In Production)	5A	LSIC2SD120C05		LSIC2SD120A05	
	8A	LSIC2SD120C08		LSIC2SD120A08	
	10A	LSIC2SD120C10	LSIC2SD120D10	LSIC2SD120A10	LSIC2SD120E10CC
	15A		LSIC2SD120D15	LSIC2SD120A15	LSIC2SD120E15CC
	20A		LSIC2SD120D20	LSIC2SD120A20	LSIC2SD120E20CC
	30A				LSIC2SD120E30CC
	40A				LSIC2SD120E40CC

- Wide portfolio of 650V and 1200V diodes
- 650V diodes are AECQ101
- Both surface mount and through-hole
- Other options : 2L TO-247, SOT-227, ISOPLUS, bare die.
- Competitive performance and price with best-in-class delivery in market : samples available.

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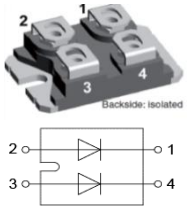
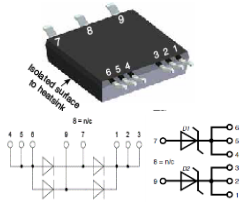
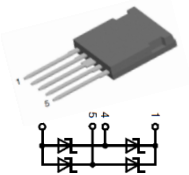
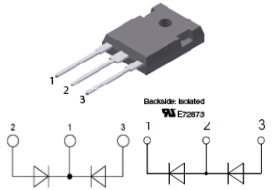
Expertise Applied | Answers Delivered

SiC Diode Advanced Package Portfolio









In production

In development

Idea

		SOT-227 (MiniBloc)	SMPD	ISOPLUS i4	ISO247
600/650V	2 x 10 A		DCG20B650LB # Sample available	FBS18-065SC #	DCG20C600HR[1]
				MXB12R650DCGFC *3 (boost) Sample available	
	2 x 16 A				DCG30C650HR [1]
	2 x 80 A	DCG160X650NA Sample available			
1200V	2 x 5 A			FBS10-12SC #	DCG10C1200HR[1]
	2 x 10 A				DCG10P1200HR [2] Sample available
					DCG20C1200HR[1] Sample available
	2 x 20 A	DCG45X1200NA (2x22 A)	DCG40X1200LB (2x20 A)		DCG17P1200HR[2] Sample available
			DCG20B1200LB #		DCG35C1200HR[1] Sample available
	2 x 40 A	DCG85X1200NA (2x43 A)			
	2 x 50 A	DCG100X1200NA (2x49 A)			
	2 x 60 A	DCG130X1200NA (2x64 A)			
1700V	2 x 10 A	DCG20X1700NA (2x9 A)			
	2 x 25 A	DCG50X1700NA (2x24 A)	DCG45X1700LB (2x22 A)		

Full Bridge
[1] Common Cathode
[2] Phase Leg
[3] X2 Class Mos + SiC Boost

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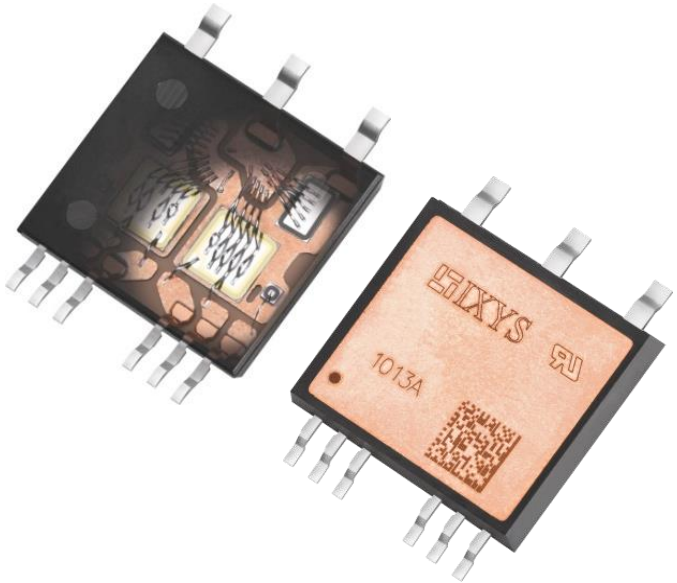
ISOPLUS™ Family

ISOPLUS™ SMPD

Surfaced Mounted Power Device



Why the customer needs SMPD?

1. Provide the optimum space utilization, SMPD very suitable for poor thermal dissipation or small size enclosure.→ Good thermal resistance.

2. Easy to mount on PCB→ Tape & reel process, save the assembly time and money.

3. With the insulation ability→ Meet safety requirements and no needs to consider the arc issue on the SMPD top side.

4. Customized Configurations→ Provide differ kind of topology in circuit design.

5. Reduce EMI side effect→ Optimized package design, low resistance and stray inductance.

Ultra-low profile SMPD package

➔ **Provide the optimum space utilization**

➔ **Excellent heat treatment capability**

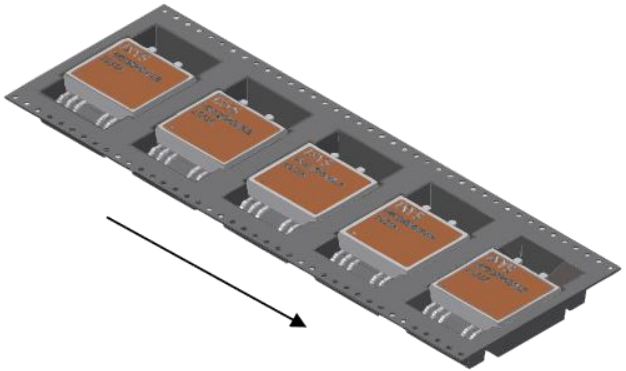
Mini-SMPD	SMPD	SOT-227	TO-264	PLUS247
Height=5.3mm	Height=5.3mm	Height=8.92mm	Height=4.8mm	Height=4.8mm

The above accentuates the compact and low profile nature of the device. Compared to a conventional high power package such as the SOT-227, the IXYS SMPD features ¼ the weight and 1/3 the volume and provides similar electrical and thermal characteristics.

The figure above illustrates a comparison of the Mini-SMPD with other industry standard packages. The volume of it ($3cm^3$) is only at 60% of that of the SMPD ($1.8cm^3$). But the Mini SMPD is able to maintain a high voltage isolation of 4.5kV and weighs just 5g.

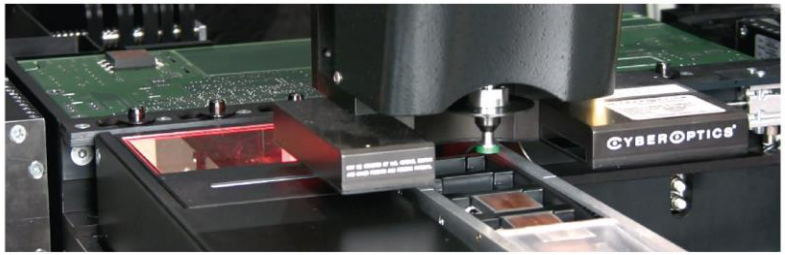
Advantage ISOPLUS™ SMPD

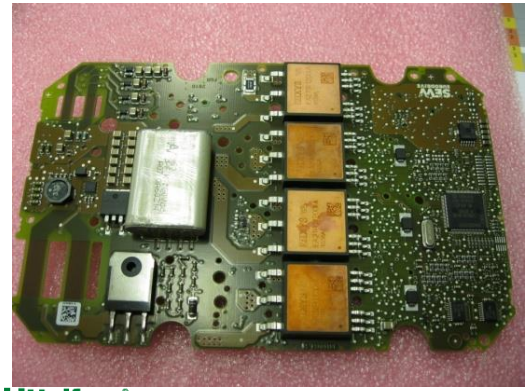
➔ **Easy to mount on PCB**



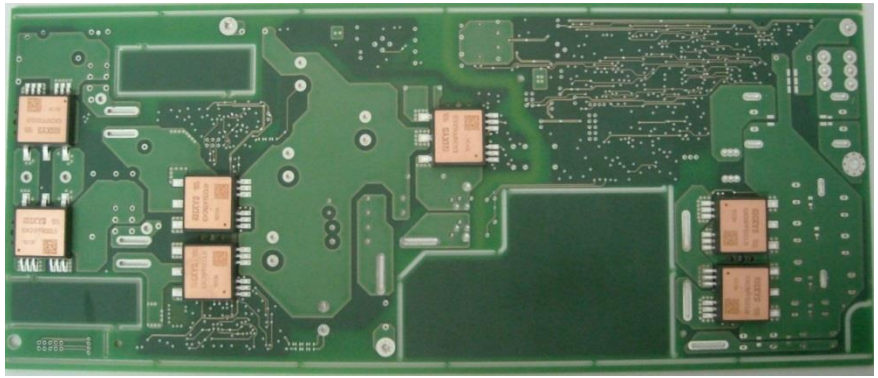
SMPD in Tape & Reel

👍 Cost Reduction in Assembly





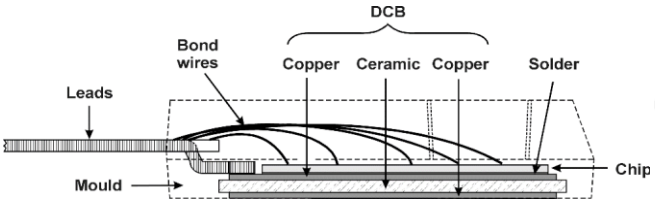
➢ Video

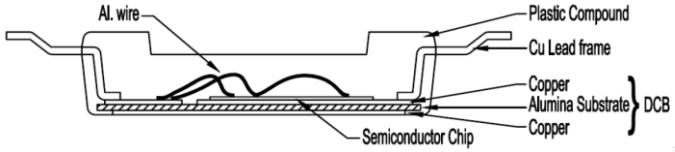


Benefits of ISOPLUS™ Package Construction

➔ **With the insulation ability**

Package Cross Section



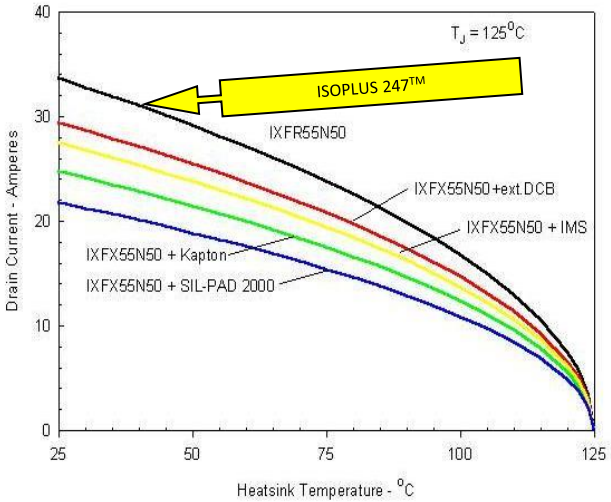


SMPD PACKAGE ILLUSTRATION

Features:

- 2500V isolation voltage (UL recognized)
- Low thermal resistance
- High power cycling capability
- Reduces parasitic inductance and capacitance
- Transfer molded housing for low cost
- Allows module circuit configurations
  - Half bridge configuration
  - Series connected and common anode FREDs
  - MOSFET with series Schottky diode
- Replaces multiple discretes

Comparative Current Capability



.....Means Higher Current Output

SMPD Power Cycling Capability

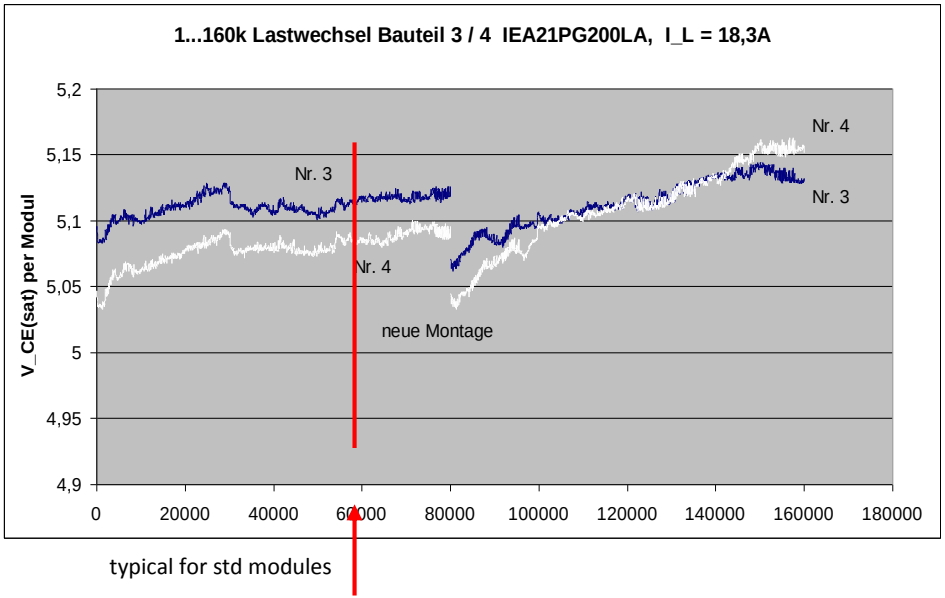
➔ **Excellent and stable packaging process**

Power cycling test condition

- 80° C temperature cycle (Tj 45° C ➔ 125° C ➔ 45° C)
- Ic = 18,3 A for 20A / 1200A rated IGBT

Result

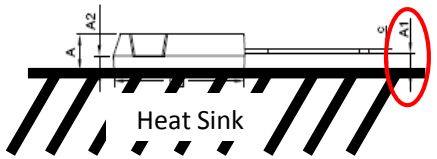
☺ *More than 160 000 cycles without wire bond liftoff !!*

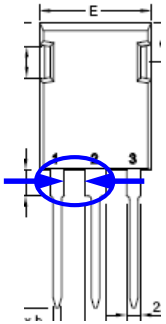


ISOPLUS™ SMPD - Creepage and clearance

➔ **Provide good electrical isolation distance, meet safety requirements**

ISOPLUS 247

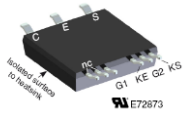


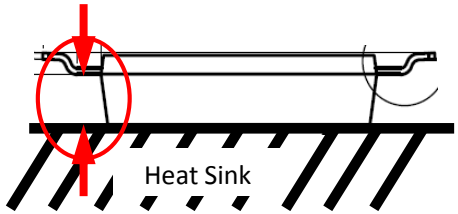


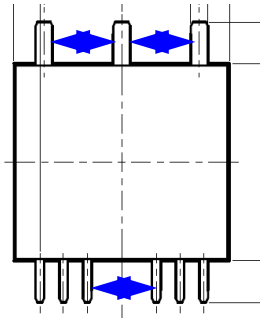
ISOPLUS 247

- Pin – Heat Sink: 2,29 mm min
- Pin – Pin: 2,73 mm min

SMPD







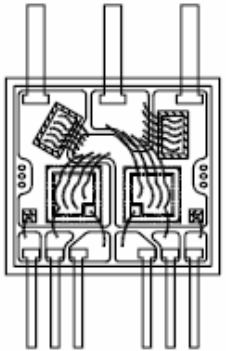
SMPD

- improved creepage and clearance distance

- Pin – Heat Sink: 4,0 mm min
- Pin – Pin: 7,0 mm min

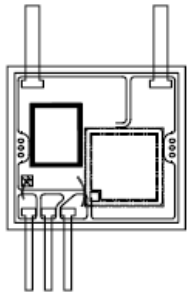
Customized Configurations possible

➔ **Suitable for all kinds of topology**

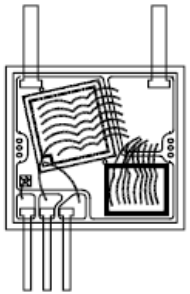


Inverter V12

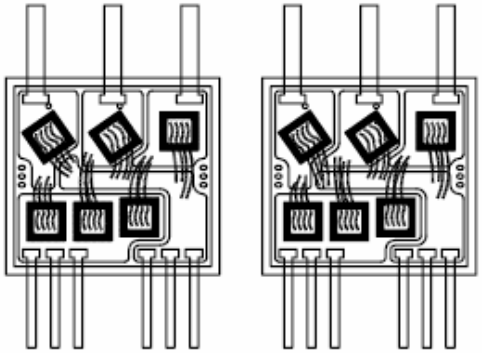
Vce monitoring, small high voltage diode integrated in this version



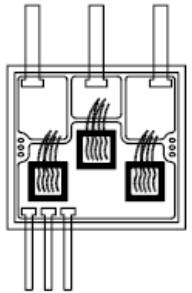
Inverter V14



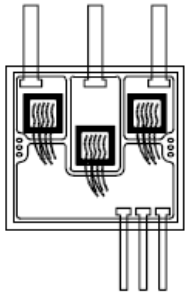
Inverter V14



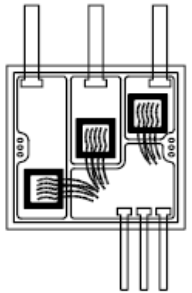
Eingangsbrücke V3



Eingangsbr. V4a



Eingangsbr. V4b

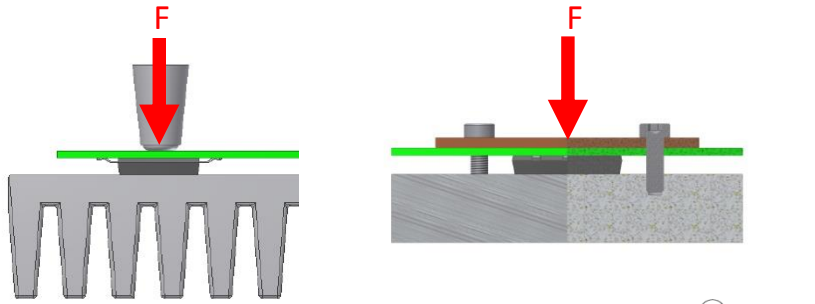


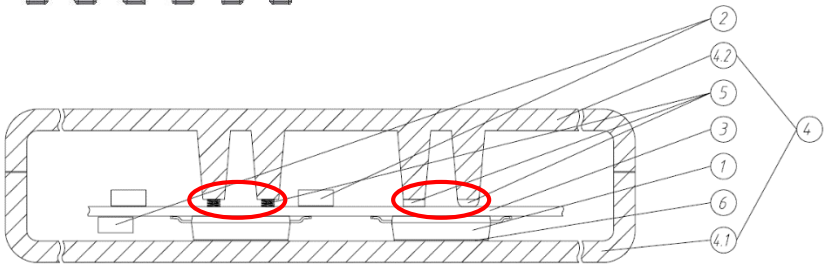
Eingangsbr. V4b alternativ

Littelfuse
Expertise Applied | Answers Delivered

SMPD Mounting Examples

➔ **Installation method of heatsink**



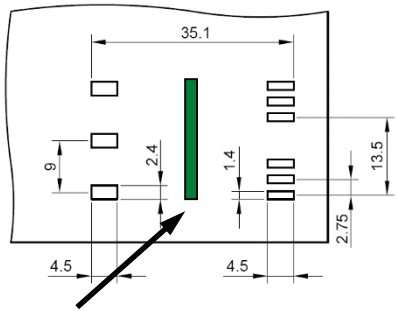


1) ISOPLUS-SMPD power device
2) other electronic components
3) PCB board
4) enclosure, two parts, screwed together
5) spring elements (different versions)
6) heat transfer material (thermal grease)

Recommended Mounting Fource F:

40 … 130 N

Proposal for the pad design for pin soldering on a PCB

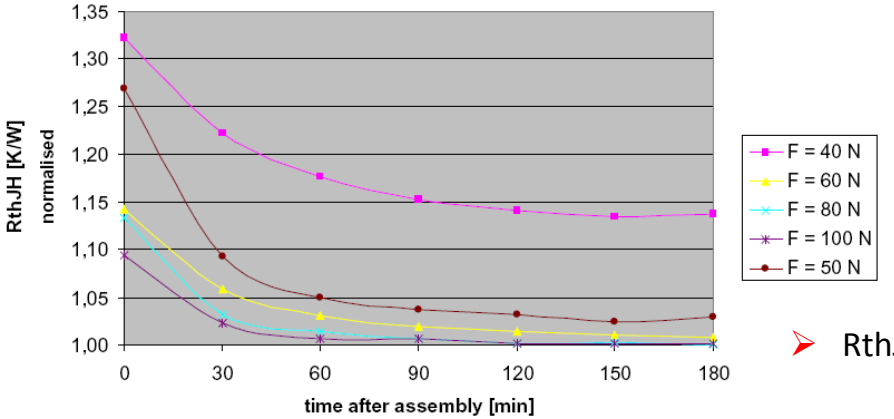


A slit in the board may be used for board stress relief

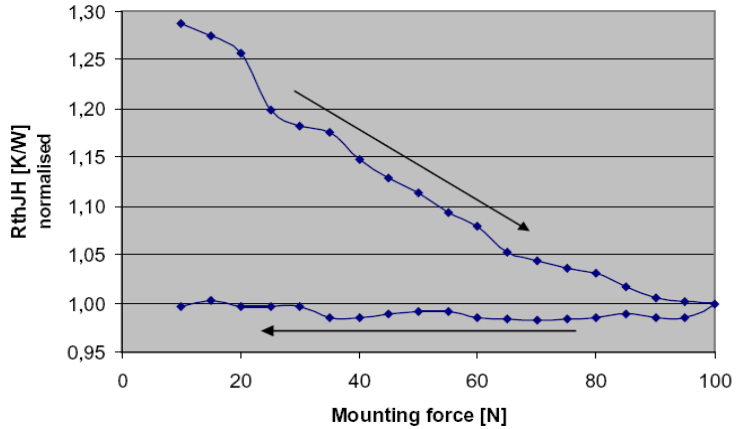
➢ Mounting instruction

SMPD Mounting Force

➔ **Robust package type**



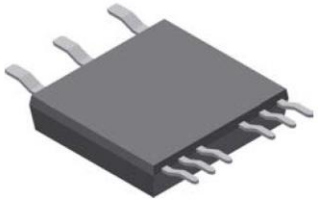
➢ RthJH settles after ~ 2h



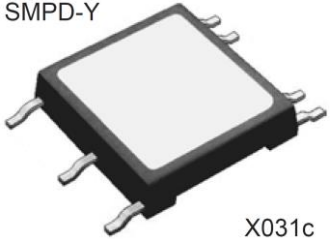
➢ Force may be reduced without increase of RthJH

SMPD Package Type

SMPD-B X030a

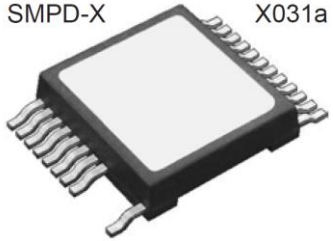


SMPD-Y

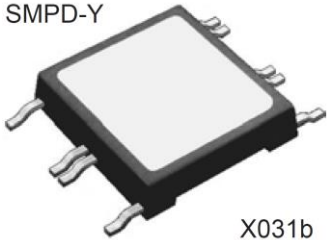


X031c

SMPD-X X031a

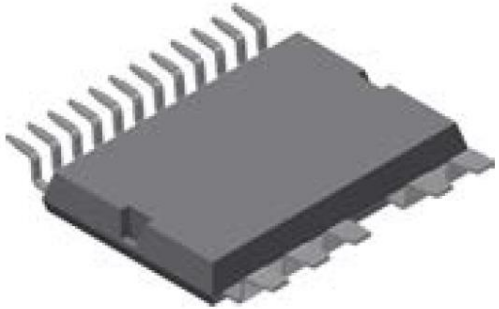


SMPD-Y

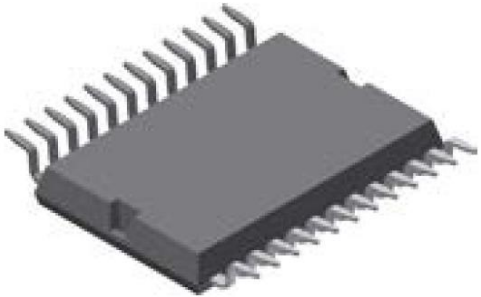


X031b

MiniSMPD X032



X026c **ISOPLUS-DIL™**

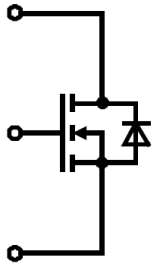


X026d **ISOPLUS-DIL™**

SMPD Circuit Diagram – MOSFET(1/2)

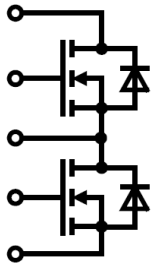
Single

A



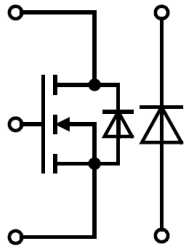
Phase leg

B

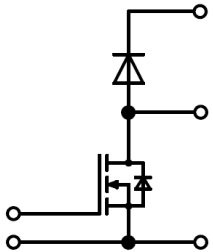


Buck/ Boost

C

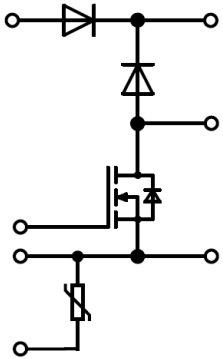


D



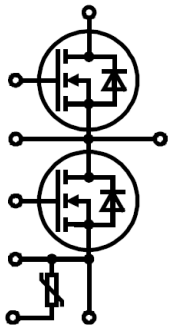
Buck/ Boost
+ NTC

E



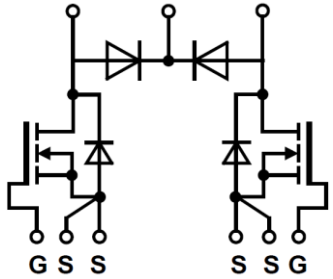
Phase leg
+ NTC

F



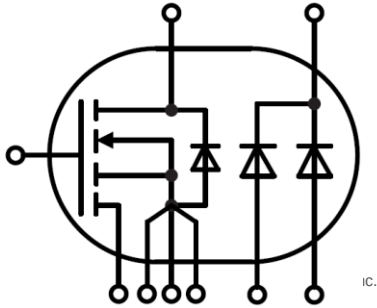
Dual Buck/ Boost

G



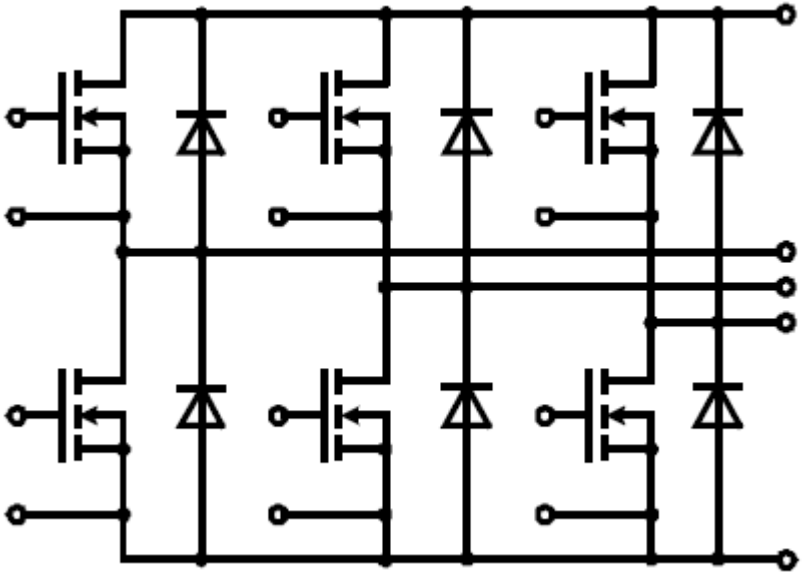
Single with Current and
Temperature Sense

H

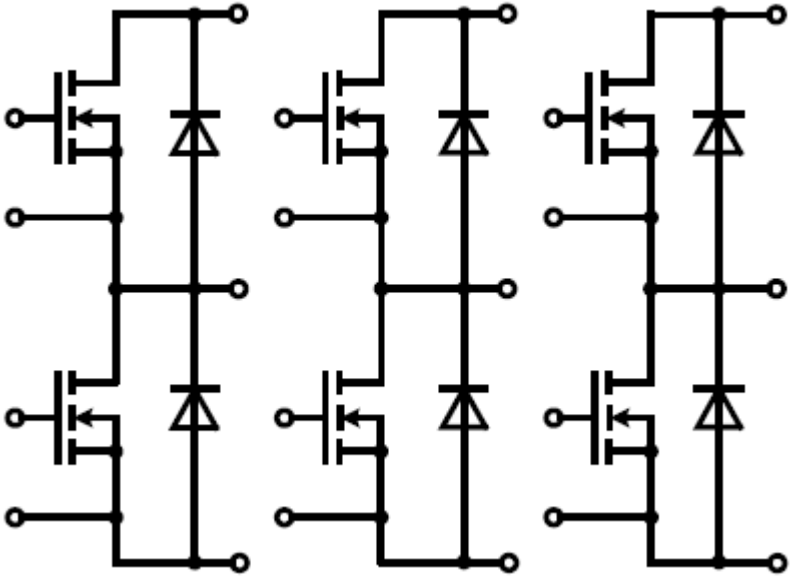


SMPD Circuit Diagram – MOSFET(2/2)

Six pack
3 phase inverter

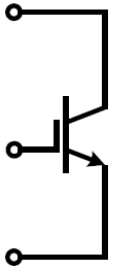


Six pack
3x phase leg

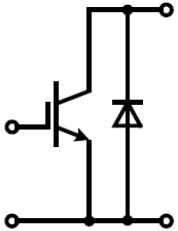


SMPD Circuit Diagram - IGBT

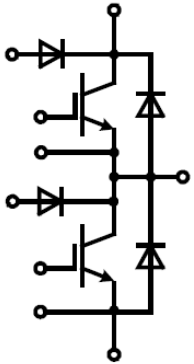
Single
A



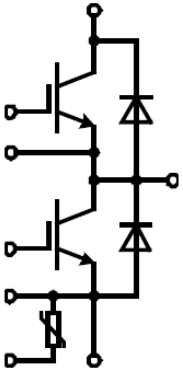
Single
Co-Pack
B



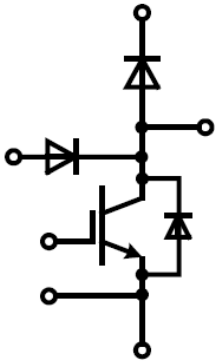
Phase leg
C



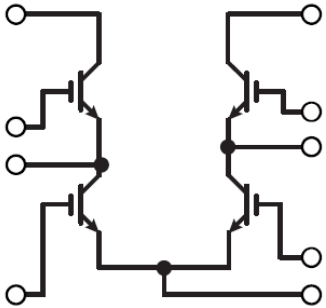
Phase leg
+ NTC
D



Boost
E



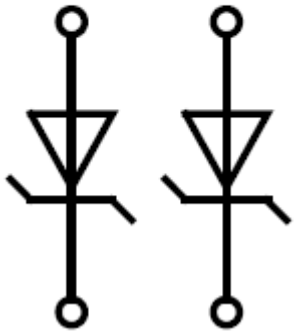
Full Bridge
F



SMPD Circuit Diagram - Diode

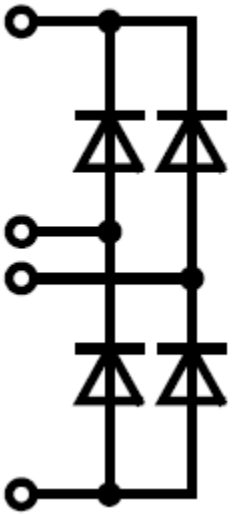
Dual

A



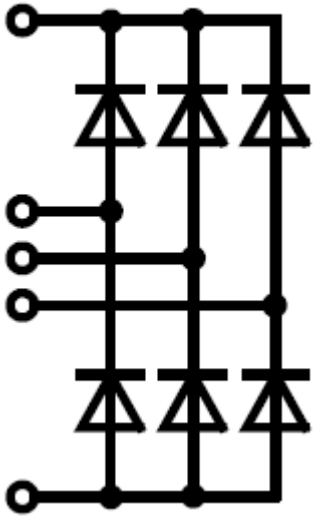
Full Bridge

B

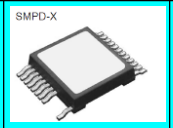
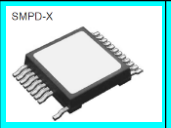
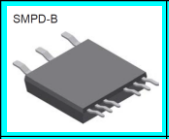
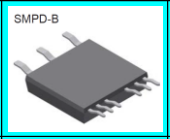
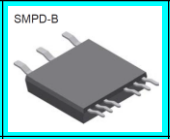
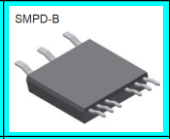
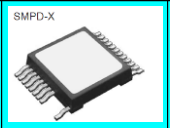
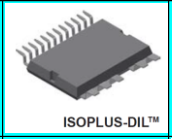
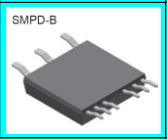
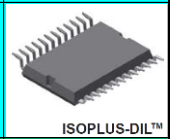
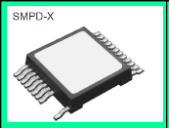
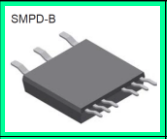
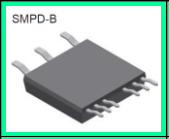
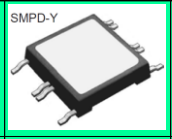
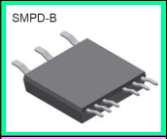
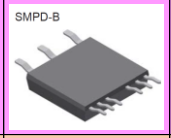
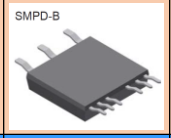
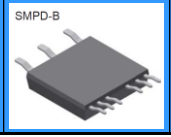


3 phase Bridge

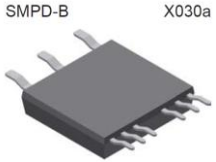
C



Package vs. Power Device vs. Topologies

Product	Topologies										
	Single	Single Co-Pack	Phase leg	Buck/ Boost	Buck/ Boost + NTC	Phase leg + NTC	Dual Buck/ Boost	Full Bridge	Single with current & temp. Sense	3 phase inverter	3x Phase leg
MOSFET											
											
IGBT											
											
Diode											
Single Bridge											
3 Phase Bridge											

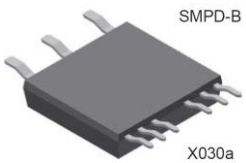
SMPD Product List - Diode

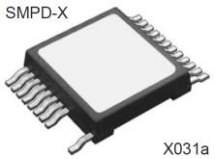


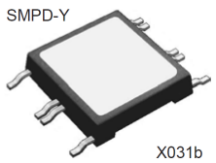
PartNumber	CircuitDiagram /DiodeType	Voltage(V)/VCES(V)	ID(AV)M TC=90°C(A)	FigNo.	Config	Ckt Diag	Package Style	Dimension X, Y (mm*mm)	Status
DPG60B600LB	Rectifier	600	60	X030a	1-Phase Bridge	DPG...B...	SMPD-B	25 * 32.7	Active/New Product
DLA100B800LB	**Rectifier**	**800**	**124**	**X030a**	**1-Phase Bridge**	**DLA...B...**	**SMPD-B**	**25 * 32.7**	**Active Part**
DLA100B1200LB	Rectifier	1200	124	X030a	1-Phase Bridge	DLA...B...	SMPD-B	25 * 32.7	Active Part
DMA90U1800LB	Rectifier	1800	99	X030a	3-Phase Bridge	DMA...U...	SMPD-B	25 * 32.7	Active/New Product
DSA120X150LB	Schottky	150	2x 75	X030a	Dual	DSA...X...	SMPD-B	25 * 32.7	Active/New Product
DSA120X200LB	Schottky	200	2x 65	X030a	Dual	DSA...X...	SMPD-B	25 * 32.7	Active/New Product
DHG60U1200LB	SONIC	1200	63	X030a	3-Phase Bridge	DHG...U...	SMPD-B	25 * 32.7	New Product in Dev

◎AECQ-101 qualification part: DLA100B800LB

SMPD Product List - IGBT

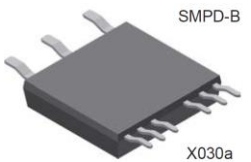


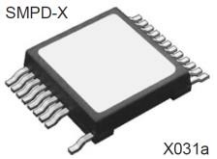




PartNumber	CircuitDiagram/ Technology	VCES(V)	IC25 TC=25°C IGBT (A)	IC90 TC=90°C IGBT (A)	IC110 TC=110°C IGBT (A)	VCE(sat) max TJ=25°C (V)	tfi typ TJ=25°C (ns)	Eoff typ TJ=125°C (mJ)	Eoff typ TJ=150°C (mJ)	RthJC max IGBT(ºC/W)	IF TC=90°C Diode(A)	IF TC=110°C Diode(A)	RthJC max Diode(ºC/W)	Config	Package Style	Dimension X, Y (mm*mm)	Status
MMIX1X340N65B4	GEN IGBT w/o Diode	650	450	295	-	1.7	80	-	2.54	0.125	-	-	-	Single	SMPD-X	25 * 32.7	Active Part
MMIX1G120N120A3V1	PT IGBT w/ Diode	1200	110	-	105	2.2	325	58	-	0.31	-	-	0.5	Copack (FRED)	SMPD-X	25 * 32.7	Active Part
IXA60IF1200DHGLB	-	1200	85	60	-	1.8	-	-	-	-	-	-	-	Copack (FRED)	SMPD	25 * 32.7	New Product in Dev
MMIX1Y25N250CV1	IGBT w/ Diode	2500	36	-	18	4	246	-	10.5	0.65	-	14	0.86	Copack (FRED)	SMPD-X	25 * 32.7	Active Part
IXA110XF650ALB	2xE 2x XPT	650	2x 72	2x 55	-	1.8	-	-	-	-	15	-	-	Dual	SMPD	25 * 32.7	New Product in Dev
MMIX1G320N60B3	GenX3 IGBT	600	400	-	180	1.5	165	5.4	-	0.125	-	-	-	Single	SMPD-X	25 * 32.7	Active Part
IXA20PT1200LB	Phase leg SCR / XPT IGBT	2x1200V	28	20	-	18	-	17	-	126	-	-	-	Phase Leg	SMPD-B	25 * 32.7	New Product in Dev
MMIX4G20N250	VHV NPT IGBT	2500	23	14	-	3.1	930	-	-	1.25	-	-	-	Single	SMPD-Y	25 * 32.7	Active Part
MMIX1G75N250	VHV NPT IGBTs	2500	110	65	-	2.9	-	-	-	0.29	-	-	-	Single	SMPD-X	25 * 32.7	Active Part
IXD80PF650LB	XPT & SONIC	650	106	80	-	1.8	-	-	-	-	-	-	-	Phase Leg	SMPD	25 * 32.7	New Product in Dev
IXD80IF650LB	XPT & SONIC	650	108	80	-	1.65	-	-	-	-	-	-	-	Single	SMPD	25 * 32.7	New Product in Dev
IXD55PF650LB	XPT & SONIC	650	72	55	-	1.8	-	-	-	-	-	-	-	Phase Leg	SMPD	25 * 32.7	New Product in Dev
IXD35PF650LB	XPT & SONIC	650	44	35	-	1.75	-	-	-	-	-	-	-	Phase Leg	SMPD	25 * 32.7	New Product in Dev
IXD110IF650LB	XPT & SONIC	650	145	110	-	1.75	-	-	-	-	-	-	-	Single	SMPD	25 * 32.7	New Product in Dev
IXA20PG1200DHGLB	XPT & SONIC	1200	23	-	-	1.8	-	-	-	1	18	-	1.35	Phase Leg	SMPD-B	25 * 32.7	Active/New Product
IXA20RG1200DHGLB	XPT & SONIC	1200	32	-	-	1.8	-	-	-	-	-	-	-	Boost	SMPD-B	25 * 32.7	Active/New Product
IXA30RG1200DHGLB	XPT & SONIC	1200	43	-	-	1.8	-	-	-	-	-	-	-	Boost	SMPD-B	25 * 32.7	Active/New Product
IXA30PG1200DHGLB	XPT & SONIC	1200	43	-	-	1.9	-	-	-	-	-	-	-	Phase Leg	SMPD-B	25 * 32.7	Active/New Product
IXA40PG1200DHGLB	XPT & SONIC	1200	63	-	-	1.85	-	-	-	-	-	-	-	Phase Leg	SMPD-B	25 * 32.7	Active/New Product
IXA40RG1200DHGLB	XPT & SONIC	1200	61	-	-	1.8	-	-	-	-	-	-	-	Boost	SMPD-B	25 * 32.7	Active/New Product
IXA85IF1200DHGLB	XPT & SONIC	1200	120	85	-	1.8	-	-	-	-	-	-	-	Single	SMPD	25 * 32.7	New Product in Dev
MMIX1X200N60B3	XPT IGBT	600	223	-	120	1.7	110	-	3.45	0.24	-	-	-	Single	SMPD-X	25 * 32.7	Active Part
MMIX1X200N60B3H1	XPT IGBT	600	175	-	72	1.7	110	-	3.45	0.24	-	28	0.83	Copack (FRED)	SMPD-X	25 * 32.7	Active Part
MMIX1X100N60B3H1	XPT IGBT	600	145	-	68	1.8	150	-	2.8	0.31	54	-	0.62	Copack (FRED)	SMPD-X	25 * 32.7	Active Part
MMIX1Y82N120C3H1	XPT IGBT	1200	78	-	36	3.4	93	3.7	-	0.39	-	34	0.54	Copack (Sonic-FRD)	SMPD-Y	25 * 32.7	Active Part
MMIX1Y100N120C3H1	XPT IGBT	1200	92	-	40	3.5	110	3.55	-	0.31	-	34	0.54	Copack (Sonic-FRD)	SMPD-Y	25 * 32.7	Active Part

SMPD Product List - MOSFET





PartNumber	VDSS Max (V)	ID(cont) TC=25°C (A)	ID100 Tc=100°C (A)	RDS(on) max TJ=25°C	Ciss Typ (pF)	Qg Typ (nC)	trr Typ (ns)	trr Max (ns)	PD (W)	RthJC Max (ºC/W)	Config	Package Style	Dimension X, Y (mm*mm)	Status
MMIX1T600N04T2	40	600	450	0.0013	40000	590	100	-	830	0.18	Single	SMPD-X	25 * 32.7	Active Part
MMIX1T660N04T4	40	660	550	0.00085	44000	860	60	-	830	0.18	Single	SMPD-X	25 * 32.7	Active Part
MMIX1T550N055T2	55	550	410	0.0013	40000	595	100	-	830	0.18	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F520N075T2	75	500	360	0.0016	41000	545	-	150	830	0.18	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F420N10T	100	334	275	0.0026	47000	670	-	140	680	0.22	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F360N15T2	150	235	168	0.0044	47500	715	-	150	680	0.22	Single	SMPD-X	25 * 32.7	Active Part
MMIX2F150N20T	200	84	54	0.0165	11700	177	100	-	305	0.41	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F230N20T	200	168	113	0.0083	24000	358	-	200	680	0.22	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F180N25T	250	132	85	0.013	23800	364	-	200	570	0.22	Single	SMPD-X	25 * 32.7	Active Part
MMIX2F94N30T	300	52	35	0.04	11400	190	155	-	305	0.41	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F160N30T	300	102	66	0.02	24500	376	-	200	570	0.22	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F210N30P3	300	108	71	0.016	16200	268	-	250	520	0.24	Single	SMPD-X	25 * 32.7	Active Part
MMIX2F60N50P3	500	30	19	0.11	6250	96	-	250	320	0.39	Single	SMPD-X	25 * 32.7	Active Part
MMIX1T132N50P3	500	63	42	0.043	18600	267	600	-	520	0.24	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F132N50P3	500	63	42	0.043	18600	250	-	250	520	0.24	Single	SMPD-X	25 * 32.7	Active Part
MKE38P600TLB	600	50		40	-	-	-	-	-	-	Phase Leg	SMPD-B	25 * 32.7	Active Part
MKE38RK600DFELB	600	50	38 @ 80°C	40	6800	150	600	-	-	0.4	Boost	SMPD-B	25 * 32.7	Active Part
MKE38P600LB	600	50	38 @ 80°C	40	6800	150	600	-	-	0.4	Phase Leg	SMPD-B	25 * 32.7	Active Part
MKG40RK600LB	600	54	34	41	6500	290	-	950	-	0.4	Boost/Buck	SMPD-B	25 * 32.7	Active Part
MMIX1F44N100Q3	1000	30	19	0.245	13600	264	-	300	694	0.18	Single	SMPD-X	25 * 32.7	Active Part
MMIX1F40N110P	1100	24	15.6	0.29	19000	310	-	300	500	0.25	Single	SMPD-X	25 * 32.7	Active Part

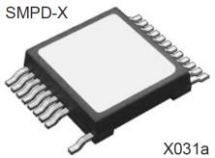
SMPD Product List – MOSFET_6-Pack/3x Phase lag/with NTC

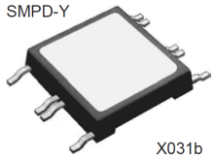

X026c ISOPLUS-DIL™


X026d ISOPLUS-DIL™

PartNumber	VDSS Max (V)	ID25 Tc=25°C (A)	ID80 Tc=80°C (A)	ID90 Tc=90°C (A)	RDS(on) Max Tj=25°C (mOhms)	tf typ (ns)	tr typ (ns)	RthJC max (K/W)	Config	Package Style	Dimension X, Y (mm*mm)	Status
MTI200WX75GD-SMD	75	255	-	190	1.3	55	70	0.85	Triple phase leg	ISOPLUS-DIL™	39 * 37.5	Active Part
MTI145WX100GD-SMD	100	190	-	145	2.2	40	75	0.85	Triple phase leg	ISOPLUS-DIL™	39 * 37.5	Active Part
MTI85W100GC-SMD	100	120	-	90	4	40	55	1.2	Six Pack	ISOPLUS-DIL™	39 * 37.5	Active Part
MTC120WX75GD-SMD	75	180	144	128 (100°C)	3.1	-	-	0.7	Triple phase leg	ISOPLUS-DIL™	39 * 37.5	New Product in Dev
MTC120W55GC-SMD	55	150	120	-	3.1	100 (125°C)	110 (125°C)	1	Six Pack	ISOPLUS-DIL™	39 * 37.5	New Product in Dev
MTC120WX55GD-SMD	55	150	120	-	3.1	100 (125°C)	110 (125°C)	1.3	Triple phase leg	ISOPLUS-DIL™	39 * 37.5	New Product in Dev
GMM3x60-015X2-SMD	150	57	-	45	22	-	-	1	Triple phase leg	ISOPLUS-DIL™	39 * 37.5	Active Part

SMPD Product ist - BiMOSFET

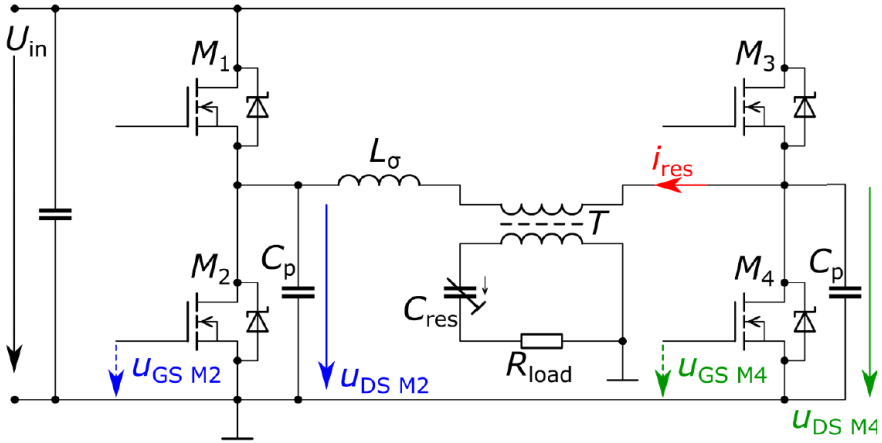


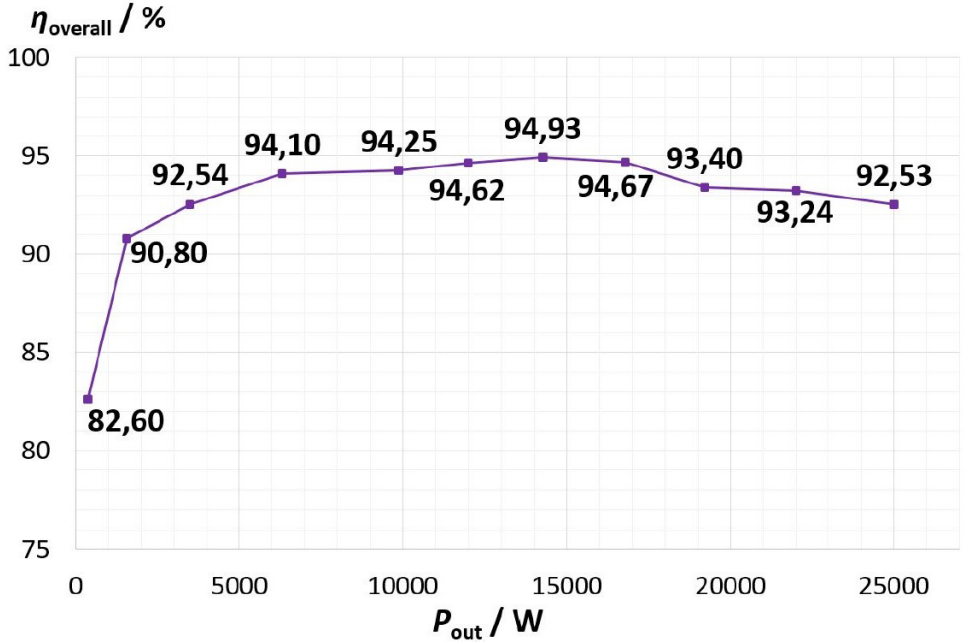


PartNumber	VCES(V)	IC25 TC=25°C (A)	IC90 TC=90°C (A)	IC110 TC=110°C (A)	VCE(sat) max TJ=25°C (V)	tf typ TJ=25°C ns	tfi typ TJ=25°C ns	Gatedrive (V)	RthJC max (ºC/W)	Config	Package Style	Dimension X, Y (mm*mm)	Status
MMIX4B12N300	3000	26	-	11	3.2	540	-	-	1	Copack (FRED)	SMPD-Y	25 * 32.7	Not for New Designs
MMIX4B20N300	3000	34	-	14	3.2	504	-	-	0.83	Copack (FRED)	SMPD-Y	25 * 32.7	Not for New Designs
MMIX1B15N300C	3000	37	-	15	6	-	90	-	0.42	Copack (FRED)	SMPD-X	25 * 32.7	Inactive Part
MMIX4B22N300	3000	38	22	-	2.7	205	-	15	0.83	Dual	SMPD-Y	25 * 32.7	Active Part
MMIX1B20N300C	3000	50	-	20	6	-	110	-	0.3	Copack (FRED)	SMPD-X	25 * 32.7	Inactive Part

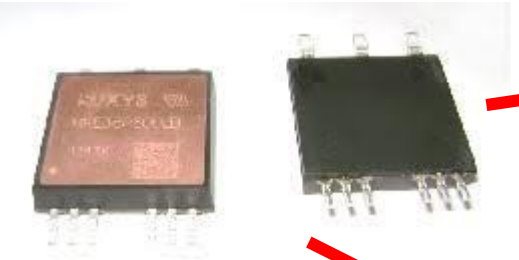
Appendix for SMPD

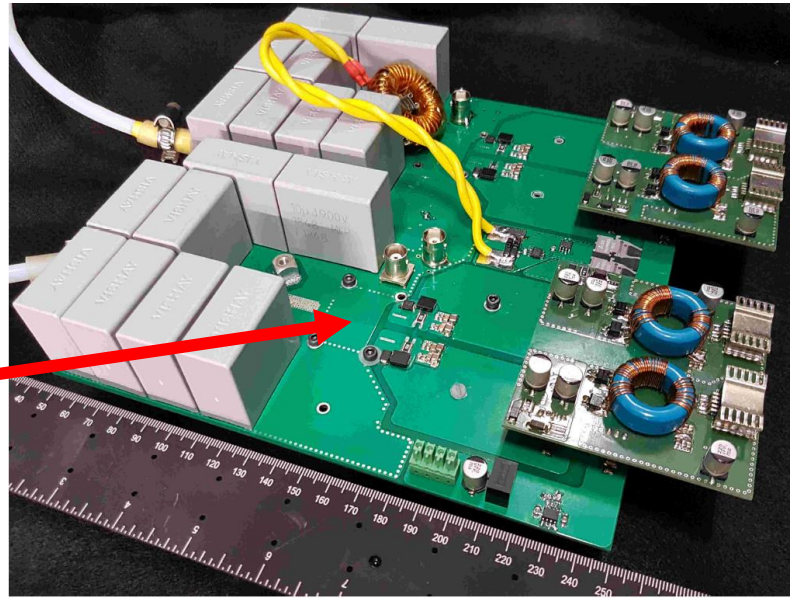
25 kW high power resonant application– 1/2

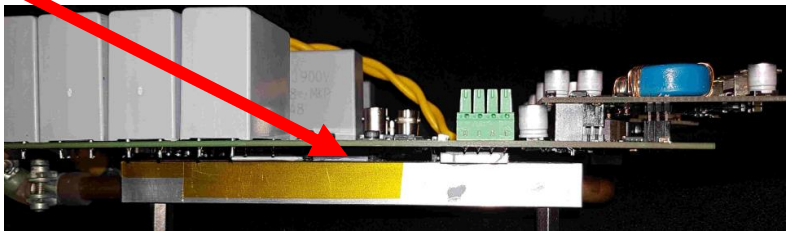




25 kW high power resonant application– 2/2

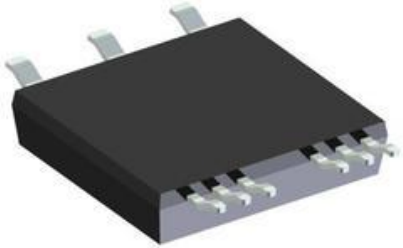


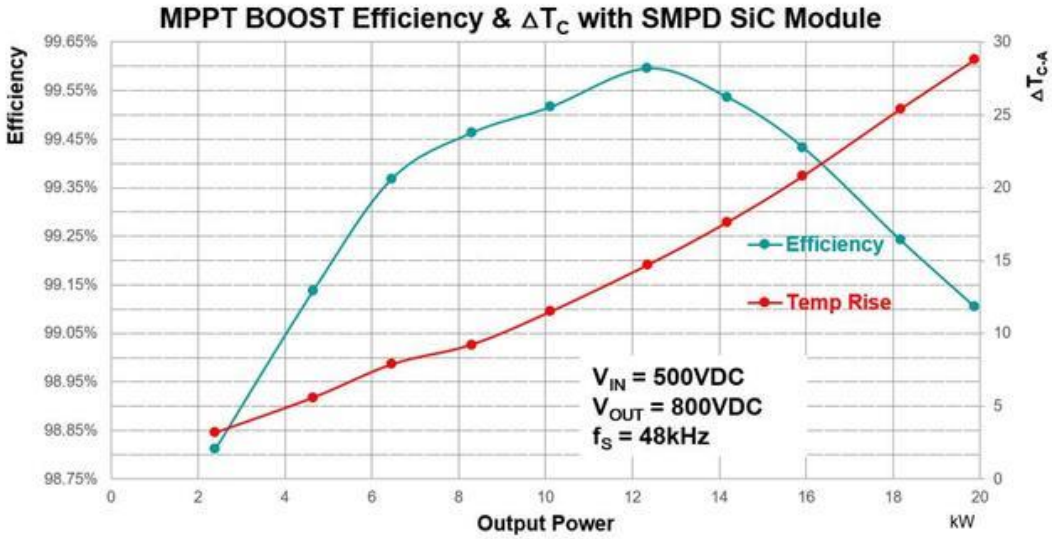




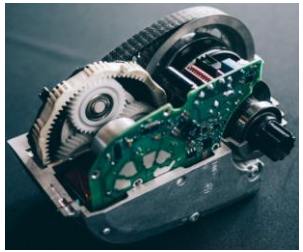
PV boost application

High-power SMD SiC boost module for photovoltaic MPPT cells, highly integrated SiC MOSFET, SiC Diode, and bypass Diode and NTC. The excellent performance of SiC MOSFETs and SMPD's true Kelvin Source and ultra-low parasitic inductance. One 30A SMPD(MCB30RL1200TLB) module can easily achieve 20kW and 25A high peak efficiency 99.6% on boost unit, while 48kHz switch. The frequency can greatly reduce the size of the inductor and total system. The SMPD module can efficiently produce MPPT system units with high reliability. Also, SMPD can provide the high-power density switch in a small package and has a very high performance. That's why it is the best choice for SiC modules in MPPT applications.

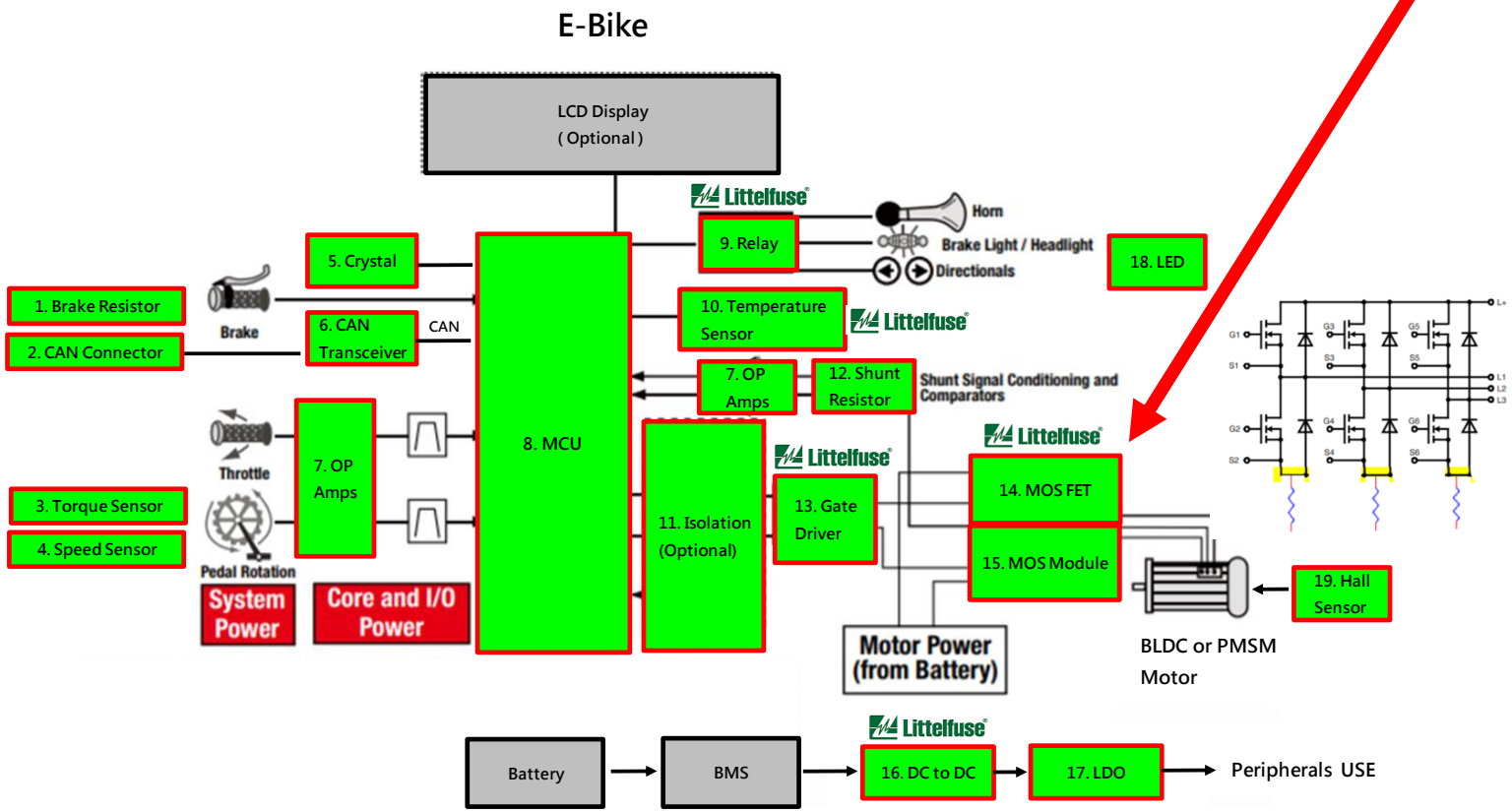




E-Bike/ E-Scooter application



X026d ISOPLUS-DIL™



Littelfuse
Expertise Applied | Answers Delivered

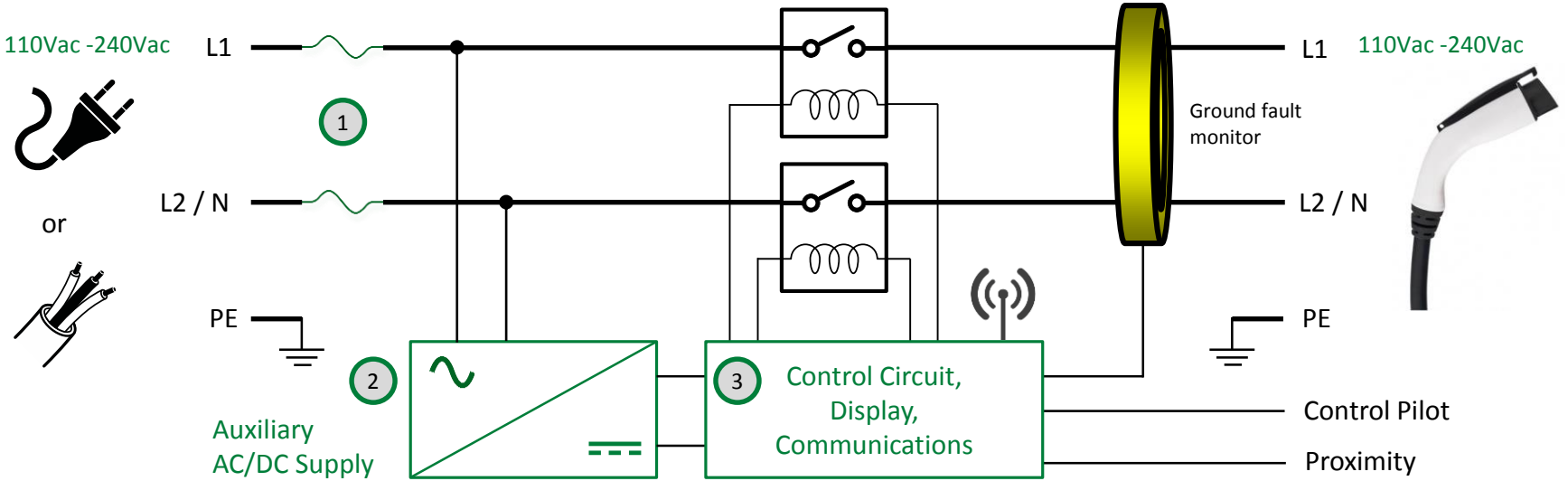
Circuit / Power Protection

Littelfuse®

Expertise Applied | Answers Delivered

AC Chargers (L1 & L2) – Off-Board

~1.9 kW to 19.2 kW / 1 Phase



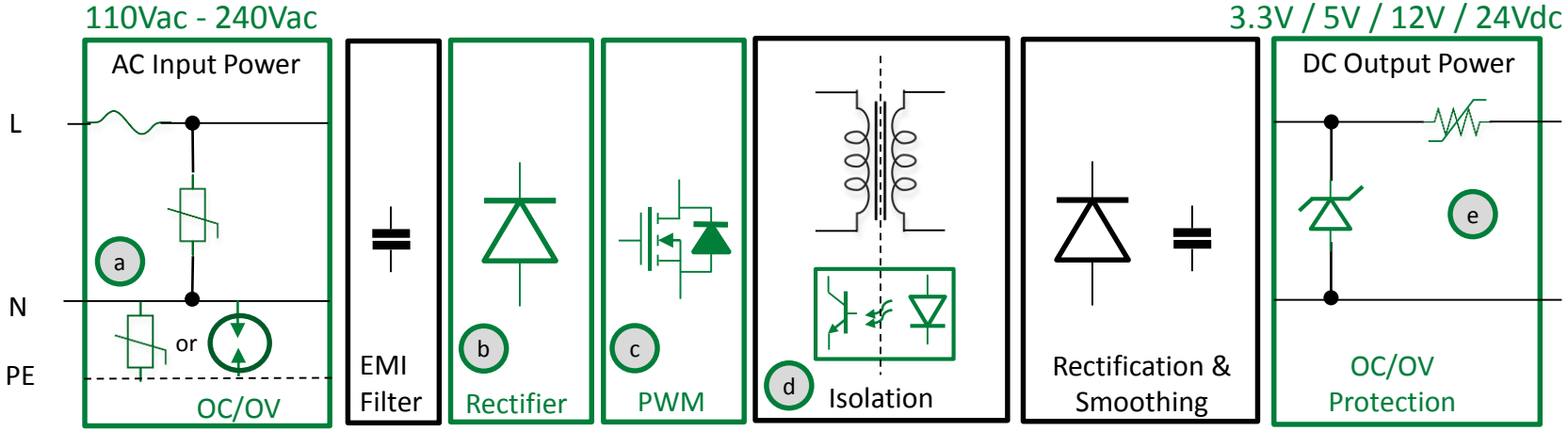
1	Technology	Series
	UL Listed AC Fuse	JLLS, JLLN, KLKD series

2	Technology	Series
	AC Fuse	314/324 series
	MOV	TMOV, UltraMOV series
	GDT	CG3, CG2 series
	SCR	SJ series

3	Technology	Series
	TVS Diode	SMF, SMAJ, SAC
	Diode Array (Wired Comms)	SEP0xx series
	Polymer ESD (Wireless Comms)	XGD series

2 Auxiliary (AC/DC) Power Supply

Provides power to user interface, control circuits, communications, etc.



a

Technology	Series
AC Fuse	314/324 series
MOV	TMOV, UltraMOV
GDT	CG3 series (high V) CG2 series

b

Technology	Series
SCR for active rectification	SJ series
Diode for passive rectification	DPG series, VBExx series

c

Technology	Series
MOSFET	Polar™ Power series, CPC37xx series

d

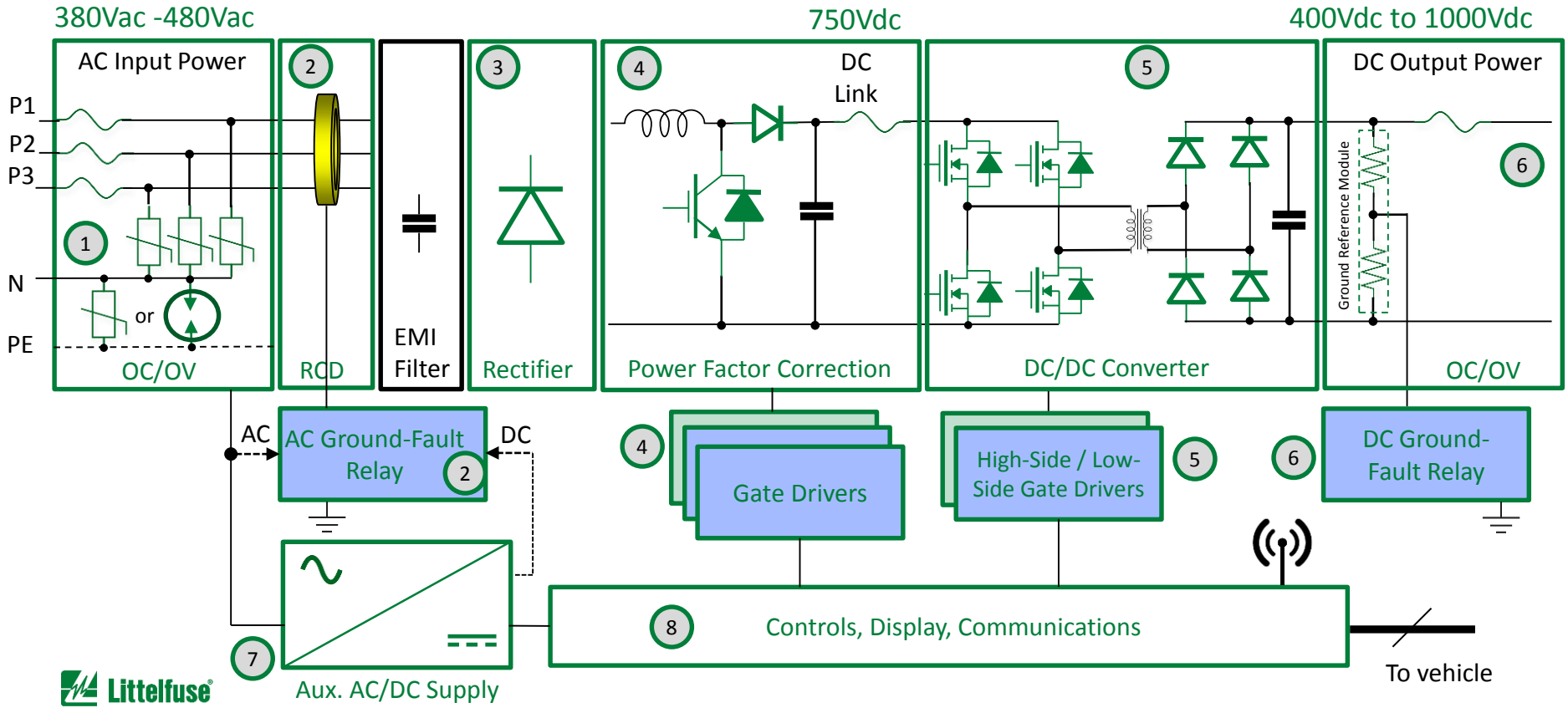
Technology	Series
Optical isolator	LOC11x series

e

Technology	Series
TVS diode	SMBJ series
PPTC (near connectors)	miniSMD series

DC Fast Charger – Off-Board (~ 100kW+ / 3 Phases)

Single 1x 100kW or modular structure 4x 15-30kW



DC Fast Charger System (~ 100kW+ / 3 Phases)

Product solutions for off-vehicle system

1 AC Input Power

Technology	Series
AC fuse (cabinet level)	JLS, JLLS, LDC series
AC fuse (PCB level)	606, 504, 505 series
GDT	CG3 series (high V) CG2 series
MOV	AUMOV, TMOV

4 Power Factor Correction (PFC)

Technology	Series
Si Rectifier diode SiC Schottky diode	FRED DSE series LSIC2SD series
IGBT discrete or module (for low frequency)	XPT™ series MG12 series
Si or SiC MOSFET (for high frequency)	X-Class HiPerFET™ series LSIC1MOS series
Gate driver	IX44** series, IXD*6** series
High-speed DC fuse	L70QS, PSR series

2 Residual Current Device (RCD)

Technology	Series
Current transformer	SE-CS30 series
AC ground-fault relay	SE-704 series

5 DC/DC Converter

Technology	Series
SiC MOSFET	LSIC1MO series
Si MOSFET	X-Class & X2-Class HiPerFET™ series, VKM 40-06P1
Gate driver	IXD*614 series

7 Auxiliary AC/DC Power Supply

See detail diagram on prior slide for product recommendations

3 Rectifier

Technology	Series
Standard rectifier (parallel legs)	DMA200X1600NA
3-phase rectifier bridge module	MDNA240U2200ED
Discrete diode	SONIC-FRD™ series

6 DC Output Power

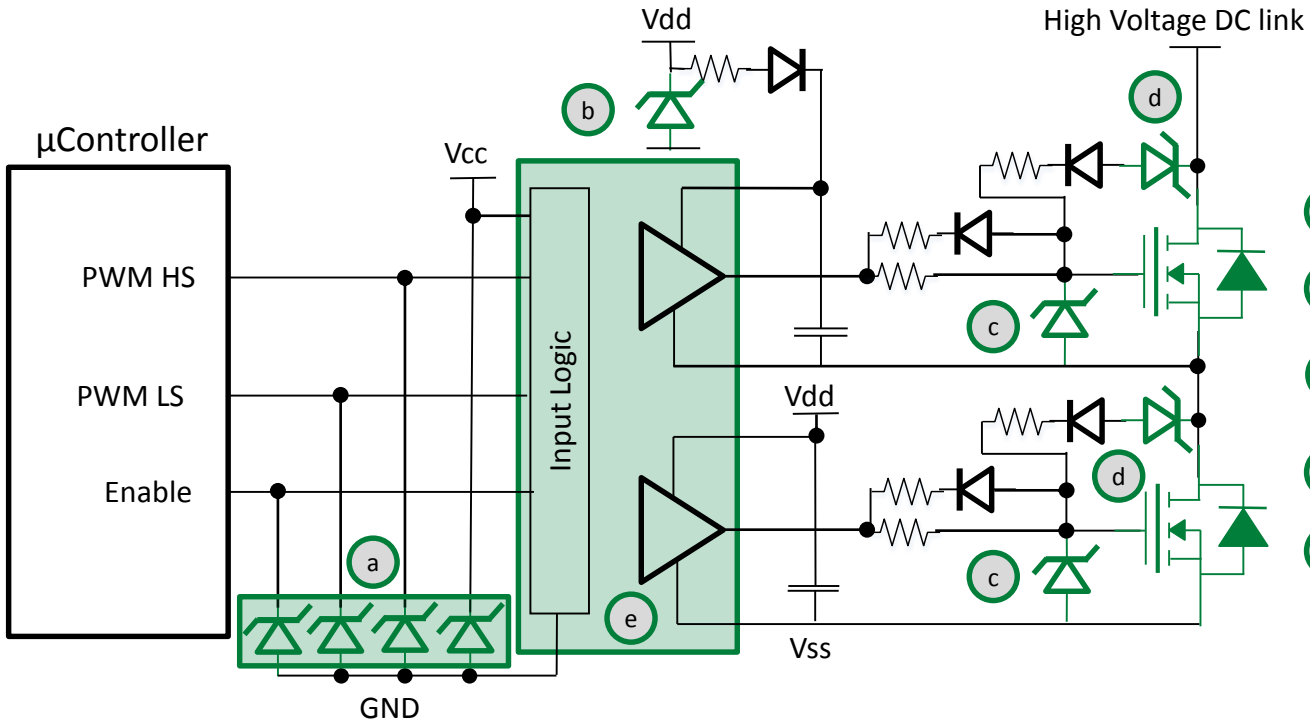
Technology	Series
Ground/Earth-Fault Protection	SE-601, SE-GRM
DC Fuse	L70QS, PSR series 505 and 525 series for Modular Topology

8 Controls, Display, Communications

Technology	Series
TVS Diode	SMF, SMAJ, SAC
Diode Array (Wired Comms)	SEP0xx series
Polymer ESD (Wireless Comms)	XGD series

5 DC/DC Converter

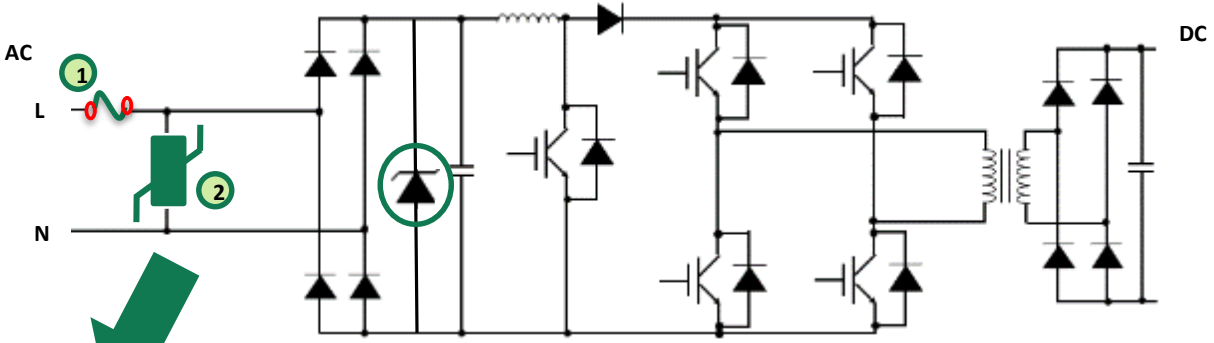
IGBT / MOSFET Gate Driver Protection

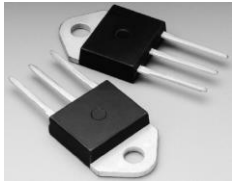


	Technology	Series
a	Diode Array (input logic protection)	SPx series
b	Multi-layer varistor, TVS diode (power lines protection)	ML & AUML series, TPSMx series
c	TVS diode Gate protection and negative bias voltage	TPSMx series
d	TVS diode(s) Active clamping	TPSMx series
e	Gate driver	IX21xx series

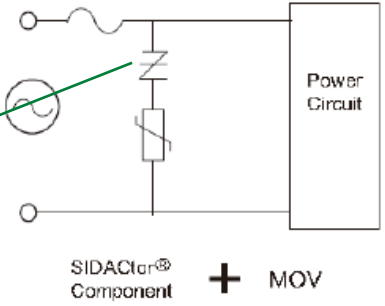
On Board Charger System (OBC)

Protection Needs – **SIDACtor application**

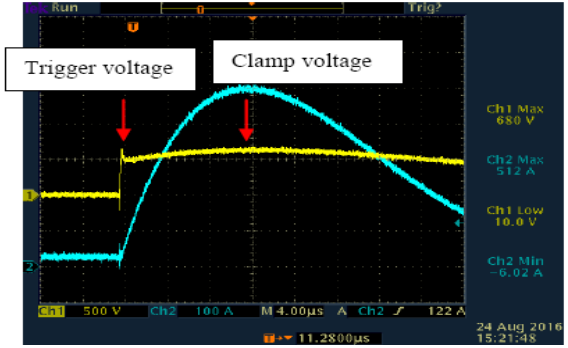




SIDACtor
P3800FNL
3kA 8/20 surge rating
AEC-Q101



- MOV+SIDACtor Application
- No HI-POT test
- lower clamping voltage



	MOV solution	MOV+ SIDACtor solution
1st +hit	1070V/508A	690V/520A
2nd +hit	1080V/514A	680V/528A
3rd +hit	1080V/512A	680V/532A
4th +hit	1070V/510A	680V/532A
5th +hit	1080V/510A	680V/532A
1st -hit	1040V/514A	650V/516A
2nd -hit	1050V/516A	660V/528A

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Design & Electrical Key Features for Mega 48V

High Current Fuses

MEGA® 70V HP Fuse-SF51

COLOR CODING
SEE CHART

MEGA® High Performance Fuse Rated 70V-SF51

The MEGA® 70V-SF51 High Performance (HP) Fuse is designed for high current circuit protection up to 500A with "Diffusion Pill Technology." The MEGA 70V HP features 1MOhm Open State Resistance after fuse opening to guarantee safe interruption at any voltage up to 70V. The MEGA® 70V HP Fuse is ideal for battery and alternator protection application and other heavy gauge cables requiring ultra-high current protection.

Specifications

Interrupting Rating:	2500A @ 70 VDC
Voltage Rating:	70 VDC
Operating Temperature Range:	-40°C to + 125°C
Housing Material:	PPA-GF33
Terminals:	ETP Copper (Tin plated)
Mounting Torque M6:	9Nm+/-1Nm
Mounting Torque M8:	20Nm+/-1Nm
Open State Resistance (after fuse opening)	>1MOhm
According to:	ISO 20934 - Type SF51

Features and special requirements:

- based on standard MEGA Fuse (Same dimensions)
- T/C characteristic acc. ISO 8820-5
- Breaking Capacity: **~2500A @ >70V**
- Isolation Resistance: >1MOhm
- if coding necessary pitch = 54 mm

BMS Protection

Littelfuse®

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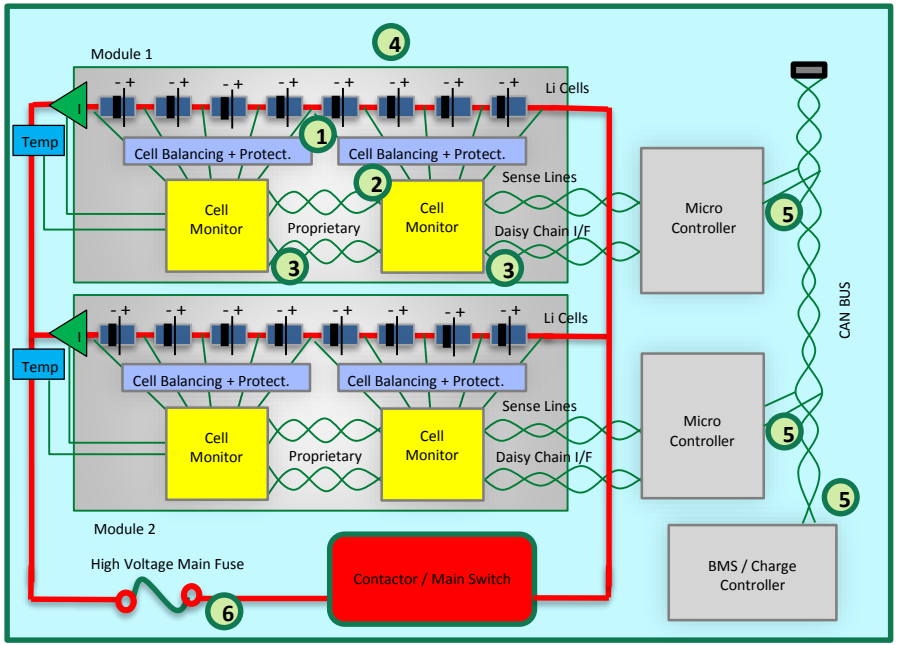
High Voltage Battery System

Building Blocks & Protection Needs

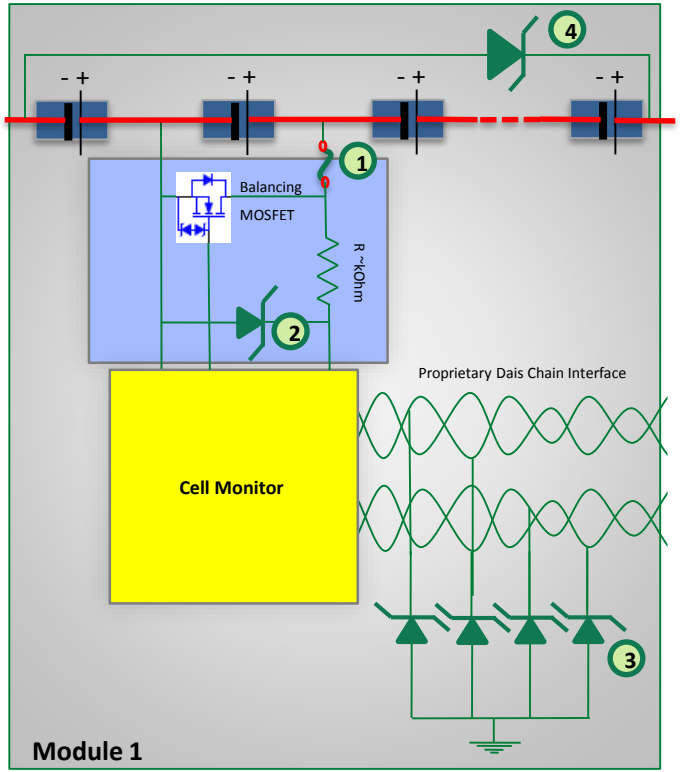
High Voltage Li Ion Battery Pack



1. Sense Line Fuse to protect from shorting of Sense Lines
2. Cell Monitor IC Sense Line Input Overvoltage Protection
3. Overvoltage / ESD Protection for Daisy Chain I/F
4. High Voltage TVS across Battery String for Transient Protection
5. Overvoltage / ESD Protection for CAN Bus I/F
6. High Voltage / High Current fuse for power line protection

High Voltage Battery System

Sense Line & Cell Monitor Protection - Details



1. Sense Line Fuse to protect from shorting of Sense Lines:
   - Depending on Battery System there can be 12 to ~200 Sense Lines per car
   - Shorting can theoretically happen between random sense lines depending on failure modes
   - Potential Failures: Assembly Issues, Car Accident or Crash, Leakage of coolants or other liquids that can build conductive deposits

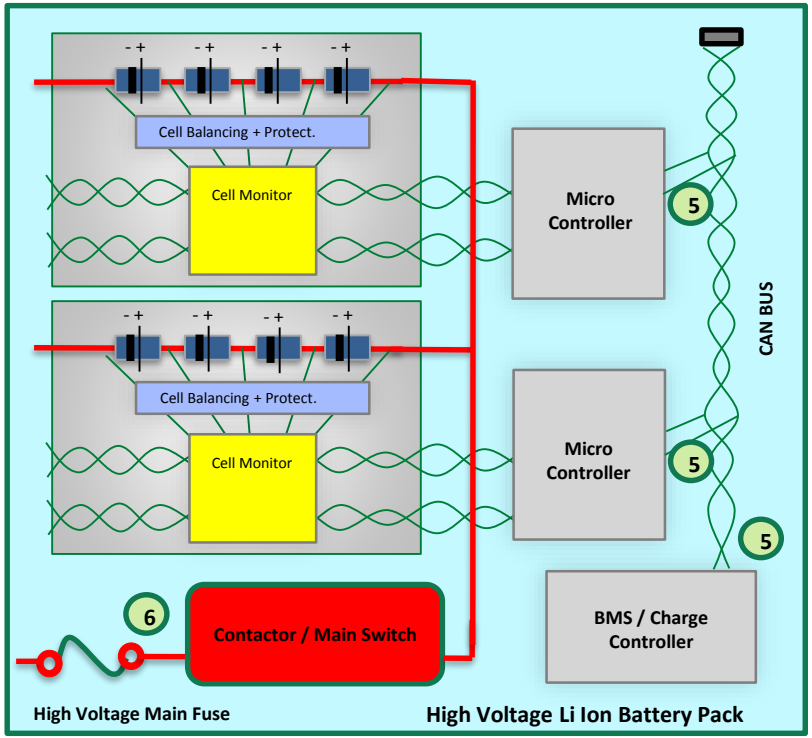
2. Cell Monitor IC Sense Line Input Overvoltage Protection:
   - Protects low voltage (5V) input terminals of Cell monitor from transients
   - Hot Plug Transients occur during assembly and maintenance of battery pack; other transients can be induced from vehicle systems like charger, inverters, motor drives either via conduction or inductive coupling via adjacent cabling

3. Overvoltage / ESD Protection for Daisy Chain I/F (e.g. Hot Plug, ESD)

4. High Voltage TVS across Battery String for Transient Protection (e.g. Hot Plug)

High Voltage Battery System

Microcontroller & Power Line Protection - Details



5 Overvoltage / ESD Protection for CAN Bus I/F:

- CAN Bus is the typical interface in order to link the Cell Monitoring Controllers to Higher Level BMS Controllers which then communicate with other controllers in the car
- In the densely packed environment of a car battery system CAN lines can be subjected to overvoltage stress caused by ESD (e.g. during assembly & maintenance) or other transients introduced from other car systems via coupling or via conduction.

6 High Voltage / High Current fuse for power line protection :

- The high voltage / high current main fuse is the last resort of safety in the case of excessive current or short circuit events in the high power system of the car
- Suitable fuses need to be well coordinated with other fuses being dowstream in the system (e.g. junction boxes)
- Fuse needs to be able to withstand several thousand amps and need to be able to continuously conduct high amount of energy for a long time

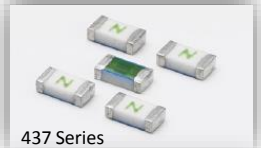
High Voltage Battery System

Littelfuse Protection Portfolio

1 Sense Line Fuse Options*


462 Series


453 Series


437 Series


505 Series

2 Cell Monitor IC Input OV Protection

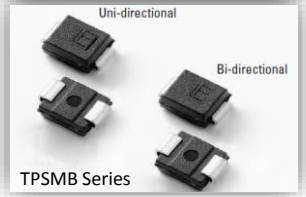
3 OV / ESD Protection for Daisy Chain I/F


SP3030 Series


SP4021Series

4 High Voltage TVS Transient Protection

TPSMA6L Series



TPSMB Series

5 OV / ESD Protection for CAN Bus I/F


SM24CAN Series


SPHV_C Series

6 High Voltage / Current Power Line Fuses


0HEV Low Current


HEV Medium Current


HEV High Current

***Sense Line Fuses:**
Sense Line Short Circuit Protection with electronic fuses can have very different requirements and not all fuses might be suitable. Littelfuse offers a variety of special tested electronic fuses for sense line applications. Please contact your Littelfuse sales or FAE for more details.

High Voltage Battery System

Littelfuse Protection Portfolio – Selection Criteria

1 Sense Line Fuse Options*

- Voltage range depends on battery configuration, same for interrupt rating
- Fuse should have a low temperature de-rating
- Low tolerance of cold resistance as well as long term stability is required
- Fuse should be able to cope with temperature cycles and vibrations
- Small Formfactor
- Ideally fulfills AEC-Q test conditions
- LF recommended: 453 Series, 462 Series, 437 Series, (505 Series)

2 Cell Monitor IC Input OV Protection

3 OV / ESD Protection for Daisy Chain I/F

- 5V Operating Voltage seems to be most common
- Low Capacitance is desirable
- Silicon Diode Arrays provide fastest protection and lowest clamp voltages
- Small Formfactors of 0402 to 0603
- Power Capability several 10 to several 100W (8/20µs)
- AEC-Q101 qualified
- LF recommended: SP3030, SP4021

4 High Voltage TVS Transient Protection

- Voltage range depends on battery configuration
- Power requirements depend on transient environment and battery configuration
- LF offers 600W up to 3000W Diodes
- AEC-Q101 qualified
- Small Formfactor like TPSMA6L (Low Profile 600W Diode)
- LF recommended: TPSMA6L, TPSMB

5 OV / ESD Protection for CAN Bus I/F

- Typical operating voltage of CAN Bus protectors is 24V
- Power rating between 200W to 500W
- ESD Contact Capability of 30kV recommended
- Low capacitance between 11 to 30pF
- AEC-Q101 qualified
- Small Formfactor Packages SOD882 or SOT23-3 (2 channels)
- LF recommended: SM24CANA, SM24CANB, SPHV-C Series

6 High Voltage / Current Power Line Fuses

- Operating voltage up to 450VDC
- Low current fuse ratings 10A to 30A, 40A (425VDC)
- Medium current ratings 60A to 125A
- High current ratings 150A to 250A
- Form Factors 10x38, 42x20, 52x30
- High Interrupt Rating of 10kA
- Various mounting options: board mount, bolt down, blade, inline cable
- LF recommended: 0HEV Series (available) Medium / High Current Versions under development
- Following ISO8820-8 Requirements

***Sense Line Fuses:**
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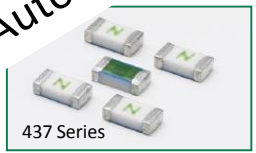
Littelfuse Electronic Fuses Qualification Testing

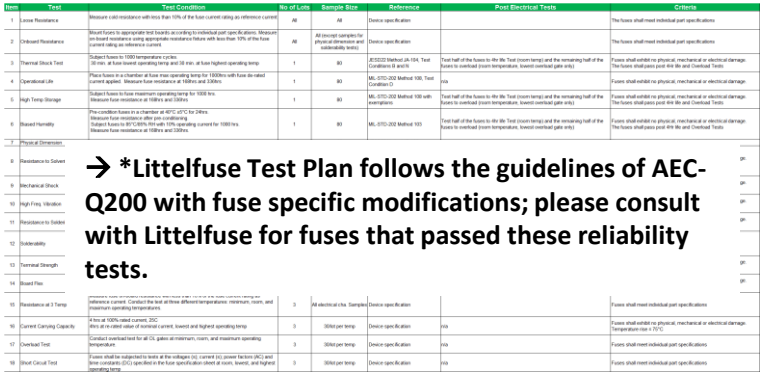
Reliability Testing for Electronic Fuses in Automotive Apps

- More Automotive Applications like e.g. Battery Sense Line Protection rely on electronic fuses
- There are no official standards that define the qualification of electronic fuses for use in Automotive
- Littelfuse has developped a test plan following AEC-Q200 guidelines to test fuses for their suitability and reliability for Automotive Applications
- Test Plan contains18 test cases like 1000hrs op life, temperature cycling, elevated temp testing, vibration testing etc. and uses increased sample quantities
- Littelfuse is continuously adding part numbers and ratings to the Automotive qualified range of electronic fuses

Fuses for Battery Sense Line Applications	Voltage Rating	Current Rating	Interrupt Rating	Size	Type
0453.630MR	32VDC / 125VDC	630mA	300A / 50A @ rated voltage	7x2.7mm	NANO
0437002.WRA	63VDC	2A	50A @ r	.8mm	CCF
0437.750WRA	63VDC	750m		3.2x1.6x0.8mm	CCF
46206300000	250VDC / 350V		100A @ ated voltage	10.5x4.5x4.5mm	NANO

Automotive Grade*





→ ***Littelfuse Test Plan follows the guidelines of AEC-Q200 with fuse specific modifications; please consult with Littelfuse for fuses that passed these reliability tests.**

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Comparison of 606 Series with Competition

	LF 606 Series	Competitor	Competitor
Product Photo/ Illustration			
Footprint/Height	32 x Φ 10 mm	38 x Φ 10 mm	38 x Φ 10 mm
Current Rating	40 A ~ 63 A	Up to 30A	Up to 30A
Voltage Rating	500VAC	500VAC	500VAC
Interrupting Rating	2,000 A @ 500VAC	10,000A @500VAC	10,000A @500VAC

What differentiates 606 Series?

- **Higher** current rating than competition
- **Shorter length** than 10 x 38 mm size competition

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DC Fuse Solutions

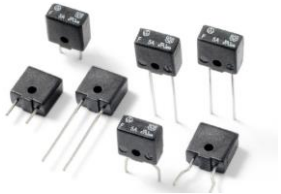
	507 Series	513 Series
Photo		
Fuse Dimensions	6x32mm	6x32mm
Voltage Rating	650Vdc	800Vdc
Breaking Capacity	150A @650Vdc	400A @800Vdc
Current Rating	1-8A	5-10A
Agency Approval	c US	c US

DC Fuse Solutions

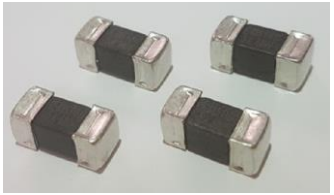
Fuse Type	Series	Form Factor	Voltage (V)	Current (A)
Through Hole	**505**	6x32mm	500Vac, Vdc	15A – 30A
	504	6x32mm	420Vdc, 500Vac	25A – 30A
	506	6x32mm	600Vdc	15A – 20A
	507	6x32mm	650Vdc	1A – 8A
	508	6x32mm	1000Vac, Vdc	315mA – 1A
	477	5x20mm	400Vdc, 500Vac	0.5A – 16A
	977	5x20mm	450Vdc, 500Vac	0.5A – 16A
	487	5x20mm	420Vac, Vdc	8A – 20A
	808	4.65x8.9mm	250/350/450Vdc	2A – 5A
Surface Mount	**885**	4.78x10.86mm	450/500Vdc	1A – 5A
	485	4.5x12.1mm	600Vdc	1A – 3.15A

504/505/506/507/508 Series
6x32mm

477/977/487 Series
5x20mm



808 Series
4.65x8.9mm



885 Series (4.78x10.86mm)

485 Series (4.5x12.1mm)

High Voltage/Current New Products

Series	Key Characteristics	Key Application Areas
505 Series 	6x32mm, 15-30A, 30KA/500Vac	Charing Pile UPS 
514 Series 	6x32mm, 1.6-12.5A, 5KA/500Vac	Power Supply E-meter 
606 Series 	10x32mm, 40-63A, 2KA/500Vac	UPS Industrial Air Conditioner Charging Pile 
881 Series 	12.5x10x7mm, 60-100A, 1.5KA/75Vdc	Datacenter Telecom Power Tools/ESS/BBU 
881F Series 	12.5x10x7mm, 60-100A, 1.5KA/75Vdc	Datacenter Telecom Power Tools/ESS/BBU 
456SD Series 	12.2x4.5mm, 40-50A, 600A/75VDC, 100A/125VAC	Datacenter Telecom Power Tools/ESS/BBU 
405 Series 	5x20mm, 25A, 1KA/250Vac/dc	Datacenter 
885 Series 	10.9x4.8mm, 1-5A, 100A/500Vdc	BMS Motor Driver 
525 Series 	6x32mm, 15-30A, 10KA/305Vac, 10KA/450Vdc	OBC DC/DC 

509A Series – Product Overview

Product Family/Package

- 6x32mm Cartridge Fuse Product Family
- Through-hole Fuse

Series Ratings/Type

- **AECQ compliant**
- 15A – 30A Current Rating
- 500Vac rated
- 10KA Interrupting current @ 500Vac
- -55°C to 125°C operating temperature

Agency Approvals

- UL Recognized Component

Environmental Compliance

- RoHS Compliant
- Halogen free
- 100% Pb free

Packaging

- Bulk
- Pack quantity = 1000 pieces

- **Engineering samples available in Sep, 2019**

609 Series – Product Overview

Product Family/Package

- 10x32mm Cartridge Fuse Product Family
- Through-hole Fuse

Series Ratings/Type

- **AECQ compliant**
- 40A – 60A Current Rating
- 500Vac rated
- 10KA Interrupting current @ 500Vac
- -55°C to 125°C operating temperature

Agency Approvals

- UL Recognized Component

Environmental Compliance

- RoHS Compliant
- Halogen free
- 100% Pb free

Packaging

- Tray
- Pack quantity = 500 pieces

- **Engineering samples available in Sep, 2019**

Hamlin's Strategic Markets and Standard Products

Standard Products	Speed and Direction	Safety	Utilities and Fluid Management
▪ Reed switches ▪ Reed relays ▪ Catalog sensors	▪ Automatic transmission speed sensors ▪ Actuator position ▪ Gear shifter position ▪ Cam & crank sensors ▪ Fan speed sensing	▪ Seatbelt buckle and tension sensors ▪ Crash sensors ▪ Seat position sensing	▪ Remote utility meter reading counters & tamper detection ▪ Industrial sensors ▪ Fluid level sensors

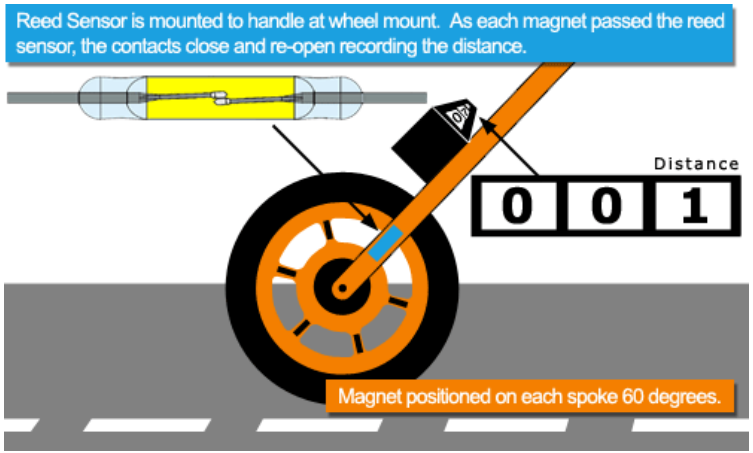
Reed Switches

Reed Relays

Sensors

Bike Computers

- Speed and distance.



ESD/EOS Protection

Littelfuse®

Expertise Applied | Answers Delivered

Why is circuit protection so important

Electrostatic discharge (ESD)

	Simulator Model: Charging Capacitor	Simulator Model: Discharge Resistor	Test Voltage (max)	Environmental focus	
Human Body Model	100 pF	1,500Ω	0.5V to 2kV	Simulates the environment inside the factory environment (wafer fab/assembly	ESD capability on component level
IEC 61000-4-2	150 pF	330Ω	8 to 30kV contact discharge	Simulates the field level ESD to which applications will be subjected in the field	Gap to be filled by ESD protection
ISO 10605, interior	330 pF	330Ω	15kV contact discharge	Simulates ESD environment inside the automobile; also used for electronic modules	System ESD requirements
ISO 10605, exterior	150 pF	330Ω	25kV air discharge	Simulates ESD environment around the exterior of the automobile	

Main ESD standards for Automotive Applications

Transient surges

Major Transients defined in ISO 7637-2*

Automotive EMC transient requirements from ISO 7637:

Standard Surge Protection	Pulse 1	Interruption of inductive load – refers to disconnection of the power supply from an inductive load while the device under test (DUT) is in parallel with the inductive load
	Pulse 2	Interruption of series inductive load – refers to the interruption of current and causes load switching
	Pulse 3	Switching spikes 3a negative transient burst 3b positive transient burst Refers to the unwanted transients in the switching events
	Pulse 4	Starter crank – refers battery voltage drop during motor start. This always happens in cold weather
Load dump Protection	Pulse 5	Load dump – refers to the battery being disconnected when it is charged by the alternator.
	Pulse 6	Ignition coil interruption
	Pulse 7	Alternator field decay
	Pulses 1, 2, 3a, 3b, 5, 6, 7	Related to high voltage transient getting into the supply line; Pulse 4 defines minimum battery voltage.

*ISO 16750-2 has updated requirements on the load dump (Pulse 5) test conditions

Surge wave of different pulses and its magnitude

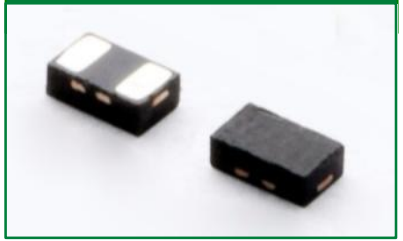
TVS Diode Arrays (SPA®)

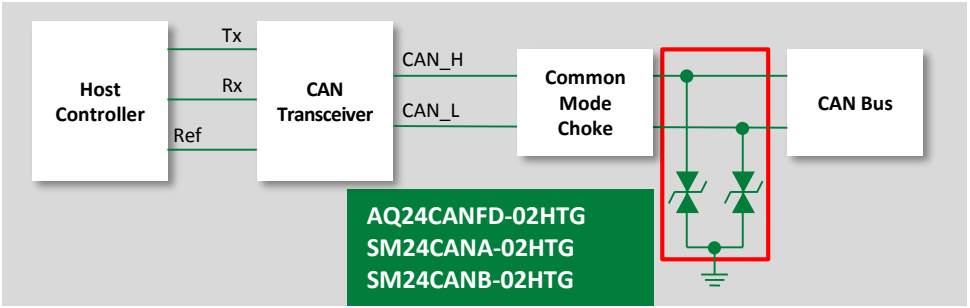
ESD protection for communication buses according ISO 10605

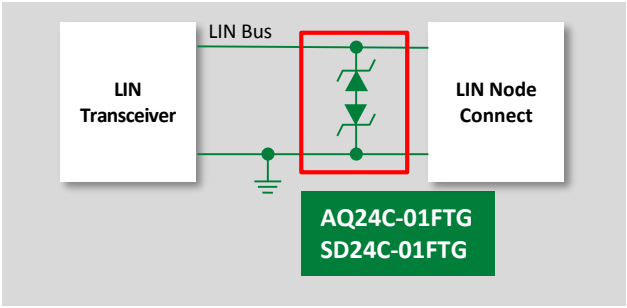
AQ, SM, and SD Automotive Series offer protection of data lines against ESD, EFT and lightning surges

- **Uni- and bidirectional** devices with leakage current < 100nA
- ESD absorption capability of upto ±30kV for up to 4 channels
- Low loading capacitance for high data rates of USB, GPS, LTE, and many more

All AQ products are:
- **AEC-Q101**
- **RoHS compliant**
- **HAL-free**







Vbus Protection for DC Charging Interfaces

Voltage	0201 WLCSP	SOD882		1610DFN	SOD323		SOT-23	2.0x1.8
	BiDirectional	UniDirectional	BiDirectional	UniDirectional	UniDirectional	BiDirectional	UniDirectional	UniDirectional
5	SP1005-01WTG	SP1003-01ETG	SP1005-01ETG	SP1105S-01UTG	SD05-01FTG	SD05C-01FTG	SM05-02HTG	
12	SP12-01WTC-HV-C	SPHV12-01ETG	SPHV12-01ETG-C	SP1112-01UTG	SD12-01FTG	SD12C-01FTG	SM12-02HTG	SP1255-01UTG
15	SP15-01WTC-HV-C	SPHV15-01ETG	SPHV15-01ETG-C	SP1115-01UTG	SD15-01FTG	SD15C-01FTG	SM15-02HTG	SP1555-01UTG
24	SP24-01WTC-HV-C	SPHV24-01ETG	SPHV24-01ETG-C	SP1124-01UTG	SD24-01FTG	SD24C-01FTG	SM24-02HTG	SP1224-01UTG
36	SP36-01WTC-HV-C	SPHV36-01ETG	SPHV36-01ETG-C		SD36-01FTG	SD36C-01FTG	SM36-02HTG	



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Littelfuse TVS Array selection table

	First Choice	Second Choice
LIN Bus	AQ24-01FTG or AQ15-01FTG	AQ24C-01FTG or AQ15C-01FTG
CAN Bus	AQ24CANFD-02HTG	SM24CANA-02HTG or SM24CANB-02HTG

Application	Protocol	Part Number	Config.	Primary Package	Alternative Package
Antenna Protection	FM, Satellite, Bluetooth, Wifi	AQ3041-01ETG AQ3045-01ETG AQ3118-01ETG AQ3130-01ETG	5V uni 5V bi 18V bi 30V bi	SOD-882 SOD-882 SOD-882 SOD-882	AQ4023-01FTG-C SOD-323 AQ4024-01FTG-C SOD-323
Entertainment	I/O Buttons	AQ1005-01ETG AQ1003-01ETG	5V Bi 5V Uni	SOD-882 SOD-882	AQ1026-01UTG, AQ1006-01UTG
	HDMI	RF3077-000	4 Ultra Low Cap	DFN10 (2.5x1.0)	Discretes
	USB 3.0	RF3077-000	4 Ultra Low Cap	DFN10 (2.5x1.0)	Discretes
SSD/ Navigation	SATA-A SATA-B	RF3077-000 RF3077-000	4 Ultra Low Cap	DFN10 (2.5x1.0)	Discretes
Audio	Speaker and Microphone	AQ1005-01ETG AQHVxx-01ETG-C	Bi 5V Bi 12-36V	SOD-882 SOD-882	AQ1026-01UTG AQxx-01FTG-C
Wheel Speed Sensor/Air-pressure	Wireless	RF2945-000 AQ3045-01ETG AQ3041-01ETG	1 Uni 1 Bi 1 Uni	SOD-882 SOD-882 SOD-882	0201 0201 0201

Xtreme-Guard (XGD)

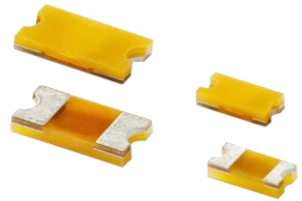
ESD protection for high speed comm. according IEC 61000-4-2

XTREME-GUARD Series protects sensitive electronics against extreme ESD conditions

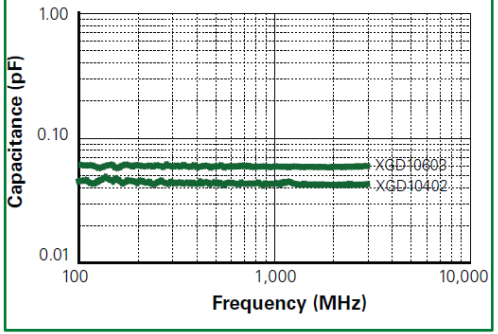
- Ultra low capacitance of 0.04/0.09 pF allows for **distortion free protection of high speed data and RF**
- High operating temperature of **up to 125ºC**
- Used for RF Applications such as USB, HDMI, Ethernet, Industrial, and Automotive Antenna Systems

All XGD parts are:

- **RoHs compliant**
- **HAL free**
- **AEC-Q200**



Typical Device Capacitance



Shark fin GPS antenna protection

Transient surges hazards

Threats acc. ISO 7637-2/16750-2 and typical application schemes

Major Transients defined in ISO 7637-2* (update with ISO16750-2)

Automotive EMC transient requirements from ISO 7637:

Standard Surge Protection	Pulse 1	Interruption of inductive load – refers to disconnection of the power supply from an inductive load while the device under test (DUT) is in parallel with the inductive load
	Pulse 2	Interruption of series inductive load – refers to the interruption of current and causes load switching
	Pulse 3	Switching spikes 3a negative transient burst 3b positive transient burst Refers to the unwanted transients in the switching events
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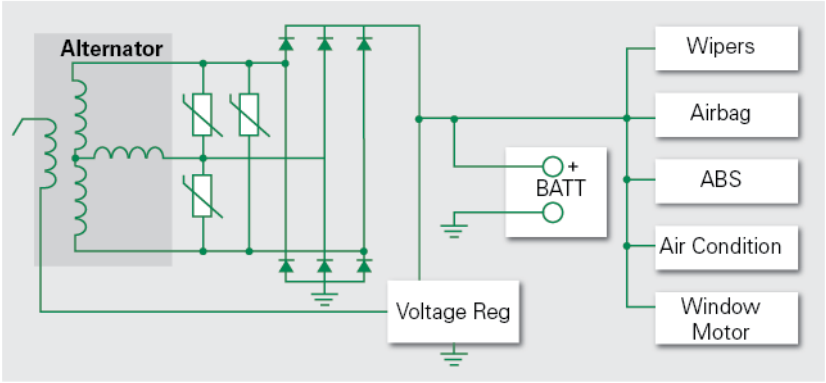
	Pulse 6	Ignition coil interruption
	Pulse 7	Alternator field decay
	Pulses 1, 2, 3a, 3b, 5, 6, 7	Related to high voltage transient getting into the supply line; Pulse 4 defines minimum battery voltage.

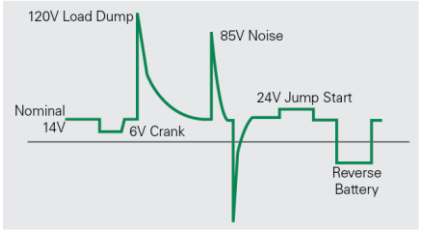
*ISO 16750-2 has updated requirements on the load dump (Pulse 5) test conditions

Typ. Applications for Protection Elements

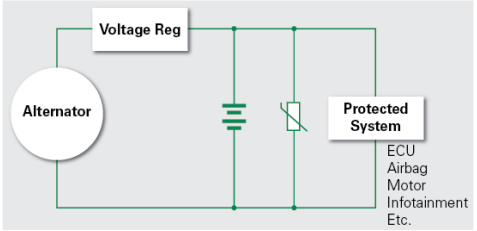
System Protection Against Alternator Translents



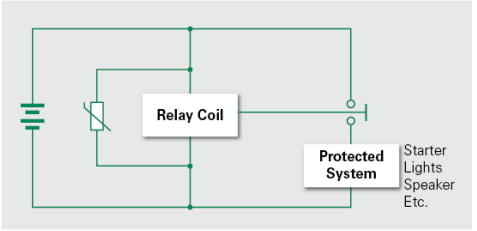
Surge Wave of Different Pulses and its Magnitude



Vehicle Subsystem Module Transient Protection



Automotive Relay Surge Protection



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Littelfuse TVS Diodes

Automotive product series (AEC-Q101)

Littelfuse Series (preferred for new design)	Aquired Series	Package	Directional	Power rating (by 10x1000μs)	Reverse Standoff Voltage (VR)
TP6KE		DO-15	Uni & Bi	600W	11-78
TPSMF4L	SZSMF (200W)	SOD-123FL	Uni	400W	5-85
	SZ1SMA	DO-214AC	Uni & Bi		5-85
TPSMA6L		DO-221AC	Uni	600W	5-85
TPSMB	SZ1SMB/SZP6SMB	DO-214AA	Uni & Bi		6.4 -650
TP1.5KE		DO-201		1500W	11-78
TPSMC	SZ1.5SMC	DO-214AB			10.2-78
TPSMDJ		DO-214AB		3000 W	10-43
SLD8S		SMTO-263		7000 W	10-57
SLD		P600			10-60

- **SLD and SLD8S** dedicated for Load Dump application (ISO 7637-2 5a/b and ISO 16750-2 5a/b)
- **TPSMF4L/TPSMA6L** low profile and small package
- **TPSMB Hi-Vol (400V+)** for IGBT active clamping application in Automotive, Bi-Directional is our unique AECQ101 product

Automotive TVS Diode App Note
Automotive TVS Diode Selection Guide

Littelfuse
Expertise Applied | Answers Delivered

Conclusions

Littelfuse not only provides protective device, but also provides customers with more complete integrated power solutions through power semiconductor, such as MOSFET, IGBT, Thyristor, Gate driver, SiC, Diode, advanced power package type(SMPD), power modules and high rating press pack device.