CoolSiC™ – Revolution to rely on

SiC solutions enabling radical new product designs with best system cost-performance ratio

www.infineon.com/coolsic

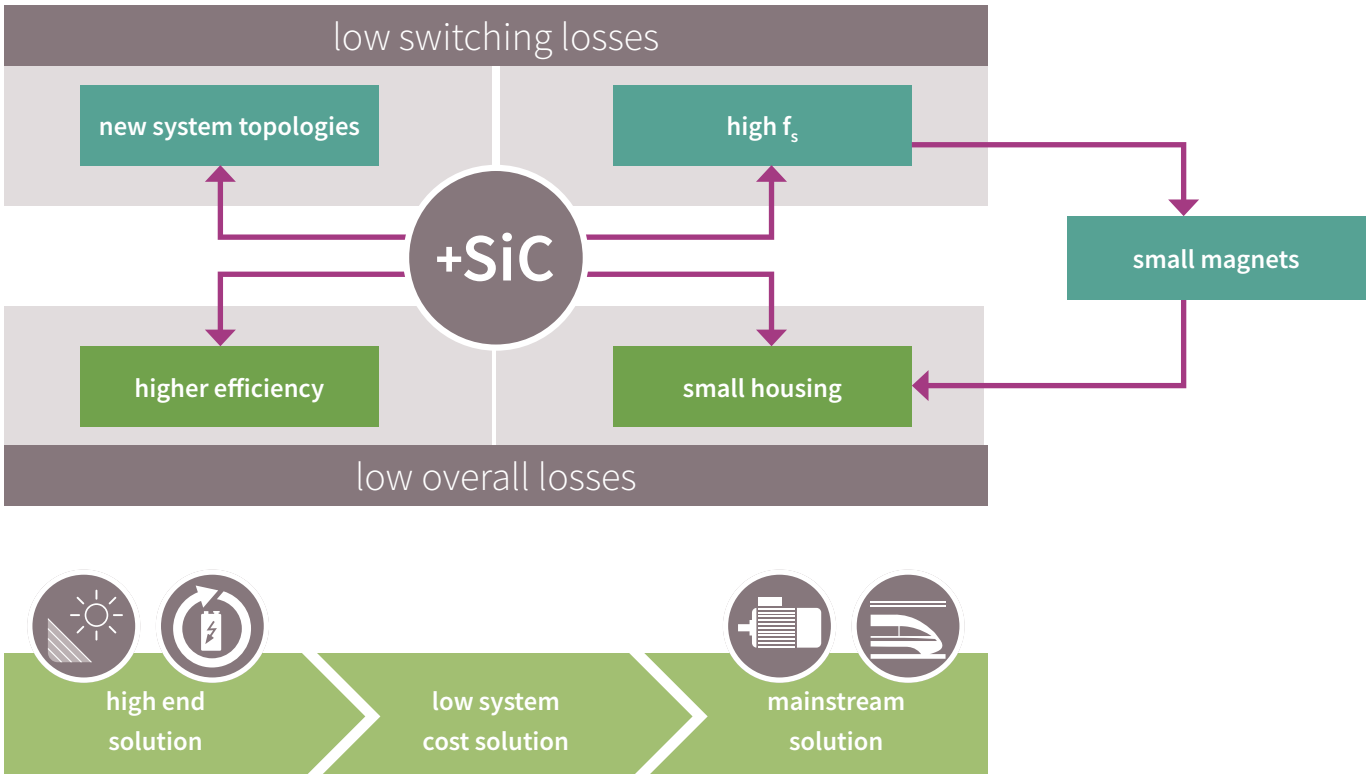
The future of power semiconductors

The use of SiC based power semiconductor solutions has shown a huge increase over the last years, it is a revolution to rely on. Driving forces behind this market development are the following trends: energy saving, size reduction, system integration and improved reliability.

The combination of a fast silicon based switch with a SiC diode – is often termed a “hybrid” solution. In recent years Infineon has manufactured several millions of hybrid modules and has seen them installed in various customer products.

The increase of switching frequency for a converter using SiC MOSFETs can result in dramatically reduced volume and weight of the magnetic components. From an analysis carried out by Infineon, a converter built on SiC devices is a third of the size and 25 percent of the weight compared to a current Si based reference solution. Thanks to the significant reduction in volume and weight, the system cost can also be reduced by more than 20 percent.

Over the next few years, SiC solutions will expand into other application fields such as industrial or traction drives. The reasons for this are the market forces pushing for loss reduction, not only for the sake of improved efficiency but also for smaller packages – resulting from reduced heat sink requirements. As shown in figure above, SiC is already being used for high end and niche solutions. Today’s designs use these benefits to reduce system cost in specific application areas.


low switching losses
new system topologies
high f_s
+SiC
small magnets
higher efficiency
small housing
low overall losses

high end solution
low system cost solution
mainstream solution

Infineon CoolSiC™ – Revolution to rely on

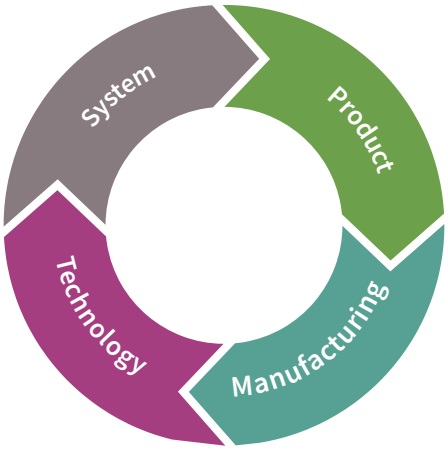
Infineon CoolSiC™ semiconductor solutions are the next essential step towards an energy-smart world. Being the #1 in power semiconductors, we have an extensive application know-how resulting in the right SiC product portfolio, enabling our customers to develop radical new product designs with best system cost-performance ratio. Based on proven, high quality volume manufacturing, Infineon CoolSiC™ solutions combine revolutionary technology with benchmark reliability – making our customers successful today and tomorrow.

Extensive system expertise

- Extensive application system understanding
- Focus on system cost-performance ratio
- System-relevant complementing products as gate driver ICs
- Global application design support

Unique power technology portfolio

- Pioneer in the commercial use of SiC technology (2001)
- MOSFETs in Trench Technology
- Expertise in all leading power technologies (Si, SiC, GaN, GaN-on-Si)
- Huge and substantial IP portfolio



Application-dedicated products

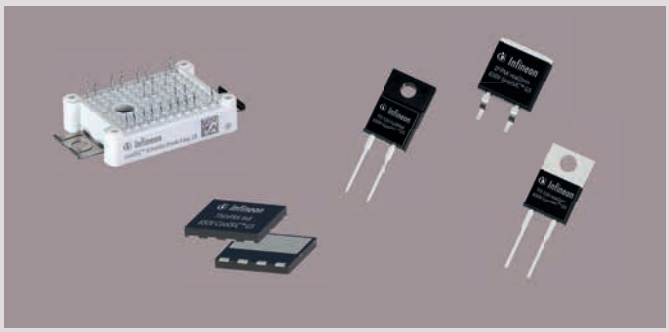
- Most comprehensive power portfolio ensures always best-fit (Si and SiC)
- SiC product portfolio optimized for the specific application requirements
- SiC MOSFETs in Trench technology
- SiC chips are provided as bare dies in best-in-class packaging: discretes, modules

Benchmark in manufacturing

- Complete production on 6” SiC wafer
- Extreme high volume flexibility and reliability due to integration in the high volume silicon power manufacturing line
- Automotive qualified manufacturing process
- Multi million track record

Cool SiC™

Schottky Diodes



MOSFETs

CoolSiC™ MOSFET

Features
- Low device capacitances
- Temperature independent switching losses
- Intrinsic diode with low reverse recovery charge
- Threshold-free on-state characteristics

Advantages
- Superior gate oxide reliability
- Best in class switching and conduction losses
- IGBT compatible driving (+15 V)
- Threshold voltage, V_{th} > 4 V
- Short-circuit robustness

Benefits
- Highest efficiency for reduced cooling effort
- Longer lifetime and higher reliability
- Higher frequency operation
- Reduction in system cost
- Increased power density
- Reduced system complexity
- Ease of design and implementation

Applications
- Photo-Voltaic inverters (PV)
- Energy storage / Battery charging
- Un-interruptable Power Supplies (UPS)
- Switch Mode Power Supplies (SMPS)
- Industrial drives
- Medical

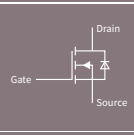
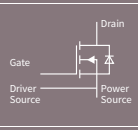
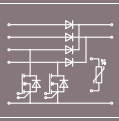
Based on volume experience and compatibility know-how, Infineon introduces the revolutionary CoolSiC™ MOSFET technology which enables radically new product designs. In comparison to traditional Si based switches like IGBTs and MOSFETs, the SiC MOSFET offers a series of advantages. These include, the lowest gate charge and device capacitances levels seen in 1200 V switches, no reverse recovery losses of the internal commutation proof body diode, temperature independent low switching losses and threshold-free on-state characteristics. CoolSiC™ MOSFET first products in 1200 V target photovoltaic inverters, battery charging and energy storage. CoolSiC™ MOSFET represents the best performance, reliability and ease of use for system designers to harness never before seen levels of efficiency and system flexibility.

CoolSiC™ MOSFET first products are targeted for photovoltaic inverters, battery charging and energy storage.

TO-247-4pin package contains an additional connection to the source (Kelvin connection) that is used as a reference potential for the gate driving voltage, thereby eliminating the effect of voltage drops over the source inductance. The result is even lower switching losses than for TO247-3pin version, especially at higher currents and higher switching frequencies. Easy1B modules offer a very good thermal interface, a low stray inductance and robust design as well as PressFIT connections.

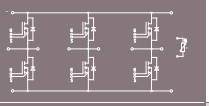
The products portfolio will be extended within the next years. The first step is a roll-out of different topologies like Sixpack and Halfbridge covering a power range from 2kW until 200kW.

Lead products

Schematic	Type	R_{DSON}	V_{DS}	Package
Single switch 	IMW120R045M1	45 mΩ	1200 V	TO-247-3pin 
Single switch 	IMZ120R045M1	45 mΩ	1200 V	TO-247-4pin 
Booster with NTC 	DF11MR12W1M1_B11	11 mΩ	1200 V	Easy 1B 
	DF23MR12W1M1_B11	23 mΩ	1200 V	
Half bridge with NTC 	FF11MR12W1M1_B11	11 mΩ	1200 V	
	FF23MR12W1M1_B11	23 mΩ	1200 V	

Samples available

Roll-out products phase 1

Schematic	Type	R_{DSON}	V_{DS}	Package
SixPACK with NTC 	FS45MR12W1M1_B11	45 mΩ	1200 V	Easy 1B 
Half bridge with NTC 	FF8MR12W2M1_B11	8 mΩ	1200 V	Easy 2B 
Half bridge 	FF6MR12KM1	6 mΩ	1200 V	62 mm 

Selectively sampling in 2017

1EDI EiceDRIVER™ Compact

Gate driver ICs with perfect fit to CoolSiC™ MOSFET

Perfect fit to CoolSiC™ MOSFET

Ultra-fast switching 1200 V power transistors such as CoolSiC™ MOSFETs can be easier handled by means of isolated gate output sections. Therefore, the following galvanically isolated gate driver ICs based on Infineon's coreless transformer technology are recommended as most suitable. The drivers incorporate most important key features and parameters for SiC MOSFET driving such as tight propagation delay matching, precise input filters, wide output side supply range, negative gate voltage capability, and extended CMTI capability.

Recommended gate drivers

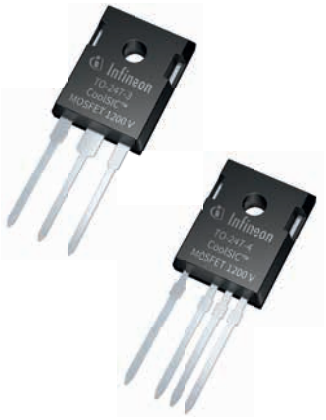
Product	Part number	Typ. peak drive current	VCC2-VEE2	Typ. prop. delay	Typ. UVLO ON	Typ. UVLO OFF	Miller clamp	Other key features	Package
1EDI compact isolated high-side driver family	1EDI20N12AF	3.5 A	40.0 V	≤ 120 ns	9.1 V	8.5 V	No	Functional isolation	DSO-8 150 mil 
	1EDI60N12AF	9.4 A	40.0 V	≤ 120 ns	9.1 V	8.5 V	No		
	1EDI20I12MF	3.5 A	20.0 V	≤ 300 ns	11.9 V	11.0 V	Yes		
	1EDI20H12AH	3.5 A	40.0 V	≤ 125 ns	12.0 V	11.1 V	No	8 mm creepage clearance	DSO-8 300 mil 
	1EDI60H12AH	9.4 A	40.0 V	≤ 125 ns	12.0 V	11.1 V	No		
	1EDI20I12MH	3.5 A	20.0 V	≤ 300 ns	11.9 V	11.0 V	Yes		
1ED-F2 isolated high-side driver with integrated protection	1ED020I12-F2	2.0 A	28.0 V	≤ 170 ns	12.0 V	11.0 V	Yes	Short circuit clamping; DESAT protection; active shutdown	DSO-16 
2ED-F2 isolated dual high-side driver with integrated protection	2ED020I12-F2	2.0 A	28.0 V	≤ 170 ns	12.0 V	11.0 V	Yes	Short circuit clamping; DESAT protection; active shutdown	DSO-36 
1ED slew rate control (SRC) isolated high-side driver	1EDI20I12SV	2.0 A	28.0 V	≤ 485 ns	11.9 V	11.0 V	Yes	Real-time adjustable gate current control; over-current protection, soft turn-off shut down, two-level turn-off	DSO-36 

CoolSiC™ MOSFET

Naming system

Discrete Silicon Carbide MOSFETs

I	M	W	120	R	45	M1	



Company
I = Infineon

Device
M = MOSFET

Package type
(max. 2 digits)
W = TO247-3
Z = TO247-4

Breakdown voltage
Divided by 10
120 = 1200 V

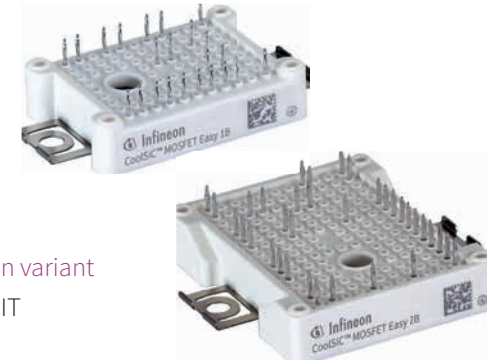
Reliable grade
blank = Industrial
A = Automotive
S = Standard

Series name (2 digits)
M1 = SiC MOSFET first generation

$R_{DS(on)}$ [mΩ]

R = $R_{DS(on)}$
As a seperator between voltage und $R_{DS(on)}$

Module solutions with Silicon Carbide MOSFETs



New!

FF	11	MR	12	W1	M1	_B11

Topology
FF = Halfbride
DF = Chopper module

$R_{DS(on)}$ [mΩ]

Scale unit $R_{DS(on)}$
M = mΩ

Breakdown voltage
Devided by 100
12 = 1200 V

Constructrion variant
B11 = PressFIT

Series name (2 digits)
M1 = SiC MOSFET first generation

Package type (max. 2 digits)
W1 = Easy1B
W2 = Easy2B

New! CoolSiC™ MOSFET modules are marked with the typical $R_{DS(on)}$ instead of nominal current.

CoolSiC™ Schottky diodes G5

The differences in material properties between Silicon Carbide and Silicon limit the fabrication of practical Silicon unipolar diodes (Schottky diodes) to a range up to 100 V–150 V, with relatively high on-state resistance and leakage current. In SiC material Schottky diodes can reach a much higher breakdown voltage. Up to 1200 V as discrete products and up to 1700 V in modules is offered by Infineon. The fast switching characteristics of SiC Schottky diodes provide clear efficiency improvements at system level. The performance gap between SiC and high-end Si diodes increases with the operating frequency.

Features
- No reverse recovery charge
- Purely capacitive switching
- High operating temperature

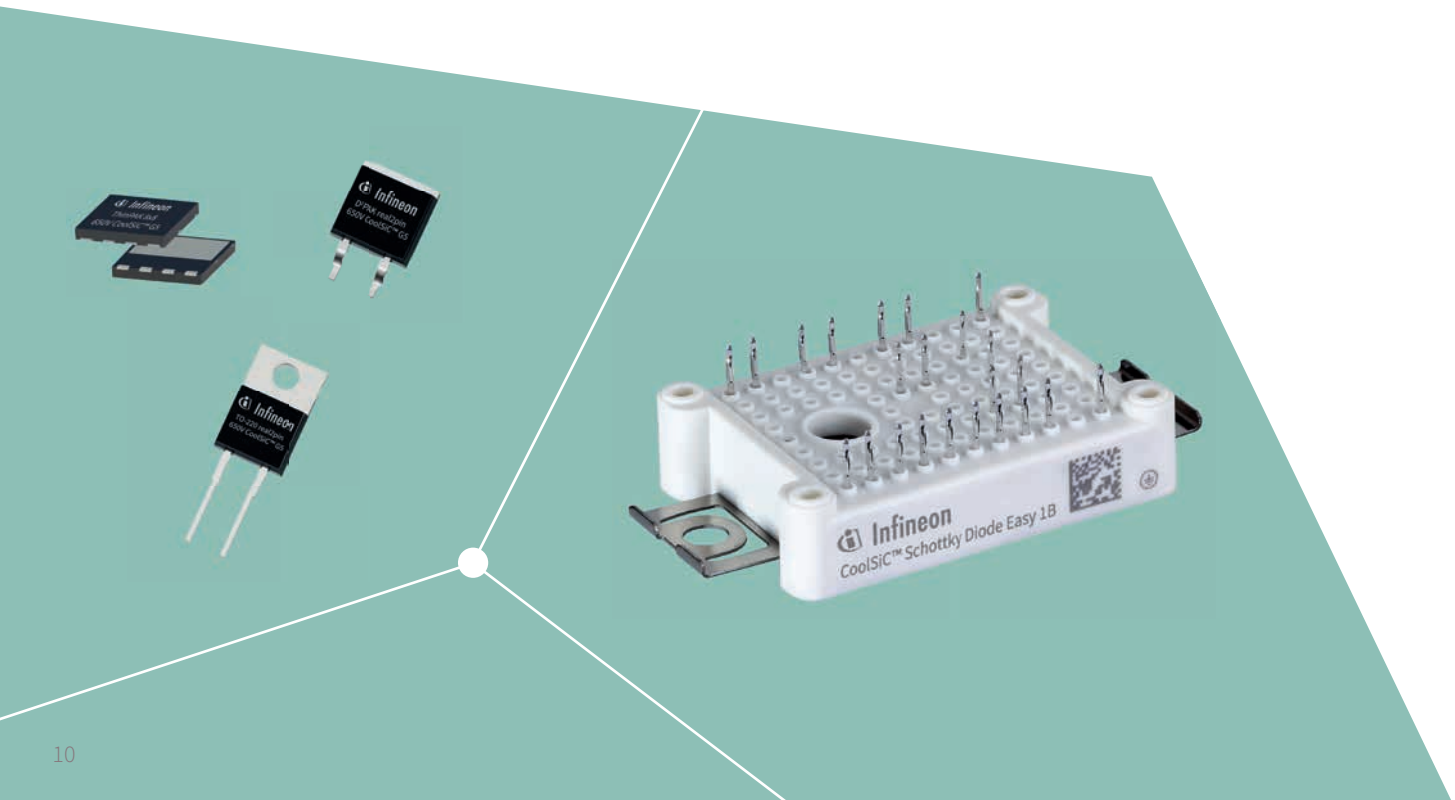
Advantages
- Low turn-off loss
- Reduction of CoolMOS™ or IGBT turn-on loss
- Switching loss independent from load current, switching speed and temperature

Benefits
- System efficiency improvement
- Reduced cooling requirements
- Enabling higher frequency/increased power density
- Higher system reliability
- Reduced EMI

Applications
- Photo-Voltaic inverters (PV)
- Switch Mode Power Supplies (SMPS)
- Energy storage / Battery charging
- Un-interruptable Power Supplies (UPS)
- Lighting
- Medical
- Welding

Excellent efficiency and surge current capability

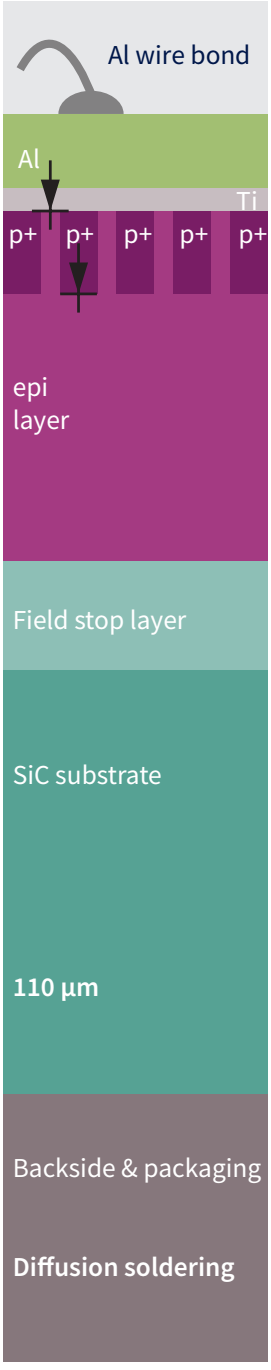
SiC Schottky Diode generation 5 offers the optimum efficiency and ruggedness. Lower V_F means lower conduction loss and lower Q_c means lower switching loss. Q_c x V_F is the figure of merit for efficiency and comparison indicates that generation 5 matches the best competitors on the market. In addition, SiC generation 5 offers a surge current robustness far better than that offered by the most efficient products. Thus, under abnormal conditions this surge current capability offers excellent device robustness. All around, SiC generation 5 offers excellent efficiency and surge current capability at the same time. No other SiC diode product on the market offers such good balance between efficiency and surge current capability. Some vendors offer better efficiency but weak surge current, while others offer better surge current but are less attractive in efficiency.



CoolSiC™ Schottky diodes G5: best price/ performance

This product family has been optimized from all key aspects including junction structure, substrate and die attach. It represents a well-balanced product family which offers state of the art performance and high surge current capability at competitive cost level.

Innovation: optimized junction, substrate and die attach
Infineon SiC Schottky Diode generation 5 is optimized with regard to all key aspects relevant for high power and high efficiency SMPS applications.



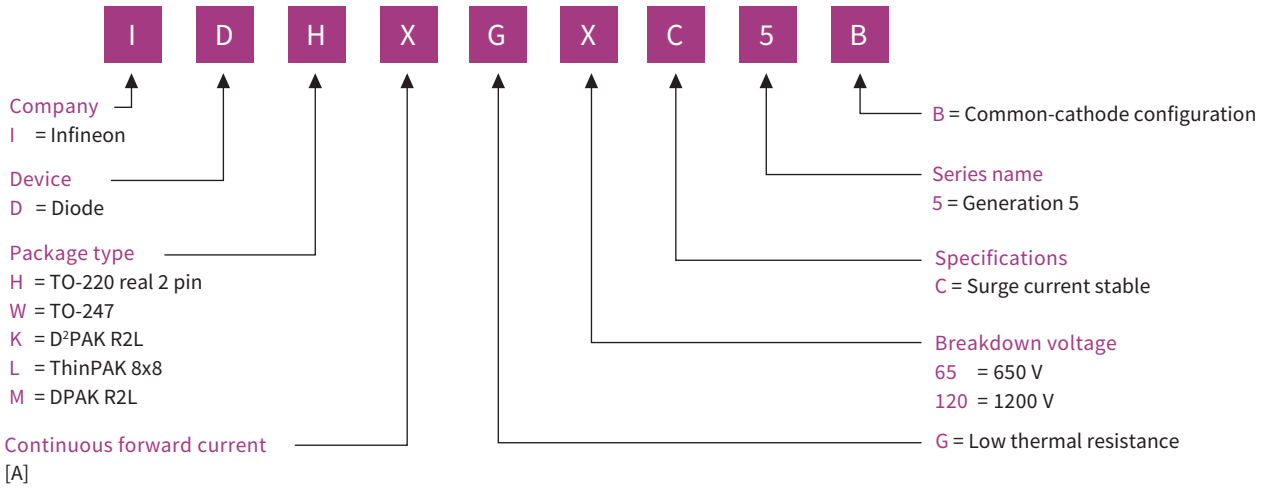
Junction: merged PN structure
On the junction level, it has an optimized merged PN structure. Compared to competitors, Infineon's SiC diode has additional P doped area, together with the N doped EPI layer, it forms a PN junction diode. Thus it is a combination of Schottky diode and PN junction diode. Under normal conditions it works like a standard Schottky diode. Under abnormal conditions such as lighting, AC line drop-out, it works like a PN junction diode. At high current level, the PN junction diode has significantly lower V_F than Schottky diode, this leads to less power dissipation, thus significantly improving the surge current capability.

Substrate: thin wafer technology
On the substrate level, Infineon introduced thin wafer technology, at the later stage of our SiC diode production thin wafer process is used to reduce the wafer thickness by about 2/3, this significantly reduces the substrate resistance contribution thus improve both V_F and thermal performance.

Die attach: diffusion soldering
On the backside, package level diffusion soldering is introduced, which significantly improves the thermal path between lead frame and the diode, enhancing the thermal performance. With the same chip size and power dissipation, the junction temperature is reduced by 30°C.

CoolSiC™ Schottky diodes G5

Naming System



650 V generation 5

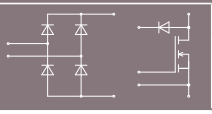
I_F [A]	TO-220 R2L	TO-247 Dual Die	TO-247	D²PAK R2L	ThinPAK 8x8
2	IDH02G65C5			IDK02G65C5	IDL02G65C5
3	IDH03G65C5			IDK03G65C5	
4	IDH04G65C5			IDK04G65C5	IDL04G65C5
5	IDH05G65C5			IDK05G65C5	
6	IDH06G65C5			IDK06G65C5	IDL06G65C5
8	IDH08G65C5			IDK08G65C5	IDL08G65C5
9	IDH09G65C5			IDK09G65C5	
10	IDH10G65C5		IDW10G65C5	IDK10G65C5	IDL10G65C5
12	IDH12G65C5		IDW12G65C5	IDK12G65C5	IDL12G65C5
16	IDH16G65C5		IDW16G65C5		
20	IDH20G65C5	IDW20G65C5B	IDW20G65C5		
24		IDW24G65C5B			
30/32		IDW32G65C5B	IDW30G65C5		
40		IDW40G65C5B	IDW40G65C5		

1200 V generation 5

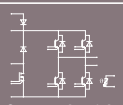
I_F [A]	TO-220 R2L	TO-247 Dual Die	TO-247	TO220-2 R2L	DPAK R2L
2				IDH02G120C5	IDM02G120C5
5				IDH05G120C5	IDM05G120C5
8				IDH08G120C5	IDM08G120C5
10		IDW10G120C5B		IDH10G120C5	IDM10G120C5
15/16		IDW15G120C5B		IDH16G120C5	
20		IDW20G120C5B		IDH20G120C5	
30		IDW30G120C5B			
40		IDW40G120C5B			

„B“ refers to common-cathode configuration

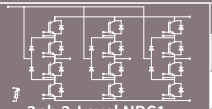
Bridge rectifier & AC-switches

Type	V_{DRM} / $V_{RRM\ (V)}$ [V]	I_{RMSM} [A]	$I_{(FSM)}$ max [A]	Housing	Configuration
	Diode Bridges with Brake Chopper and NTC				
DDB2U50N08W1R_B23 +SiC	800.0 V	50.0 A	450.0 A	Easy1B	

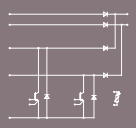
EASY Solar/High Efficiency Line 650 V_{CES}

Type	V_{CE} V	I_C* A T_C = 80°C	I_C A T_C = 25°C	V_{CEsat} V T_{vj}= 25°C	Eon+ $E_{off, mJ}$ T_{vj}= 125°C
 fourpack with booster and NTC	TRENCHSTOP™ IGBT 3 H3				
F4-75R07W2H3_B51 +SiC	650	75	75	1.35	2.50

EASY Solar/UPS-High Efficiency Line 650 V_{CES}

Type	IGBT Inverter				IGBT 3-Level			
	V_{CE} V	I_C* A T_C = 80°C	V_{CEsat} V T_{vj}= 25°C	Eon+ $E_{off, mJ}$ T_{vj}= 125°C	V_{CE} V	I_C* A T_C = 80°C	V_{CEsat} V T_{vj}= 25°C	Eon+ $E_{off, mJ}$ T_{vj}= 125°C
 3ph 3-Level NPC1 with NTC	TRENCHSTOP™ IGBT 3 H3							
FS3L30R07W2H3F_B11 +SiC	650	30	1.50	1.94	650	30	1.55	1.04
FS3L50R07W2H3F_B11 +SiC	650	50	1.45	2.80	650	30	1.55	1.08

EASY Solar/UPS-High Efficiency Line 650 V_{CES} and 1200 V_{CES}

Type	V_{CE} V	$I_{c\ nom}$* A	V_{CEsat} V Tvj=25°C	E_{on} + E_{off} mJ Tvj=125°C
 Booster with NTC	TRENCHSTOP™ IGBT 2 H4			
DF75R12W1H4F_B11 +SiC	1200	25 A (T_H 75°C)	2.10	2.35
	TRENCHSTOP™ IGBT 3 H3			
DF80R12W2H3F_B11 +SiC	1200	20 A (T_H 100°C)	1.55	1.52
DF160R12W2H3F_B11 +SiC	1200	20 A (T_H 100°C)	1.55	1.52
DF200R12W1H3F_B11 +SiC	1200	20 A (T_H 100°C)	1.30	2.78
	TRENCHSTOP™ 5 H5			
DF100R07W1H5FP_B11 +SiC	650	25 A (T_H 100°C)	1.35	0.40

PrimePACK™ 1200 V_{CES}

Type	V_{CES} [V]	I_C [A]	V_{CEsat} [V] T_{vj}= 25°C typ.	E_{on}/E_{off} [mWs] T_{vj}=125°C typ.
 halfbridge with NTC	IGBT2 fast			
FF600R12IS4F +SiC	1200	600	3.20	20/40

* as specified in data sheet

SiC at Infineon

More than 15 years of field experience

Infineon is a pioneer in the commercial use of this technology. As the first company worldwide SiC based diodes were introduced in the market in 2001 already, followed by the worldwide first commercial power modules containing SiC components in 2006. Meanwhile the 5th generation of such parts is available as discrete devices.

In power modules Infineon offers solutions based or empowered by SiC mainly for solar applications and selected motor drive applications . The product design was strongly oriented on a careful cost performance evaluation in order to use the new technology in systems and circuits where a tangible system advantage could be identified.

+SiC

1992

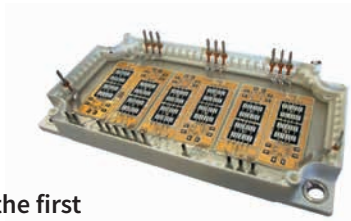
Start of power device development, SiC diodes and transistors for high power industrial applications

1998

Start of 2” wafer technology integration in the high volume silicon power manufacturing line of Infineon

2001

Worldwide first release of commercial SiC power devices



2006

Release of the first power modules with SiC devices inside for industrial motor drive applications (hybrid modules)

2008

Release of 3rd diode generation with improved thermal properties

2006

Release of 2nd generation diodes based on Infineon’s unique MPS principle

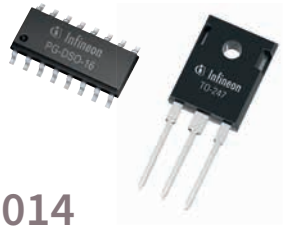
2007

Move to 3” wafer production

2009

Release of first high power module with SiC Diodes

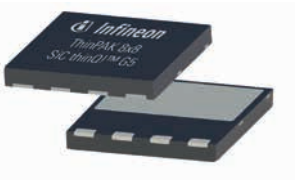
2012
Roll out of SiC portfolio for solar power string inverters



2014
Commercial release of Infineon's ultra reliable SiC JFET switch

2014
Extension of the 5th generation principle towards 1200 V diodes

2017
Commercial release of CoolSiC™ MOSFET lead products in power modules and discrete versions



2013
Release of 5th generation of diodes, introduction of thin wafer manufacturing for SiC

2010
Move to 100 mm 4" wafer diameter

2016
Technology launch of CoolSiC™ MOSFET at the PCIM in Nuremberg

2015
Start of 150 mm conversion in manufacturing

Where to buy

Infineon distribution partners and sales offices:
www.infineon.com/WhereToBuy

Service hotline

Infineon offers its toll-free 0800/4001 service hotline as one central number, available 24/7 in English, Mandarin and German.

- Germany ..... 0800 951 951 951 (German/English)
- China, mainland ..... 4001 200 951 (Mandarin/English)
- India ..... 000 800 4402 951 (English)
- USA ..... 1-866 951 9519 (English/German)
- Other countries ..... 00* 800 951 951 951 (English/German)
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