Tech Comparison

Modena, 15 Aprile 2014

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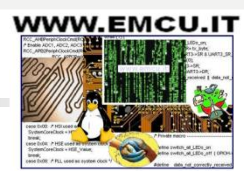
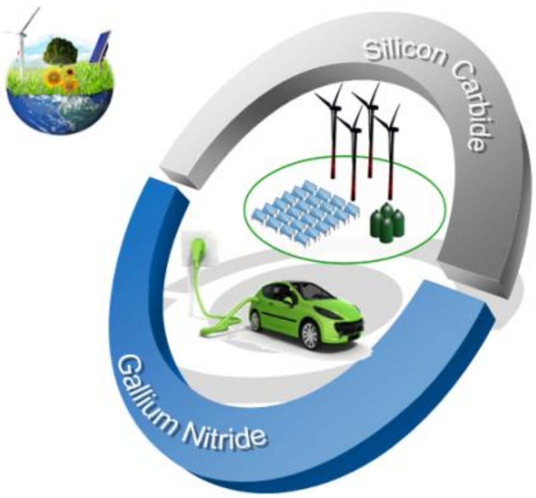
Power 'n More
SILICA Power Solutions



Breakthrough in Power Electronic

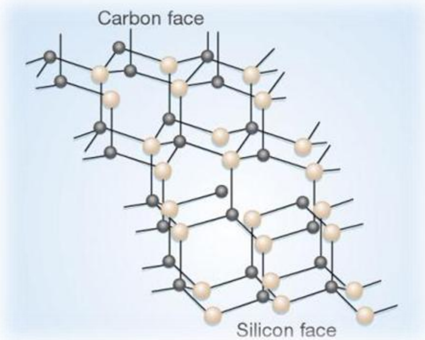
SiC Technology
SiC MOSFETs & SiC Rectifiers



What is silicon-carbide?

- Silicon Carbide (chemical formula SiC), is a compound of silicon and carbon
- Most Silicon Carbide is of synthetic nature

Crystal…



…made of silicon and carbon atoms

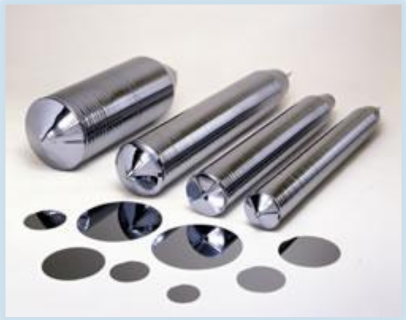
Applications

Seals rings for industrial applications

Cutting tools

Sports car brakes

AND…



Semiconductor

What is silicon-carbide?

Mechanical properties: Mohs Hardness scale

Mohs Hardness Scale		
Hardness Number	**Original Scale**	**Modified Scale**
1	Talc	Talc
2	Gypsum	Gypsum
3	Calcite	Calcite
4	Fluorite	Fluorite
5	Apatite	Apatite
6	Orthoclase	Orthoclase
7	Quartz	Vitreous Silica
8	Topaz	Quartz or Stellite
9	Corundum	Topaz
10	Diamond	Garnet
11	…	Fused Zirconia
12	…	Fused Alumina
13	…	**Silicon Carbide**
14	…	Boron Carbide
15	…	Diamond

Almost as hard as Diamond!!!

What is silicon-carbide?

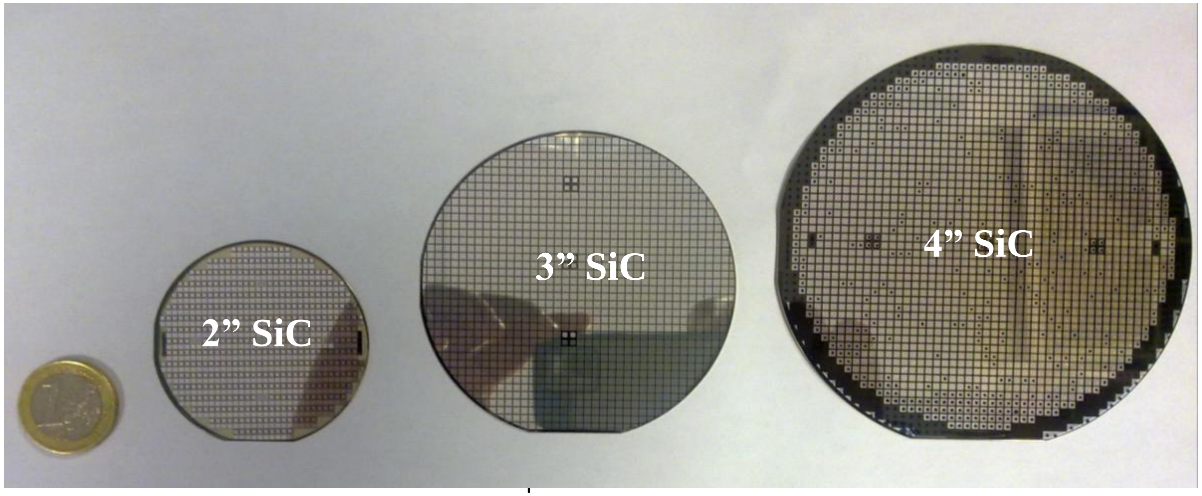
Electrical properties

Properties at 300 K, $1^{e}15$ – $1^{e}16$ cm^{-3} Material	E_G (eV)	E_{BR} (V/µm)	Thermal conductivity (W/cm/K)
Si	1.12	20	1.5
4H-SiC	3.26	200	4.5
Diamond	3.45	560	20

Much wider band gap (E_G) than silicon resulting in a higher critical electrical field (E_{BR}).

ST has Well-established Expertise on SiC Material & Devices: Wafer Size Evolution

2003 – 2” line startup → 2006 – 3” line startup → 2011 – 4” line startup → 2014 – 6” line startup



Both MOSFET and Diode in SiC are manufactured in the same fab

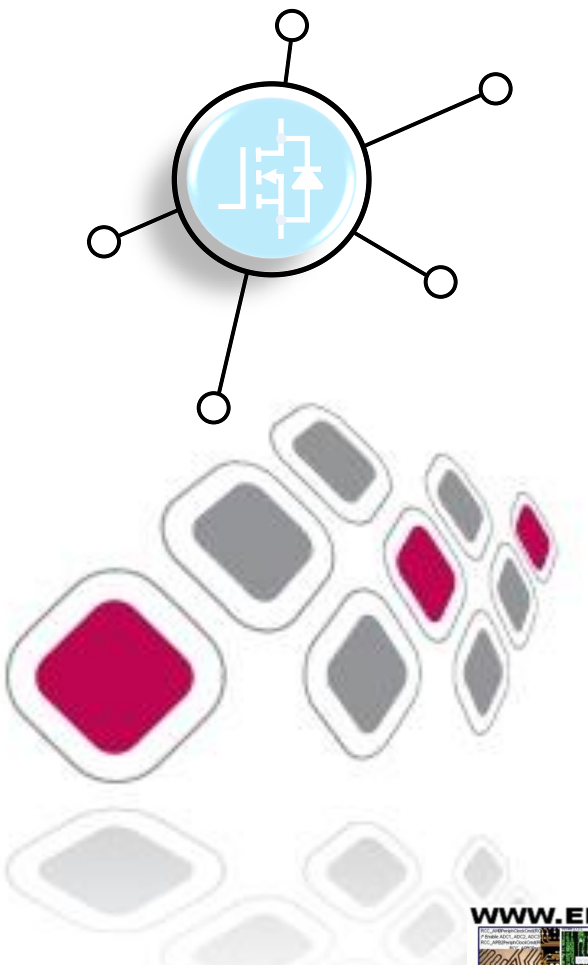
Properties of Si vs. SiC

Silicon vs. Wide-bandgap Silicon Carbide					
Parameter	**Symbol**	**SI**	**Silicon**	**4H-SiC**	**Benefits**
Bandgap	E_g	eV	1.1	3.3	Lower Leakage, Higher T_j
Electron Saturation Velocity	V_s	cm/s	$1x10^7$	$2x10^7$	Higher working frequency
Electron Mobility	μ_n	$cm^2/V \cdot s$	1350	947	
Dielectric Constant	ε_r	-	11.8	9.7	
Critical Electric Field	E_c	V/cm	$0.3x10^6$	$3x10^6$	Lower On-Resistance
Thermal Conductivity	k	$W/cm \cdot K$	1.5	4.5	Higher thermal handling capability

➢ **Wide-bandgap semiconductors are materials with a bandgap significantly larger than 1 eV.**

SiC Diode

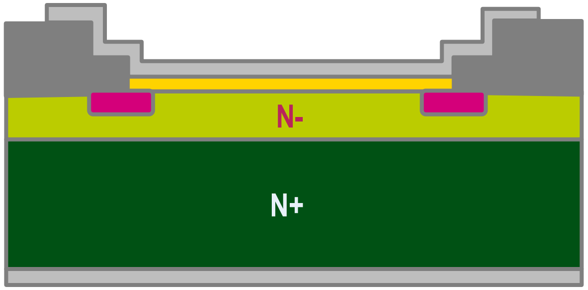
Gen1 & Gen2



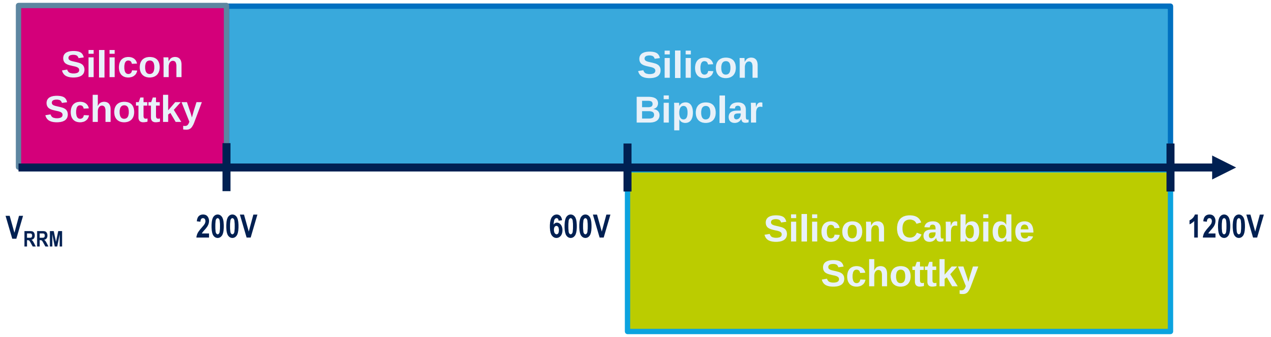
Silicon Carbide Schottky Diode

SiC Schottky Diode

- 4 times better dynamic characteristic and 15% less forward voltage than silicon diodes
- Need less thickness and resistivity to sustain the same breakdown voltage
- Outstanding electrical characteristics:
  - SiC E_{BR} = 200 V/µm
  - Si E_{BR} = 20 V/µm
- Repetitive Peak Reverse Voltage (V_{RRM}) up to 1200V

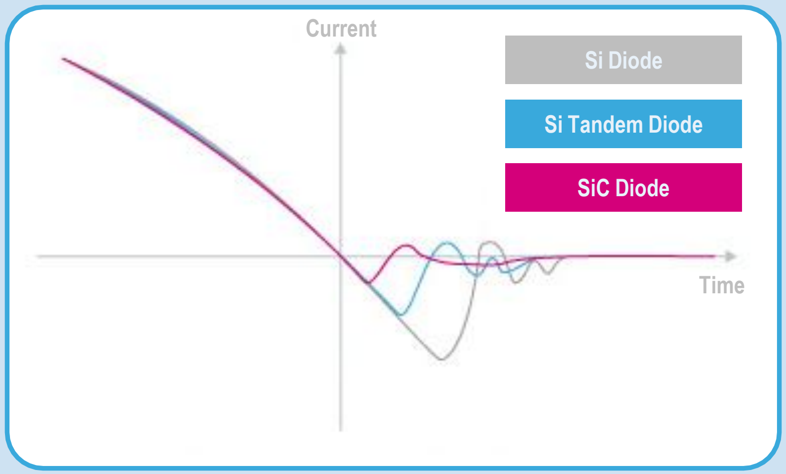


Schottky Diode structure diagram



HV Rectifiers: Si vs. Sic

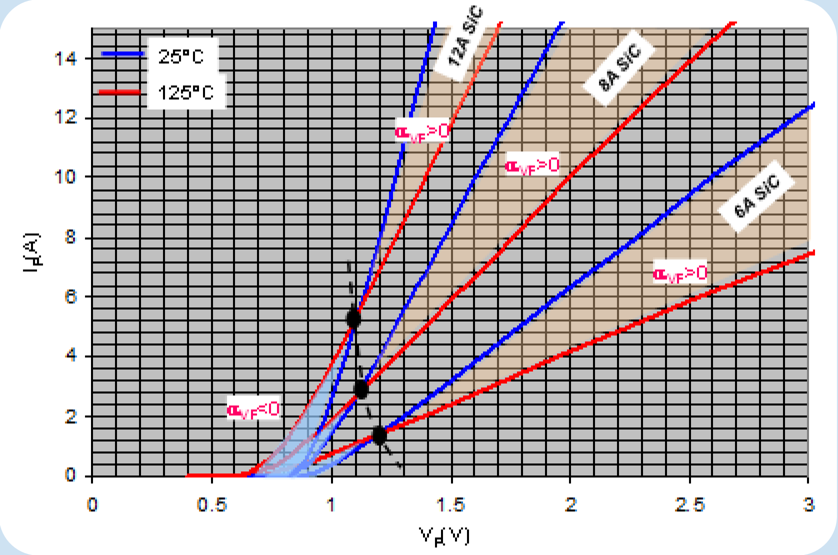
Ultra-fast Diode Recovery Time



HV Rectifiers	Si Diode	Si Tandem Diode	SiC Diode
Recovery Time	High	Low	Extremely Low
Switching losses	High	Low	Negligible
Reverse Recovery Charges Qrr (nC)	150	50	6

SiC Schottky Diode: any drawback?

Drawback of Diodes made out of SiC material



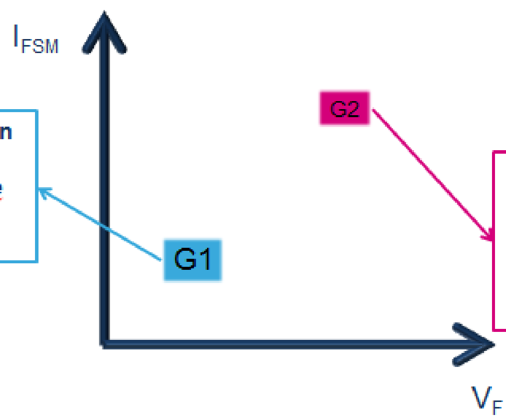
SiC material	Consequence	Drawback
SiC features a **positive** thermal coefficient	The higher the temperature, the higher the V_F	**Thermal runaway risk when high current is applied!**

SiC Rectifiers

Gen1 or Gen2 for Designer's choice

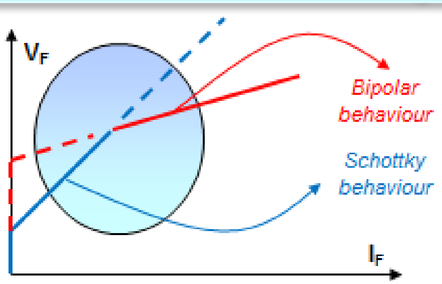
Gen1 or Gen 2? Vf or IFSM trade off

- Ideal for use in appl. without current surge issues (Solar, UPS)



- Ideal for use in appl. with high surge current constraints (PFC circuits like in Telecom SMPS)

The BEST out of 2 Technologies



The addition of P+ implantation in the schottky structure creates P/N junctions.The surge forward current capability can be increased while keeping $T_J < T_{J(MAX)}$

10 times better Surge Capability

- **Datasheet**:

New voltage rating for higher reverse safety margin

Gen 2

Symbol	Parameter		Value	Unit
V_{RRM}	Repetitive peak reverse voltage		650	V
$I_{F(RMS)}$	Forward rms current		21	A
$I_{F(AV)}$	Average forward current	DPAK, T_c = TBD °C, $\delta = 0.5$ TO-220AC, T_c = 122 °C, $\delta = 0.5$ D^2PAK, T_c = TBD °C, $\delta = 0.5$	6	A
I_{FSM}	Surge non repetitive forward current	t_p = 10 ms sinusoidal, T_c = 25 °C t_p = 10 ms sinusoidal, T_c = 125 °C t_p = 10 µs square, T_c = 25 °C	60 52 400	A
T_{stg}	Storage temperature range		-55 to +175	°C

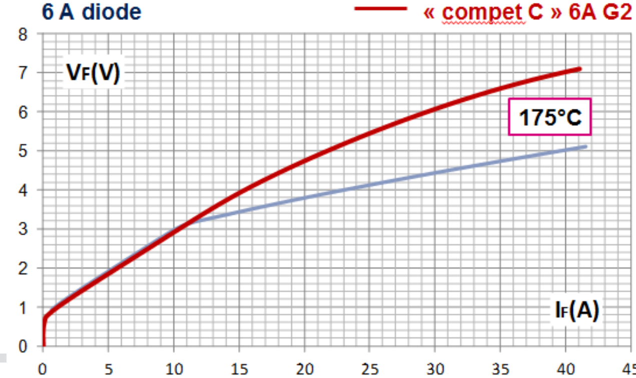
Improved surge capability
I_{FSM} = 10x $I_{F(AV)}$

Table 2. Gen 1 ...ings (limiting values at 25 °C unless otherwise specified)

Symbol	Parameter		Value	Unit
V_{RRM}	Repetitive peak reverse voltage		600	V
$I_{F(RMS)}$	Forward rms current		18	A
$I_{F(AV)}$	Average forward current	T_c = 125 °C, $\delta = 0.5$	6	A
I_{FSM}	Surge non repetitive forward current	t_p = 10 ms sinusoidal, T_c = 25 °C t_p = 10 ms sinusoidal, T_c = 125 °C t_p = 10 µs square, T_c = 25 °C	27 22 110	A
I_{FRM}	Repetitive peak forward current	$\delta = 0.1$, T_c = 110 °C, T_j = 150 °C	27	A
T_{stg}	Storage temperature range		-55 to +175	°C
T_j	Operating junction temperature range		-40 to +175	°C

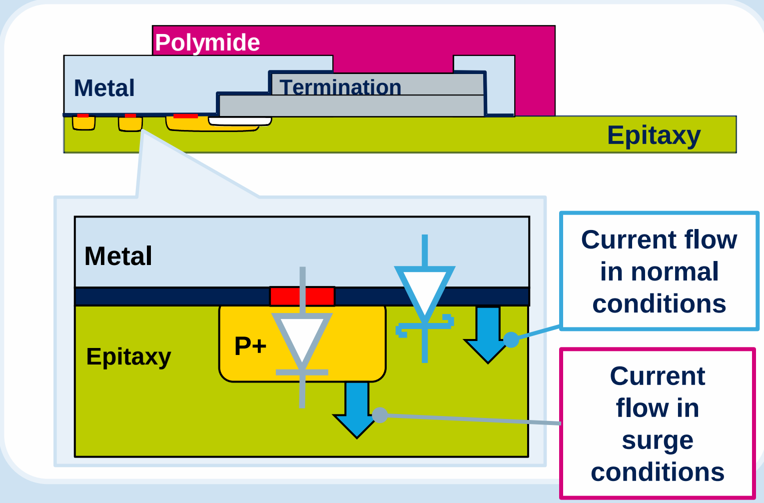
Better Vf in surge conditions

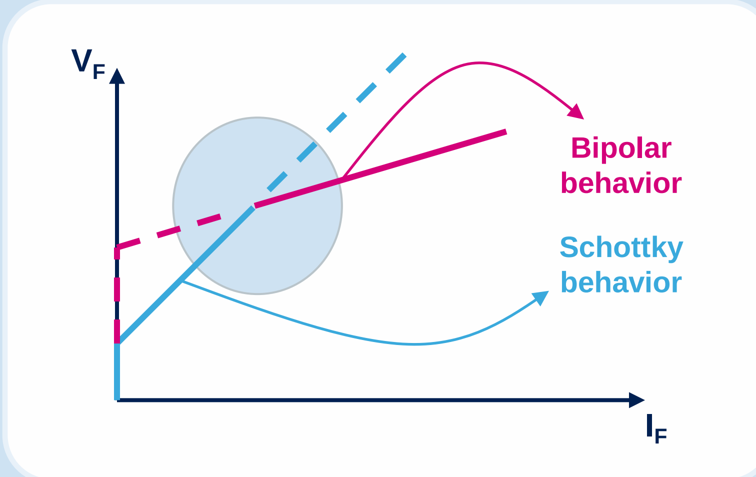
Competition benchmark
6 A diode



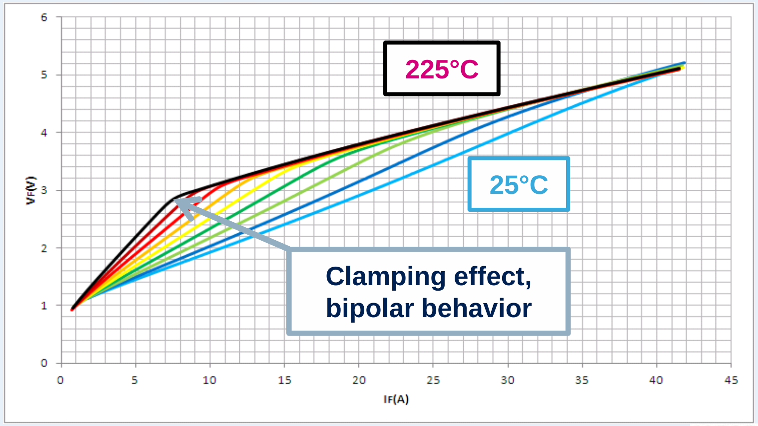
New: SiC Diode Generation 2

From 600V Generation 1 to 650V Generation 2



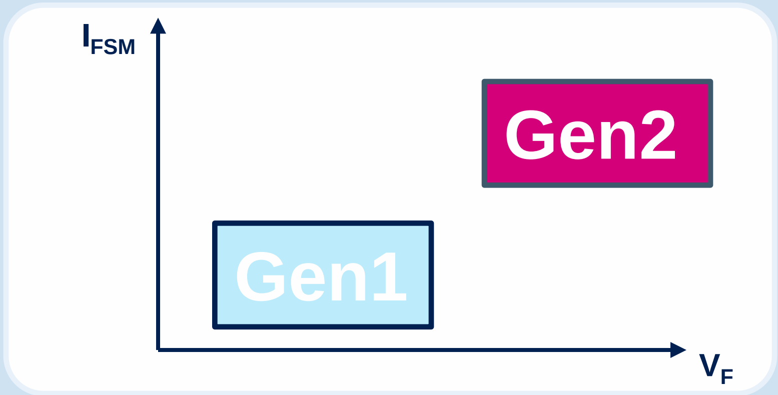


- Generation 2 SiC Diode is using a JBS design (Junction-Barrier Schottky)
- The JBS structure overcomes the drawback of positive thermal coefficient present in Generation 1
- The addition of P+ implantation in the Schottky structure creates P/N junctions
- The surge forward current capability can be increased while keeping $T_J < T_{J(MAX)}$



SiC Diode Gen 1 vs. Gen 2

Differences between Generation 1 and Generation 2



600V SiC Diode Generation 1	650V SiC Diode Generation 2
Lower forward conduction losses (linked to V_F)	Higher surge robustness (linked to I_{FSM})
Brings good efficiency levels thanks to the low forward voltage drop	Provides the best trade-off between efficiency and robustness thanks to the high I_{FSM} level
Ideal for use in applications without current surge issues (e.g. solar, UPS)	Ideal for use in applications with high current surge constrains (e.g. PFC circuits in server or telecom SMPS)

Gen 2 does NOT replace Gen 1!!

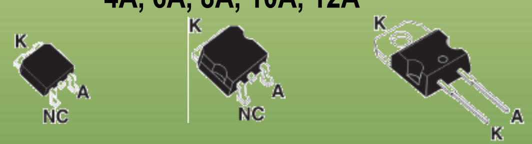
Generation 1 600 V diodes

Single diodes

STPSC xx 06 yy

SiC Schottky | $I_{F(AV)}$ | V_{RRM} | Package

4A, 6A, 8A, 10A, 12A



Dual diodes / common cathode

STPSC xx 06 C yy

Common cathode

2 x 10A, 600V

Generation 2 650 V diodes

Single diodes

STPSC xx H 065 yy

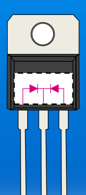
SiC Schottky | $I_{F(AV)}$ | Gen 2 | V_{RRM} | Package

4A, 6A, 8A, 10A, 12A

Dual diodes Common cathode

STPSCxxH065Cyy

2 x 4A, 650V
2 x 6A, 650V
2 x 8A, 650V
2 x 10A, 650V



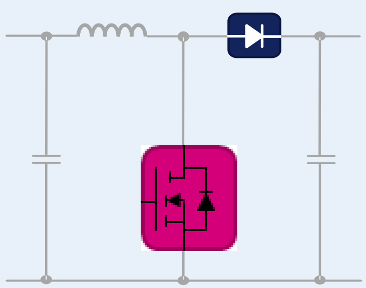
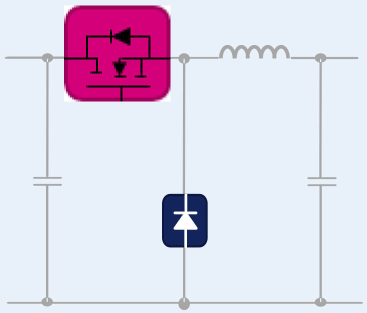
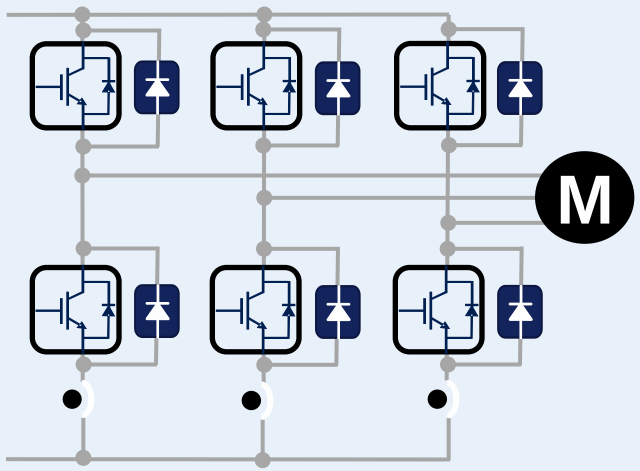
Dual diodes In series

STPSCxxTH13TI

6A, 2 x 650V
8A, 2 x 650V
10A, 2 x 650V

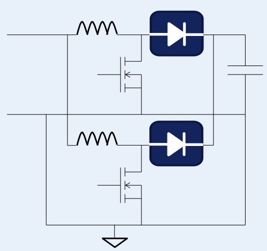
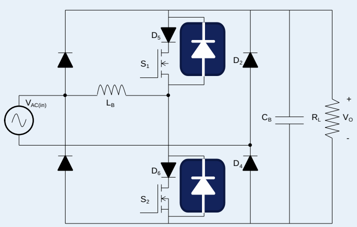
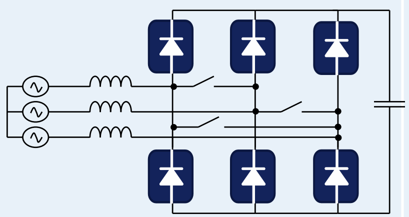
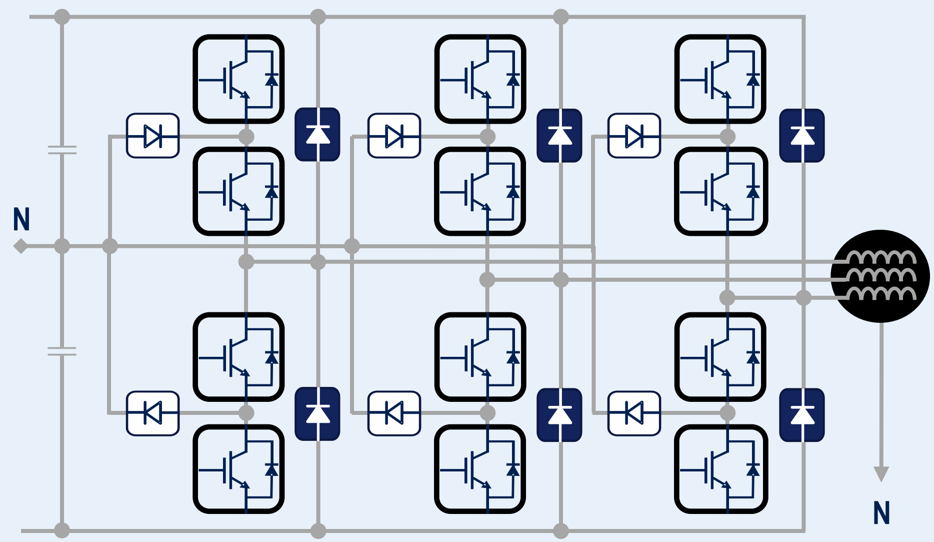
Applications and topologies /1

Topologies requiring 1200V SiC MOSFET and 600/650V SiC Diodes

Boost Converter	Buck Converter	3-Phase Motor Drive
		
SCT30N120 1200V SiC MOSFET **STPSCxxH065yy** 650V Generation 2 SiC Diodes **STPSCxxH12yy** 1200V Generation 2 SiC Diodes In continuous current conduction mode, low recovery charge = higher efficiency	**SCT30N120** 1200V SiC MOSFET **STPSCxxH065yy** 650V Generation 2 SiC Diodes **STPSCxxH12yy** 1200V Generation 2 SiC Diodes In continuous current conduction mode, low recovery charge = higher efficiency	**STPSCxxH065yy** 650V Generation 2 SiC Diodes Generation 2 SiC Diodes Additional free-wheeling diodes to lower free-wheeling power losses

Applications and topologies /2

Topologies requiring 600V/650V/1200V SiC diodes

Interleaved or Bridgeless PFC	3-Phase PFC	3-Phase Photo Voltaic Inverter
 		
SCT30N120 1200V SiC MOSFET **STPSCxxH065yy** 650V Generation 2 SiC Diodes **STPSCxxH12yy** 1200V Generation 2 SiC Diodes	**SCT30N120** 1200V SiC MOSFET **STPSCxxH065yy** 650V Generation 2 SiC Diodes **STPSCxxH12yy** 1200V Generation 2 SiC Diodes	 **STPSCxx06yy** 600V Generation 1 SiC Diodes  **STPSCxxTH13yy** 650V Generation 2 SiC Diodes in Series SiC free-wheeling diodes to lower free-wheeling power losses

SiC Diode Nomenclature

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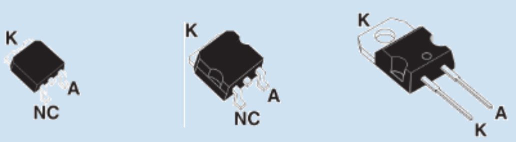
SILICA An Avnet Company

Generation 1 · 600V Diodes

Single Diodes

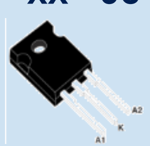
STPSC xx 06 yy



STPCS	ST SiC Schottky
xx	$I_{F(AV)}$ 4A, 6A, 8A, 10A, 12A
06	V_{RRM} 600V
yy	TO-220AC, DPAK, D^2PAK

Dual Diodes / Common Cathode

STPSC xx 06 C yy

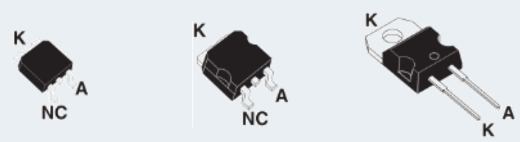


C	Common Cathode
xx	$I_{F(AV)}$ 2 x 10A
yy	TO-247

Generation 2 · 650V Diodes

Single Diodes

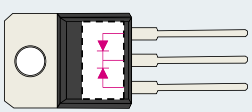
STPSC xx H 065 yy



STPCS	ST SiC Schottky Gen2 (H)
xx	$I_{F(AV)}$ 4A, 6A, 8A, 10A, 12A
065	V_{RRM} 650V
yy	TO-220AC, DPAK, D^2PAK

Dual Diodes / Common Cathode

STPSC xx H 065 C yy

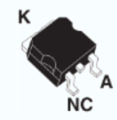


C	Common Cathode
xx	$I_{F(AV)}$ 2 x 4A, 6A, 8A, 10A
yy	TO-220AB, TO-247

Generation 2 · 1200V Diodes

Single Diodes

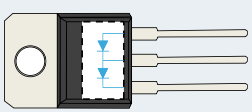
STPSC xx H 12 yy



STPCS	ST SiC Schottky Gen2 (H)
xx	$I_{F(AV)}$ 6A
12	V_{RRM} 1200V
yy	DPAK HV 2 Leads

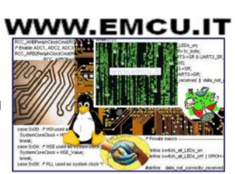
Dual Diodes in Series

STPSC xx TH 13 TI yy



TI	Diodes in Series
xx	$I_{F(AV)}$ 2 x 6A, 8A, 10A
yy	TO-220AB Insulated

Remember: Generation 2 does not replace Generation 1



ST SiC 1200V diodes

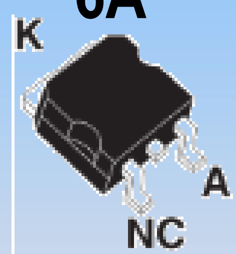
1200 V diodes

Single diodes

STPSC xx H 12 yy

- SiC Schottky → STPSC
- $I_{F(AV)}$ → xx
- Gen 2 → H
- V_{RRM} → 12
- Package → yy

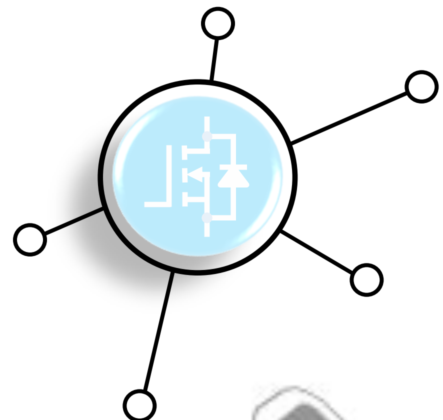
6A



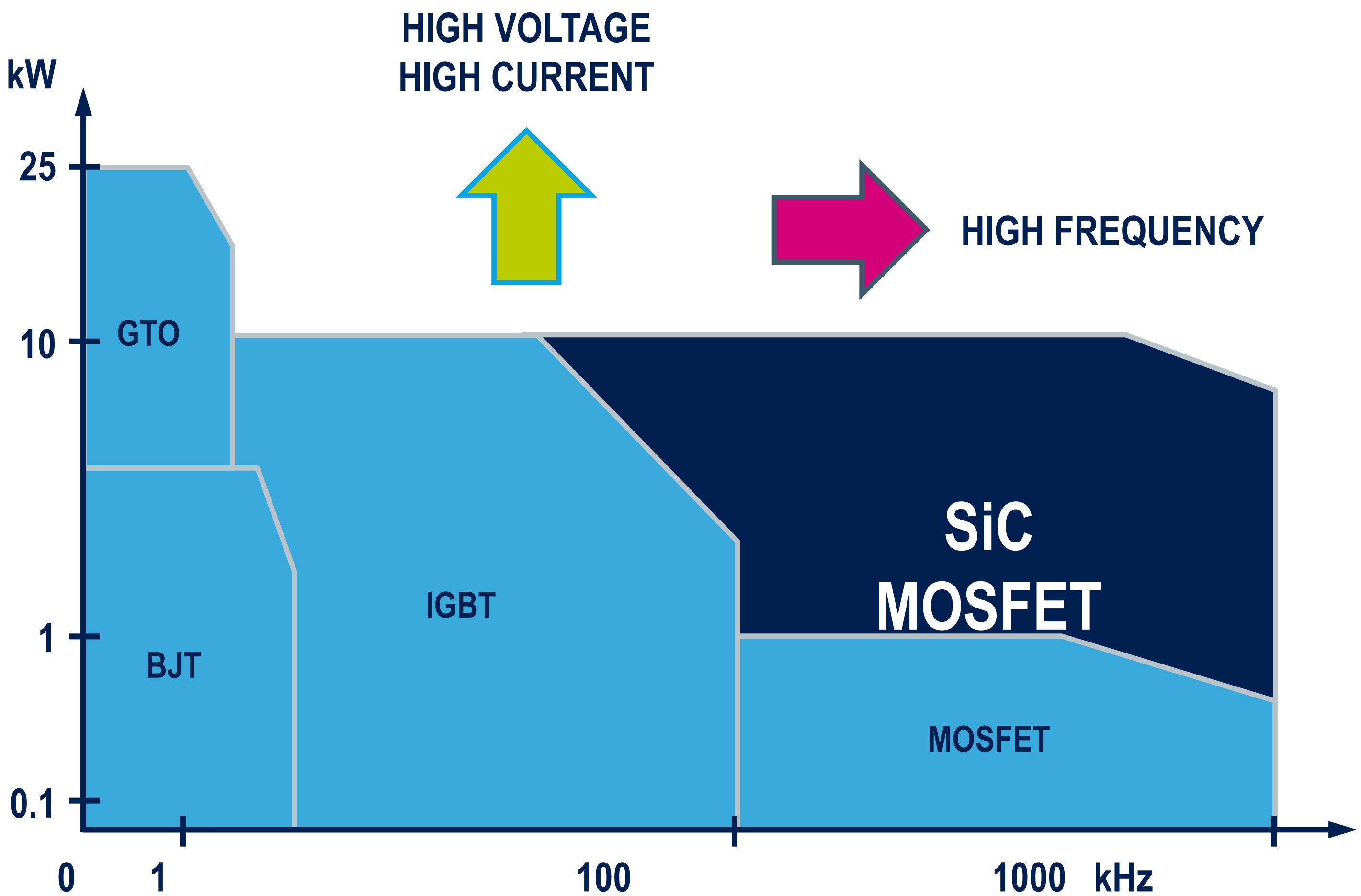
To be extended…

SiC MOSFET

Positioning

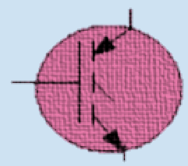
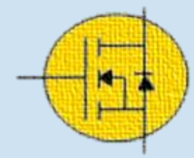
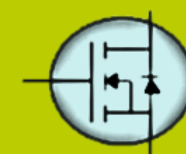


Power Transistors: functional range



Power Devices: benchmark summary

Benchmark Summary

Power Transistor / Parameter	IGBT	MOSFET	SiC MOSFET
Symbol			
Control parameter	Voltage	Voltage	**Voltage**
Control power	Low	Low	**Low**
Control circuit	Simple	Simple	**Simple**
On-resistance	Vce_sat (≈2V)	Medium	**Low**
Switching speed	Medium	Fast	**Fast**
Switching loss	Medium	Low	**Extremely low**
Load current	High	Medium	**High**
Operating junction temperature	Up to 175°C	Up to 150°C	**> 200°C**

Switching power losses:
SiC MOSFET vs. IGBT

SiC MOSFET vs. best in class IGBT

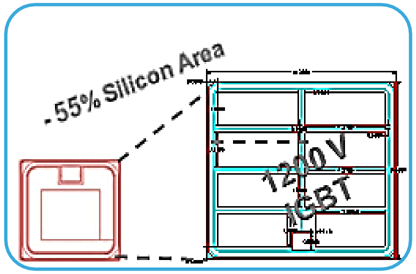
Parameters and Conditions	Die size	V_{on} typ. (V) @ 20A, 25°C	V_{on} typ. (V) @ 20A, 175°C	E_{on} (µJ) @ 20A, 900V 25°C / 175°C	E_{off} (µJ) @ 20A, 900V 25°C / 175°C	E_{off} 25°C / 175°C difference (%)
SiC MOSFET	0.45	2	2.4	725 / 965*	245 / 307	+25% from 25°C to 175°C
IGBT	1.00	1.95	2.35	2140 / 3100	980 / 1850	+90% from 25°C to 175°C

SiC MOSFET

- Results have been measured on SiC MOSFET engineering samples
- SiC device: SCT30N120, 1200V, 45A, 80mΩ, N-channel MOSFET
- IGBT device: best in class field-stop IGBT

- SiC switching power losses are considerably lower than the IGBT ones
- At high temperature, the gap between SiC and IGBT is insurmountable

➤ SiC MOSFET is the optimal fit for high-power, high-temperature applications



SiC die size compared to IGBT

* E_{off} measured using the SiC intrinsic body diode

SiC Power MOSFET: SCT30N120

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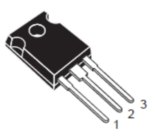
SCT30N120

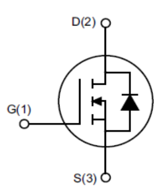
Silicon carbide Power MOSFET
45 A, 1200 V, 80 mΩ, N-channel in HiP247™ package

Datasheet - preliminary data



HiP247™

Figure 1. Internal schematic diagram



Features

- Very tight variation of on resistance vs. temperature
- Slight variation of switching losses vs. temperature
- Very high temperature operation capability (200 °C)
- Very fast and robust intrinsic body diode
- Low capacitance
- Easy to drive

Applications

- Solar inverters, UPS
- Motor drives
- High voltage DC-DC converters
- Switch mode power supply

Description

This silicon carbide Power MOSFET is fabricated exploiting the advanced and innovative properties of wide bandgap materials. These include unsurpassed on-resistance per unit area and very good switching performance almost independent of temperature. The outstanding thermal properties of the SiC material together with the adoption of the proprietary HiP247™ package allows designers to use an industry standard outline with significantly improved thermal capability. All these features make the device perfectly suitable for high-efficiency and high power density applications.

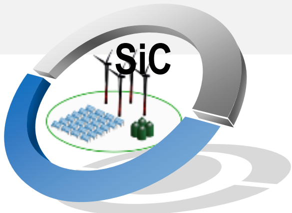
Table 1. Device summary

Order code	Marking	Package	Packaging
SCT30N120	SCT30N120	HiP247™	Tube

Note: The device meets ECOPACK standards, an environmentally-friendly grade of products commonly referred to as "halogen-free". See Section 3: Package mechanical data.

24 April 2013 DocID023109 Rev 2 1/9

This is preliminary information on a new product now in development or undergoing evaluation. Details are subject to change without notice. www.st.com



1200V SiC MOSFET

V_{BR} > 1,200 V

In = 45 A

$R_{on(typ)}$ < 80 mΩ

$Q_{g(typ)}$ < 105nC

Gate Driving Voltage = 20 V

HiP247 Package : Tjmax=200 °C

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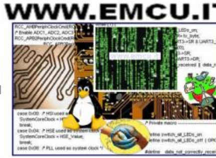


SiC MOSFET

Switching power losses vs IGBT

SiC MOSFET vs. best in class IGBT

Device	Von typ (V)(@ 25° C, 20A	Von typ (V) (@ 175° C, 20A	Eon (uJ) @ 20A, 900V 25° C/175° C	Eoff(uJ) @ 20A, 900V 25° C/175° C	Chip size
SCT30N120 (ST SiC MOSFET	2	2.4	725/ 965(*)	245/307	0.45
IGBT	1.95	2.35	2140/3100	980/1850	1

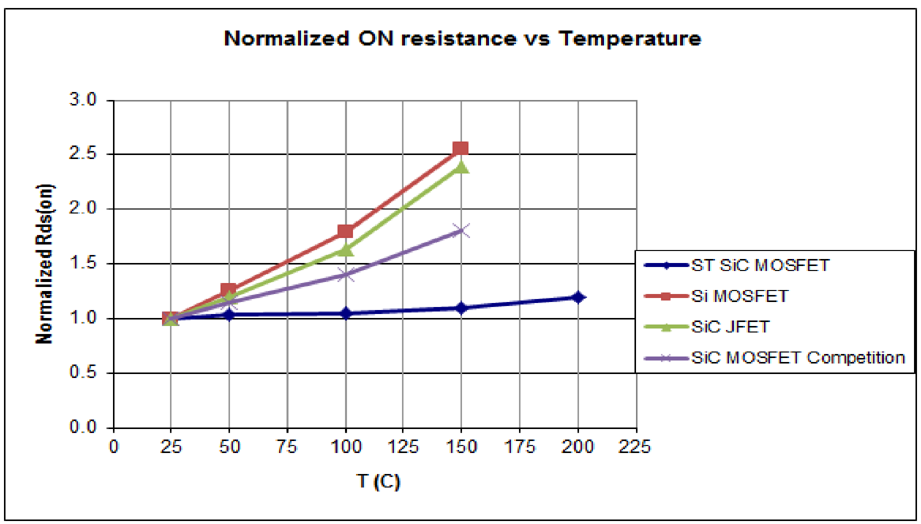
+ 30 % at 175°C

+ 90 % at 175°C

Outstanding RDSon/mm² with SiC-Mosfets

Part number	BV	Package	Ron (mΩ)	Ron*A (mΩ*cm^2)
SCT30N120 (ST SiC MOSFET)	1200V	HiP247	80	***11.5!***
STWN120K5	*1200V*	*TO 247*	*320*	*220*
IGBT 25A (Vcesat=2.05V@25°C)	1200V	TO 247	80 (*)	20

At high temperatures "simply the best"



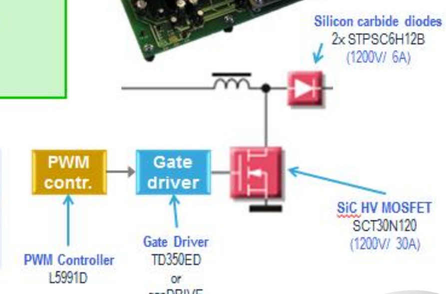
Sorry, 99.3% Efficiency?

- Complete solution of boost inverter 4kW from 400-600VDC to 800Vdc

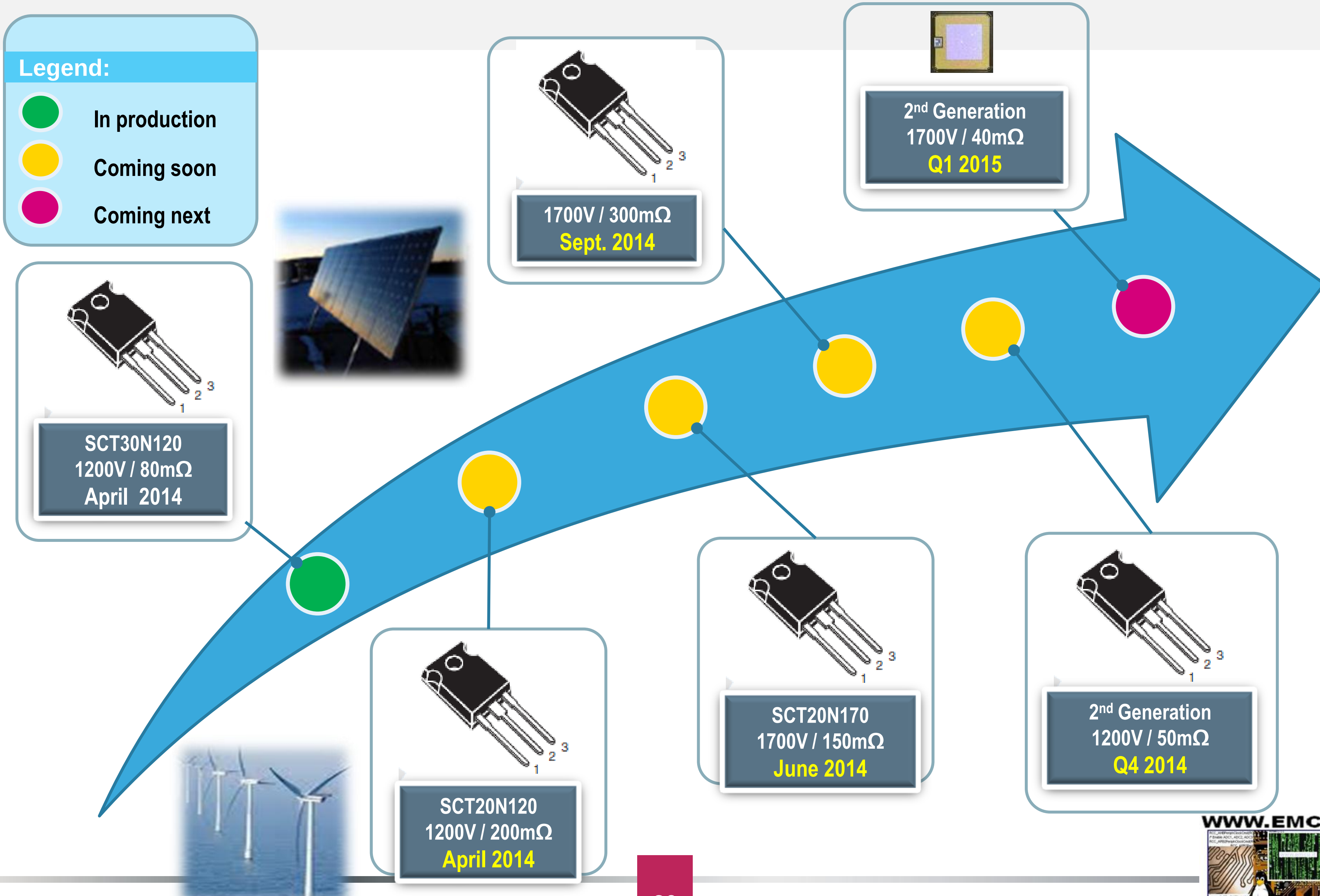
new

- Tested also with GapDrive with same results
- Very appreciated demo – used on several events already
  - PCIM, Daimler day, Paris techday, FAE training
- Final PCB revision arrived
- SiC 1200V diode now mature!

Input voltage (VDC)	Pout (W)	Eff total (%)	Eff without AUX (%)	Heatsink temperature
600	2094	99.11	99.29	57.5C



SiC MOSFET Product Roadmap

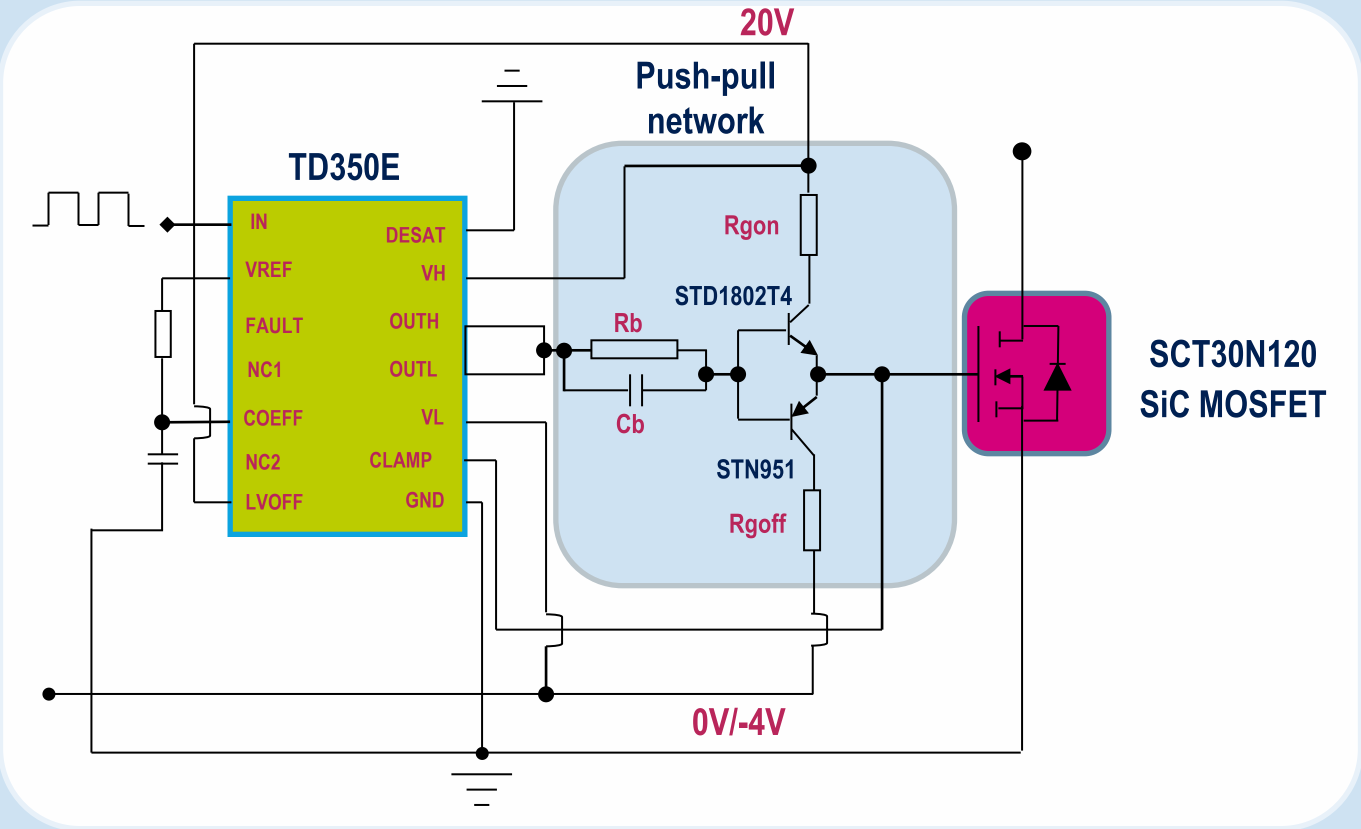


How to drive a SiC MOSFET

SiC MOSFET driving circuit (1)

Driving SiC MOSFET with TD350E

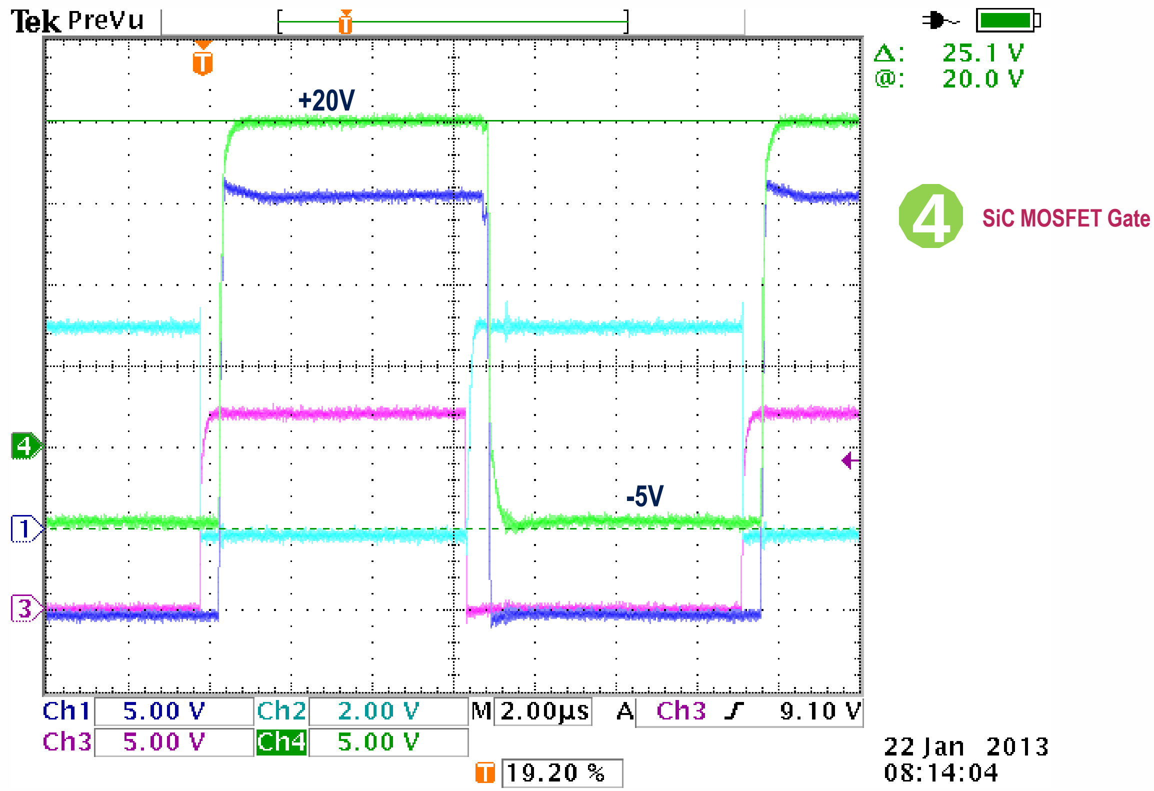
The ST **TD350E** is an advanced gate driver for IGBTs and power MOSFETs.
To drive a SiC MOSFET, simply add an external push-pull network to increase current capability.



How to drive a SiC MOSFET

Driving SiC MOSFET

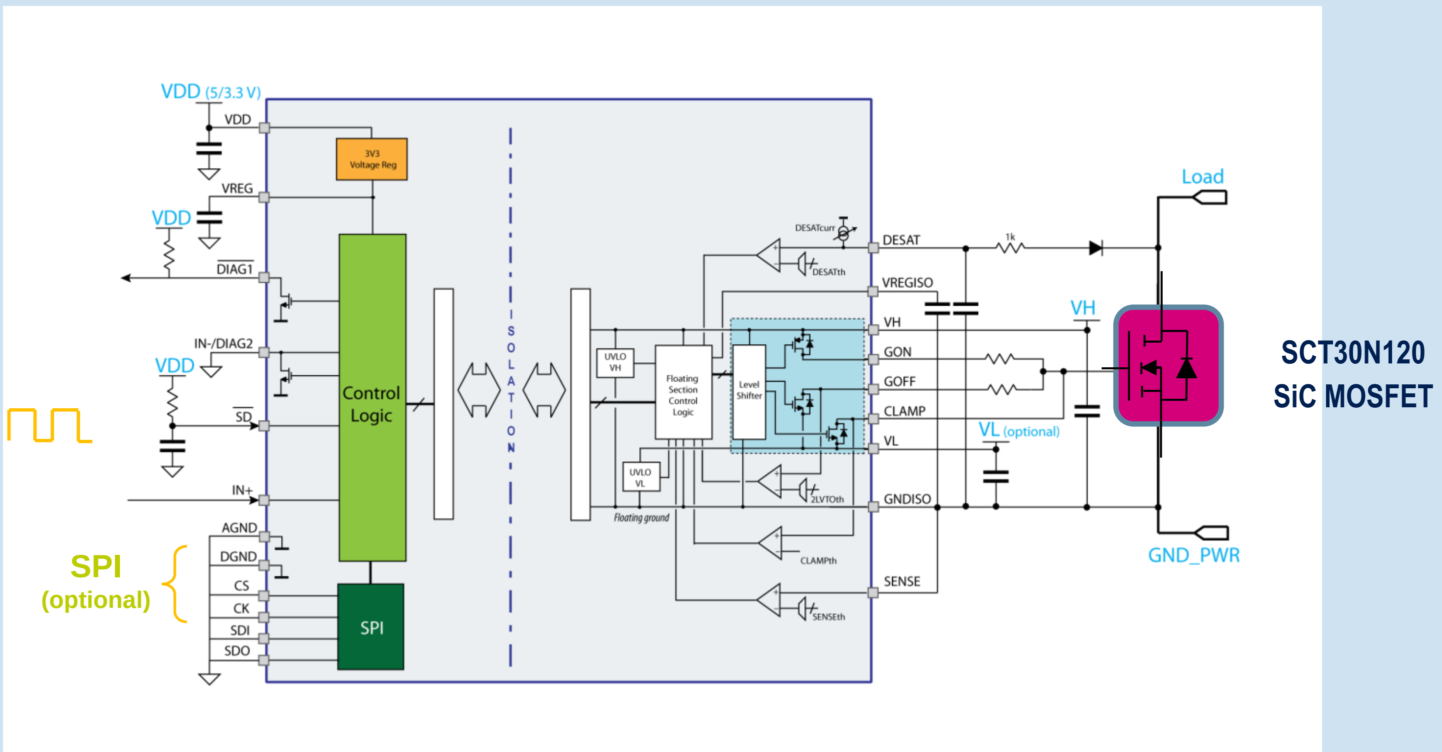
For its driving, SiC MOSFET requires a +20V/-5V gate signal.



SiC MOSFET driving circuit (2)

Driving SiC MOSFET with GapDrive

The **GapDrive** is a 4000V galvanic isolated gate driver from ST, for IGBTs and power MOSFETs.



HV Gate Driver: Market position & Roadmap

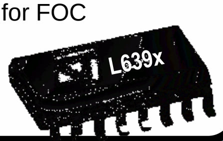
Market position

- Today Market Share ~25%
- Leadership in Appliances (~80% MS in EMEA)

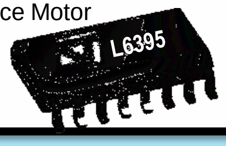
HA Leader 25% MS

More than 50Mpcs sold in 2011

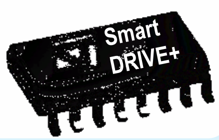
smartDRIVE L639x,L638xE
- Easy sensor-less Driver optimized for FOC



L6395 smartDRIVE
- Optimized for Switched-Reluctance Motor



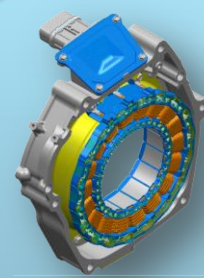
smartDRIVE+
4 A Driver 10x power & Speed



gapDRIVE
- Galvanic Isolated Gate Driver with SPI & Advanced Protection

gapDrive/Lite
- Lite version with selected features
- Smaller size
- Lower cost

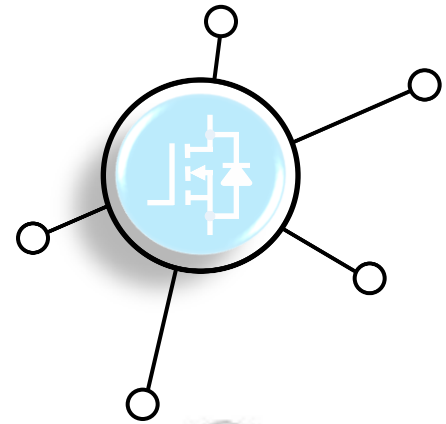
Industrial Drives & EV 10kW - 200kW

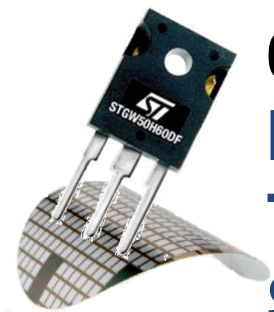


2012 — **2013** — **2014**

Full production | Design | Concept

SiC Vs IGBT

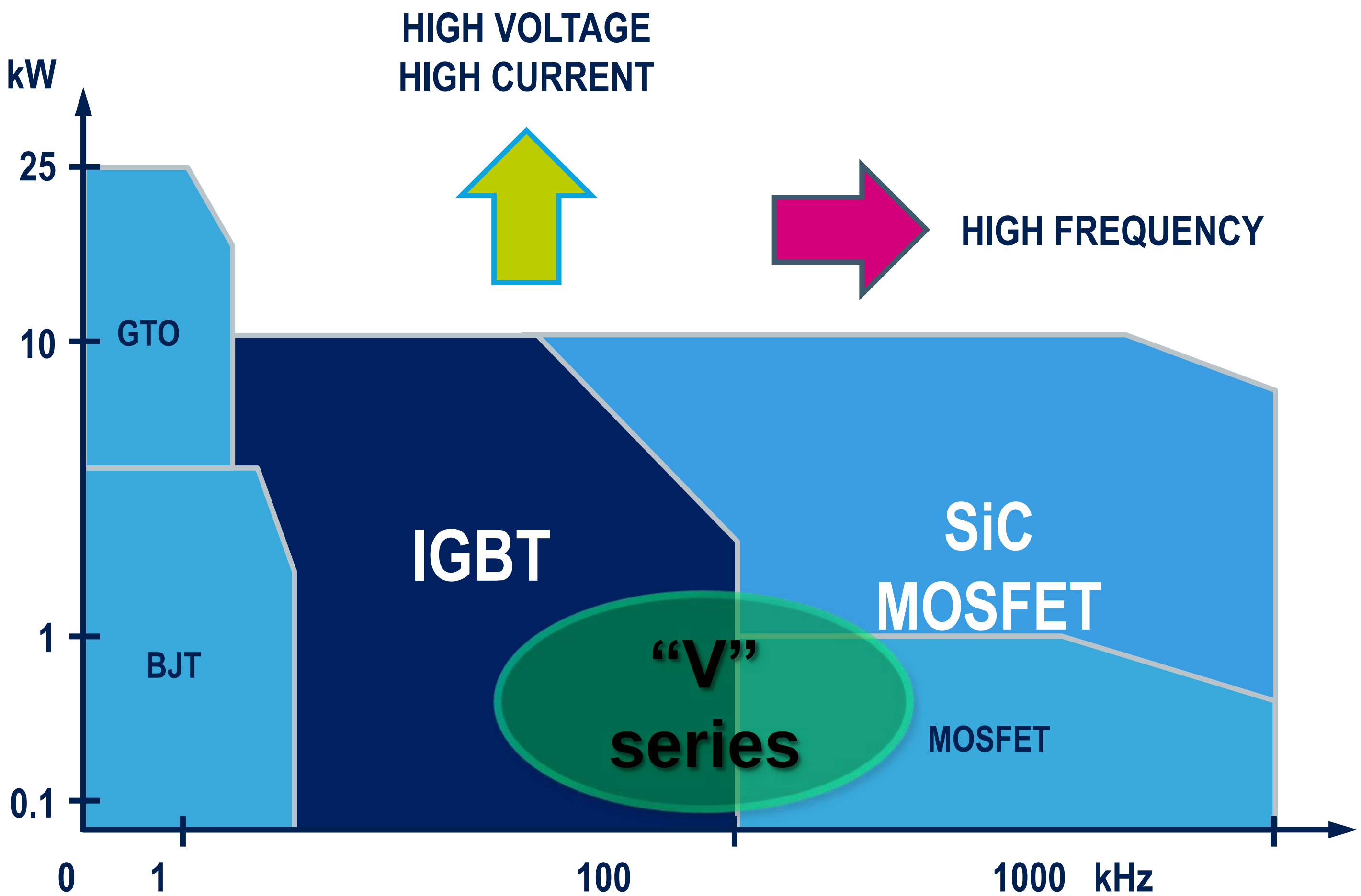




600V IGBTs – V & HB Series

New Trench Gate Field Stop Technology – Very High Speed Series

Power Transistors: functional range



New ST Trench Gate Field Stop H, HB, V series

The ideal companion for frequency converter

H

Up to 25 kHz

- Low Frequency Converter
- Motor Control, PFC

HB

Up to 35 kHz

- Medium Frequency Converter, Soft Switching
- PV Inverter; Welding Induction Heating, PFC

V

Above 35 kHz

- High Frequency Converter
- Welding, UPS, PV, PFC

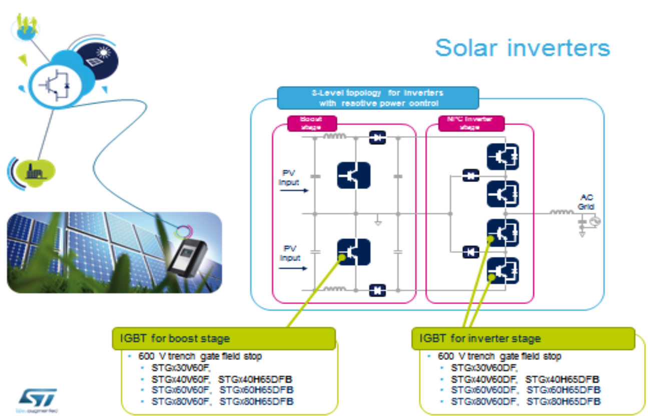
Energy saving

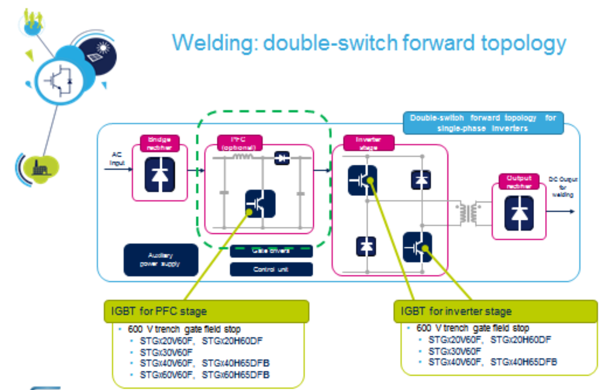
Power scalability

Robustness and reliability

From Silicon to application

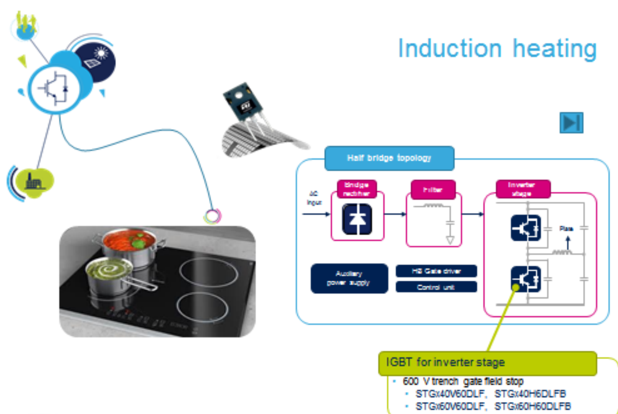
more than a simply IGBT supplier

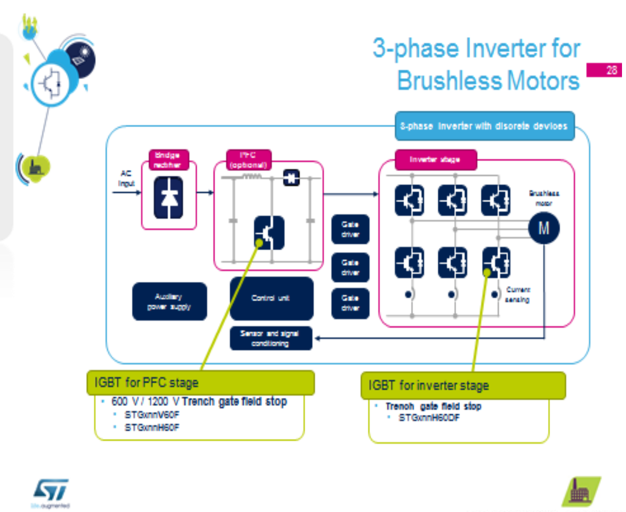




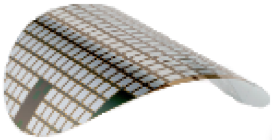
Supported by

IGBT application guidelines

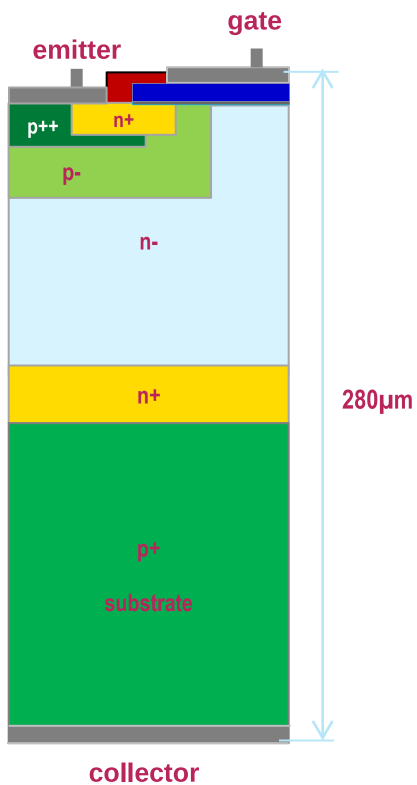


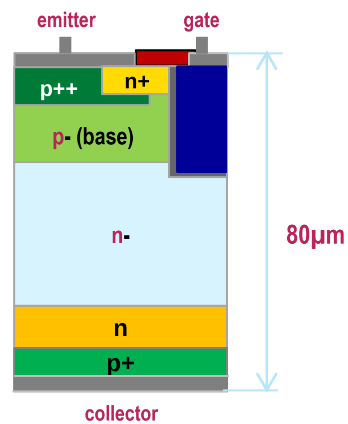


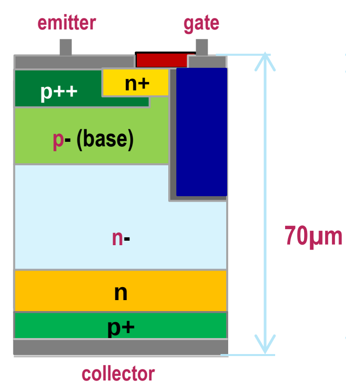
IGBTs Trench Gate Field Stop: Technology Milestones and Features

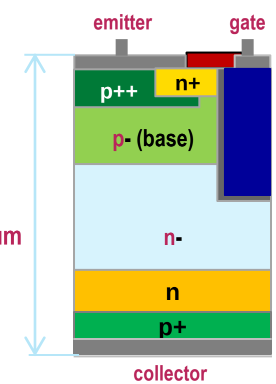


Planar PT | **H** | **V** | **H-B**







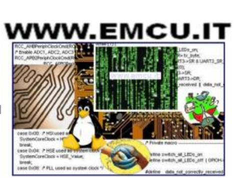


Energy Saving

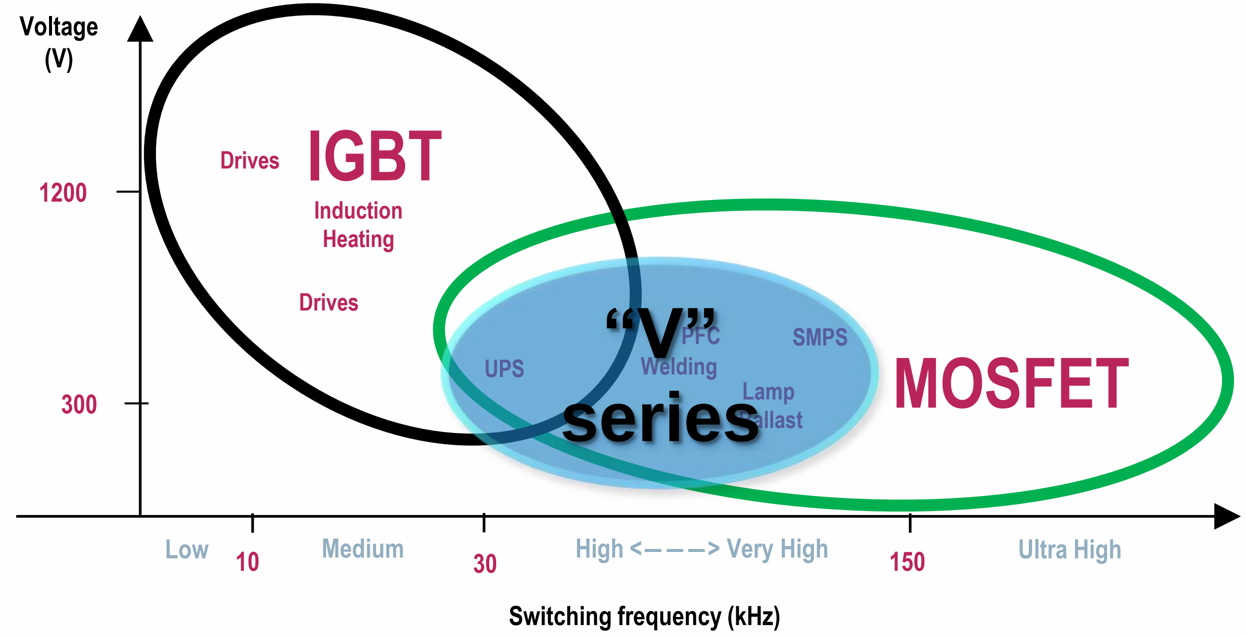
Extremely low switching-off combined with a low conduction losses.

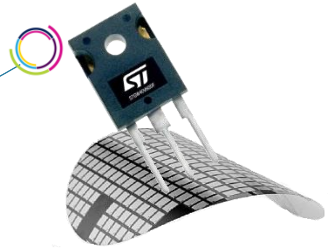
Robustness and Reliability

The Increasing up to 175°C of the max Junction Temperature Tj(max), Ensures an higher lifetime



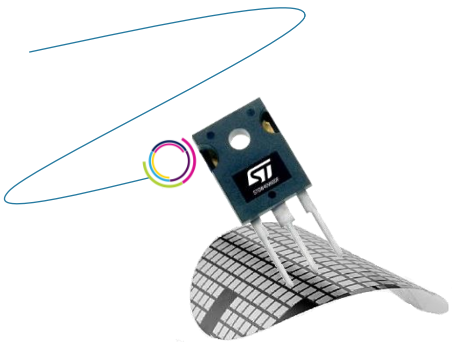
600V IGBT "V" Series Positioning





New IGBT "V" series: developed to bridge the gap between IGBTs and MOSFETs in high frequency hard switching applications above 20kHz

V & H-B series: focus applications



Motor Control

Welding

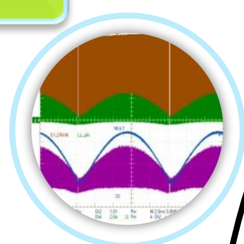
Induction heating

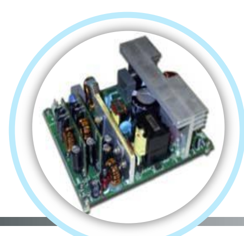
Solar inverters

UPS

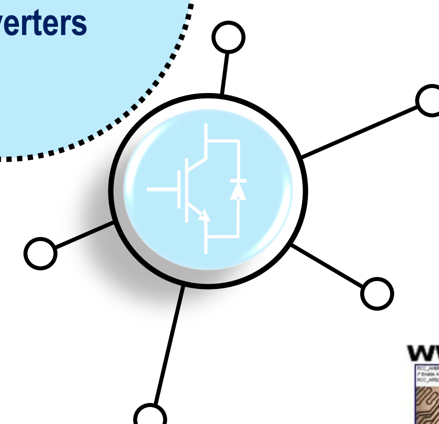
PFC converters

SMPS





The best actuator for high switching frequency converters



IGBTs: Investment in Efficiency

Moving from Planar to Trench Field-Stop

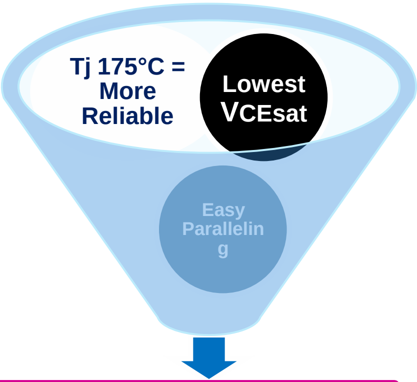
1st time aligned or even better than the market leader!

"H" series	"H-B" series	"V" series
Applications: Low Frequency Conv. Motor Ctrl, Drives	**Applications:** Medium Frequ. Conv. Welding, UPS, Induction Heating	**Applications:** High Frequency Conv. PFC, SMPS, Welding
Main Competitors: Renesas D2, D3, IFX "T" series	**Main Competitor:** IFX "T" series, FCS UPD series	**Main Competitor:** IFX: H3, H5, FSC: SMD
Up to 25kHz 600V,	Up to 35kHz 650V	> 35kHz 600V

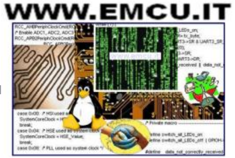
Just a Snapshot:

P/N	Package	BV_{CES} (V)	I_{CN} (A)	$V_{ce(sat)}$ (V)	Eoff (uJ)	Diode Option
STGP20V60DF	TO-220	600	20	1.8	130	Very Fast
STGP20V60F	TO-220	600	20	1.8	130	-
STGB30V60DF	D2PAK	600	30	1.85	233	Very Fast
STGB30V60F	D2PAK	600	30	1.85	233	-
STGP40V60F	TO-220	600	40	1.8	411	-
STGW40H65DFB	TO-247	650	40	1.6	450	Very Fast
STGW60V60DLF	TO-247	600	60	1.85	270a)	Low Drop
STGW60V60F	TO-247	600	60	1.85	550	-
STGW60H65FB	TO-247	650	60	1.65	650	-
STGWT60H60DLFB	TO-3P	600	60	1.65	130a)	Low Drop
STGW80H65DFB	TO-247	650	80	1.65	850	Very Fast
STGY80V60DF	MAX-247	600	80	1.85	850	Very Fast

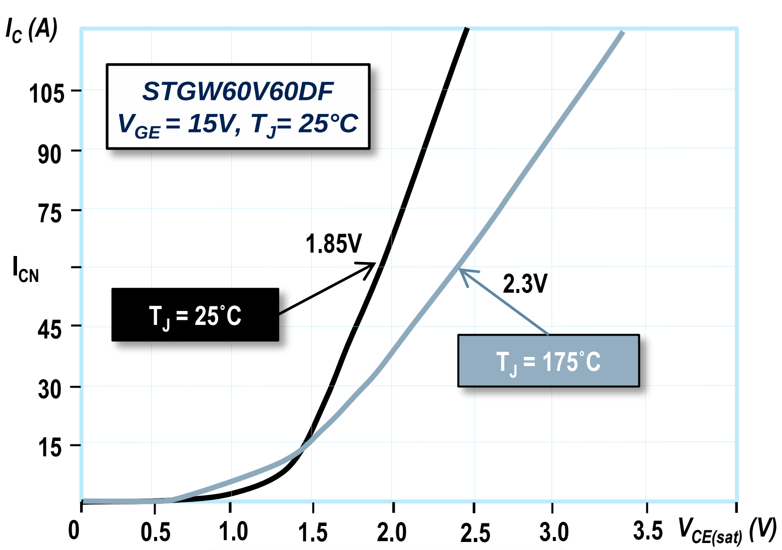
No-Compromise in Efficiency and Competiveness

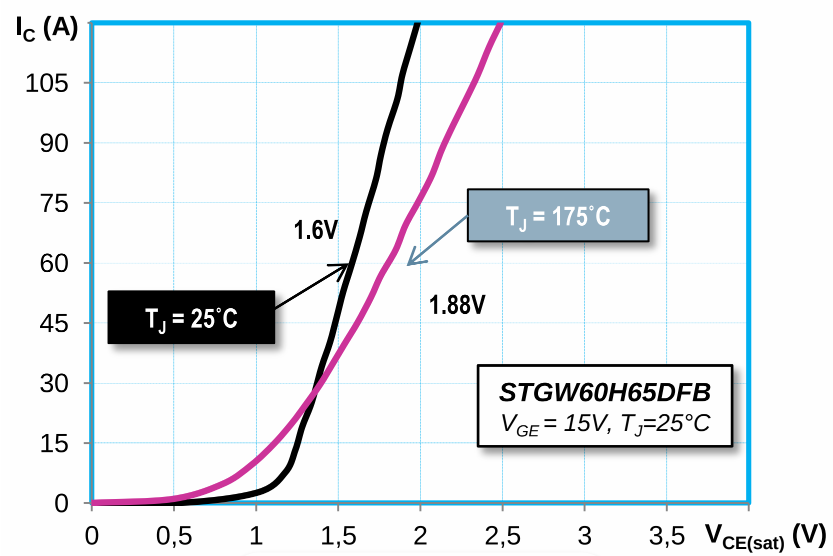


Top Class Efficiency & Reliability



V (600V) & H-B (650V) series positioning(1/3)



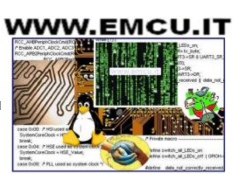


V

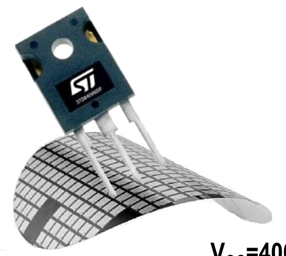
Above 35 kHz

HB

Up to 35 kHz

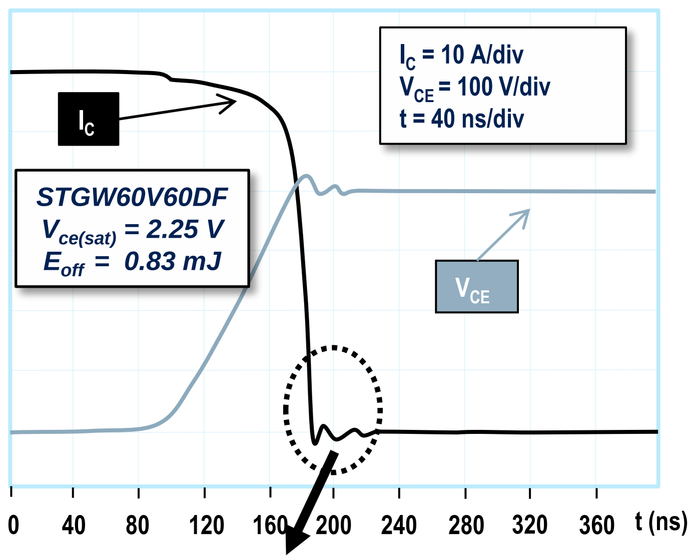


V (600V) & H-B (650V) series positioning (2/3)



Switching-off waveforms

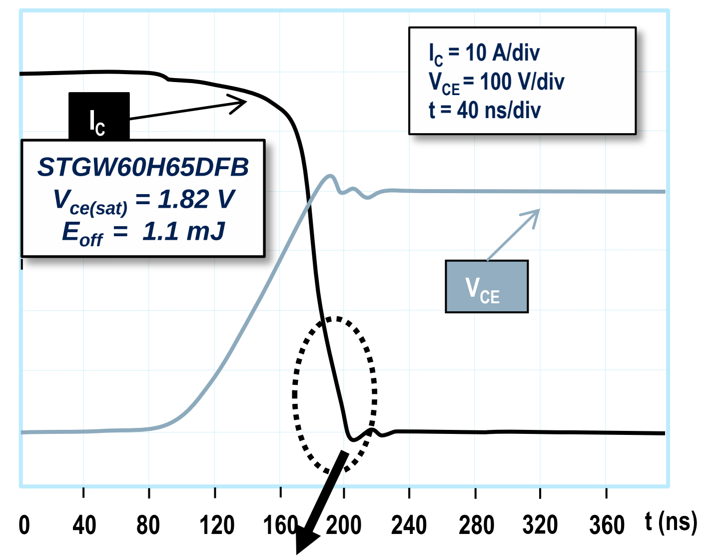
V_{CC}=400V, R_G=5Ω, I_C=I_{CN}, T=150°C



Tail-less switching-off …
… MOSFET "like" switching-off behavior

Switching-off waveforms

V_{CC}=400V, R_G=4.7Ω, I_C=I_{CN}=60A, V_{GE}=15V, T=150°C

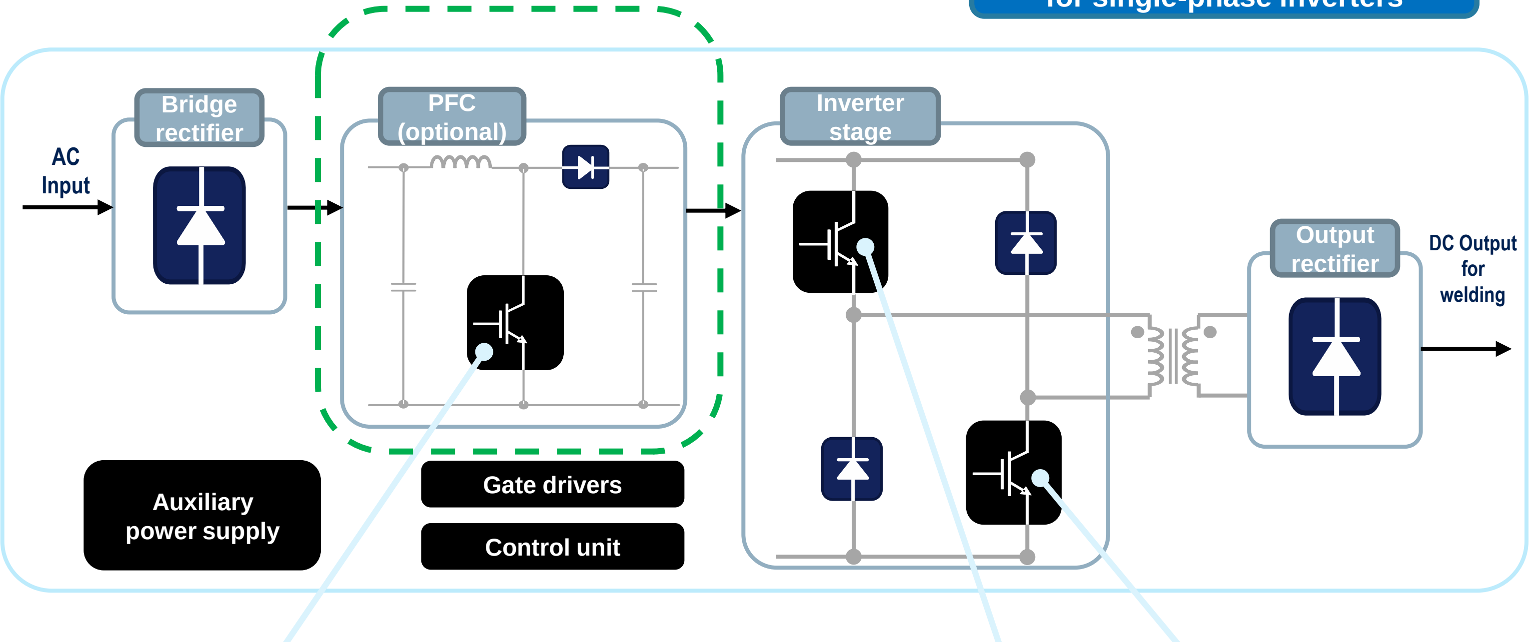


Almost tail-less switching-off …

Stressfull Benchmark Test: Welding:

Double-switch forward topology

Double-switch forward topology for single-phase inverters



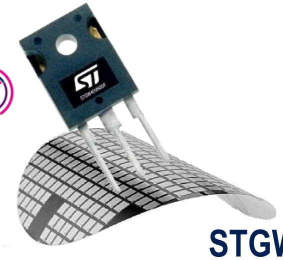
IGBT for PFC stage

- 600 V trench gate field stop
  - STGW20V60F, STGW20H60DF
  - STGW30V60F
  - STGW40V60F, STGW40H65DFB
  - STGW60V60F, STGW60H65DFB

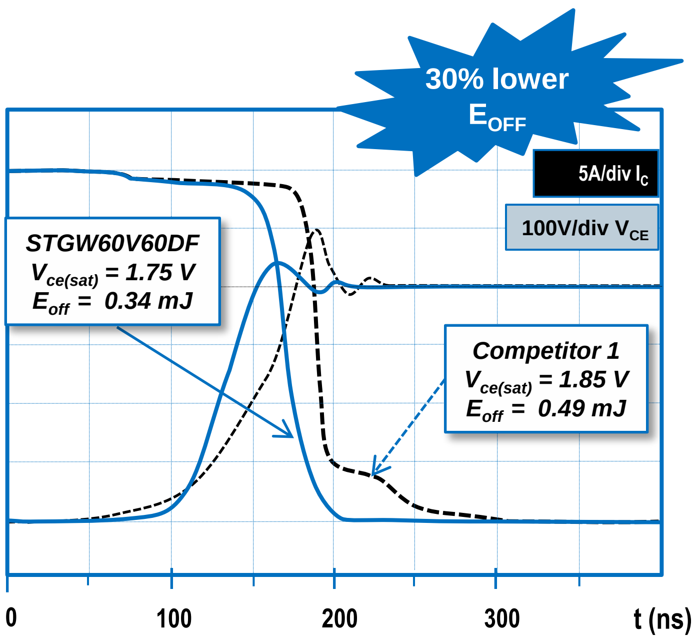
IGBT for inverter stage

- 600 V trench gate field stop
  - STGW20V60F, STGW20H60DF
  - STGW30V60F
  - STGW40V60F, STGW40H65DFB

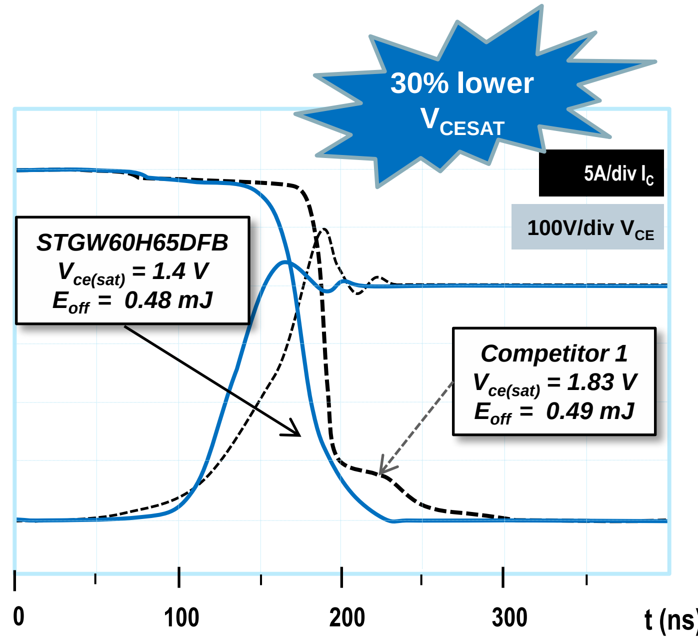
Switching-off benchmarking (3/3)



STGW60V60DF vs. Competitor 1

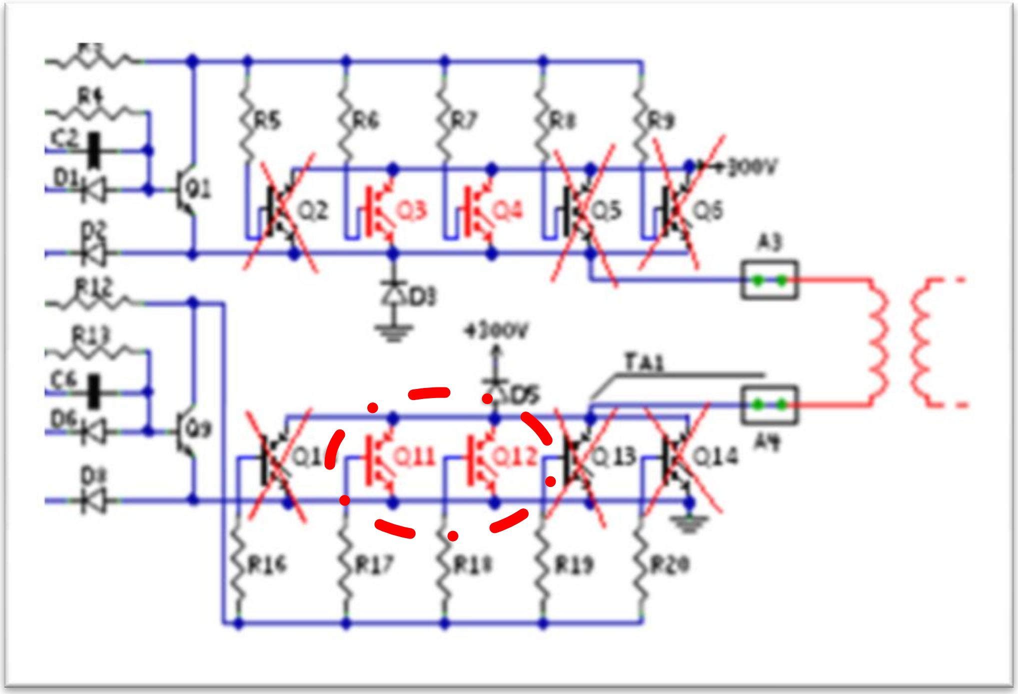


STGW60H65DFB vs. Competitor 1



Test condition: V_{CC} = 400V, R_G = 4.7Ω, I_C = ½ I_{CN} = 30A, V_{GE} = 15V, T_J = 150 °C

The used Welding stage



The signal waveforms were acquired and evaluated for two devices Q11 and Q12 which are connected in parallel in the low side part of the double switch forward converter section

Devices under analysis:

STGW40V60DF

Competitor 1

Competitor 2

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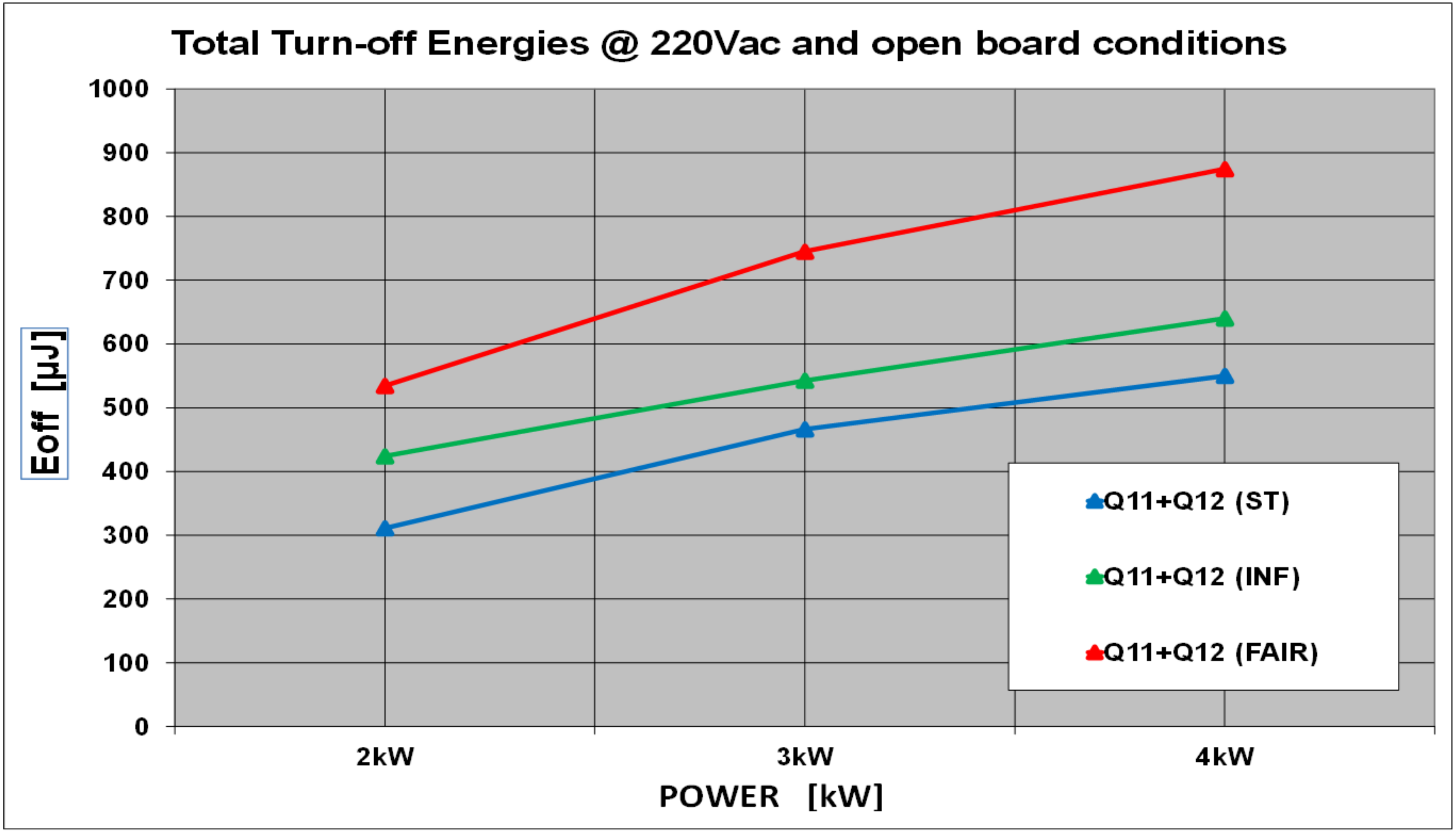
Result Overview- turn-off comparison



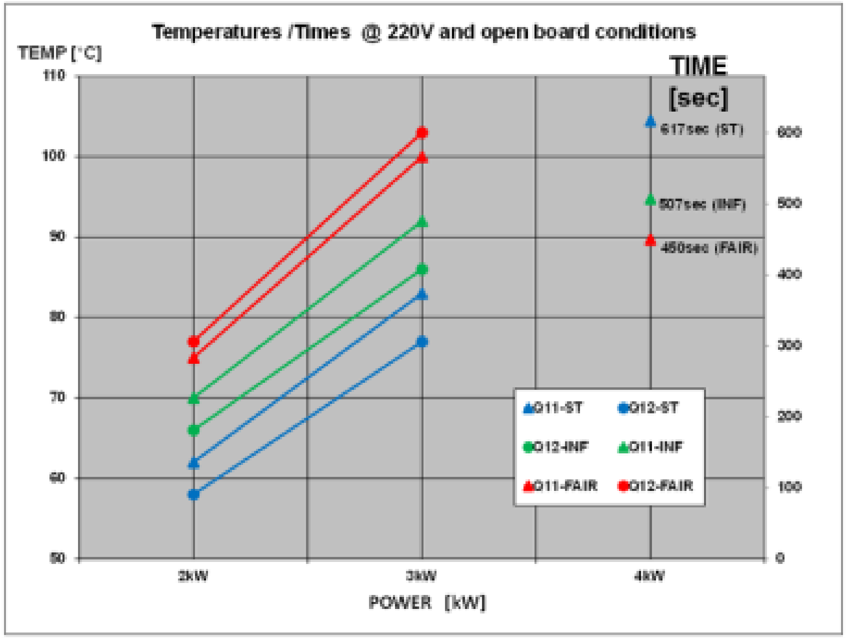
WWW.EMCU.IT

Thermal measurement

DEVICE	Pin (W)	Input Ic (A)	PF	T [ºC]
STGW40V60DF	2	15.4	0.58	62º - 58º
	3	22.2	0.61	83º – 77º
	~3.8 (MAX)	26.3	0.66	10 min:17 sec

DEVICE	Pin (W)	Input Ic (A)	PF	T [ºC]
Competitor 1	2	15.6	0.58	70º - 66º
	3	22.3	0.61	92º – 86º
	~3.8 (MAX)	26.4	0.66	8min:27sec

DEVICE	Pin (W)	Input Ic (A)	PF	T [ºC]
Competitor 2	2	15.7	0.58	75º - 77º
	3	22.9	0.61	100º – 103º
	~3.8 (MAX)	26.5	0.66	7min:30sec

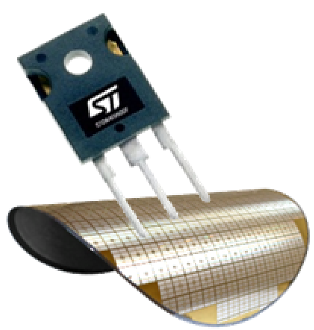


Operating times measured at the maximum input power condition (4kW) just before the welding machine stops running due to the activation of the thermal protection.

full load steady state operation

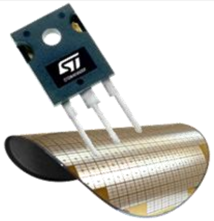
1200V IGBT

IGBT P/Ns	I_{CN} 1) (A)	$V_{ce(sat)}$ 2) (V)	E_{off} 3) (mJ)	t_{sc} 4) (µs)	Max T_J (°C)	Switching freq. range	FRD Option	Production (MAT 30)
STGW15H120F2	15	2.1	0.4	5	175°C	H (20 - 100kHz)	-	Full production
STGW25H120F2	25	2.1	0.75	5	175°C	H (20 - 100kHz)	-	
STGW40H120F2	40	2.1	1.3	5	175°C	H (20 - 100kHz)	-	
STGW15H120DF2	15	2.1	0.4	5	175°C	H (20 - 100kHz)	Very Fast	WK 17
STGW25H120DF2	25	2.1	0.75	5	175°C	H (20 - 100kHz)	Very Fast	
STGW40H120DF2	40	2.1	1.3	5	175°C	H (20 - 100kHz)	Very Fast	



1) I_{CN} : Nominal collector current @ T_J=100°C
2) $V_{ce(sat)}$: Typical conduction losses @ I_{CN}, T_J=25°C
3) Eoff : Typical switching energy losses @ I_{CN}, T_J=25°C, V_{CC}=600V
4) t_{sc} : min short circuit whitstand time @ V_{CC}=600V, T=150°C

1200V IGBT



For soft switching applications

Sales Type	I_{CN} 1)	Main Applications	Production (MAT 30)
STGWT20H125DF	20 A	IH, soft switching	Released
STGWT28IH125DF	30 A	IH, soft switching	

M series (up to 20 kHz)

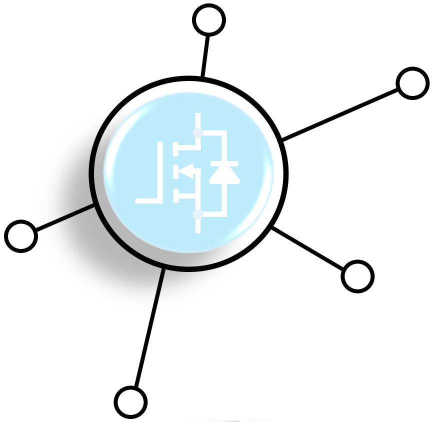
Sales Type	I_{CN} 1)	V_{CESAT} @ I_{CN}	E_{off} (mJ)	Main Applications	Samples	Production (MAT 30)
STGW15M120DF3	15 A	1.85 V	0.9	Drives, UPS, Solar	May '14	wk 24
STGW25M120DF3	25 A	1.85 V	1.5	Drives, UPS, Solar	May '14	wk 24
STGW40M120DF3	40 A	1.85 V	2.35	Drives, UPS, Solar	Available	wk 20

T_{JMAX} = 175˚C

1) continuous I_C @ 100˚C

2) Test condition → V_{CC} = 600V, V_{GE}=15V, T_{Jstart} = 150˚C

Application example with SiC MOSFET and Diodes



Boost Inverter with SiC semiconductors

- **The goal is to design a 4kW boost inverter to demonstrate the advantages of using ST Silicon Carbide Power MOSFET and Silicon Carbide Schottky rectifiers**

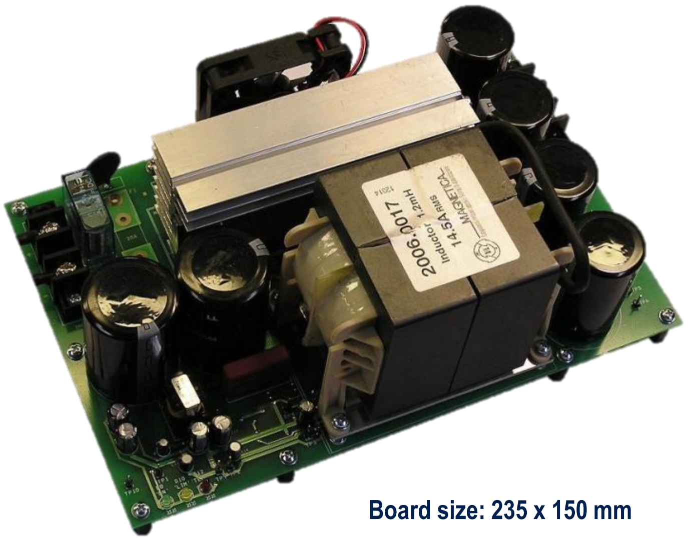
- **Design specifications:**
  - **Input Voltage: 400-600VDC**
  - **Output Voltage: 800VDC**
  - **Output Power: 4kW**

- **Target efficiency > 99%**

4kW solution based on SiC technology

Boost Inverter in detail

- Fully integrated and compact solution:
  - Power stage, aux. SMPS, controller, signal processing
- Main ST products:
  - SCT30N120 (1200V / 45A SiC MOSFET)
  - STPSC6H12B (1200V / 6A SiC Diode)
  - TD350ED (GapDrive also tested with equal results)
  - L5991D (current mode PWM controller)
- Optimized for 100kHz switching
- Board available to selected Customers



Board size: 235 x 150 mm

Performance				
Input Voltage (VDC)	Output Power (W)	Heatsink Temperature (°C)	Total efficiency including AUX (%)	Total efficiency without AUX* (%)
600	2094	57.5	99.11	99.29

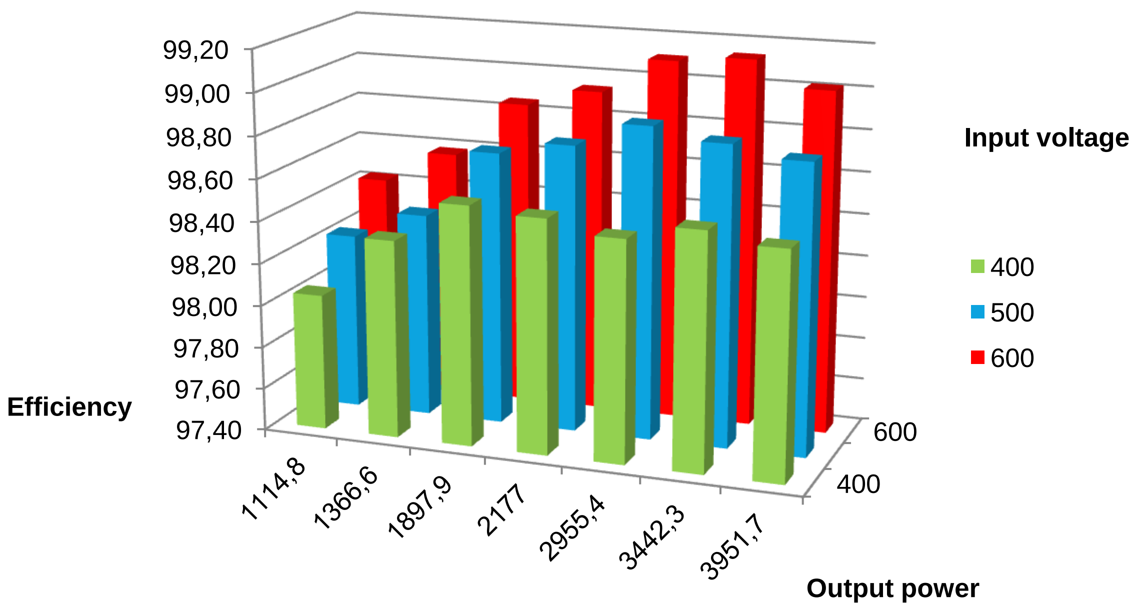
* Efficiency of boost inverter itself (SiC MOSFET, SiC diodes and main choke)

Overall efficiency vs to output power

Testing conditions:

- **Input voltage 400, 500 and 600VDC, output voltage 800VDC**
- **Switching frequency 65kHz, Rgate resistor 2.3OHM**
- **Output power 1kW to 4kW, Ambient temperature 25°C**
- **Results: The "peak efficient point" for the demo is around 3.5kW of output load**

Efficiency versus to output power

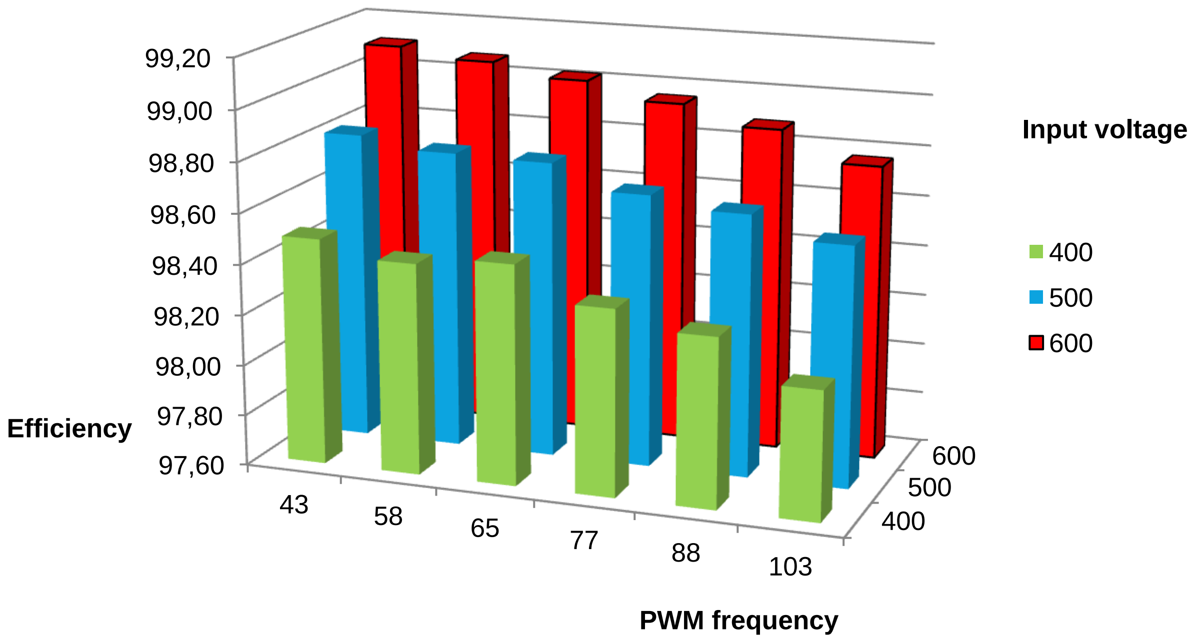


Overall efficiency vs switching freq

Testing conditions:

- **Input voltage 400, 500 and 600VDC, output voltage 800VDC, Rgate resistor 2.3OHM**
- **Switching frequency 43kHz, 58kHz, 65kHz, 77kHz, 88kHz, 103kHz**
- **Output power - 4kW, Ambient temperature 25°C**
- **Results: the overall efficiency of the demo decreasing with increasing of frequency**

Efficiency versus to PWM frequency

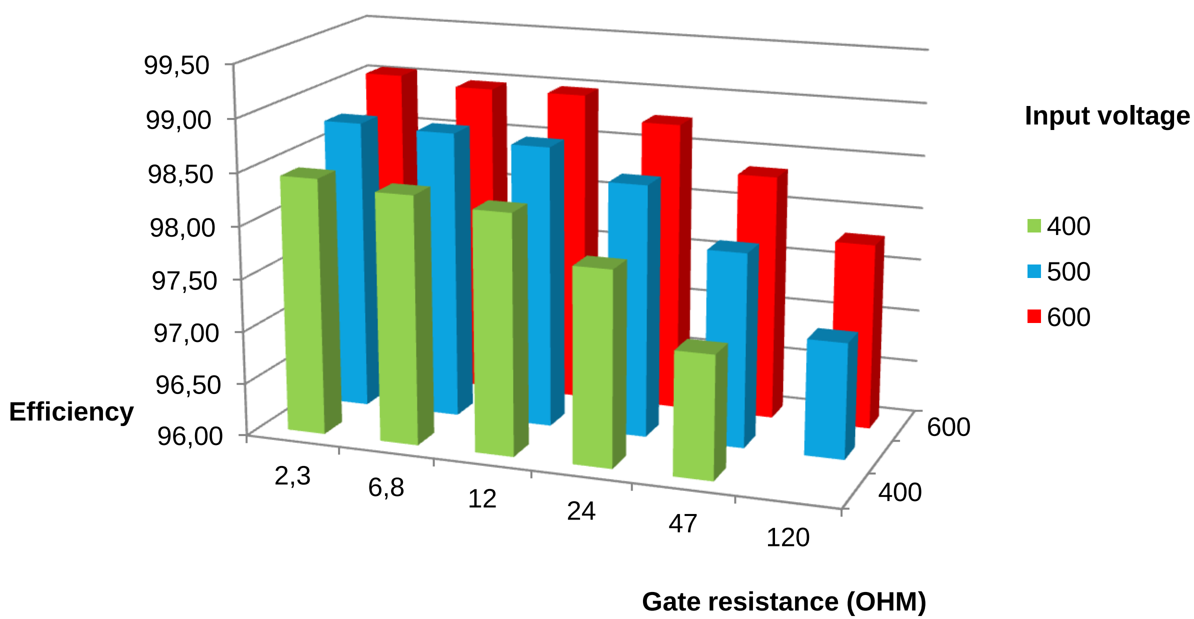


Overall efficiency vs gate resistor

Testing conditions:

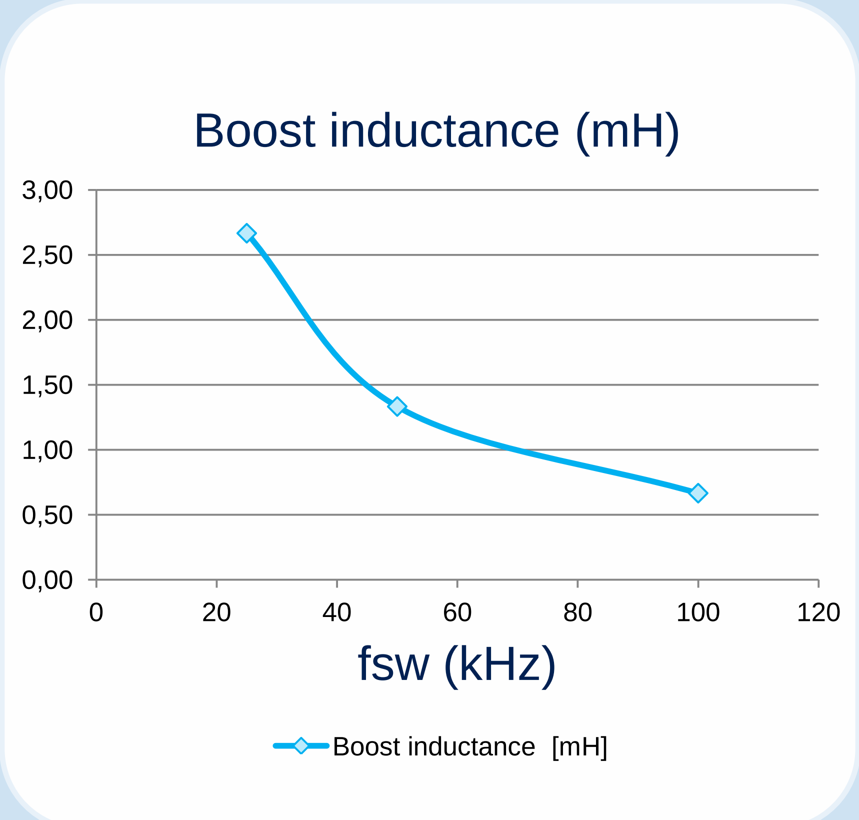
- **Input voltage 400, 500 and 600VDC, output voltage 800VDC, Rgate resistor 2.3OHM**
- **Switching frequency 60 kHz**
- **Output power - 4kW, Ambient temperature 25°C**
- **Results: Increasing of gate resistance decreasing of overall efficiency**

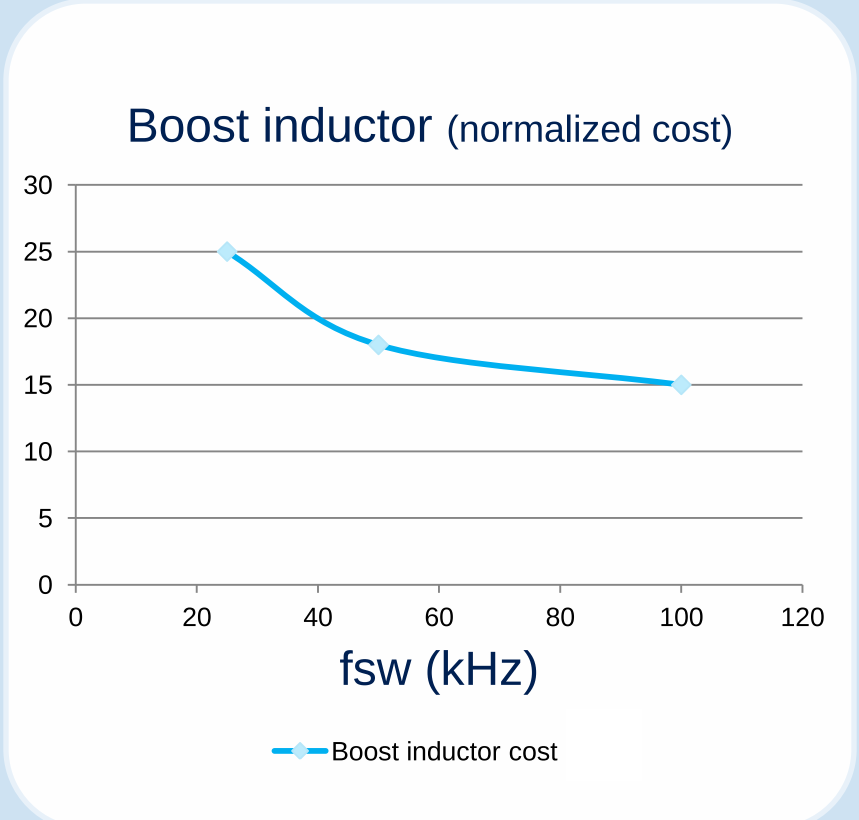
Efficiency versus to gate resistance



Inductor downsizing and cost saving

Inductor and cost patter vs. working frequency

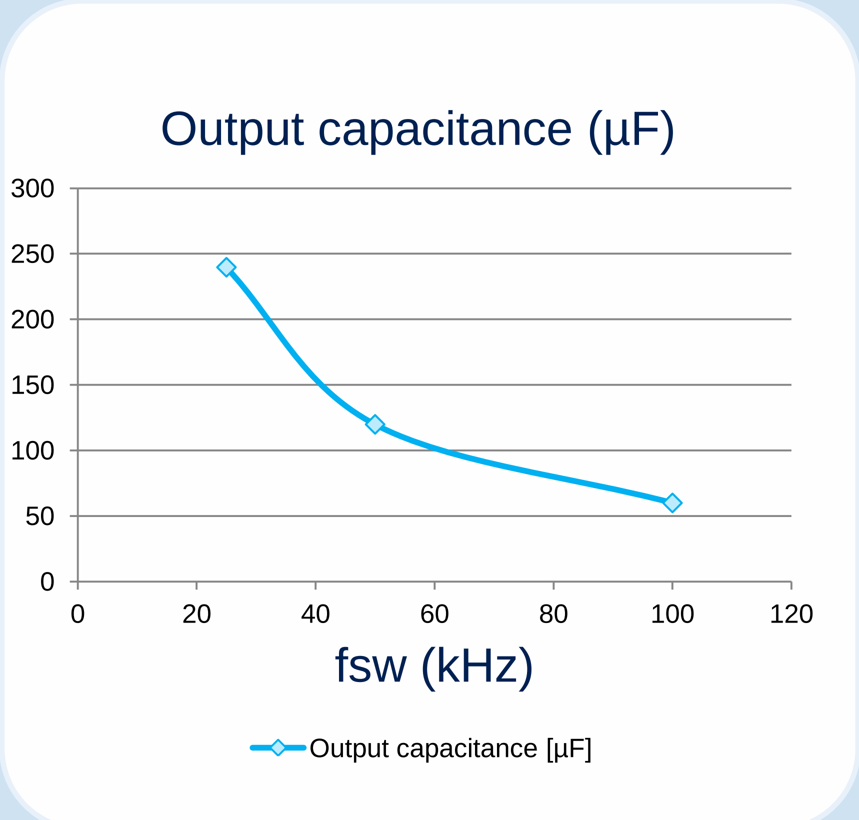


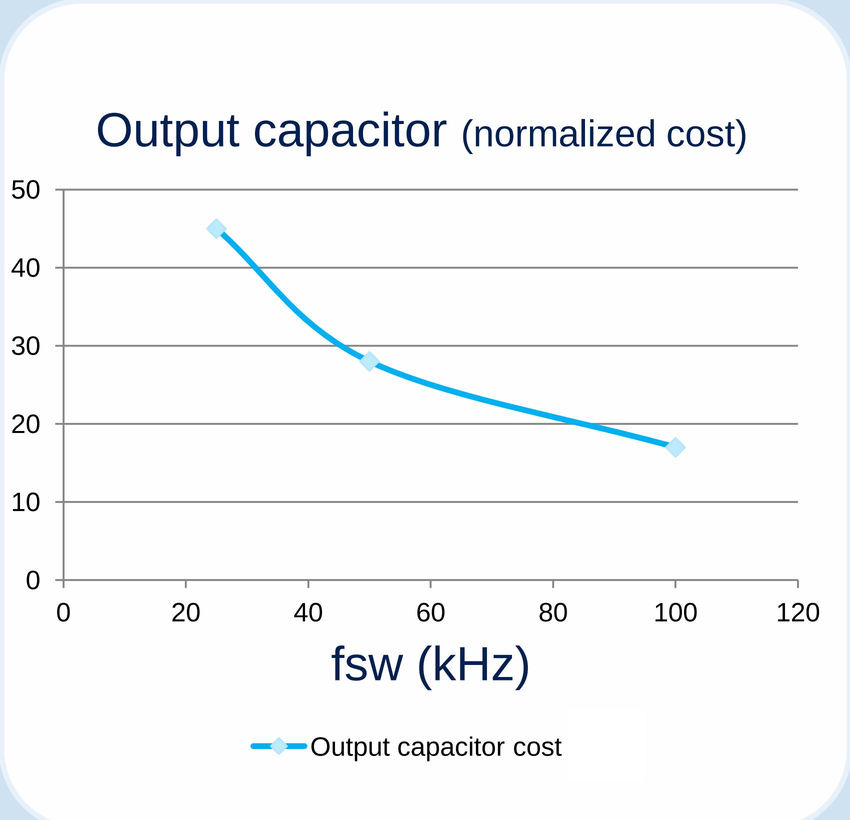


Conditions: 6kW DC/DC Boost Converter in CCM. Worst case for L calculation: V_{IN}=400V, V_{OUT}=800V, ΔI_{RIPPLE} =20%*$I_{AVG\text{-}max}$ @25kHz.

Out Cap downsizing and cost saving

Capacitance and cost patter vs. working frequency

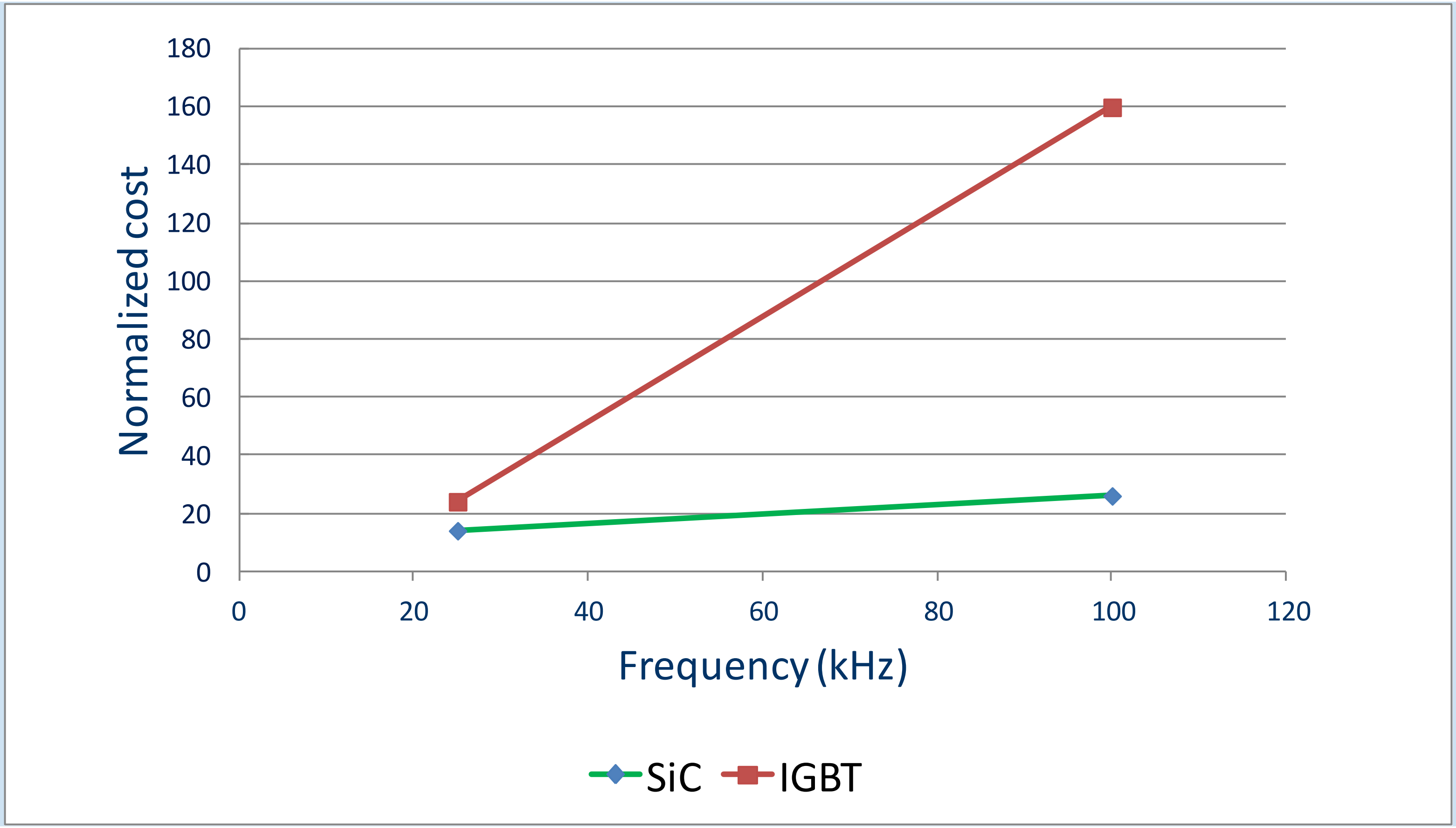




Conditions: 6kW DC/DC Boost Converter in CCM. Worst case for C calculation: V_{IN}=400V, V_{OUT}=800V. ΔV_{RIPPLE}=1V, L=2.67mH in order to make ΔI_{RIPPLE} =20%*$I_{AVG\text{-}max}$ @25kHz.

Heat sink cost vs. working frequency

Comparison between 1200V 25A IGBT and SCT30N120 SiC MOSFET



Conditions: DC/DC Boost Converter in CCM, V_{IN}=600V, V_{OUT}=800V, P_{OUT} up to 6kW, 2xSiC Diodes in parallel as Boost rectifier.

Evaluation board 1st prototype

Thanks for your attention

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