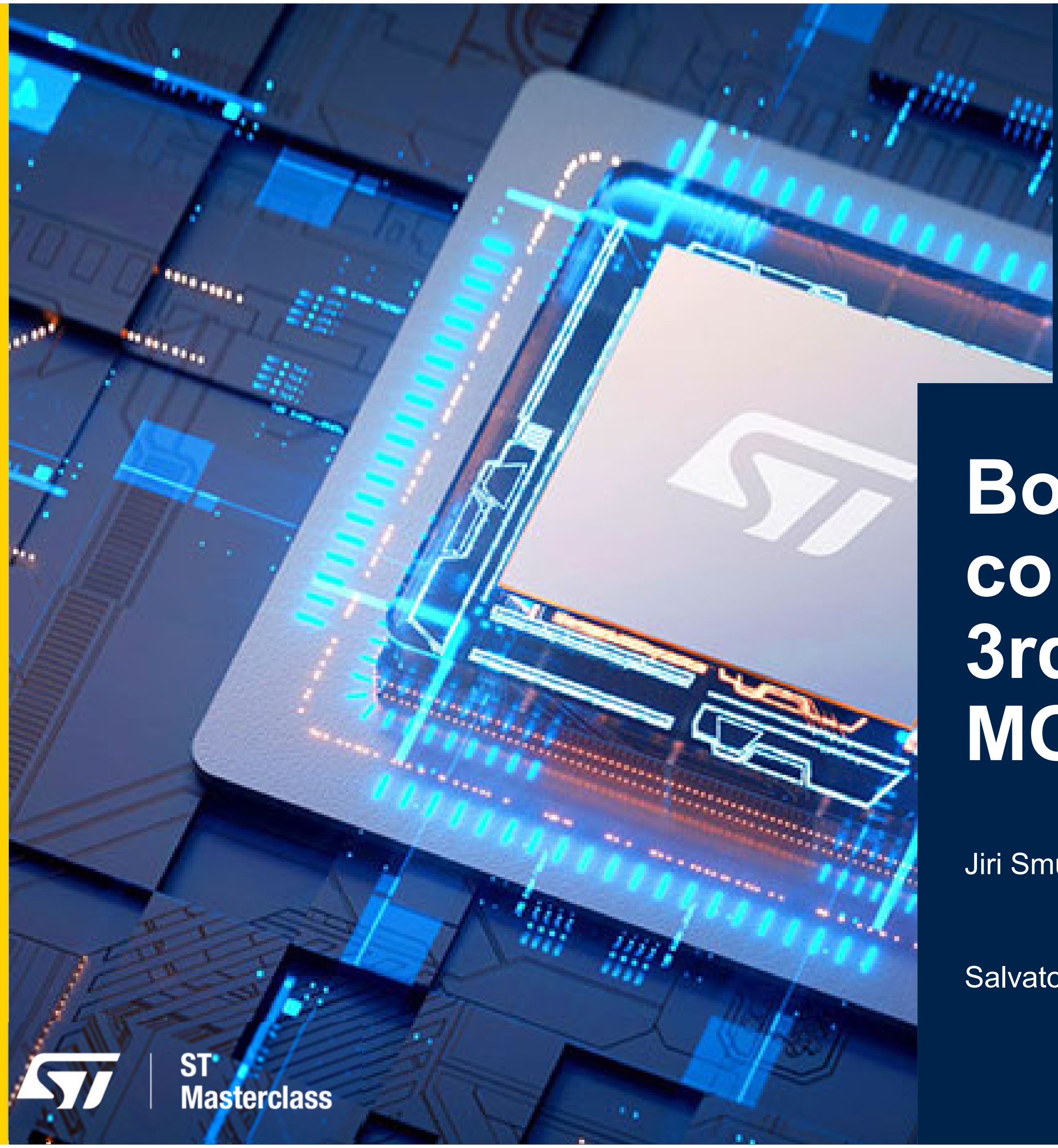

ST Masterclass

Boost your power conversion systems with 3rd generation of SiC-MOSFETs

Jiri Smutka - ST Prague - Application Engineer - EMEA

Salvatore La Mantia – ST Munich - Technical Marketing Manager – EMEA

Agenda

1 SiC MOSFETs evolution and driving

2 New generation performance improvement

3 Advanced Package Solutions

4 Supporting material

ST SiC Evolution – Gen 3

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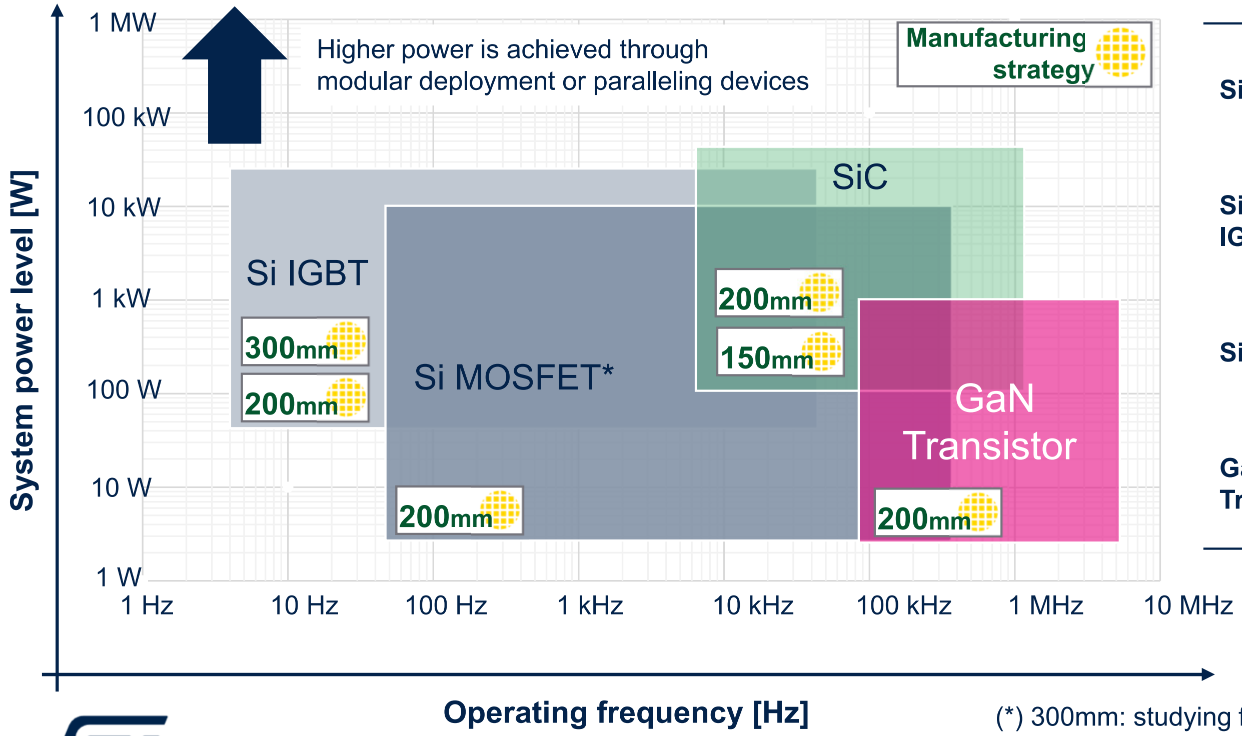
Silicon and wide-bandgap power technology positioning

A wide-ranging product offer targeting industrial and automotive power applications



Examples of power applications coverage

Si MOSFET	SMPS, server and telecom, DC-DC converter, low-power motor control, OBC, charging station, …
Si IGBT	HV motor control, home appliance, UPS, welding, induction heating, traction inverter, …
SiC	Charging station, UPS, Solar, High power DC-DC Converter, traction inverters, SMPS, OBC, …
GaN HEMT Transistor	SMPS, telecom power, DC-DC converter, OBC, PV inverters, LiDAR, …

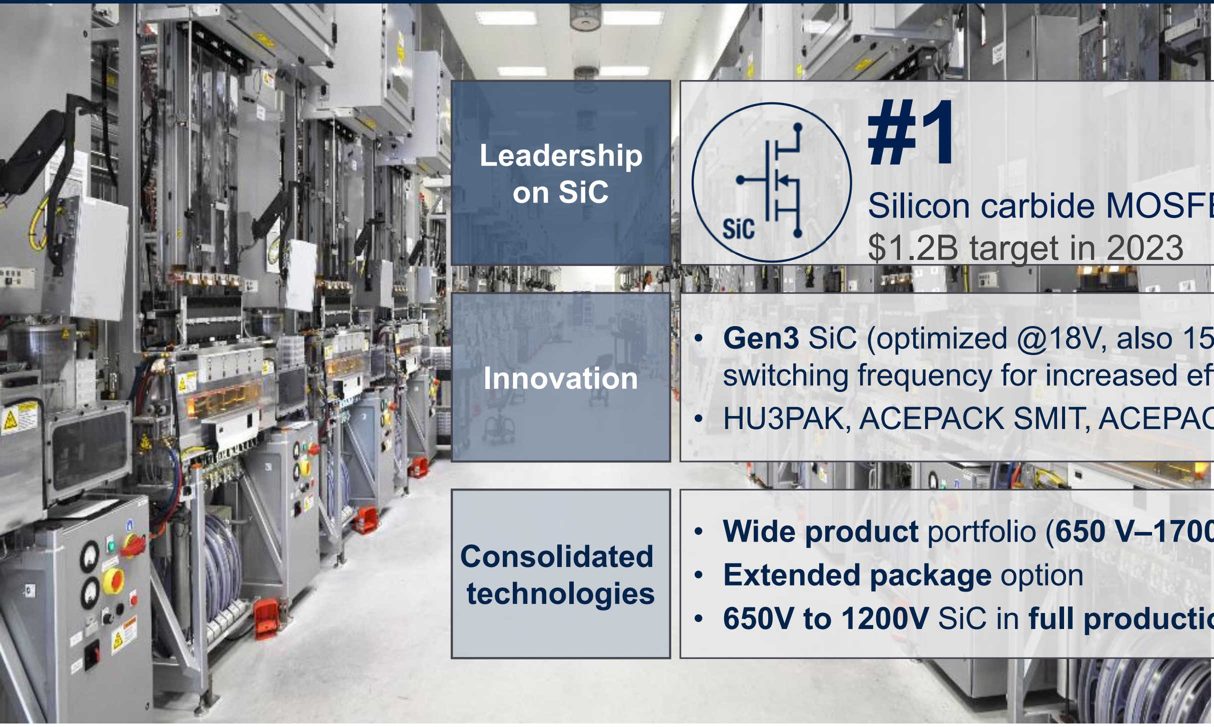
Industrial Automotive

(*) 300mm: studying future technology expansion for Silicon High Voltage Power MOSFET

Si = Silicon; SiC = Silicon Carbide

ST SiC leadership

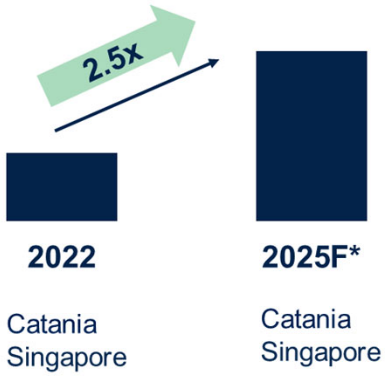
With breakthrough power technologies & packages



Leadership on SiC	**#1** Silicon carbide MOSFET $1.2B target in 2023
Innovation	• **Gen3** SiC (optimized @18V, also 15V gate drive; higher switching frequency for increased efficiency) • HU3PAK, ACEPACK SMIT, ACEPACK 1, 2
Consolidated technologies	• **Wide product** portfolio (**650 V–1700 V**) • **Extended package** option • **650V to 1200V** SiC in **full production**

Normalized F/E capacity evolution

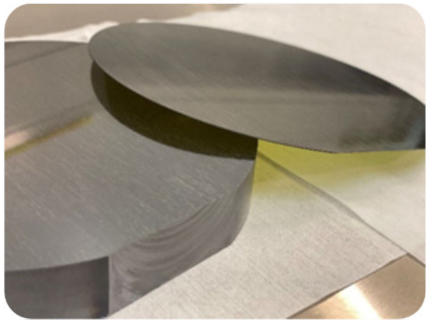
- **$1 billion** ST wafer substrates supply agreement
- Designing new plant for **>40% substrates internal sourcing** by 2024

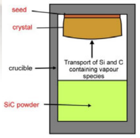


*Forecast

ST Silicon Carbide manufacturing strategy moving towards an integrated dual Fab (**synoptic view**)

Substrate Technology
From Powder to Ingot

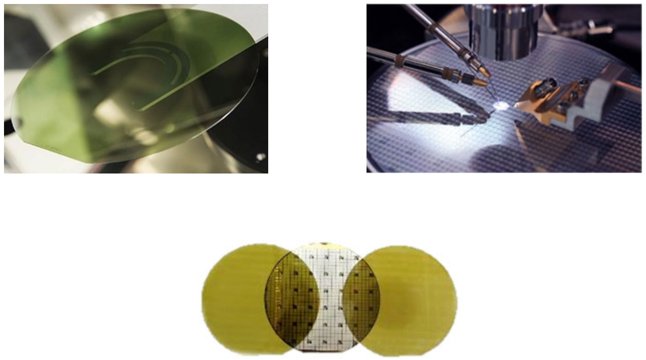




Norrköping (R&D)

Catania substrate Fab ready by 2023

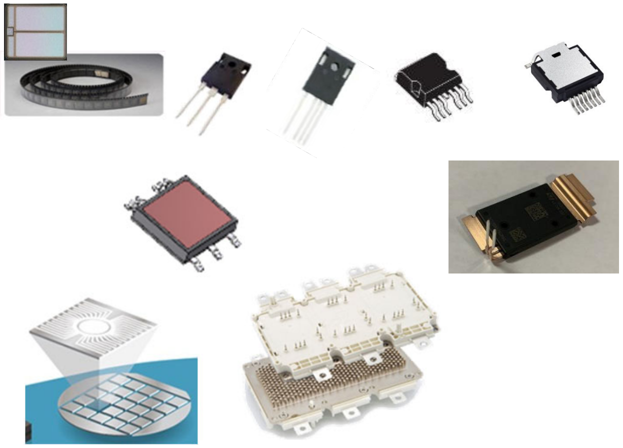
Front-End Technology with Epy and EWS testing



Catania

AMK (S'pore)

Backend Technology Bare dice, discrete, Modules



Shenzhen(China)

Bouskoura (Marocco)

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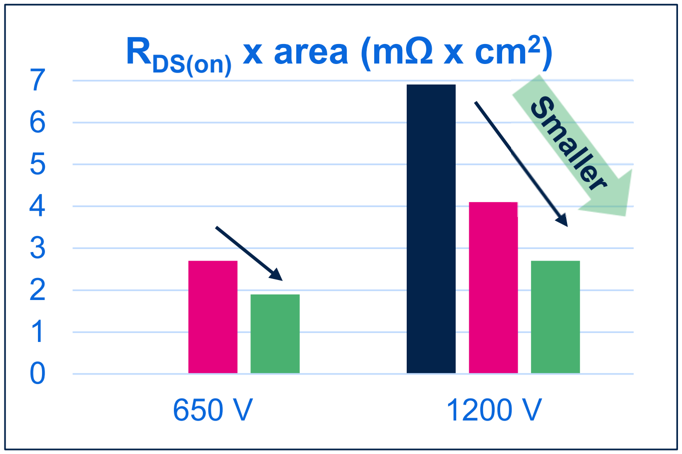
STPOWER SiC MOSFET
families overview

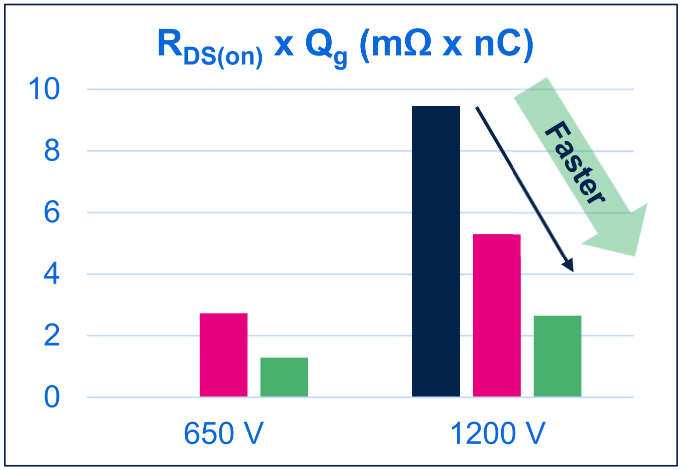
The best high voltage and high frequency switch for high density applications

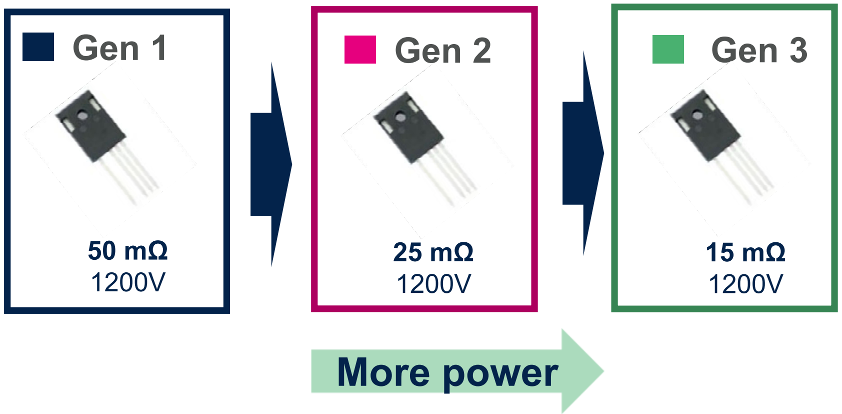
Gen1 **1200V-1700V**	Excellent **Ron vs. Tj** behavior: very suitable for SMPS and medium power Motor Drive Optimized @ **Vgs 20V**
Gen2 **650V, 1200V**	Outstanding **Ron vs. Qg trade-off** : highly suitable for a broad range of automotive and industrial applications Optimized @ **Vgs 18V**
Gen3 **650V, 750V, 900V, 1200V**	**The best Ron vs. Qg trade off:** highly suitable for very high frequency applications Industrial & Automotive Optimized @ **Vgs 18V**, enables **15V** gate drive **too**

SiC MOSFET advances in technology

Figure of merits







Improvement in MOSFET generations

Lower Ron x Area

- Lower conduction Losses
- Higher power achievable with the same form factor

Lower Ron x Qg

- Lower switching losses, higher frequency
- Smaller board size

STPOWER SiC MOSFET positioning

Breakdown voltage	**650V**		**750V / 900V**	**1200V**			**1700V**
Series	G2	G3	G3	G1	G2	G3	G1
On-state resistance	18–55 mΩ	14–55 mΩ	11 mΩ (750) 12 mΩ (900)	52–500 mΩ	25–75 mΩ	8–69 mΩ	1 Ω and 64 mΩ

Focus applications

SMPS and Energy Conversion
- Power Supply
- LED Lighting

Energy Conversion & Storage
- Welding
- UPS
- Solar Inverter

Motor Drive
- Industrial Motor

E-Mobility
- EV Charger
- DCDC, OBC
- Traction

Industrial **Automotive**

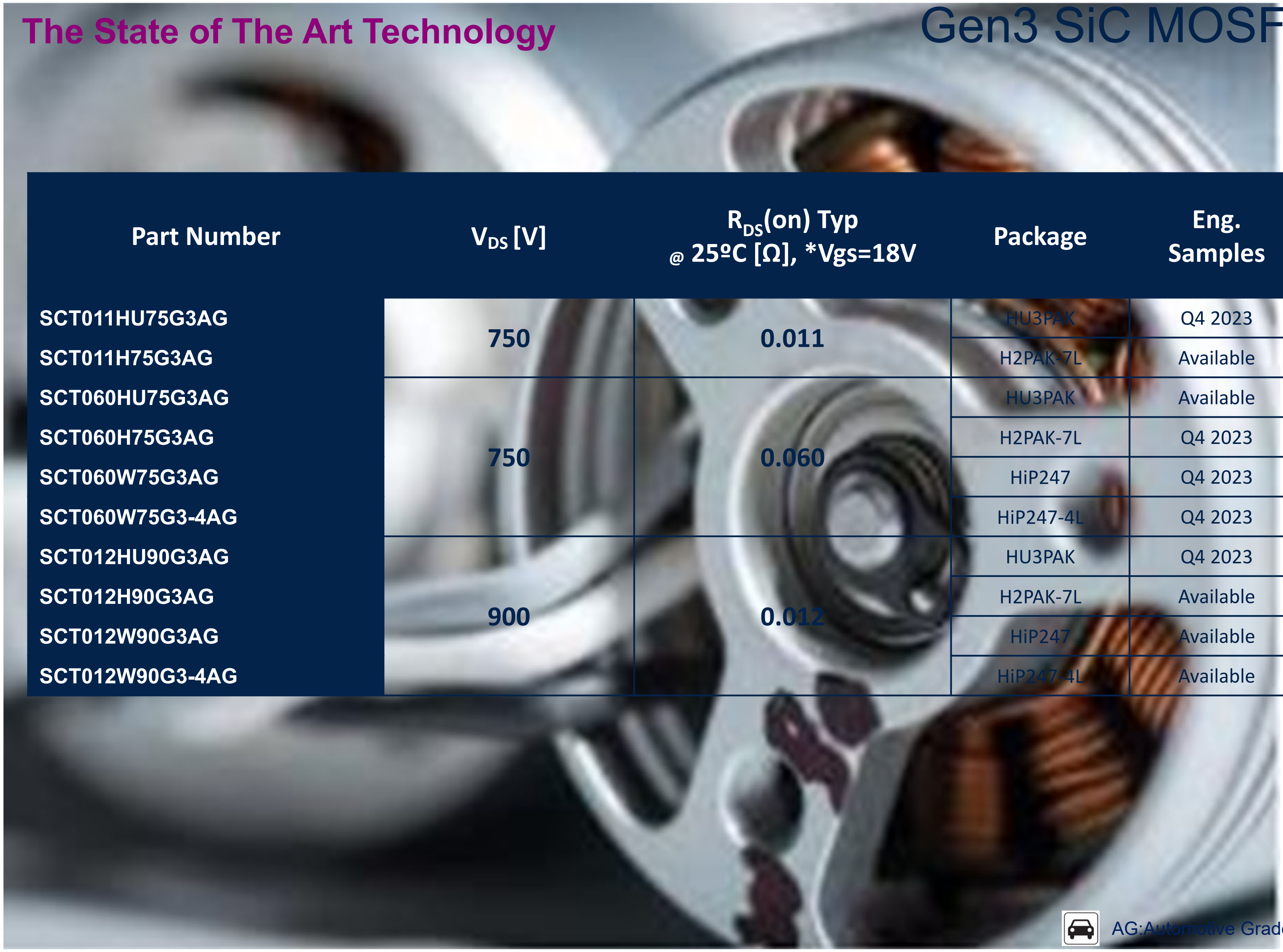
The State of The Art Technology

Gen3 SiC MOSFET Product Plan

650V Discrete

Part Number	V_{DS} [V]	R_{DS}(on) Typ @ 25ºC [Ω], *Vgs=18V	Package	Eng. Samples	Commercial Mat.
SCT055HU65G3AG	650	0.055	HU3PAK	Available	**Achieved** 🚗
SCT055H65G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT055W65G3AG			HiP247	Available	**Q1 2024** 🚗
SCT055W65G3-4AG			HiP247 4L (LL)	Available	**Achieved** 🚗
SCT040HU65G3AG	650	0.040	HU3PAK	Available	**Achieved** 🚗
SCT040H65G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT040W65G3AG			HiP247	Available	**Q1 2024** 🚗
SCT027W65G3AG	650	0.027	HiP247	Available	**Q1 2024** 🚗
SCT027HU65G3AG			HU3PAK	Q4 2023	**Q1 2024** 🚗
SCT027H65G3AG			H2PAK-7L	Available	Available 🚗
SCT027W65G3-4AG			HiP247 4L (LL)	Available	Available 🚗
SCT018W65G3AG	650	0.020	HiP247	Available	**Q1 2024** 🚗
SCT018HU65G3AG			HU3PAK	Q4 2023	**Q1 2024** 🚗
SCT018H65G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT018W65G3-4AG			HiP247 4L (LL)	Available	**Q1 2024** 🚗
SCT014HU65G3AG	650	0.014	HU3PAK	Q4 2023	**Q1 2024** 🚗
SCT014H65G3AG		0.014	H2PAK-7L	Q2 2024	**Q3 2024** 🚗
SCT014W65G3-4AG		0.014	HiP247 4L (LL)	Q2 2024	**Q3 2024** 🚗

🚗 Automotive Grade - AECQ 101 Compliant



The State of The Art Technology

Gen3 SiC MOSFET Product Plan

750/900V Discrete

Part Number	V_{DS} [V]	R_{DS}(on) Typ @ 25ºC [Ω], *Vgs=18V	Package	Eng. Samples	Commercial Mat.	
SCT011HU75G3AG	**750**	**0.011**	HU3PAK	Q4 2023	**Q1 2024**	🚗
SCT011H75G3AG			H2PAK-7L	Available	**Achieved**	🚗
SCT060HU75G3AG	**750**	**0.060**	HU3PAK	Available	**Achieved**	🚗
SCT060H75G3AG			H2PAK-7L	Q4 2023	**Q1 2024**	🚗
SCT060W75G3AG			HiP247	Q4 2023	**Q1 2024**	🚗
SCT060W75G3-4AG			HiP247-4L	Q4 2023	**Q1 2024**	🚗
SCT012HU90G3AG	**900**	**0.012**	HU3PAK	Q4 2023	**Q1 2024**	🚗
SCT012H90G3AG			H2PAK-7L	Available	**Achieved**	🚗
SCT012W90G3AG			HiP247	Available	**Achieved**	🚗
SCT012W90G3-4AG			HiP247-4L	Available	**Q1 2024**	🚗

🚗 AG:Automotive Grade - AECQ 101 Compliant

The State of The Art Technology

Gen3 SiC MOSFET Product Plan

1200V Discrete

Part Number	V_{DS} [V]	R_{DS}(on) Typ @ 25ºC [Ω], *Vgs=18V	Package	Eng. Samples	Commercial Mat.
SCT070HU120G3AG	1200	0.063	HU3PAK	Available	**Achieved** 🚗
SCT070H120G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT070W120G3AG			HiP247	Available	**Achieved** 🚗
SCT070W120G3-4AG			HiP247 4L (LL)	Available	**Q1 2024** 🚗
SCT040HU120G3AG	1200	0.040	HU3PAK	Q3 2023	**Q1 2024** 🚗
SCT040H120G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT040W120G3AG			HiP247	Available	**Achieved** 🚗
SCT040W120G3-4AG			HiP247 4L (LL)	Available	**Achieved** 🚗
SCT025HU120G3AG	1200	0.027	HU3PAK	Q3 2023	**Q1 2024** 🚗
SCT025H120G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT025W120G3AG			HiP247	Available	**Q1 2024** 🚗
SCT025W120G3-4AG			HiP247 4L (LL)	Available	**Achieved** 🚗
SCT020HU120G3AG	1200	0.0185	HU3PAK	Q4 2023	**Q1 2024** 🚗
SCT020H120G3AG			H2PAK-7L	Available	**Achieved** 🚗
SCT025W120G3-4AG			HiP247 4L (LL)	Available	**Achieved** 🚗
SCT016H120G3AG	1200	0.016	H2PAK-7L	Available	**Q1 2024** 🚗
SCT016HU120G3AG			HU3PAK	Q4 2023	**Q1 2024** 🚗
SCT015W120G3-4AG	1200	0.015	HiP247-4L	Available	**Achieved** 🚗

🚗 AG:Automotive Grade - AECQ 101 Compliant

SiC MOSFET Driving

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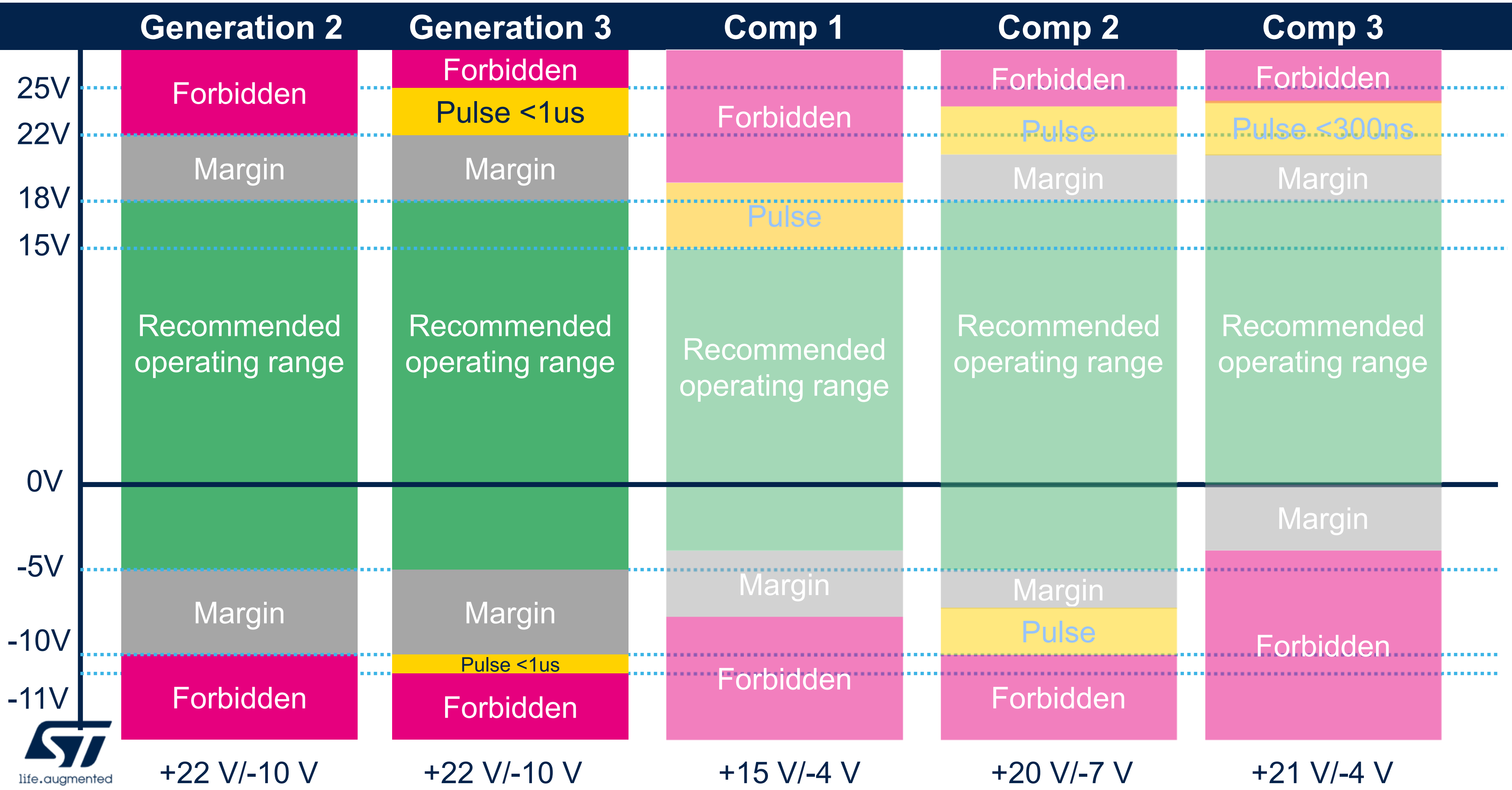
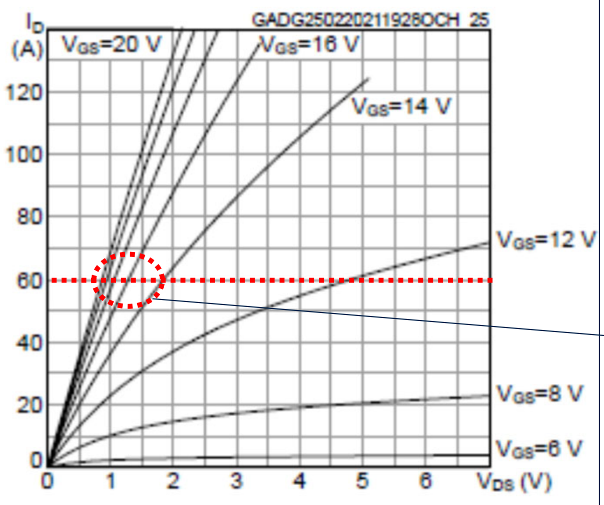
Typical Gate voltage range AMR



SiC Gen 3 MOSFETs Vgs Driving
→ 18V for best Ron but 15V possible too

Figure 3. **Typical output characteristics (T_J = 25 °C)**



Ron vs Tj @ 60A

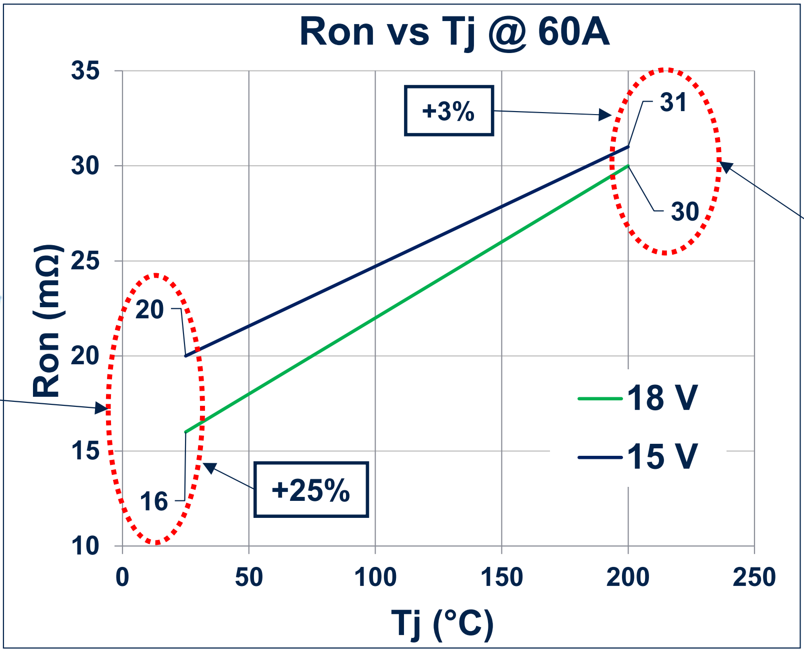
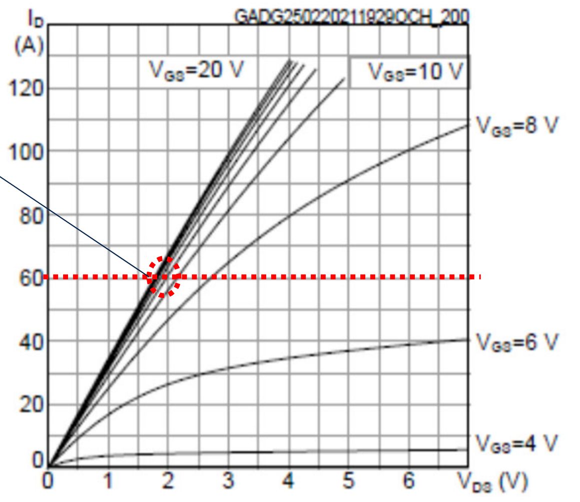


Figure 4. **Typical output characteristics (T_J = 200 °C)**



- **Gen3 Vgs Driving**
  - **Vgs recommended : 18V**
  - **Driving @ 15 V, possible but with higher Rdson (about + 25%)**
  - **Switching losses not significantly impacted (Rg fine –tuning)**
  - **As a reference, see above example on a specific Gen 3 product (SCT130N120G3D8AG)**

$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 60 A		16	22	mΩ
		V_{GS} = 15 V, I_D = 60 A		20		
		V_{GS} = 18 V, I_D = 60 A, T_J = 200 °C		30		

STGAP2SiCx & STGAP4S

Driver for SiC

Different flavors for different market

STGAP4S

AEC-Q100 grade 1
6 kV basic isolation
1200 V Pre-Driver

Optimized topology pre-driver for MOSFET & SiC MOS Push-Pull with integrated Flyback, SPI programmability and diagnostic, Desat, OCP, UVLO, OVLO, 2LTO, integrated filter, Negative supply

STGAP2SiCxN

Industrial grade
AEC-Q100 grade 1
4.8 kV functional isolation
1700 V Driver

Single channel driver for simple & compact layout (So-8 or So-16) for SiC MOS with Miller Clamp or separate options and
4 A sink/source

STGAP2SICx & STGAP2SiCD

Industrial grade
AEC-Q100 grade 1
6 kV basic isolation
1200 V Driver

Single & Dual channel, So-8 wide 8mm distance, SiC driver with Miller Clamp or separate outputs options and 4 A sink/source

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Testing – G2 vs G3

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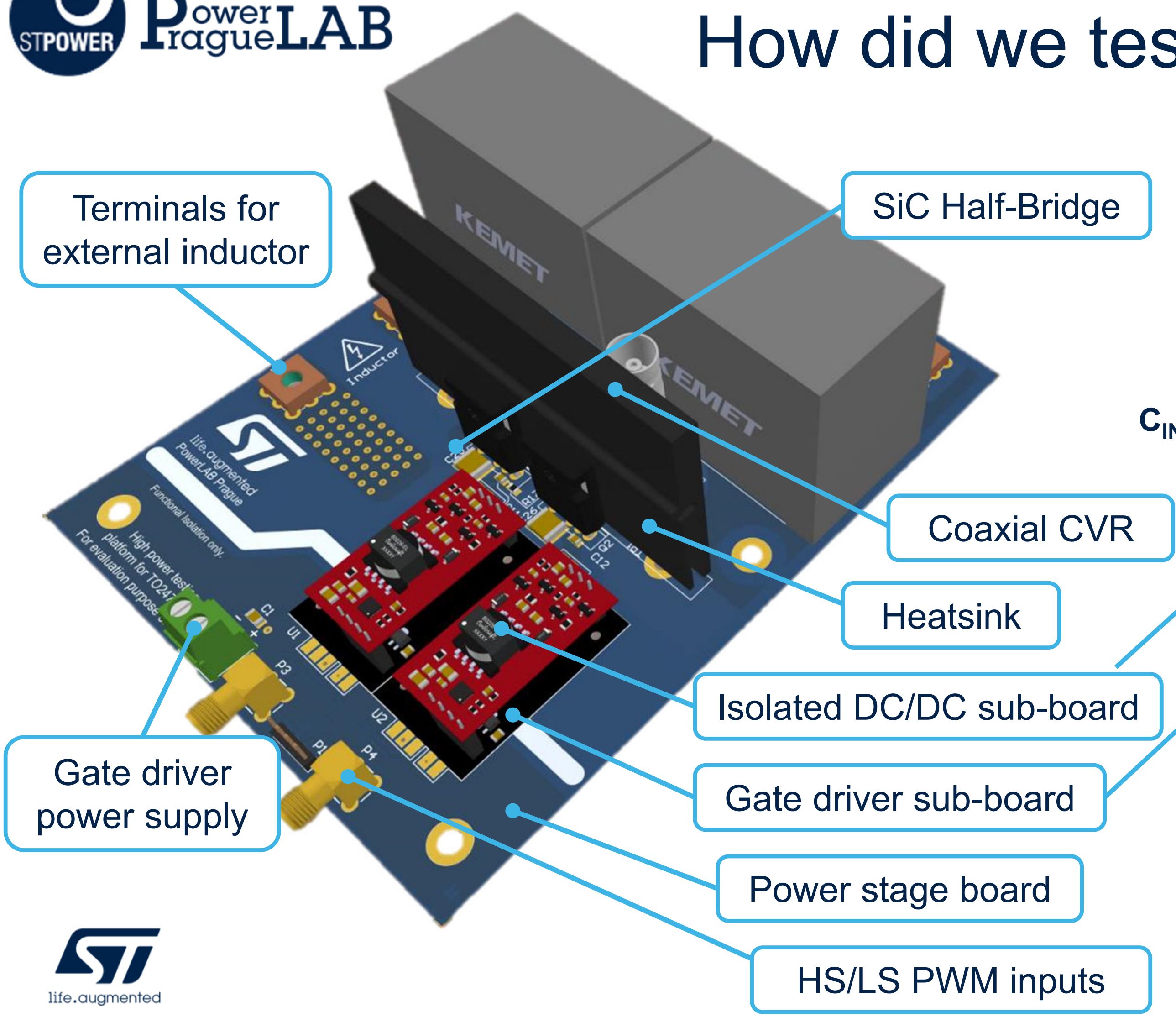
How did we test? – Test platform 1/2



Terminals for external inductor

SiC Half-Bridge

Coaxial CVR

Heatsink

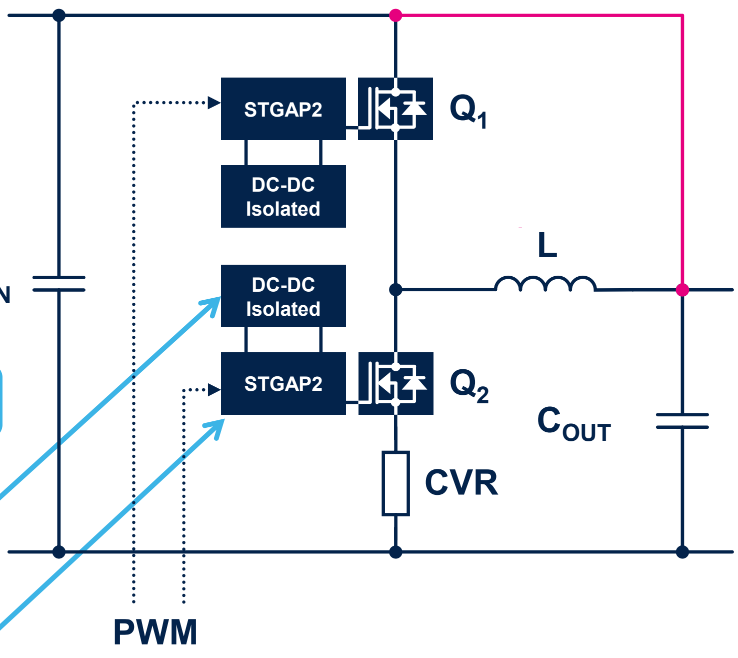
Isolated DC/DC sub-board

Gate driver sub-board

Gate driver power supply

Power stage board

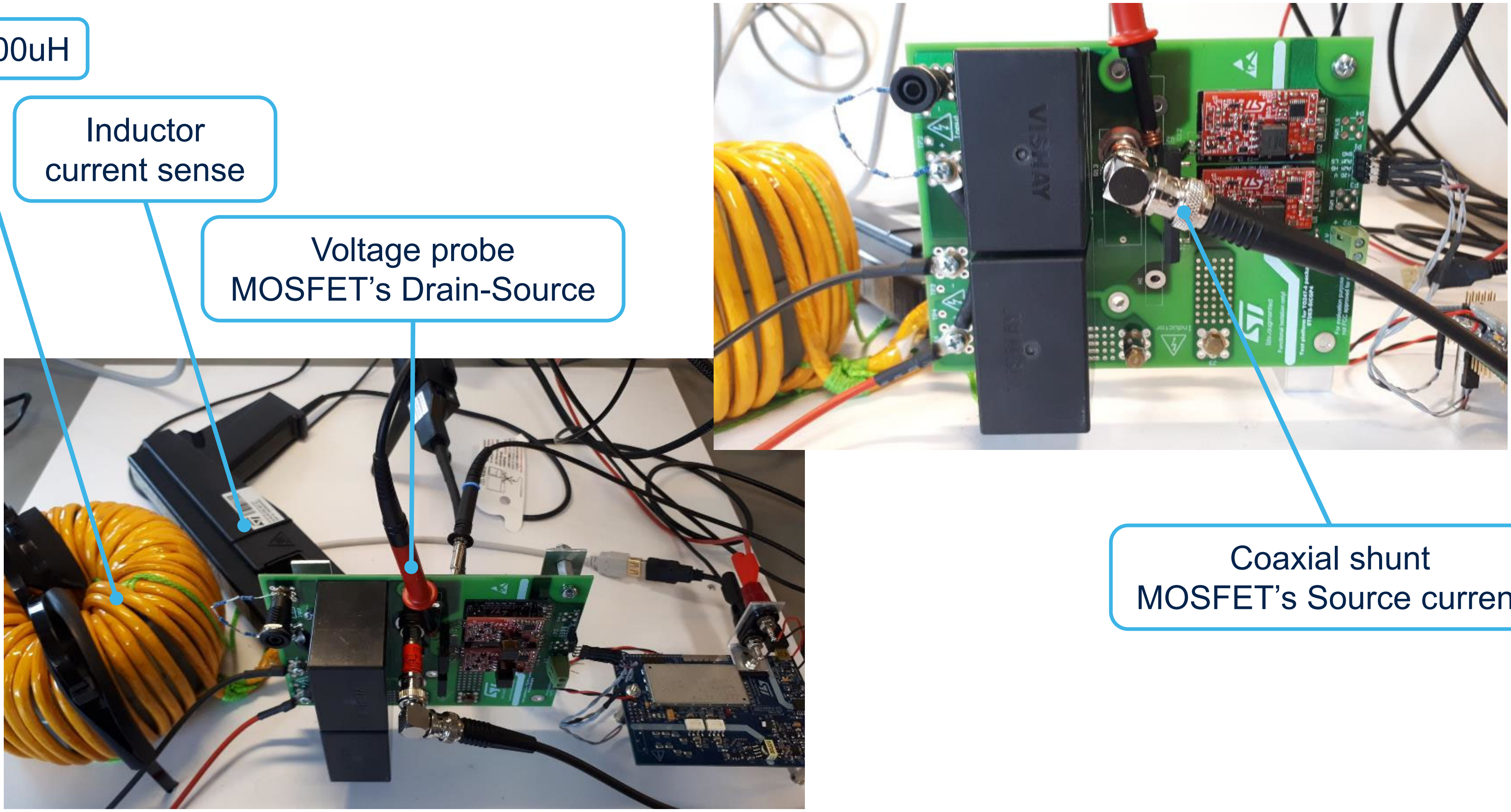
HS/LS PWM inputs



Deliverables

- **SiC MOSFET switching behavior, in combination with Switch/Diode**
- **Dynamic losses of power semiconductors**
- **Reference design for STGAP2**
- **Reference design for DC/DC converter**

How did we test? – Test platform 2/2



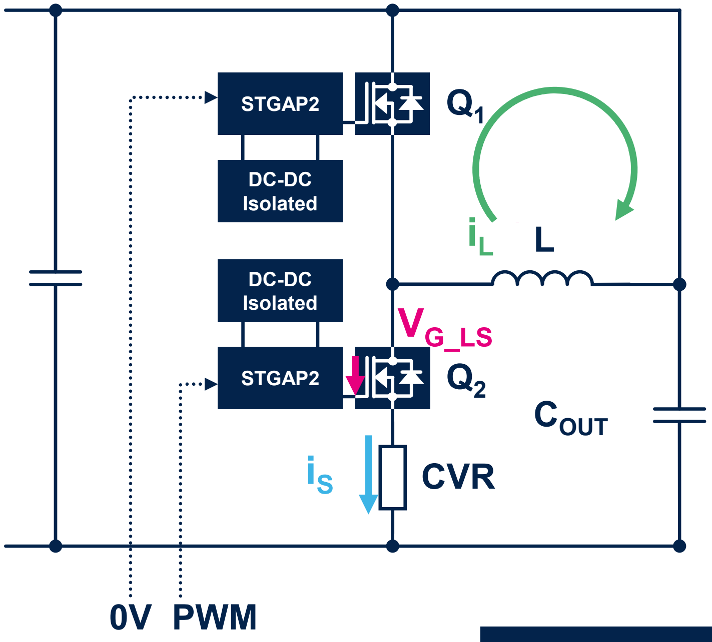
Inductor 500uH

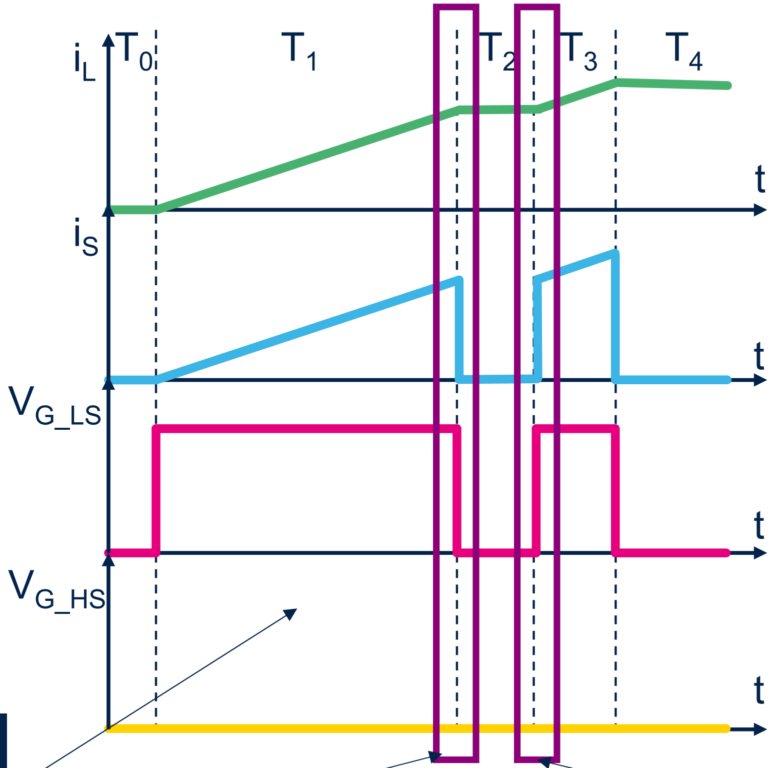
Inductor current sense

Voltage probe MOSFET’s Drain-Source

Coaxial shunt MOSFET’s Source current

How did we test? – Measurement method





Set current depending on the time duration

Turn OFF measurement

Turn ON measurement

How did we test? – Measurement tools

- **MOSFET Source current measurement**
  - T&M 50mΩ
  - SSDN-414-05 – coaxial shunt
  - Bandwidth 1000MHz

- **MOSFET Drain-Source and Gate-Source measurement**
  - TIVP05 - IsoVu Isolated Probe
  - 500MHz, 9.75 MΩ || 3.5 pF, 50 dB & 100MHz
  - Isolation – optical fiber

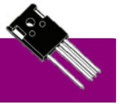
- **Scope**
  - Tektronix
  - MSO66B
  - Bandwidth 1000MHz

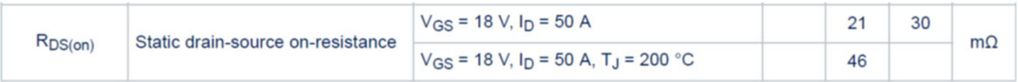
- **Voltage Source**
  - Thaoxin
  - KNX-15001D

STPOWER PowerPragueLAB

What did we test? - Gen2 vs Gen3

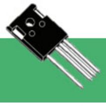
SCTWA70N120G2V-4

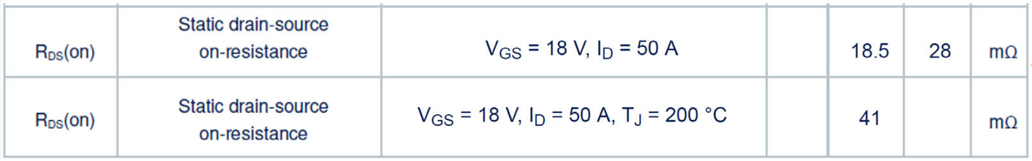




$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A		21	30	mΩ
		V_{GS} = 18 V, I_D = 50 A, T_J = 200 °C		46		

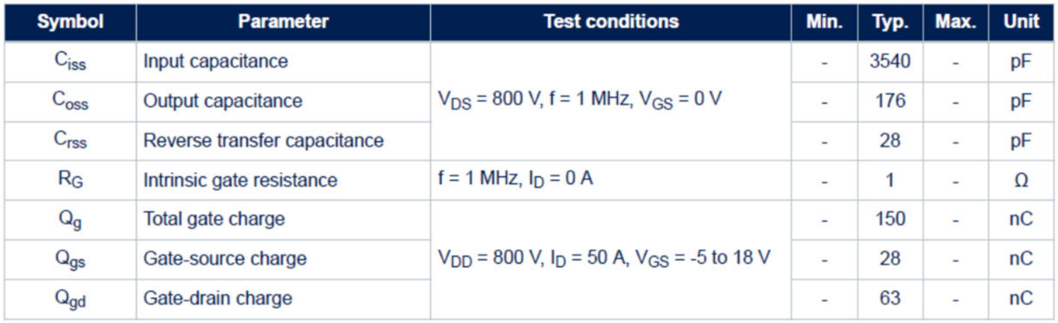
SCT020W120G3-4AG



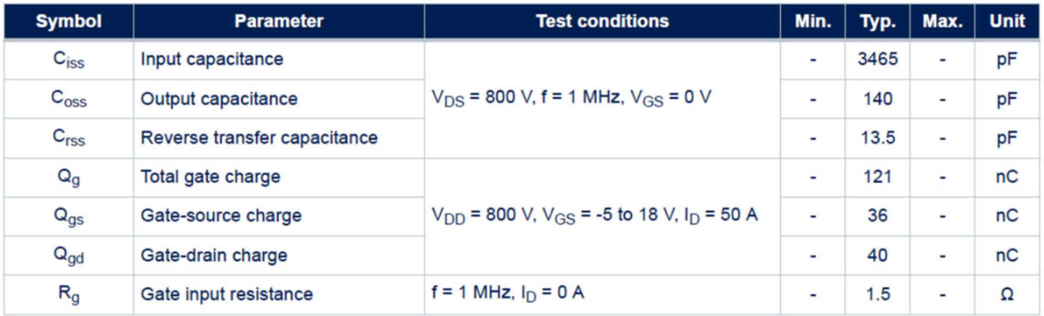


R_{DS}(on)	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A		18.5	28	mΩ
R_{DS}(on)	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A, T_J = 200 °C		41		mΩ

SCT020W120G3-4AG (18.5mΩ) has similar Rdson compare SCTW70N120G2V-4 (21.0mΩ)



Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 800 V, f = 1 MHz, V_{GS} = 0 V	-	3540	-	pF
C_{oss}	Output capacitance		-	176	-	pF
C_{rss}	Reverse transfer capacitance		-	28	-	pF
R_G	Intrinsic gate resistance	f = 1 MHz, I_D = 0 A	-	1	-	Ω
Q_g	Total gate charge	V_{DD} = 800 V, I_D = 50 A, V_{GS} = -5 to 18 V	-	150	-	nC
Q_{gs}	Gate-source charge		-	28	-	nC
Q_{gd}	Gate-drain charge		-	63	-	nC



Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 800 V, f = 1 MHz, V_{GS} = 0 V	-	3465	-	pF
C_{oss}	Output capacitance		-	140	-	pF
C_{rss}	Reverse transfer capacitance		-	13.5	-	pF
Q_g	Total gate charge	V_{DD} = 800 V, V_{GS} = -5 to 18 V, I_D = 50 A	-	121	-	nC
Q_{gs}	Gate-source charge		-	36	-	nC
Q_{gd}	Gate-drain charge		-	40	-	nC
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1.5	-	Ω

SCT020W120G3-4AG has lower Rdson and basic dynamic parameters compare to SCTW70N120G2V-4

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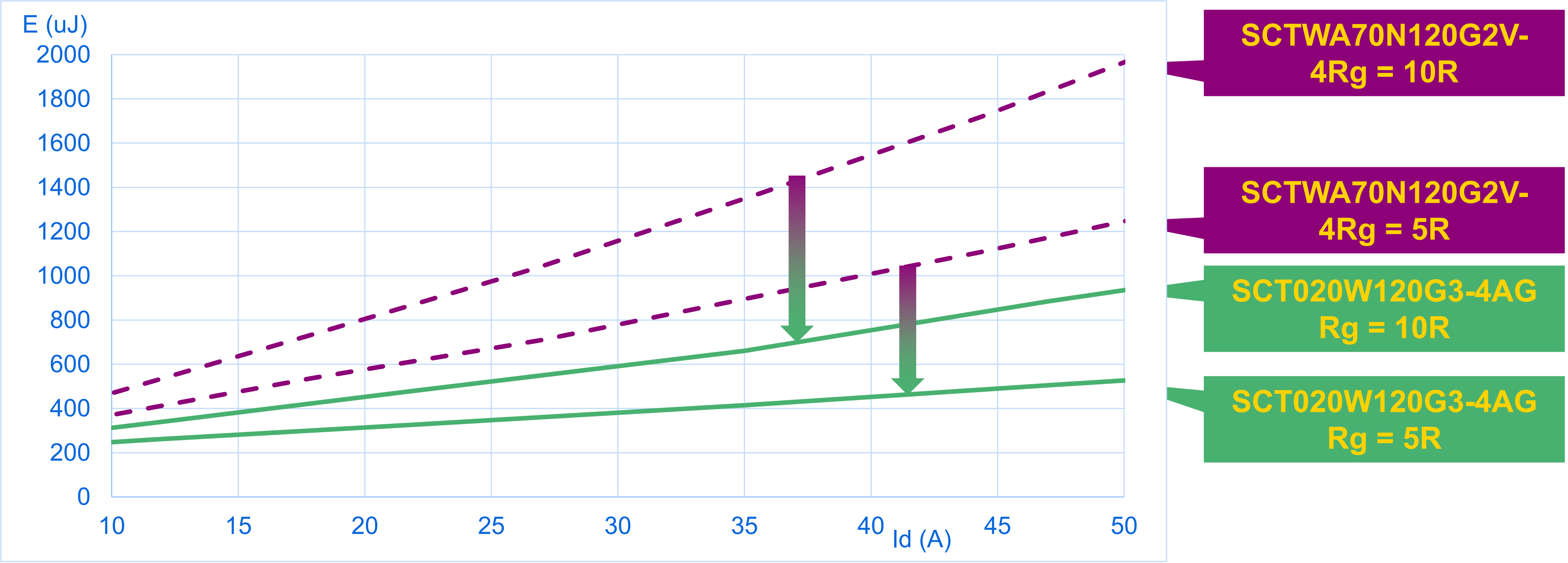
Result Comparison G2 vs G3 – Turn ON

SCTWA70N120G2V-4

SCT020W120G3-4AG



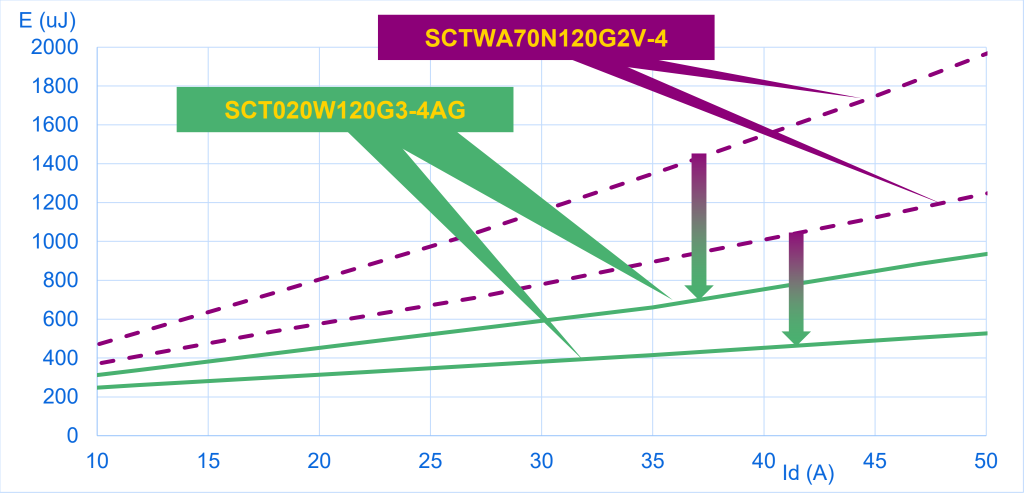
There is significant drop of Tun ON energy

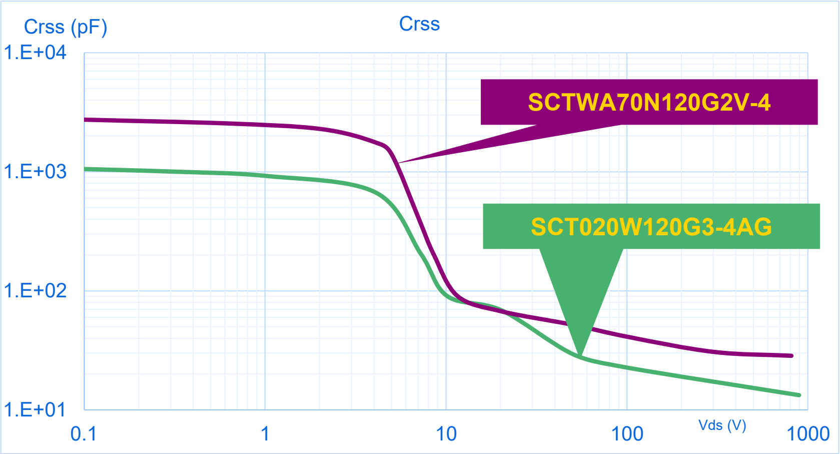
Result Comparison G2 vs G3 – Turn ON

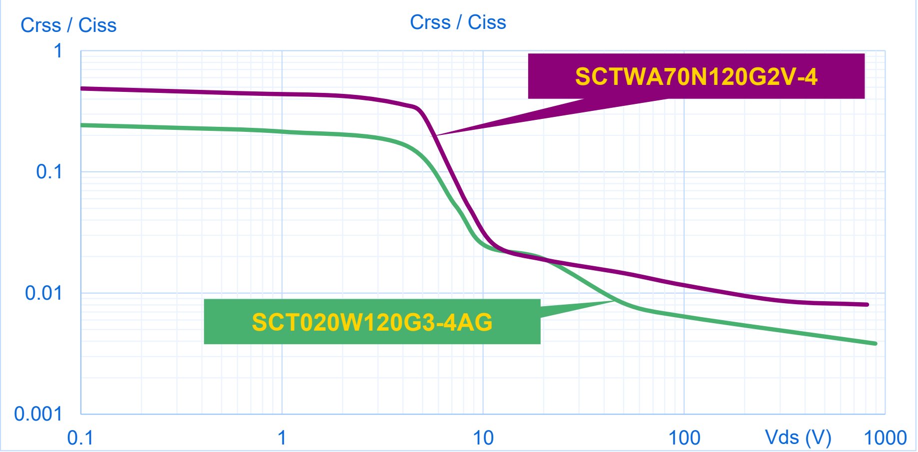
SCTWA70N120G2V-4

SCT020W120G3-4AG

Improvement of Tun ON energy
G3 reducing Crss and ratio of Crss/Ciss
The Crss affecting gate during transient. Reduction of this value improves speed of transient.







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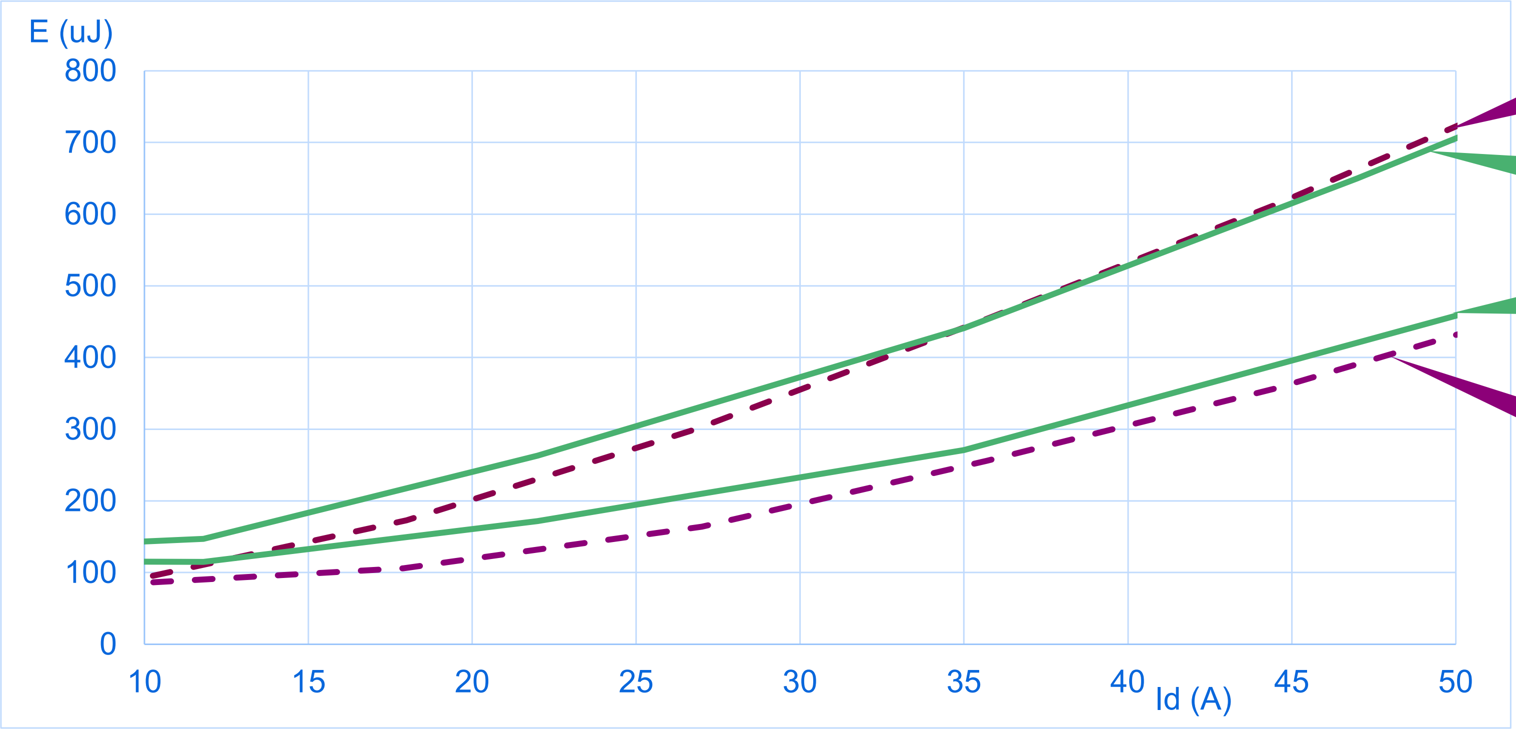
Result Comparison G2 vs G3 – Turn OFF

SCTWA70N120G2V-4

SCT020W120G3-4AG



SCTWA70N120G2V-4Rg = 10R

SCT020W120G3-4AG Rg = 10R

SCT020W120G3-4AG Rg = 5R

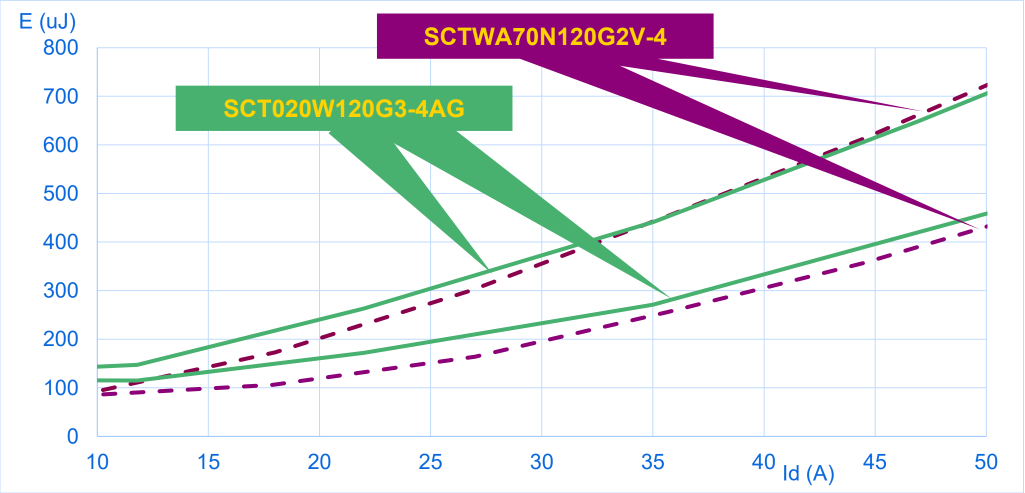
SCTWA70N120G2V-4Rg = 5R

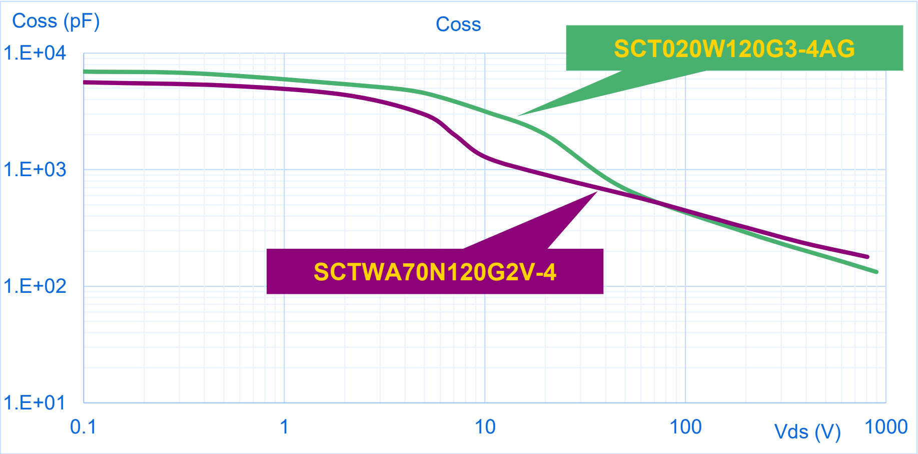
There is marginal difference between G2 and G3 in Turn OFF

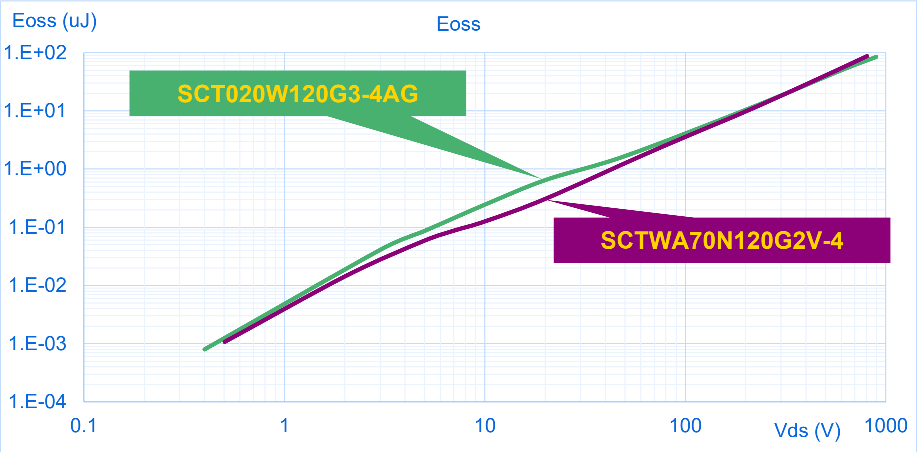
Result Comparison G2 vs G3 – Turn OFF

SCTWA70N120G2V-4

SCT020W120G3-4AG







Why Eoff is similar for both parts?
Here the dominant part is energy stored in Coss and this value is similar for both chips.

life.augmented

Conclusion

- ST introduced new Gen3 SiC MOSFETs technology
- Compared to previous technology we get:

✓Improved $R_{DS(on)}$*area → Lower Conduction Losses[1]

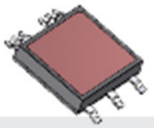
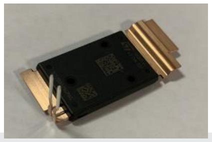
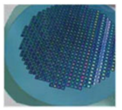
✓Improved FOM $R_{DS(on)}$* Qg → Better Switching Performances[1]

  - ➢ Much lower Eon (thanks improvement of Crss capacitance profile)
  - ➢ Comparable Eoff and Eoss

[1] For same class RDS(on) devivices

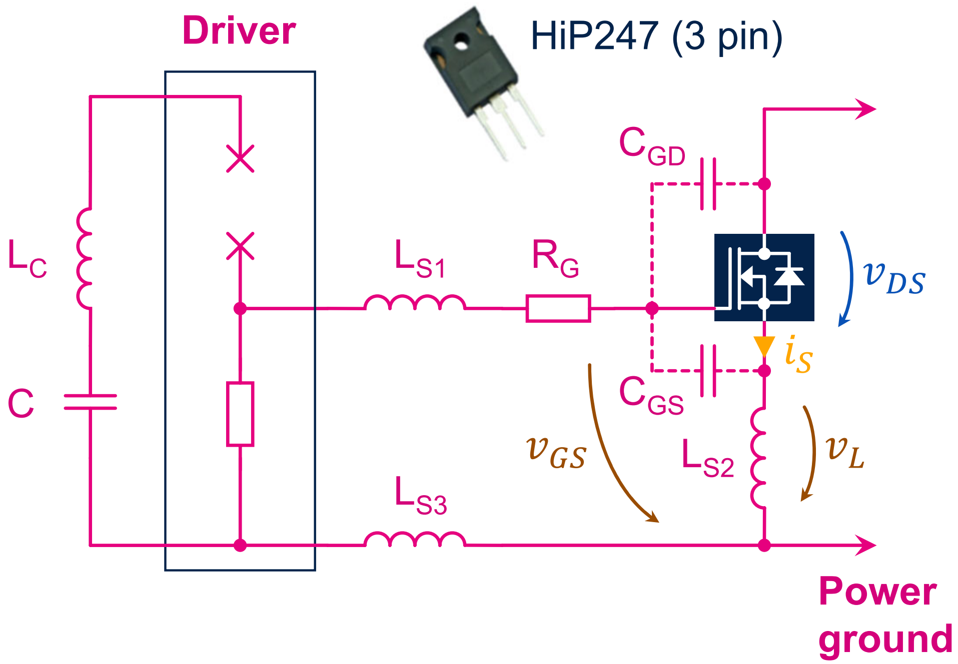
Advanced Package Solutions

SiC MOSFET Package Roadmap

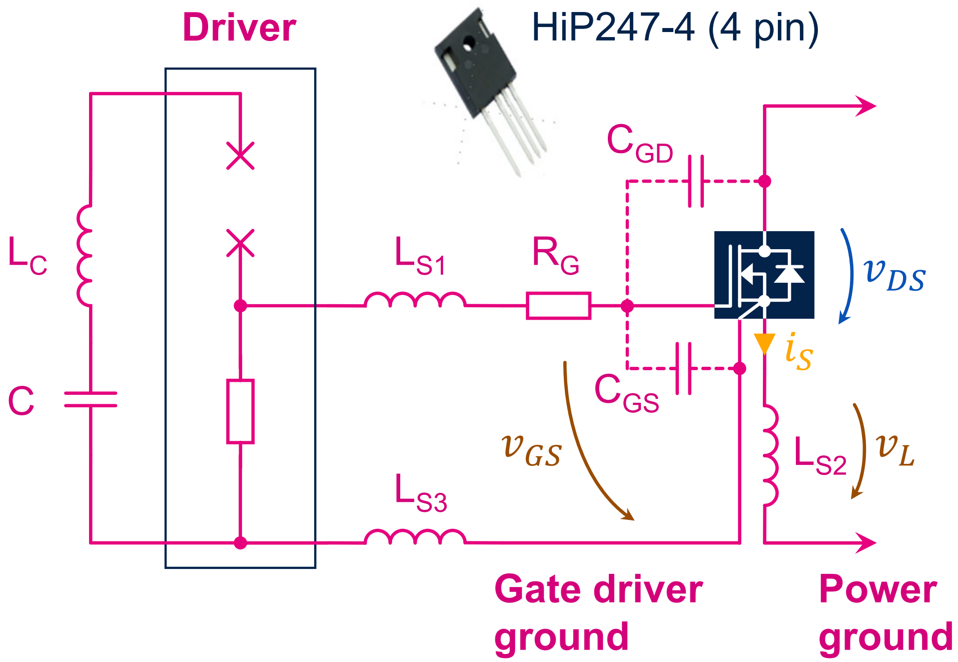
	Power FLAT 8x8 STD & DSC	H2PAK-7L	HU3PAK	ACEPAK SMIT	HiP-247 3L, 4L & 4L HC	STPAK	Bare Dice
Package							 
	Surface Mounting				Through-Hole	Special Package Solutions	
Characteristics	Very Thin (< 1mm) Well accepted in power conversion **Kelvin** Source Leadless **Industrial domain**	**AG qualified at 175dC** **Kelvin** Source for optimized driving High runner for Automotive customers	**AG qualified at 175dC** **Top side cooling** **Kelvin** Source for optimized driving Very good thermal dissipation	**AG qualified at 175dC** **Isolated Top side cooling** **Kelvin** Source Suitable for different configurations (HB, Dual die, etc.) High Power Modular Approach	**AG qualified at 200dC** **Very common Industry standard** **Kelvin** Source **4 leads** option for optimized driving High creepage version (1200V and 1700V) in development	**Unique Solution for traction Inverter** **AG qualified at 200dC** **Very High thermal dissipation efficiency** Sense pin for optimized driving Multi-sintered package **Kelvin** Source	**WLBI & KGD** **T&R or RWF options** **Compliant with the most stringent Automotive Quality Requirements**

TOP SIDE COOLING

Kelvin Source vs standard package Theory

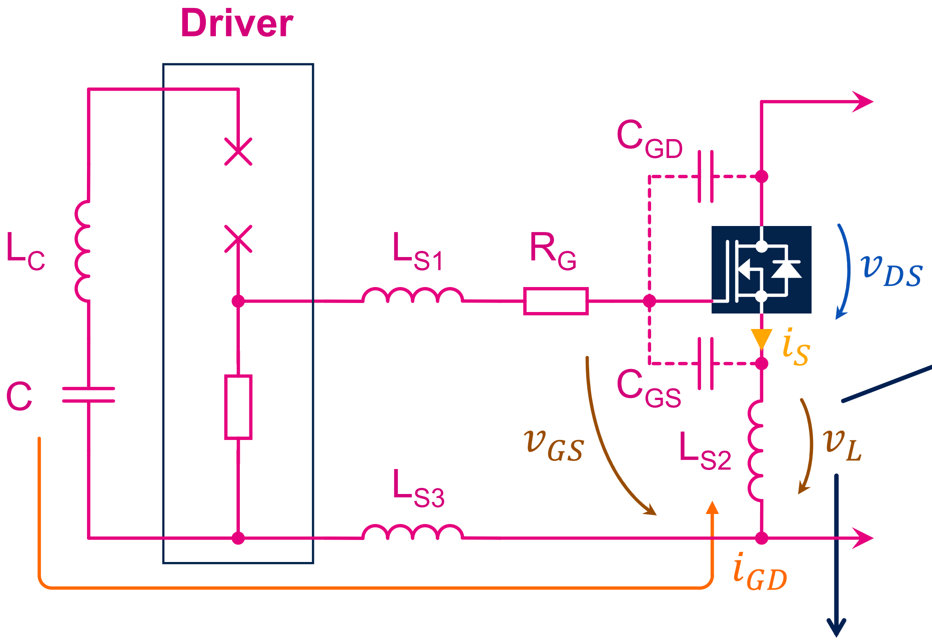


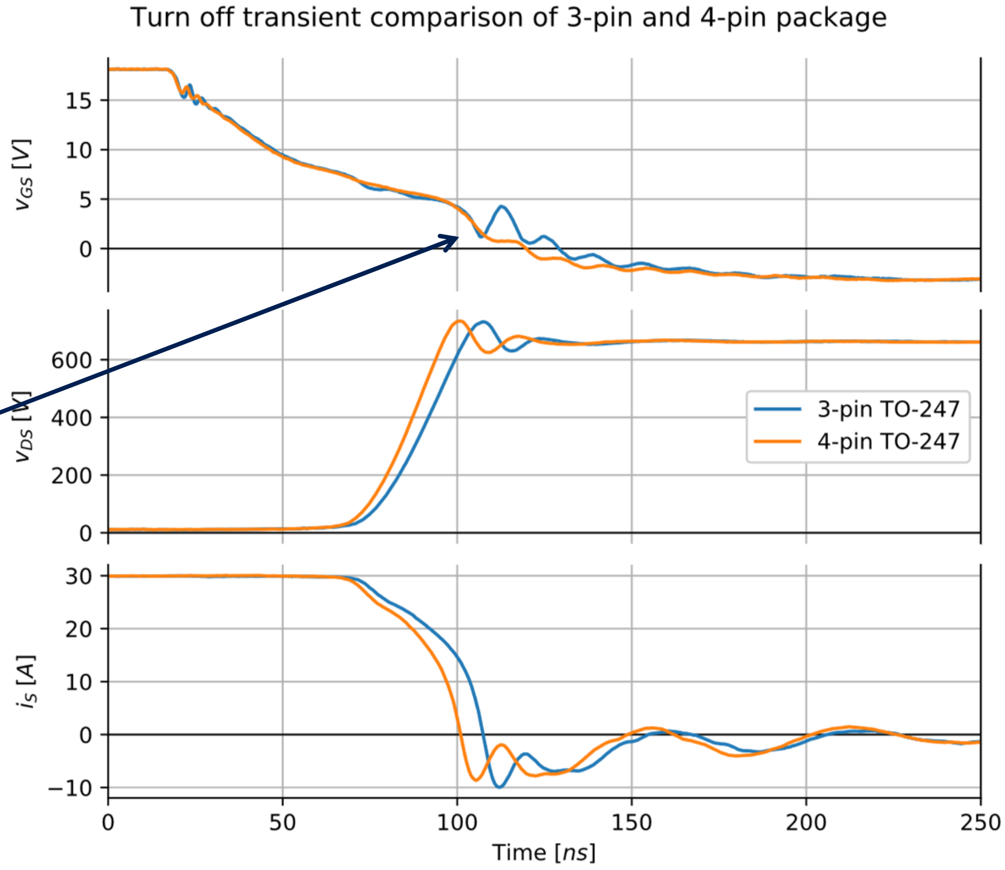
Kelvin source device



- Kelvin Source separate power path and gate loop. The v_L spike over L_{S2} is **not affecting the gate loop**.

Kelvin Source vs Standard package Example 1/2

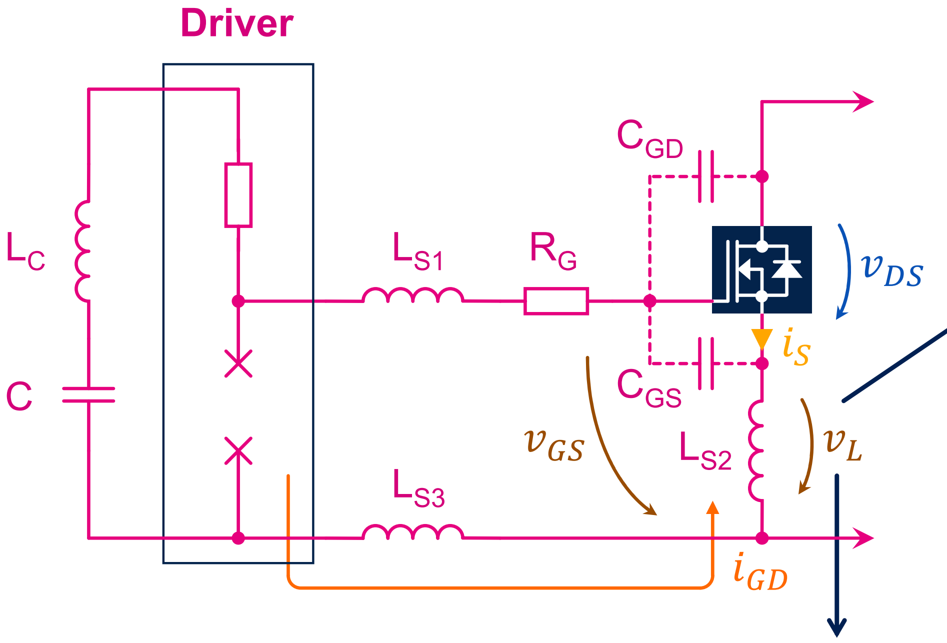


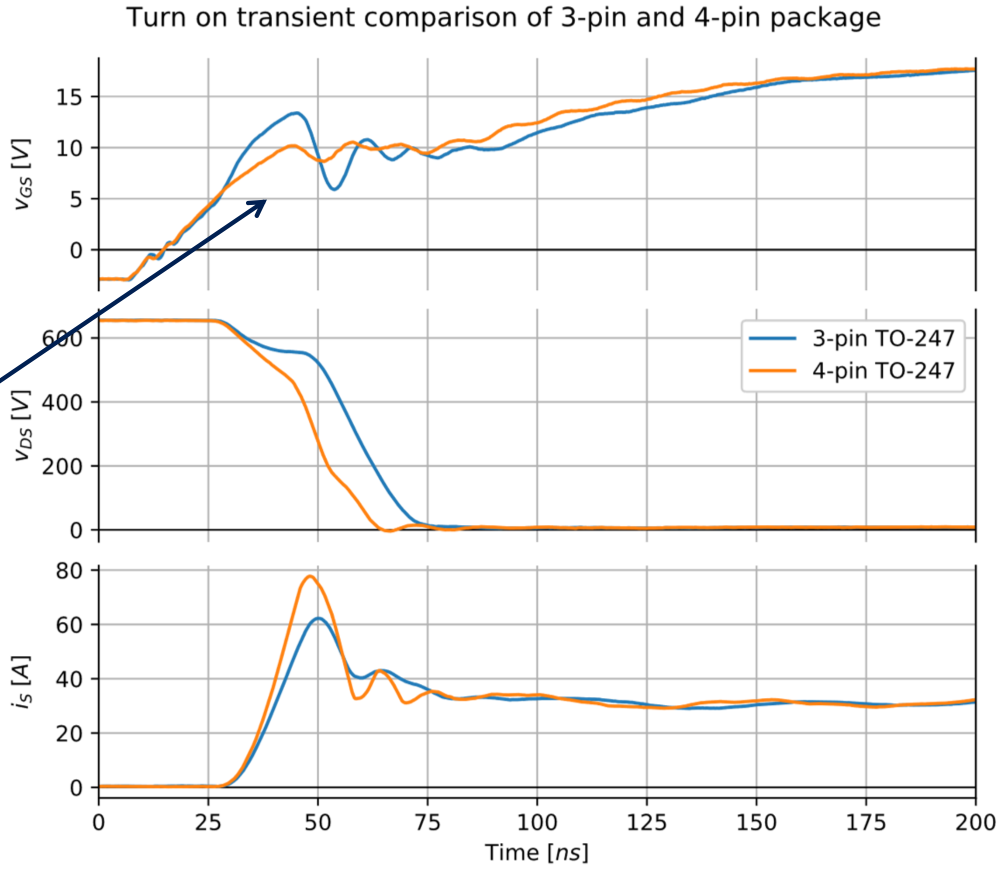

Turn off transient comparison of 3-pin and 4-pin package

$$v_L = L_{S2}\frac{di_S}{dt}$$

Voltage v_L slows down discharging of the C_{GS}

Kelvin Source vs Standard package Example 1/2



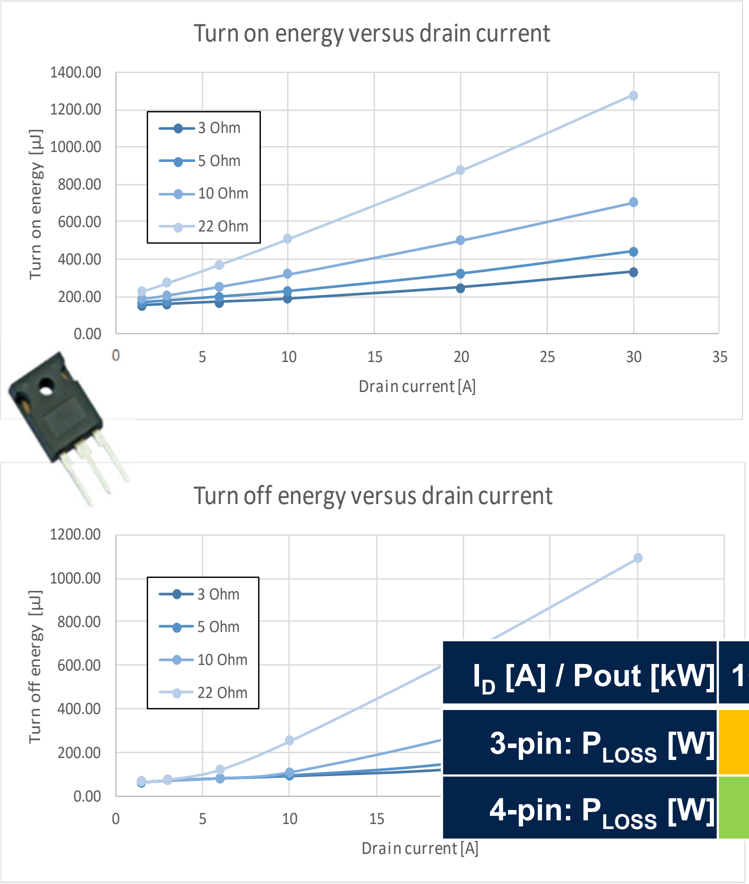

Turn on transient comparison of 3-pin and 4-pin package

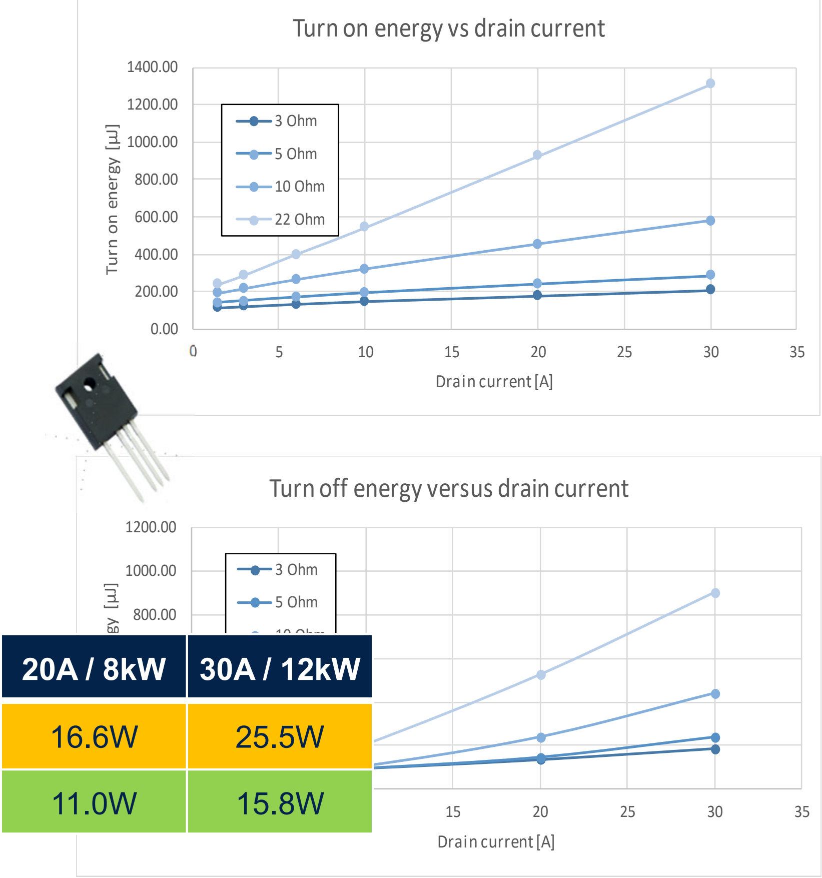
$$v_L = L_{S2}\frac{di_S}{dt}$$

Voltage v_L slows down charging of the C_{GS}

SiC MOSFET

HiP247 (3-pin) vs HiP247-4 (4-pin) package





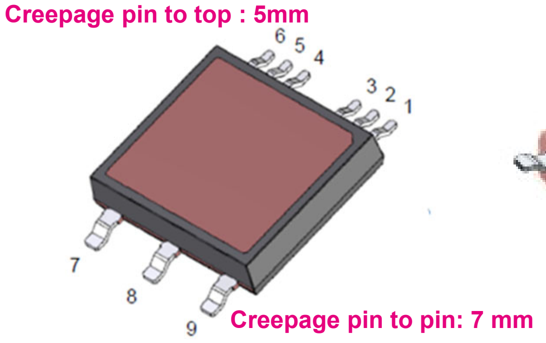
I_D [A] / Pout [kW]	10A / 4kW	20A / 8kW	30A / 12kW
3-pin: P_{LOSS} [W]	10.4W	16.6W	25.5W
4-pin: P_{LOSS} [W]	8.2W	11.0W	15.8W

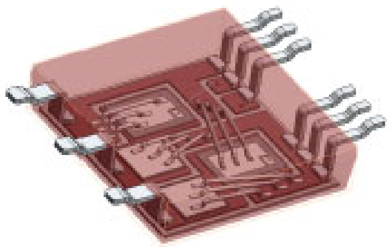
switching losses at F_{SW} = 48kHz:
R_G = 5Ω, V_{DS} = 800V, V_H = 18V, V_L = -3V

ACEPACK™ SMIT: introduction and characteristics

Why SMIT? → Surface Mounted Isolated Top-Side Cooled Package

It looks like a discrete… But it is a module!





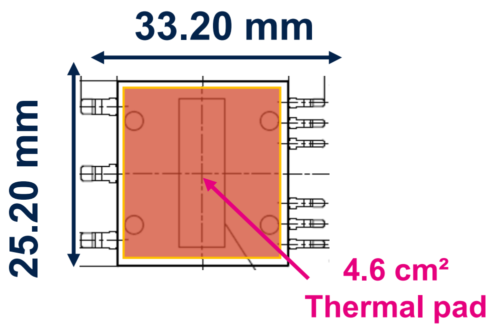
- is molded
- has a leadframe
- is an SMD
- is available in T&R*

- contains a DBC**
- has integrated dice forming simple topologies
- has an isolated thermal pad

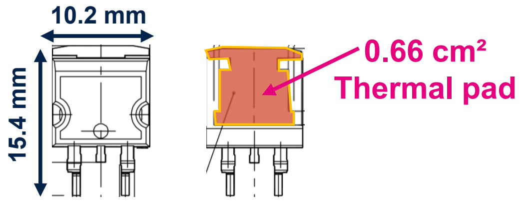
* Tape and reel

** Direct Bond Copper

Dimensions



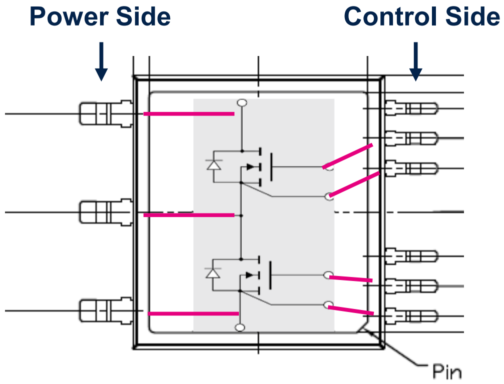
For comparison: D2PAK



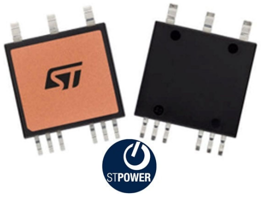
~5x smaller

~7x smaller

Pin-out



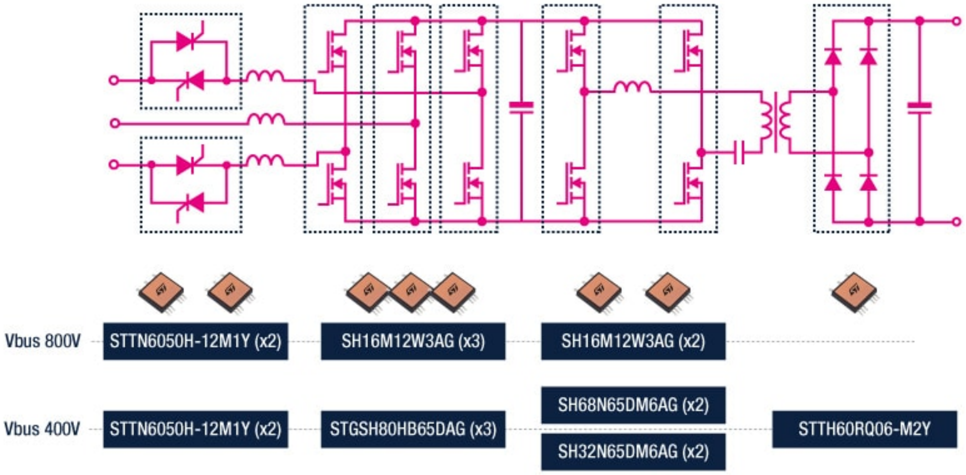
- This assembly is merely illustrative. Pin connections in real products may differ
- In rectifiers the control pins might also be used for power



ACEPACK™ SMIT package

Product ecosytem

Typical application diagram for an on-board charger (OBC)



Vbus 800V — STTN6050H-12M1Y (x2) — SH16M12W3AG (x3) — SH16M12W3AG (x2)

Vbus 400V — STTN6050H-12M1Y (x2) — STGSH80HB65DAG (x3) — SH68N65DM6AG (x2) / SH32N65DM6AG (x2) — STTH60RQ06-M2Y

Solar

SMPS

Storage system

On Board Charger (automotive or industrial)

EV Charging (bi-directional)

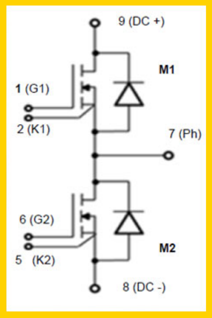
- ACEPACK SMIT devices are AQG-324-qualified
- Tailored for AC/DC and DC/DC converters like OBC, DC Wallbox and Motor Control like Servo Drives
- The ACEPACK SMIT allows high modularity flexibility by enabling many Topology options like Totem Pole, B6, 3-Level T-Type
- It is available with multiple ST Power Technologies including SiC, SJ Fast body Diode MOSFETs, IGBTs, thyristor and diodes

ACEPACK-SMIT

Gen3 SiC MOSFET Product Plan

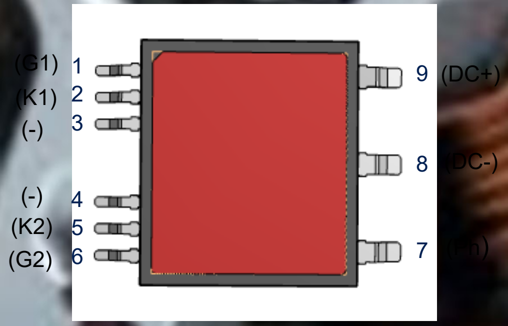
New Products Developments

Part Number	Configuration	V_{DS} [V]	R_{DS}(on) Typ @ 25ºC [mΩ], Vgs=18V	Mat
SH16M12W3AG	HB	1200	16	Q1’24
SH20M12W3AG			20	Q2’24
SH25M12W3AG			27	Q3’24
SH40M12W3AG			40	Q2’24
SH70M12W3AG			70	Q1’24
SH20M65W3AG	HB	650	20	Q2’24

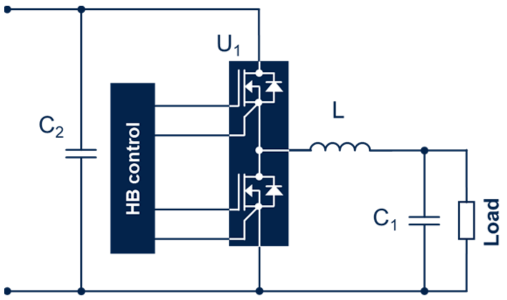


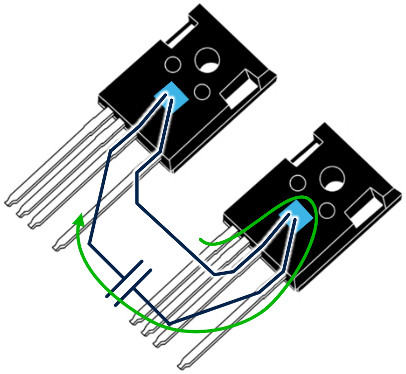
Half Bridge Configuration

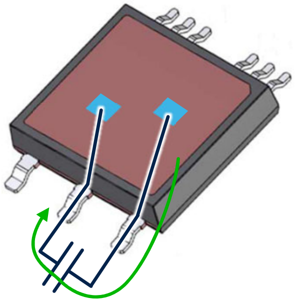
Full prod pinout and molding compound Class 1 (CTI>600)

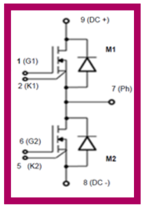


HiP247-4 pin versus ACEPACK SMIT



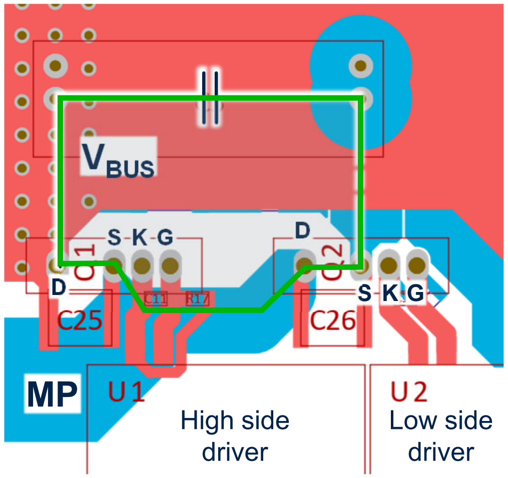


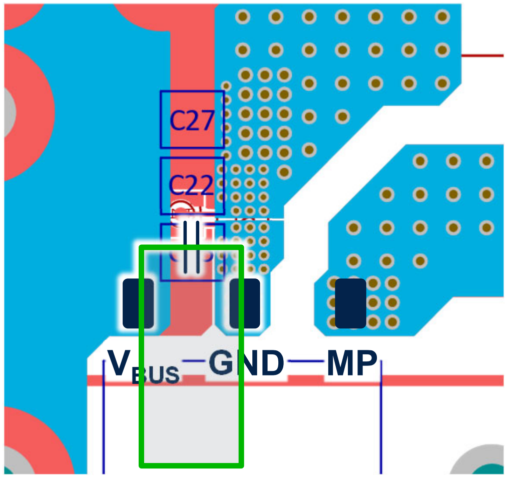




Advantage of ACEPACK SMIT **modular package**

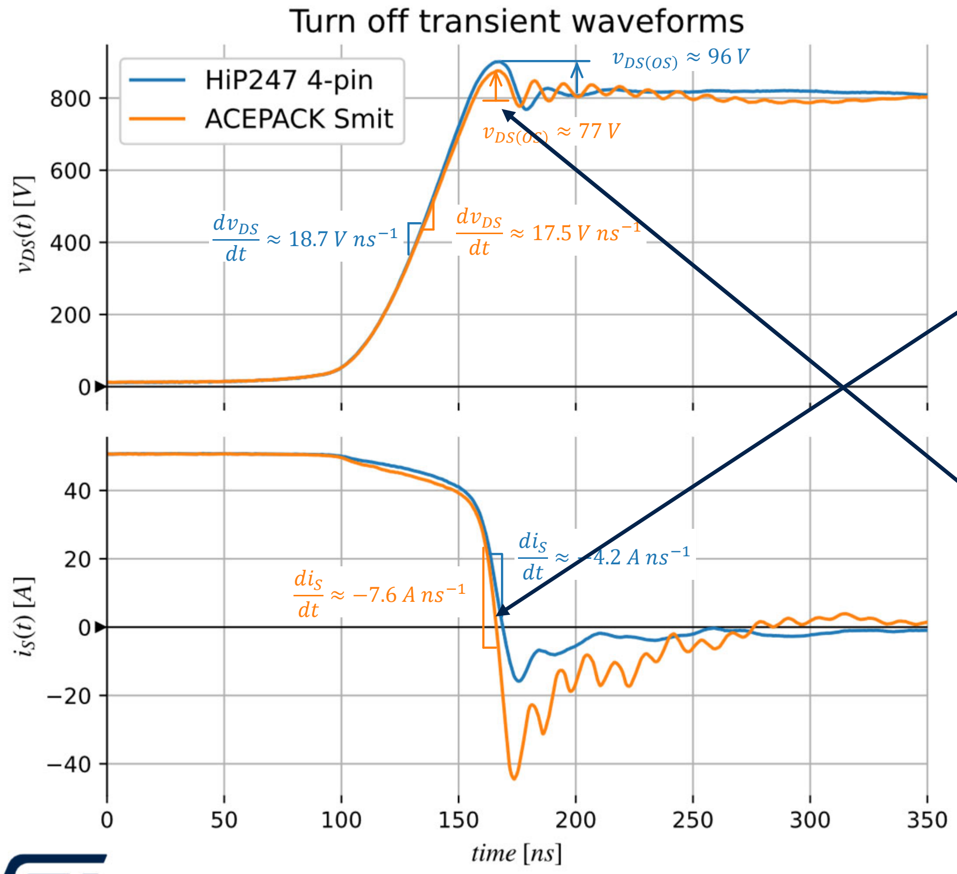
- The **length of the commutation loop is significantly smaller**
- It allows to place the SMD capacitor directly to the terminals of the module.
- Together with the shortening of the terminals due to surface mounting and the shortening of the routes inside the module, the **stray inductances are** thus **minimized.**





ACEPACK SMIT vs HiP247-4

$I_D = 50\ A, V_{BUS} = 800\ V$

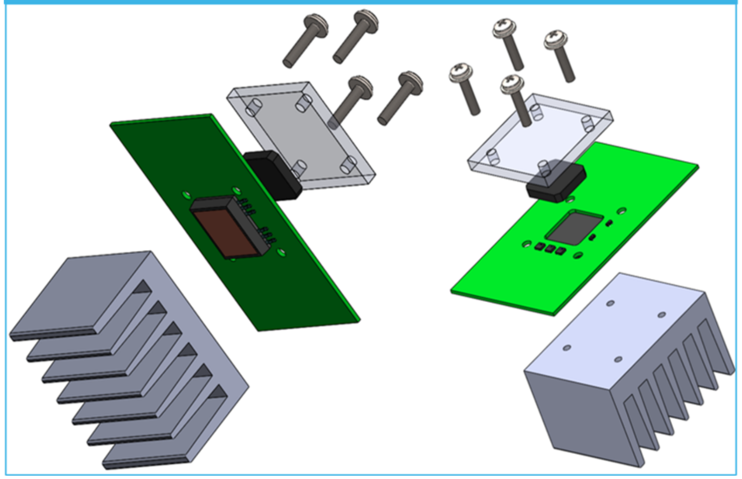


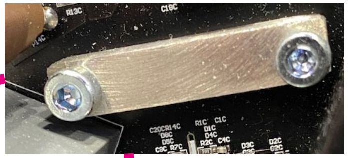
Faster di/dt
Thanks more compact layout

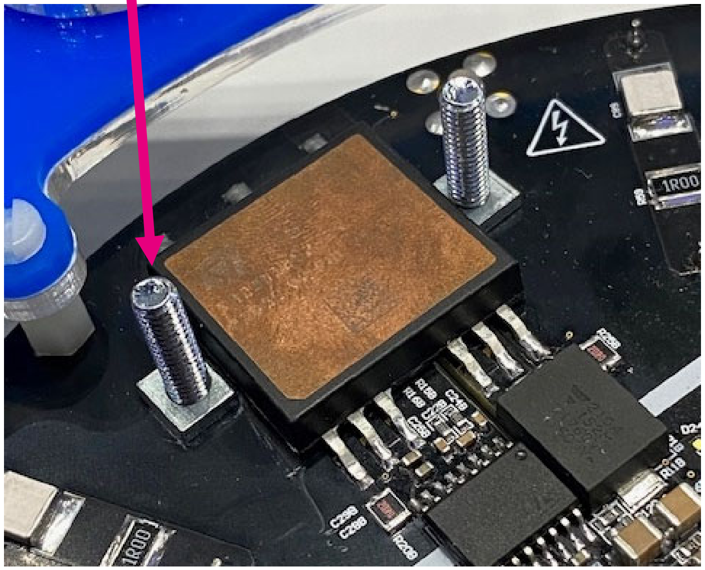
Yet,
The overshoot is lower

ACEPACK SMIT
guidelines mounting & thermal management

ACEPACK SMIT heatsink mounting instructions





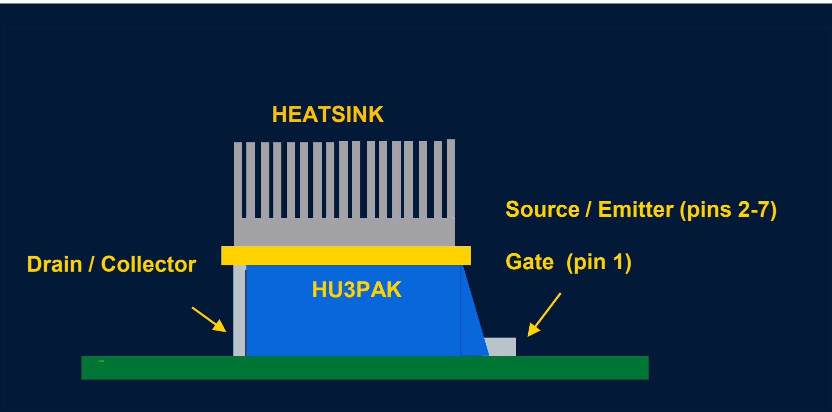


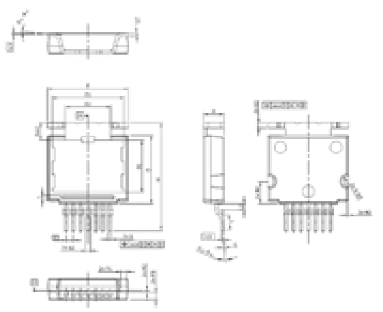
Rear-mount Inverter for Servo Drives

AN5384 @ ST.COM

Advanced (Discrete) Package Solutions

HU3PAK™





Top **S**ide **C**ooling Package: **HU3PAK™**

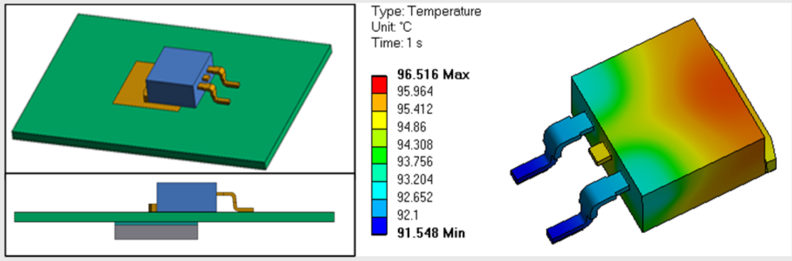
Specifically designed for DC Wallbox, OBC, DC-DC Converter, Energy Storage Systems, Servo Drives

- **AEC-Q101 qualified**
- **Tj (max) = 175 °C**
- **Voltage rated up to 1200V**
- **Top Side Cooling for improved thermal performance**
- **Kelvin source pin enables higher efficiency.**

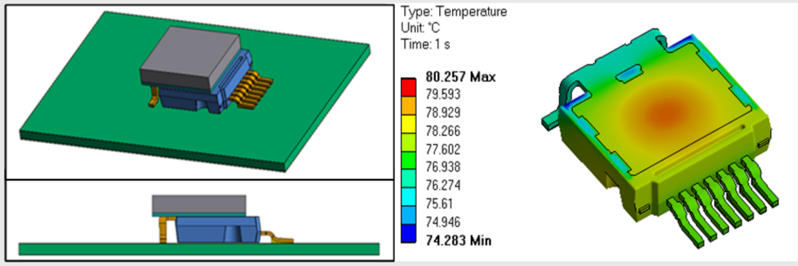
HU3PAK
Outperforming alternative to D2PAK / H2PAK-7

Thermal map @ full load

D^{2}PAK



HU3PAK

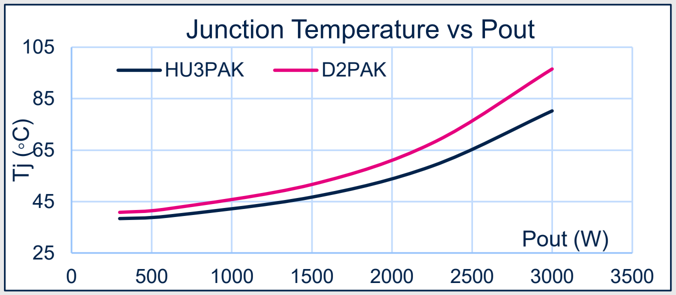


Same heatsink positioned on
- D^{2}PAK bottom side of the PCB trough thermal vias
- HU3PAK directly on the top exposed copper frame

	HU3PAK	D^{2}PAK	
$R_{th(J-H)}$(K/W)	8.91	10.47	-15%
$R_{package}$(mΩ)	80	80	//

Losses in 3kW FB LLC

	D^{2}PAK	HU3PAK	
P_{die} (W)	0.578	0.568	@ Pout 300 W
T_j(°C)	40.7	38.4	- 2.3°C
P_{die} (W)	5.908	5.275	@ Pout 3 kW
T_j(°C)	96.52	80.26	-16.26°C



Top Side Cooling solution improves capability heat dissipation keeping the same heat sink and PCB, allowing lower T_j.

Coldest device works with lower RDS(on) lowering the conduction losses

HU3PAK
mounting instructions & thermal management ←TN1378

Title	Type	Icon
TN1378: HU3PAK package mounting and thermal behavior	Technical Note	PDF

In case several HU3PAK devices share same heatsink, there is unavoidably some gaps between the packages top surface and the heat sink surface due to differences in heights between the packages and parallelism issues. These small gaps are significantly increasing the contact resistance with the heat sink, and a simple compound may not reliably fill them.

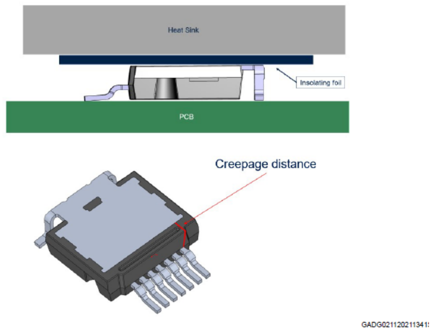
Top side cooling can best be mounted with soft gap filler or **liquid gap filler for optimal performances**. Gap filler comes with different thermal conductivity that play an important role on Rth and thermal management .

Many thermal compounds are available on the market that may provide good results

STMicroelectronics evaluated successfully silicone based material (reference WGT36 from Fischer Elektronik) and Kapton based material (reference KAP 1 P from Fischer). Other suggested gap filler Suppliers are Hala or Henkel.

We recommend the use of **screws** or in alternative **springs** for **correct mounting force**

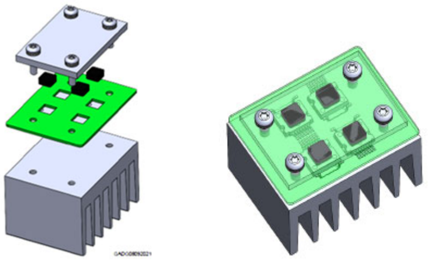
Figure 17. Creepage distance in HU3PAK on uncemented insulating foil



Depending on the pollution degree and the material group of the resin, the maximum rms voltage that can be withstand by the package is defined in the table below:

Table 4. Maximum rms voltage capability with a creepage distance of 3.7 mm

Pollution degree	Material group	Max rms voltage
1	I and II	1070 V
2	II	515 V



Example of heat sink assembly with counter plate

SiC and Discrete Packaging

Takeaways

How to get the best out of SiC

- Breakthrough power technologies and packages
- Packages do more than simply house a die
- Smart PCB and package layout are key factors
- Discretes enable the higher level of design flexibility

SiC MOSFET

(650V, 750V, 900V, 1200V, 1700V)

Power supply

UPS

EV charger

Solar inverter

Industrial motor

Welding

DCDC, OBC

Traction

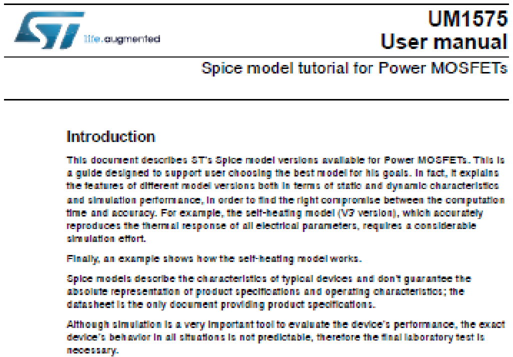
Industrial

Automotive

Application Tools

Simulation

Electrical operation simulation
Simulators
- Pspice
- Simetrix (eDsim)
- Pspice based simulators



UM1575
User manual

Spice model tutorial for Power MOSFETs

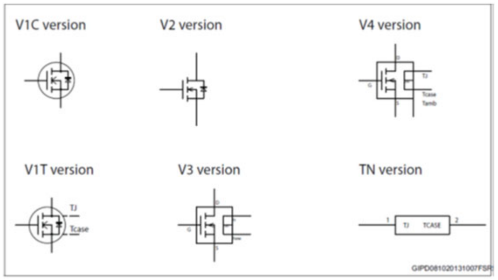
Introduction

This document describes ST's Spice model versions available for Power MOSFETs. This is a guide designed to support user choosing the best model for his goals. In fact, it explains the features of different model versions both in terms of static and dynamic characteristics and simulation performance, in order to find the right compromise between the computation time and accuracy. For example, the self-heating model (V3 version), which accurately reproduces the thermal response of all electrical parameters, requires a considerable simulation effort.

Finally, an example shows how the self-heating model works.

Spice models describe the characteristics of typical devices and don't guarantee the absolute representation of product specifications and operating characteristics; the datasheet is the only document providing product specifications.

Although simulation is a very important tool to evaluate the device's performance, the exact device's behavior in all situations is not predictable, therefore the final laboratory test is necessary.

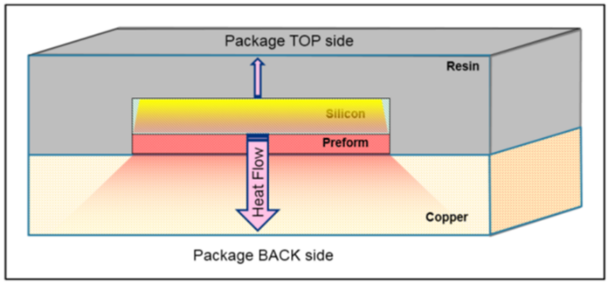


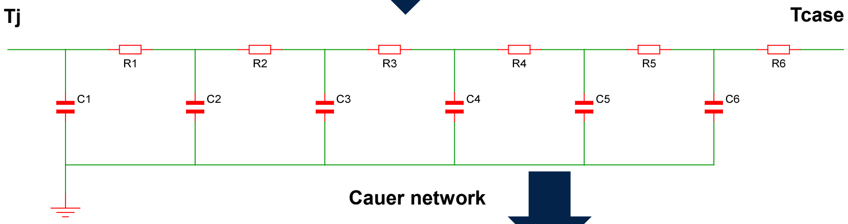
Models
- V1C/T – Basic model
- V2 – Advanced model – based on characterization results, with real cap profile
- V3 – like V2 with package thermal model including self heating
- V4 – V3 in free air environment
- TN – Cauer Network

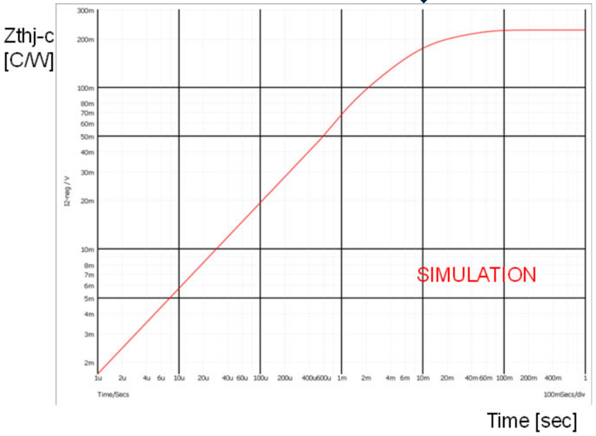
Thermal Simulation

The Cauer Network is present for most of devices.

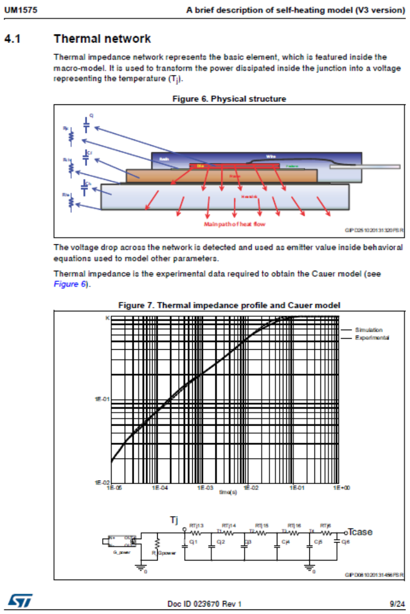
- Allows to estimate temperature of junction
- Allows to simulate dynamical load thermal effect
- Allows to simulate impact of different heatsink option







UM1575



UM1575 A brief description of self-heating model (V3 version)

4.1 Thermal network

Thermal impedance network represents the basic element, which is featured inside the macro-model. It is used to transform the power dissipated inside the junction into a voltage representing the temperature (T_j).

Figure 6. Physical structure

The voltage drop across the network is detected and used as emitter value inside behavioral equations used to model other parameters.

Thermal impedance is the experimental data required to obtain the Cauer model (see *Figure 6*).

Figure 7. Thermal impedance profile and Cauer model

Doc ID 023670 Rev 1 9/24

AN4783

AN4783
Application note

Thermal effects and junction temperature evaluation of Power MOSFETs

Maurizio Melito, Antonino Gaito, Giuseppe Sorrentino

Introduction

In modern power supply design, more and more attention is given to the electrical efficiency of the overall system and to the junction temperature of semiconductor devices, which handle the conversion of power to a usable form.

Among all semiconductor devices, the transistor is by far the most important category. Nearly all of them are three-pin devices (MOSFETs, BJTs, IGBTs) and unlike diodes, they have a driving section which makes them more sensitive to issues related to the interaction between power handling and the input signal. The aim of this application note is to illustrate the method to evaluate the thermal stress on power MOSFET devices when they are used in switch mode power supplies. By this computation and with the physics characteristics of the device, it is possible to predict the temperature reached inside the junction, and the allowable margin or heatsink required to assure that the system has a suitable thermal margin during operation. This approach is fundamental because correct computation allows more accurate evaluation of system lifetime and assures working operation within the SOA.

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Digital Power Workbench

ZVS Totem Pole PFC	Zero Voltage Switching Interleaved Totem Pole PFC (Soft Switching) Vin – Single range AC Vout – 400V/ up to 3.3kW - Unidirectional
FB LLC	Full Bridge LLC (Soft Switching) Vin – 400V DC link Vout – up to 68V/ up to 3kW - Unidirectional
Vienna Rectifier	Modified Vienna Rectifier PFC (Hard Switching) Vin – 3-phase AC Vout – 800V/ up to 15kW - Unidirectional
3-Level T-type Converter	3-Level T-type PFC (Hard Switching) Vin – 3-phase AC Vout – 800V/ up to 15kW - Bidirectional

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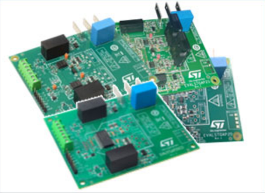
List of Reference designs - SiC



Isolated Gate driver Demos

STEVAL-DPSTPFC1

Totem Pole PFC

1 Phase

SCTW35N65G2V

TN3050H-12WY

STGAP2S

UM2792

3.6kW

STDES-7KWOBC

OBC

1 Phase

TN3050H-12GY

SCTH35N65G2V-7AGSTGAP1AS

STB47N60DM6AG

A6387

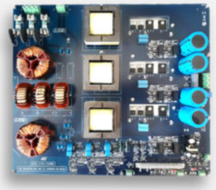
STPSC20065GY

UM2940

TN1373

7.0kW

STDES-VIENNARECT



PFC

3 Phase

SCTW35N65G2V

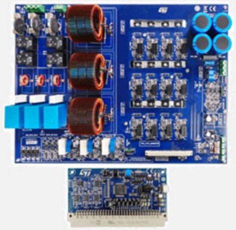
STGAP2S

STPSC20H12D

Data brief

15kW

STDES-PFCBIDIR



PFC/Inverter

3 Phase

SCTW35N65G2V

SCTW40N120G2VAG

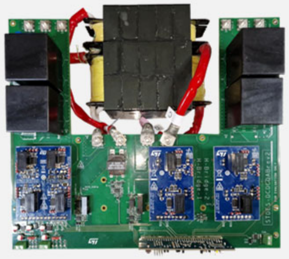
STGAP2SM

UM2979

15kW

Coming Soon

STDES-DABBIDIR



DC-DC DAB

Isolated

A2F12M12W2-F1

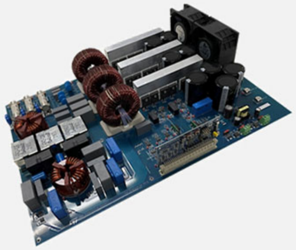
A2F6H12W3

STGAP2SICS

TN1435

25kW

STDES-30KWVRECT



PFC

3 Phase

SCTWA90N65G2V-4

STPSC40H12CWL

STGAP2SICS

UM3011

TN1408

30kW

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Thank you

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