ST power transistor solutions for vehicle electrification

- Power transistors in EVs
- Silicon carbide MOSFETs
- SiC power modules for EVs
- Advanced packaging technologies

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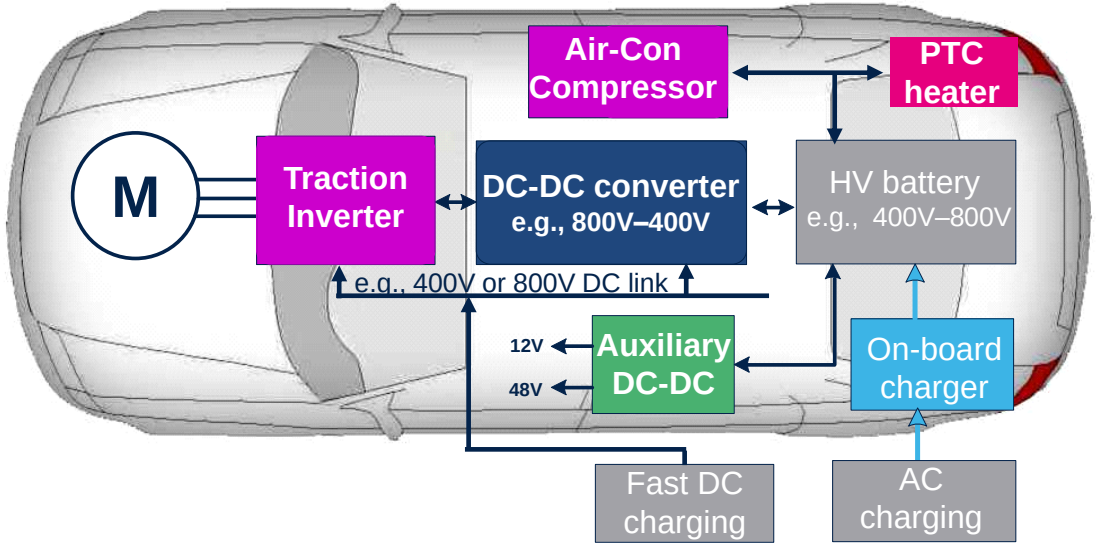
Power electronics subsystem overview

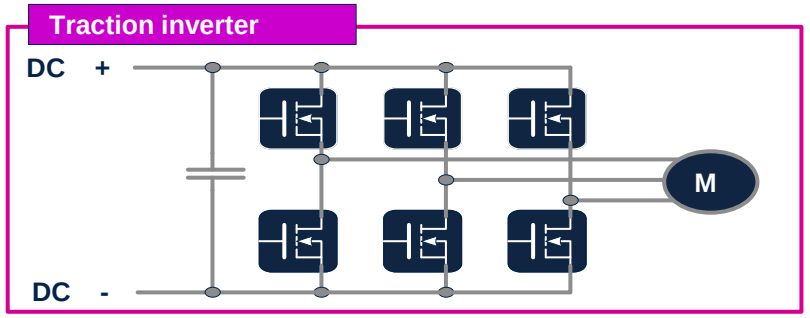
HEV/EV and ecosystem overview

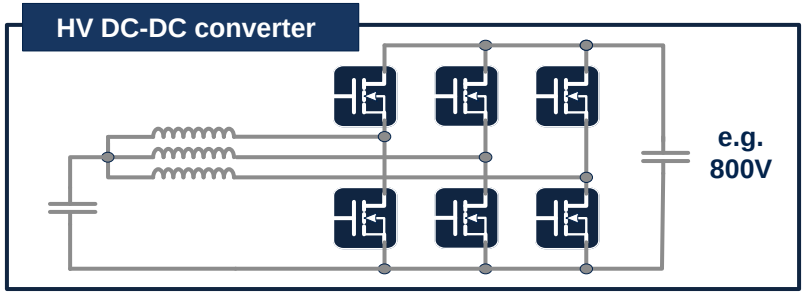


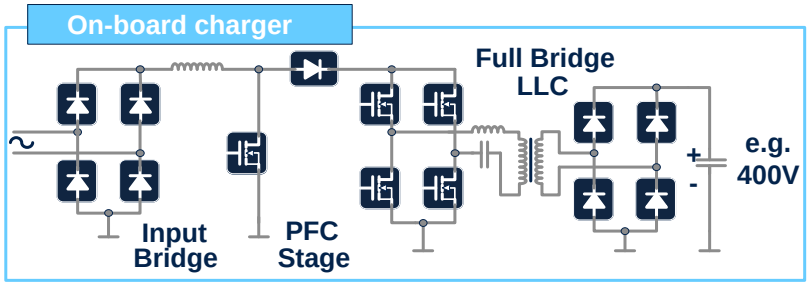
Key power technology	Focus applications
IGBT	Traction, OBC, DC-DC, PTC heater and air-con
SiC MOSFET	Traction, OBC, and DC-DC converter
HV Si MOSFET	OBC, DC-DC converter, and exploring traction inverter
Power GaN	OBC and DC-DC converter
PM and IPM	Traction, OBC, DC-DC converter and air-con

PM = power module, IPM = intelligent power module

Main power electronics subsystems







Key points

Increase traction inverter efficiency

Minimize conduction and switching losses

Speed-up system charging time

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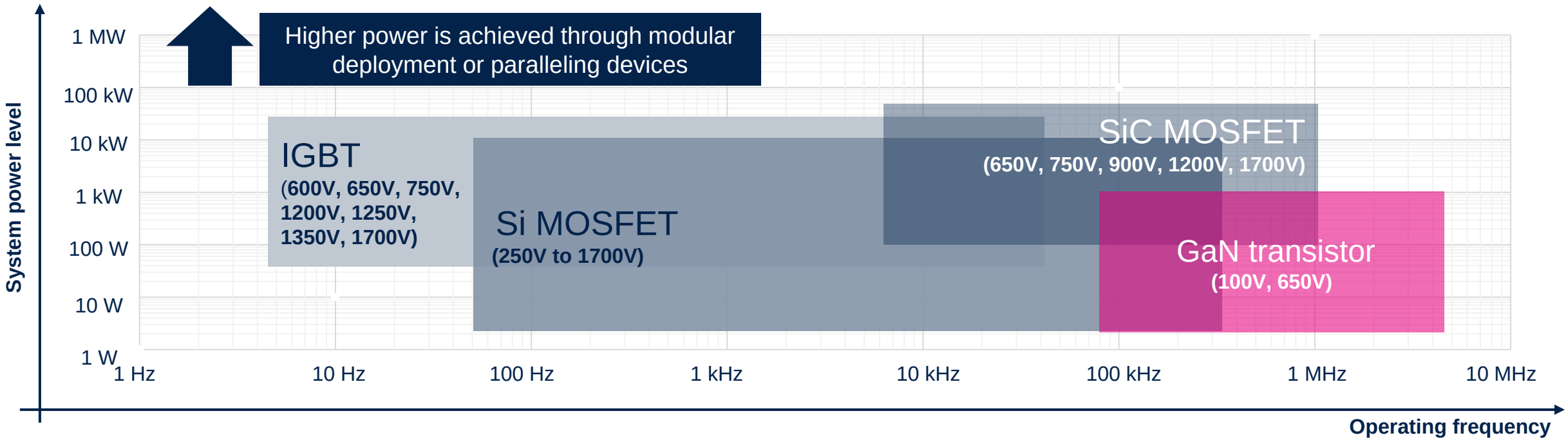
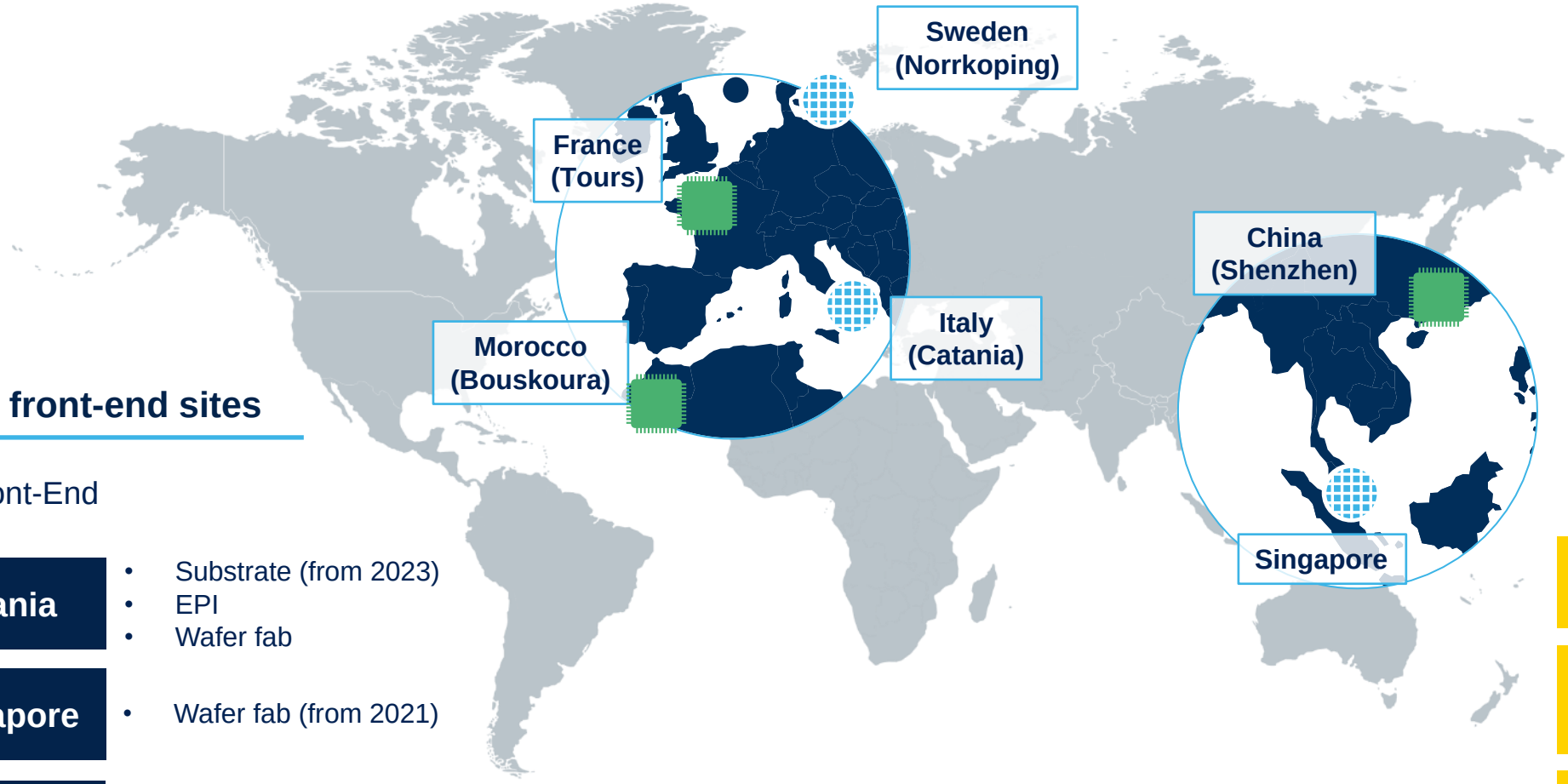
High voltage power technologies



Technology	Features	Typical automotive applications
Si HV MOSFET	Medium-high power, high voltage, high frequency	DCDC converter, motor control, on-board charger…
IGBT	Very high power, high voltage, medium frequency	Traction inverter, heating, climate compressor, on-board charger …
SiC MOSFET	Very high power, high voltage, frequency, and temperature	Traction inverter, High power DC/DC, on-board charger, Aux. DCDC …
GaN transistor	Very high frequency	LiDAR, 48V/12V DCDC, on-board charger …

ST power transistor manufacturing operations



3 x ST front-end sites

Front-End

Catania	• Substrate (from 2023) • EPI • Wafer fab
Singapore	• Wafer fab (from 2021)
Norrkoping	• R&D substrate (from 2020)

3 x ST back-end sites

Back-End

- **Tours** (KGD)
- **Shenzhen** (discrete, bare dice, module)
- **Bouskoura** (TPAK)

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ST silicon carbide history

25 years of SiC History in STMicroelectronics Catania

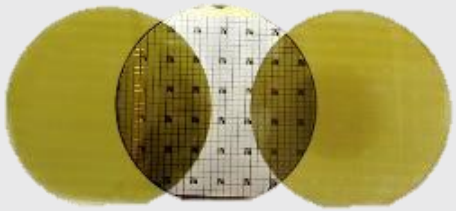
Over 70 patents

Silicon carbide was discovered by Edward G. Acheson in 1891
He named it Carborundum

1891

1907: Phenomenon of electroluminescence was discovered using silicon carbide

1907



1958: 1st silicon carbide conference held in Boston, USA.

1958

1966: First MOS transistor (H.R. Phillip, E.A. Taft)

1966

ST major milestones

June 1996: Collaboration with Physics Dept.

April 1998: 1st contract on SiC with CNR-IMETEM

May 2002: Schottky diode demonstrator (CNR line)

February 2003: ETC epitaxial reactor prototype installed in ST

May 2004: Schottky diode demonstrator (ST)

October 2007: 1st Gen **DIODE** **Start production**

March 2009: Power MOSFET 3" demonstrator

May 2012: 2nd Gen **DIODE** **Start production**

June 2014: 3rd Gen **DIODE** **Start production**

September 2014: 1st Gen **MOSFET** **Start production**

June 2017 2nd **Gen MOSFET** **Start production**

Dec 2020 3rd **Gen MOSFET** **Qualification**

1996 — 2003: 2" ST line — 2006: 3" ST line — 2011: 4" ST line — 2016: 6" ST line — 2020

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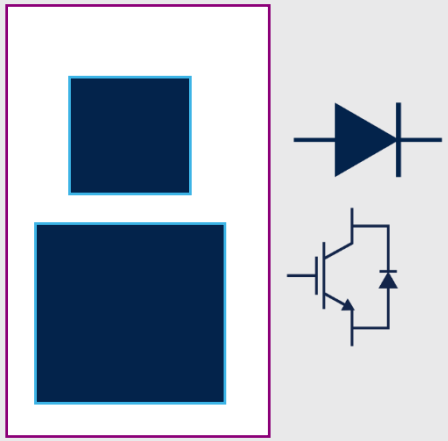
MOSFET size comparison

IGBT + diode vs SiC MOSFET

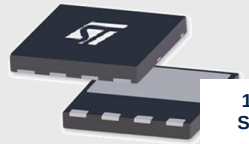
ST Gen 3 SiC 1200V
5x smaller die area



SiC vs Si MOSFET

H2PAK
SiC

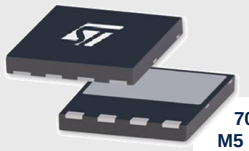
20mΩ
SiC G2



18mΩ
SiC G2

H2PAK
*Si Fast diode

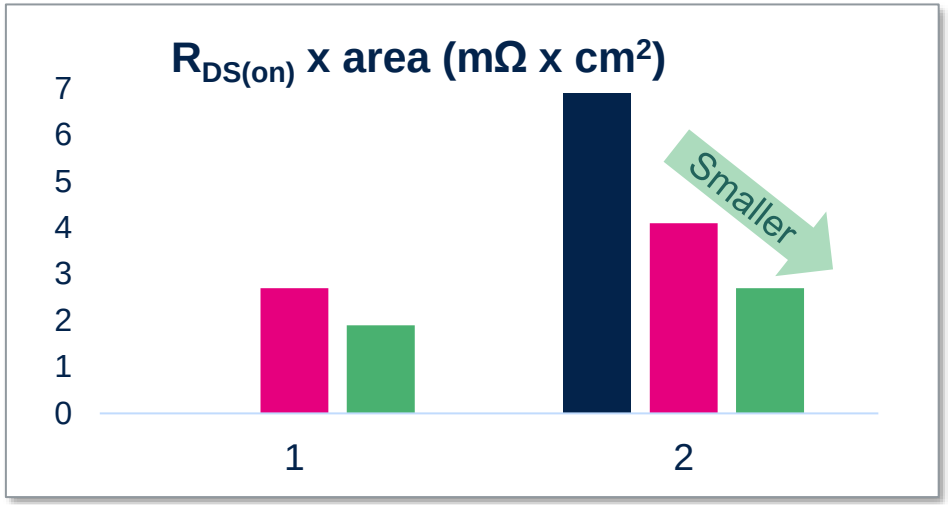
60mΩ
M6/M5
series

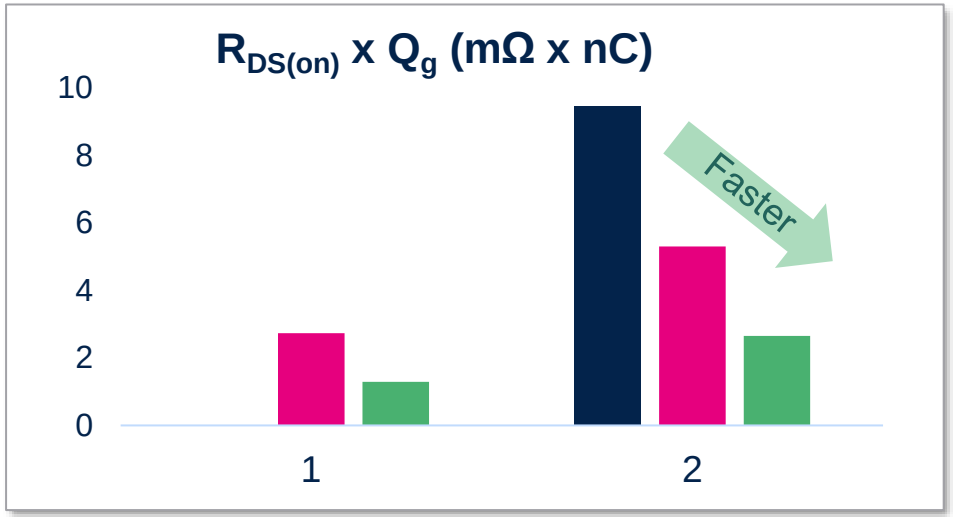


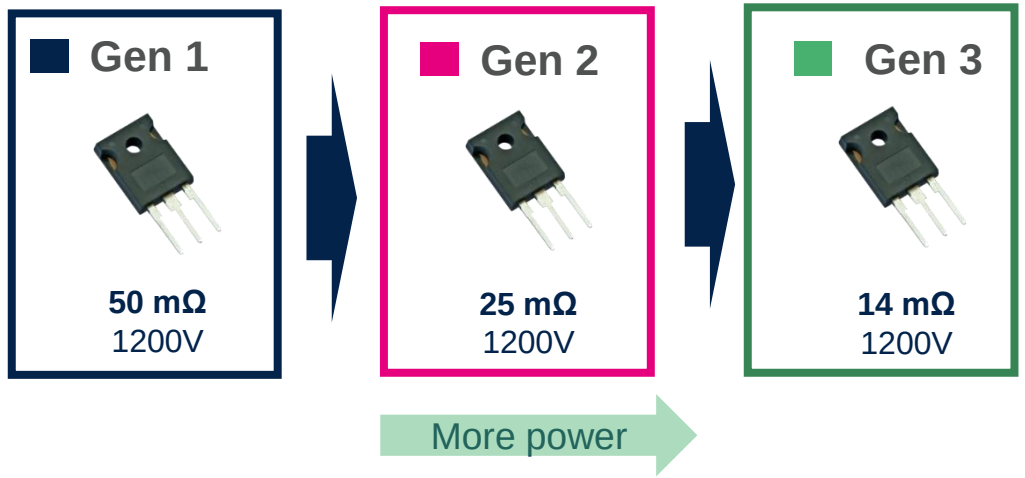
70mΩ
M5 series

Low Ron achievable with SiC in high voltage applications

ST SiC MOSFET figures of merit







Steady improvement over generations

- **Lower Ron x area → lower Ron in package (or same Ron in smaller package), higher current capability, and lower conduction losses**
- **Lower Ron x Qg → lower switching losses, higher frequency (smaller board)**

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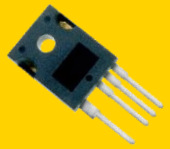
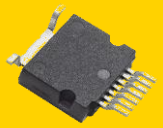
STPOWER SiC MOSFET & Diode Technologies

Market leadership in automotive with best-in-class SiC technology

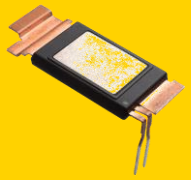
- Broad range of SiC solutions: Discrete, bare dice, module
- Proven very high reliability
- Vertical integration through Norstel AB acquisition
- Continued capacity expansion to support market demand
- Investing in advanced package technologies



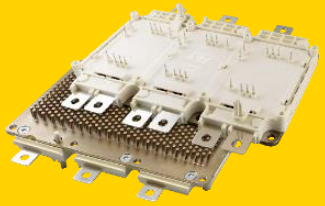
HiP247-4 leads



HU3PAK

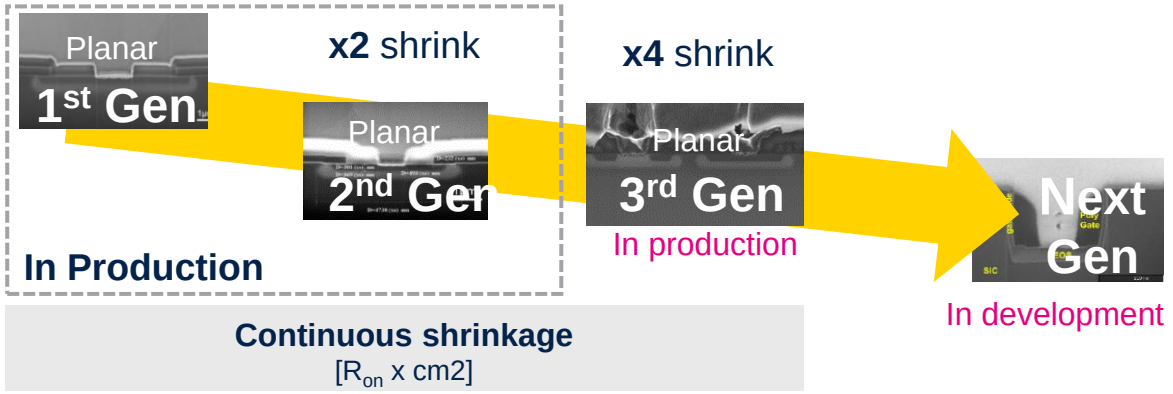


STPAK



ACEPACK DRIVE

Front-end evolution



Key advantages in automotive

Traction inverter & On-board charger

Charging Station

Car Weight Reduction

Longer Range: **>600 km** with SiC

Less charging time (from 16 to 7 min)

SiC charging station handles **2x** energy (Fast charger: 350 kW with SiC)

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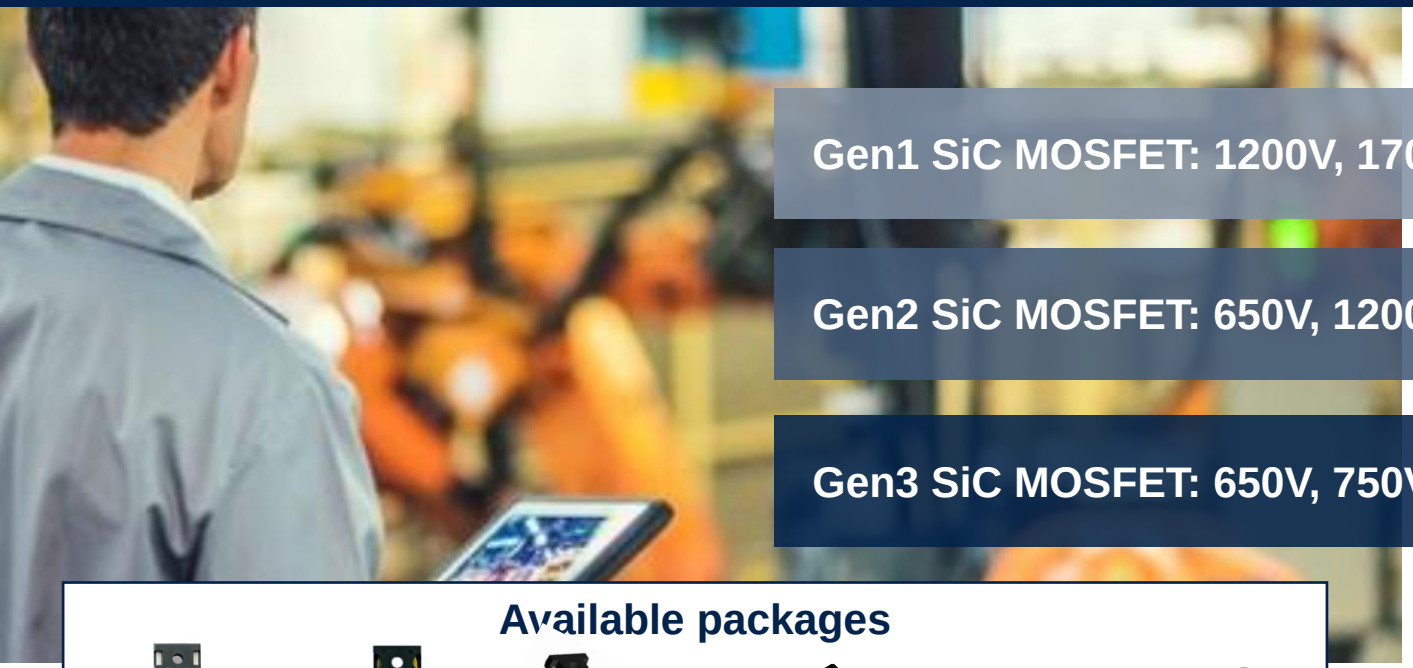
STPOWER SiC MOSFET & diodes in production

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



Gen1 SiC MOSFET: 1200V, 1700V

Gen2 SiC MOSFET: 650V, 1200V

Gen3 SiC MOSFET: 650V, 750V, 900V, 1200V

ST SiC MOSFET evolution: steady improvement in Ron and switching frequency for a broad range of automotive and industrial application **increasing power density at fast pace**

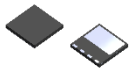
Available packages

HiP247-4L

HiP247

HiP247-LL

D2PAK- H2PAK

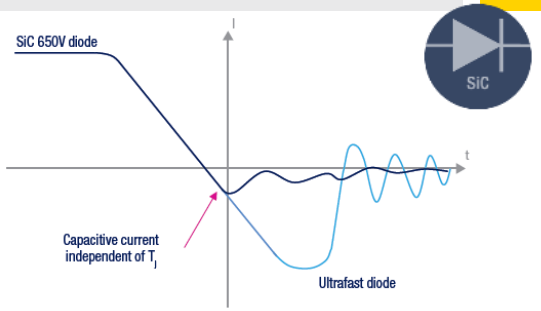


PowerFLAT

DPAK

Best switching

650V & 1200V SiC diodes



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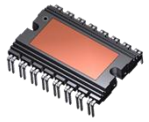
Power module solutions for automotive

SLLIMM
Intelligent Power module

ACEPACK Power module
Silicon MOSFET & IGBT, silicon carbide MOSFET


SLLIMM **HP**

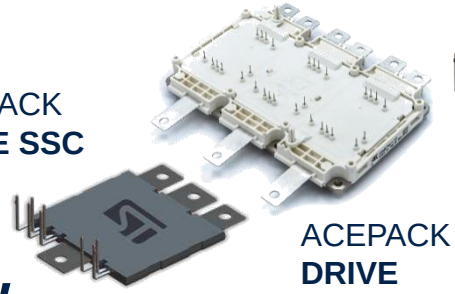

ACEPACK **DMT-32**

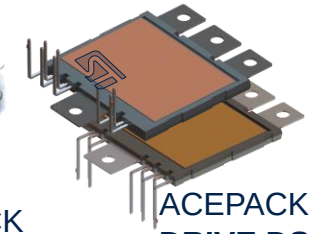

ACEPACK **SMIT**



ACEPACK **1 & 2**

ACEPACK **DRIVE SSC**

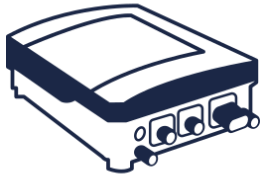

ACEPACK **DRIVE**


ACEPACK **DRIVE DSC**

5 kW — **10 kW** — **30 kW** — **150 kW** — **340 kW** →

HVAC–on-board charger–DC-DC converter


HVAC


OBC

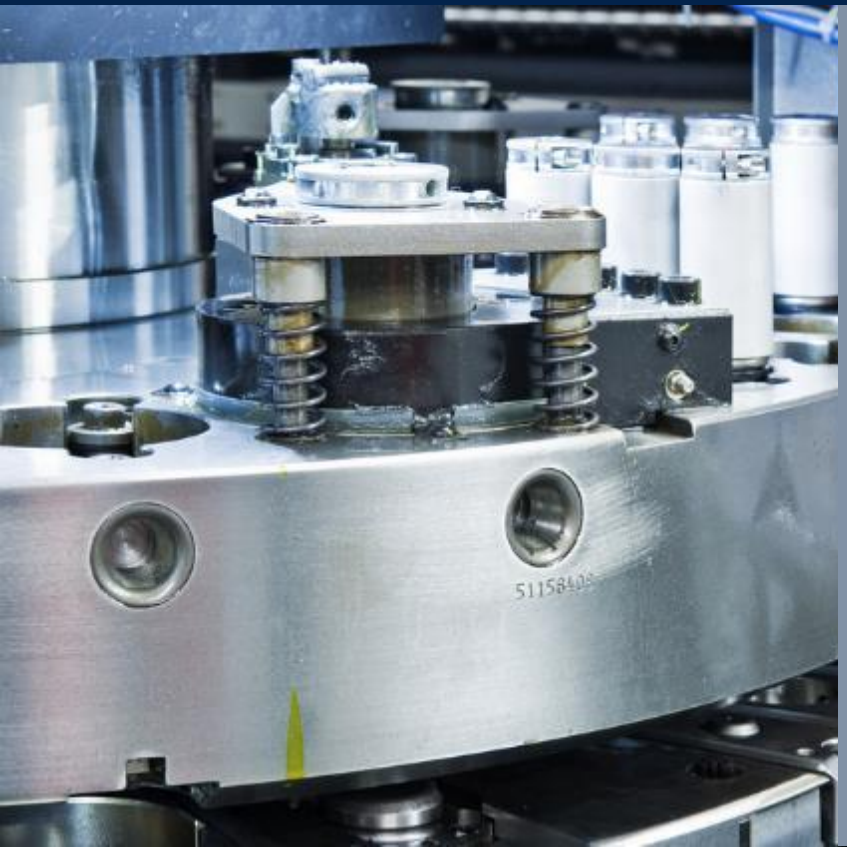

DC-DC converter

Traction inverter

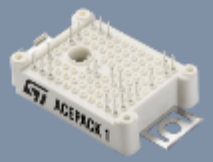

Traction inverter

Key benefits of ACEPACK 1 & 2

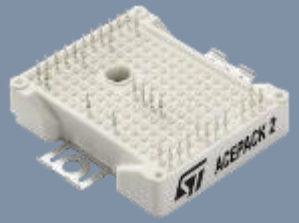
Industrial drives, motor control, UPS, and automotive EV ecosystems



ACEPACK 1 & 2



33.8 x 48 mm



48 x 56.7 mm

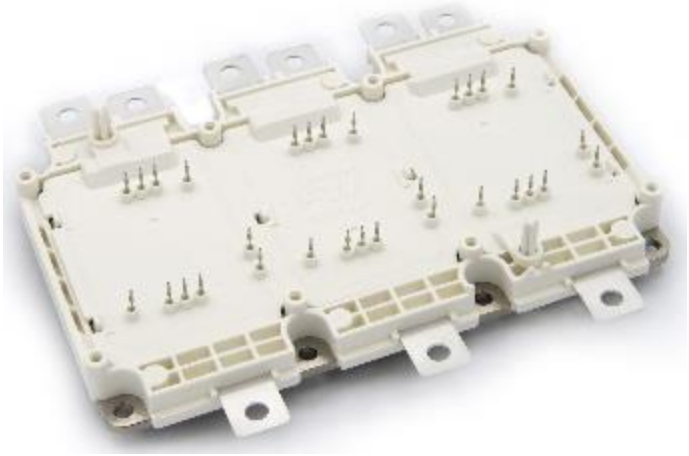
- Press fit and solder pin options, configuration flexibility
- Up to 1200V breakdown voltage
- Integrated screw clamps
- All power switches in a module including NTC
- Several current ratings available
- Several configurations (CIB, six-pack, …) available
- Low stray inductance
- High reliability and robustness, miniaturized power side board occupation
- Compact design and cost-effective system approach
- Very high power density

ACEPACK Drive

Direct liquid cooled high performance power module
For (H)EV, truck, and bus traction inverters

- Press fit connections for high reliable and long lasting connection
- Si & SiC-MOS based, 750V & 1200V
- Pin-fin for direct cooling
- Dedicated NTC for each single substrate
- Unequaled $R_{DS(on)}$

ACEPACK DRIVE



- Internal layout optimized for minimized stray inductance
- High reliability and robustness
- Different bus bar available to fit welding or screwing connection methods
- AMB substrates for better thermal management
- Extremely high-power density

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ACEPACK DRIVE for 400V battery

IGBT&Diode based

SiC MOSFET based

POWER

ADP660S75EM(*)

ADP61075W3

120kW

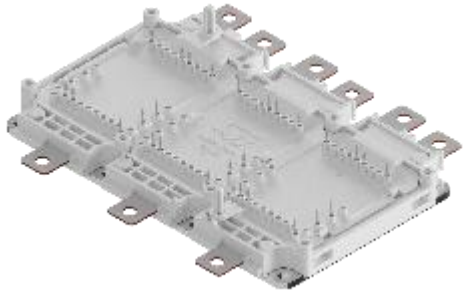
160kW

175kW

220kW

ADP820S75EM(*)

ADP46075W3



(*) IGBT& diode power modules to be pin-to-pin compatible to market reference

Date: May 2022 (timeline information can be subject to variations without advance notification)

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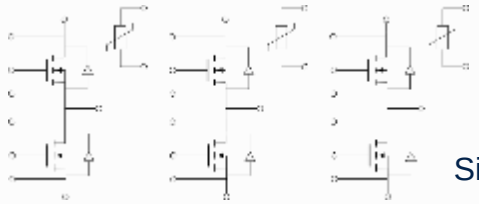
ACEPACK DRIVE for 800V battery

SiC MOSFET based



SixPack topology

SiC MOSFET Gen2 based:
For first customers electrical evaluation only

ADP300120W2-L

180kW — 230kW — 300kW — **Power**

ADP280120W3 | ADP360120W3 | ADP360120W3

SiC MOSFET Gen3 based:
Tailored for high-power traction inverters

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STEVAL-APD001K1 eval board for SiC-based devices

STEVAL-APD001K1 is fully compatible with ACEPACK DRIVE power press fit pins and requires a dedicated pressing tool to mount it.

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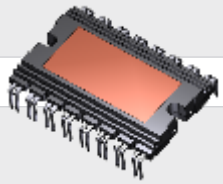
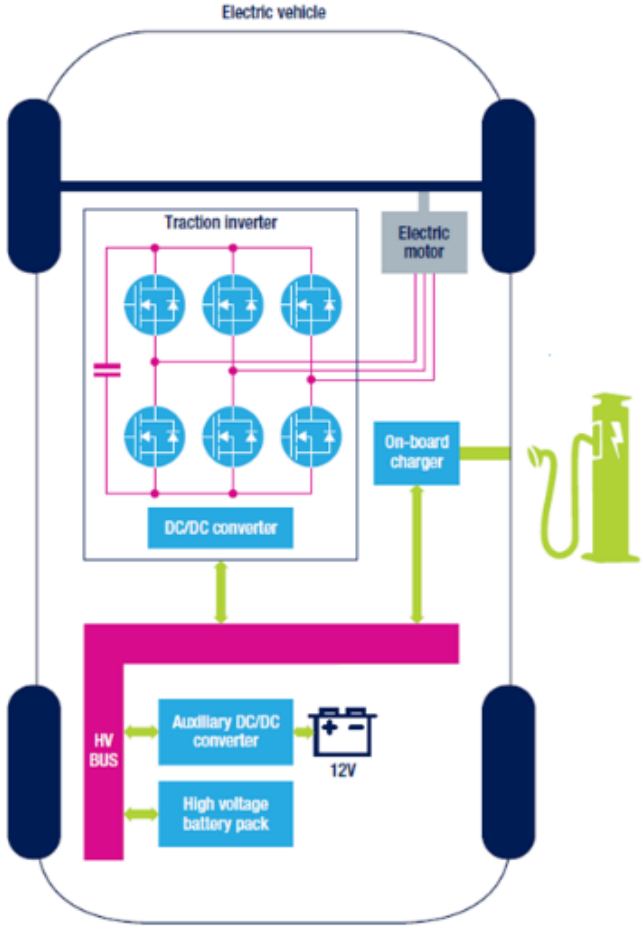
ACEPACK DMT-32 power module for electric vehicles

Power electronic bay
Bidirectional converters

Traction inverter	10-200kW	400 → 800V 48V LV/MHEV **IGBT → SiC**
On-board charger	7-22-…kW	
DCDC converter	4-10-…kW	
Battery management	8-14 cells	400V → 800V 48V LV/MHEV





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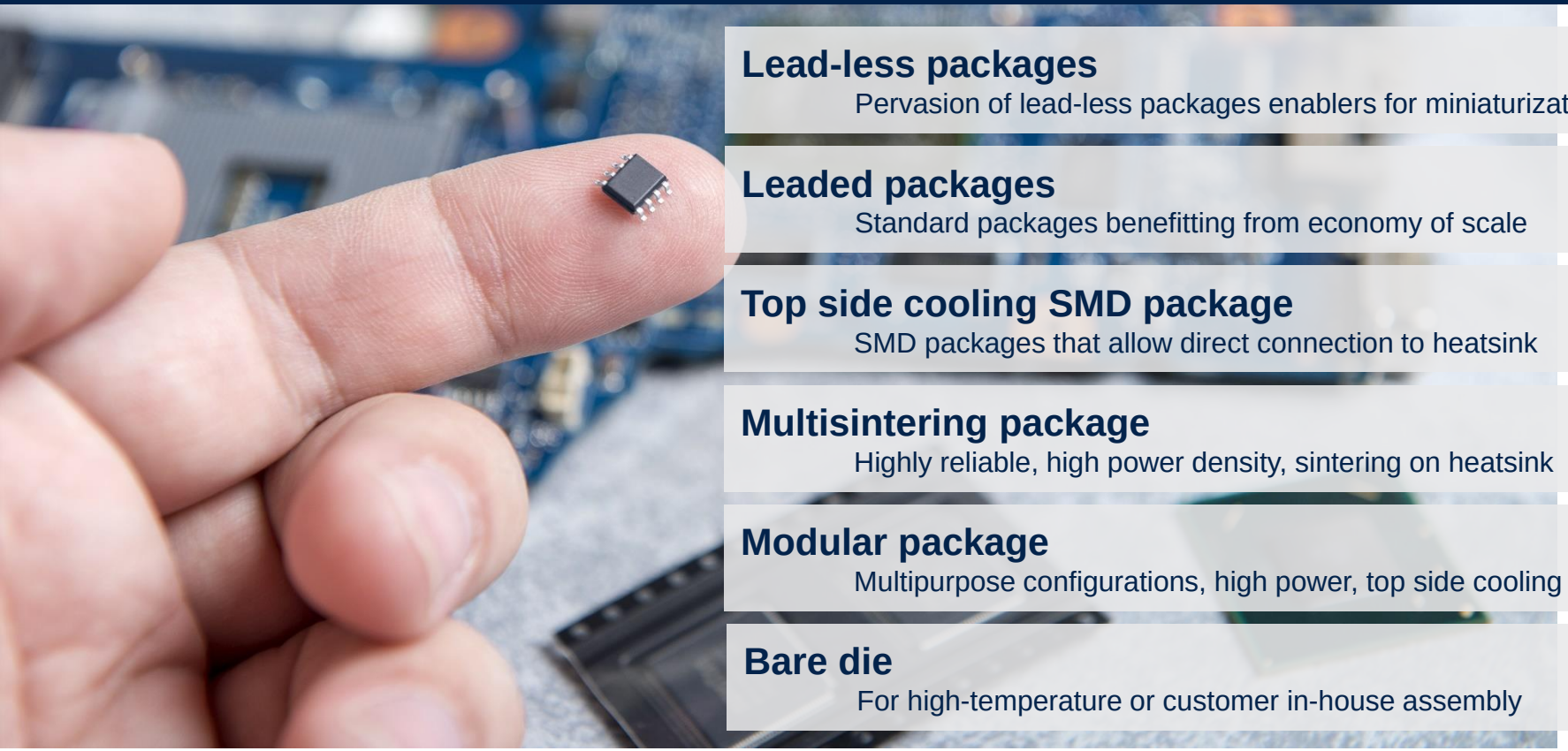
ST power packaging technologies

Investing in advanced package technologies



Lead-less packages
Pervasion of lead-less packages enablers for miniaturization

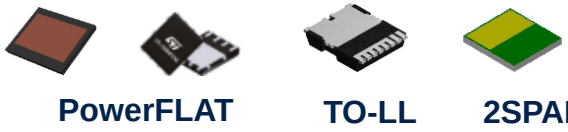
Leaded packages
Standard packages benefitting from economy of scale

Top side cooling SMD package
SMD packages that allow direct connection to heatsink

Multisintering package
Highly reliable, high power density, sintering on heatsink

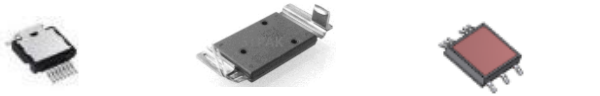
Modular package
Multipurpose configurations, high power, top side cooling

Bare die
For high-temperature or customer in-house assembly

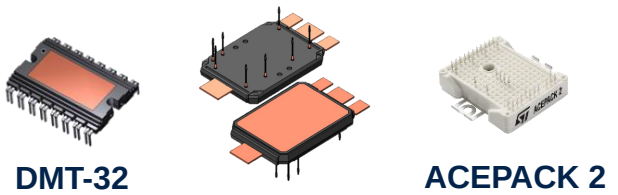


PowerFLAT TO-LL 2SPAK

SOT223-2L DPAK TO247-4L H2PAK



HU3PAK STPAK SMITPAK



DMT-32 HB Sirius ACEPACK 2

Tested cut/uncut wafer Tested dice in T&R

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