Sub-track I – Smart Mobility Presentation
ST’s power discrete solutions improve performance and density in new energy vehicles

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STMicroelectronics
SiC MOSFET technology & product roadmap
## Technology Roadmap

### 2014: Gen1
- 1200 V (0 to 300 kHz)
- 1700 V (0 to 300 kHz)
- 20 V driving voltage

### 2018: Gen2
- 650 V (0 to 500 kHz)
- 1200 V (0 to 500 kHz)
- 18 V* driving voltage

### 2020: Gen3
- 750 V (0 to 500 kHz)
- 1200 V (0 to 500 kHz)
- 18 V* driving voltage

### 2023: Gen4
- 750 V (0 to 1 MHz)
- 1200 V (0 to 1 MHz)
- 15 V* driving voltage

### 2025: Gen 5
Radical innovation

## Product Status

<table>
<thead>
<tr>
<th>Generation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen1</td>
<td>In full production</td>
</tr>
<tr>
<td>Gen2</td>
<td>In full production</td>
</tr>
<tr>
<td>3rd Gen</td>
<td>Technology qualified in Q4 2020</td>
</tr>
<tr>
<td>4th Gen</td>
<td>In development</td>
</tr>
<tr>
<td></td>
<td>Expected introduction in 2023</td>
</tr>
<tr>
<td>5th Gen</td>
<td>Feasibility and simulation results in 2022</td>
</tr>
</tbody>
</table>

* Suggested for best performance
STPOWER SiC MOSFET positioning vs. product family & package

Breakdown Voltage

<table>
<thead>
<tr>
<th>Voltage</th>
<th>G2</th>
<th>G3</th>
<th>G2</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G1</th>
</tr>
</thead>
<tbody>
<tr>
<td>650V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>750V / 900V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Series

- G2
- G3
- G3
- G1
- G2
- G3
- G1

On-state resistance

<table>
<thead>
<tr>
<th>Voltage</th>
<th>G2</th>
<th>G3</th>
<th>G3</th>
<th>G1</th>
</tr>
</thead>
<tbody>
<tr>
<td>650V</td>
<td>18 mOhm to 55 mOhm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>750V / 900V</td>
<td>14 to 55 mOhm</td>
<td>11 mOhm (750)</td>
<td>52 mOhm to 520 mOhm</td>
<td></td>
</tr>
<tr>
<td>1200V</td>
<td>25 mOhm to 75 mOhm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700V</td>
<td>8 to 69 mOhm</td>
<td>1 Ohm and 65 mOhm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Package

- PowerFLAT 8x8 STD & DSC
- H2PAK-7L
- HU3PAK
- ACEPAK SMIT
- HIP-247 (3 & 4 leads)
- STPAK
- Bare Dice

Surface Mounting | Through-Hole | Special Package Solutions
HV MOSFET technology & product roadmap
High-voltage power MOSFET for automotive

Technology roadmap

- DM2 → DM6 → DM9: Higher power level and better efficiency
- K5 → K6: Sole source for very high voltage SJ MOSFET
- M5 → M9: Increasing high power density and compactness system

Advanced packaging

- HU3PAK
- ACEPACK SMIT
- TOLT*
- TOLT DSC*

OBC DC-DC Converter
MDmesh DM2, DM6, DM9* (SOP Q4’23)

Battery Management System
MDmesh DM6, MDmesh K5
MDmesh K6* (SOP Q1’24)

Aux for Traction inverter
MDmesh K5

*Under development
The most complete product portfolio for high power and efficiency systems

- Best $R_{\text{DS(on)}} \times \text{area}$
- Step forward for both hard and soft switching
- DM9 FAST diode embedded version available
- Wider product portfolio

Why choose M9/DM9?

- Only one technology for hard (PFC) and soft switching (LLC)
- Higher power level and better efficiency maintaining same package
- Increasing power density providing smaller package
- Improved system ruggedness applying new production processes
- Better electrical parameters, giving more safety to the system

MDmesh M9/DM9
600V, 650V

ST’s Si MOSFET: the insurance in the high voltage power switches scenario

High-voltage silicon MOSFET M9 – the next step forward
**MDmesh M9 / DM9 main features**

### $R_{ds(ON)}$
- Very low $R_{ds(ON)}$ per area
- Suitable for Hard switching topologies
- Best choice for Resonant high power density system

### Power losses
- Reducing switching energy losses
- Reducing switching time
- Increasing switching frequency

### Process
- Reduced $BV_{dss}$ spread <70V
- Reduced $V_{th}$ spread <1V
- Ruggedness (UIS test)
- Increasing $f_{sw}$

### Robustness
- Static $dv/dt$ up to 120V/ns
- Dynamic $dv/dt$ up to 50V/ns (M9)
- Dynamic $dv/dt$ up to 120V/ns (DM9)
Rectifier technology & product roadmap
Leadership in power management

DFD* rectifier footprint in multiple markets

High-voltage diodes

SiC diodes

Low-voltage diodes

> 200V

STTH series
STBR series

650V & 1200V

STPSC series

< 200V

FERD series
STPS series
STPST series

✓ AEC-Q101 = Y suffix in part numbers
✓ PPAP capable

* DFD = Discrete & Filter Division
Power module solution

ACEPACK DRIVE

ACEPACK 1 & 2

ACEPACK DMT-32

Dual in line, molded, through-hole 32-pin power modules
H(EV) & Ecosystem: Traction

- Car electrification mega-trend due to CO₂ worldwide reduction programs
- Maximize production capacity of ACEPACK DRIVE SiC MOSFET: the "commodity" power module solution adopted by majority of car makers for the current and next Platform.
- ACEPACK DRIVE SiC MOSFET & IGBT+Diode
- Customized Transfer Molded Modules (TMM) for +2026 platforms Full SiC, IGBT + Diode & Hybrid
- Complete Power Box with advanced technique for interconnection to the cooler

H(EV) & Ecosystem: OBC & Other mechatronic platforms

- Car electrification market is expanding
- Use of new high efficiency topologies/solutions for an increasing miniaturization of the system
- Not only light EV but also truck, van and fuel cell vehicles requiring higher power
- Bi-directionality is requested
- ACEPACK DMT-32: compact and slim power module tailored for car OBC, DC-DC and auxiliaries: 650V/1200V SiC MOSFET based
- ACEPACK 1 & 2: to enabling DC-DC and auxiliary systems for higher power like for truck, van and fuel cell systems.

Key factors for growth

Market Segment

Products
Automotive application focus: OBC, DC-DC, and traction inverter

Power modules approach main benefits:

- lower occupation → Increased power density
- Easy of cooling system design
- Improved manufacturability: from IMS to PCB
- Improved stray inductance and parasitic components

Applications
# ACEPACK* power module package options

<table>
<thead>
<tr>
<th>ACEPACK options</th>
<th>Package design</th>
<th>Key features</th>
<th>Configurations</th>
<th>Applications</th>
</tr>
</thead>
</table>
| ACEPACK 1       | ![ACEPACK 1 Image](image1.png) | • Silicon 100% produced and controlled by ST (SiC MOSFET, IGBT, and diodes)  
• Compact design and cost-effective system approach for a plug & play system solution  
• Configuration flexibility  
• 2500Vrms electrical isolation | • CIB  
• Six-pack  
• Three level boost  
• Four-pack  
• Half-bridge |  |
| ACEPACK 2       | ![ACEPACK 2 Image](image2.png) | | |  |
| ACEPACK DMT 32  | ![ACEPACK DMT 32 Image](image3.png) | • Silicon 100% produced and controlled by ST (SiC, MOSFET and diodes)  
• Electrically insulated  
• Top-side cooling  
• Dual-in-line molded through-hole  
• 3kVrms electrical isolation | • Four-pack  
• Six-pack  
• Totem pole |  |
| ACEPACK DRIVE   | ![ACEPACK DRIVE Image](image4.png) | • 750 - 1200V SiC MOSFET-based switch  
• Improved light load performance for extended EV driving ranges  
• Active metal bonding (AMB) substrate for enhanced thermal dissipation  
• Different bus bar configuration options  
• Extremely low energies dissipation  
• Direct cooled Cu baseplate with pin fins | • Six-pack | |

* is a registered and/or unregistered trademark of STMicroelectronics International NV or its affiliates in the EU and/or elsewhere.
ACEPACK 1 and ACEPACK 2 key benefits

Industrial drives, motor control, UPS, automotive EV ecosystems and DC-DC converter

- Press fit and solder pin options for configuration flexibility
- Up to 1200V breakdown voltage
- Integrated screw clamps
- All power switches in a module including NTC
- Several current ratings available
- Several configuration options (CIB, six-pack, half-bridge etc..)
- Low stray inductance
- High reliability and robustness, lower power-side board occupation
- Compact design and cost-effective system approach
- Very high-power density
New Power Modules family suitable for OBC, DC-DC and auxiliary applications (*):

- SiC MOSFET Gen2 and Gen3 power switches used in different configurations: Four pack, Six pack, Totem Pole
- Suitable to cover several sub-function up to 22kW of power range
- SOP: Q4’23(**)

 newRow

Totem Pole

Four Pack

Six Pack

(*) Auxiliary application as: fluid pumps and HVAC and climate control for BEV/HEV; (**) depending on configuration
Direct liquid cooled high-performance power module

Traction inverter for (H)EV, trucks, and buses

Press fit connections for high reliable and long-lasting connection

AQG-324 qualified

Pin-fin base plate for direct liquid cooling

Dedicated NTC for each single substrate

Best-in-class $R_{DS(on)}$

ACEPACK DRIVE based on SiC MOSFET Gen 3
1200V & 750V

Internal layout optimized for minimized stray inductance

High reliability and robustness: dice sintered to substrate for SiC-based power modules

Different bus bar available to fit welding or screwing connection methods

AMB substrates for better thermal management for SiC-based power modules

Extremely high-power density
# ACEPACK DRIVE for 400V battery

<table>
<thead>
<tr>
<th>IGBT &amp; diode based</th>
<th>SiC MOSFET based</th>
</tr>
</thead>
<tbody>
<tr>
<td>120kW</td>
<td>175kW</td>
</tr>
<tr>
<td>150kW</td>
<td>220kW</td>
</tr>
<tr>
<td>180kW</td>
<td></td>
</tr>
</tbody>
</table>

175kW

ADP46075W3

220kW

ADP61075W3

*Power (3)*
ACEPACK DRIVE for 800V battery

Gen3 SiC MOSFETs: Tailored for high-power traction inverters

SiC MOSFETs → 3 Phase inverter

180kW
ADP280120W3

230kW
ADP360120W3

300kW
ADP480120W3

Power (1)

1. Power level coming from simulation, system power depending on inverter design and mission profile
ACEPACK DRIVE
SiC-based product portfolio in full production

ACEPACK DRIVE: Full Gen3 SiC MOSFETs

<table>
<thead>
<tr>
<th>Part number</th>
<th>SiC technology</th>
<th>BV</th>
<th>$R_{DS(on)}$ @ 25°C (per switch)</th>
<th>$R_{DS(on)}$ @ 175°C (per switch)</th>
<th>Max peak power indication$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADP480120W3(-L)</td>
<td>Gen 3</td>
<td>1200V</td>
<td>1.90 mΩ</td>
<td>3.35 mΩ</td>
<td>300 kW</td>
</tr>
<tr>
<td>ADP360120W3</td>
<td></td>
<td></td>
<td>2.55 mΩ</td>
<td>4.25 mΩ</td>
<td>230 kW</td>
</tr>
<tr>
<td>ADP280120W3</td>
<td></td>
<td></td>
<td>3.80 mΩ</td>
<td>6.50 mΩ</td>
<td>180 kW</td>
</tr>
<tr>
<td>ADP61075W3(-L)</td>
<td></td>
<td>750V</td>
<td>1.20 mΩ</td>
<td>1.95 mΩ</td>
<td>220 kW</td>
</tr>
<tr>
<td>ADP46075W3</td>
<td></td>
<td></td>
<td>1.60 mΩ</td>
<td>2.60 mΩ</td>
<td>175 kW</td>
</tr>
</tbody>
</table>

1. Power level coming from simulation, system power depending on inverter design and mission profile

STEVAL-APD02ACB eval board for SiC-based devices

STEVAL-APD02ACB is fully compatible with ACEPACK DRIVE power press fit pins and requires a dedicated pressing tool to mount it.

Proof of Concept available for ACEPACK DRIVE SiC devices only.

New STEVAL with full ASIL/D will be available by end of this year: validation running.
Thank you