
Eric Moreau
Exagan

Spin off SOITEC & CEA-LETI
Created in 2014 - employees
2 sites in France – 1 in Taiwan
3 Industrial partnerships (MFG, Sales, Quality)
Focus on GaN 650..1200 V Power Switch Solutions
Unique 200 mm GaN/Si technology
Fab-light industrial model, in-house epitaxy
Exagan’s Fab-light Model with Established 200 mm Supply Chain

- Robust & cost competitive manufacturing, for high volume production with limited CAPEX on materials using standard CMOS manufacturing

Exagan direct manufacturing & volume shipment

Process transfer to partner (exclusive)

Test transfer to partner (exclusive)

Exagan Manufacturing

MFG fab in France
- Standard & automated
- Equipment
- Process = 1 equipment

F fabs in Germany and France
- Standard CMOS 200mm
- No specific CAPEX
- High capacity available

Fabs in Germany and France
- Standard packaging lines
- Very high-volume production
- Automated testing
- Turnkey service: direct shipment to customers

Fab light
- Volume scalability
- Cost competitiveness
- Full technology control

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200-mm GaN-Si: Silicon Scalability, High Quality and Competitive Cost

G-Stack™: Enabling Ultimate balance between GaN thickness, quality & flatness on Si 200 mm

Patented Technology

Costs vs Volume: GaN vs SiC vs Si

System benefit vs Si

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Designing Products for Outstanding Standards

From JEDEC JC70-1 to AECQ100/101

eV/pHeV on board and fast charging

Design for the most demanding application in terms of quality and reliability
Material & Device Based Reliability Testing

2DEG & contact reliability
- Elementary test structure
- Metal 3
- VIA 2
- Metal 2
- VIA 1
- Metal 1
- Contact
- GaN (2DEG)

Continuous resistance monitoring

GaN-On-Si EPI Lifetime
- DC EPI leakage measurements
- DC EPI leakage model

Thermionic emission
\[ I_{\text{sub}} = T^2 \cdot e^{-\frac{2.9 \times 10^{-10}}{K} + \frac{1.8 \times 10^{-22}}{K} - 1.1 	imes 10^{-2}} V_{\text{sub}} \]

Critical parameters drifts on wafer level
- 210°C / 1000 Hrs
- Today: 45 Years less than 1 ppm 400 V/ 85°C

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Product Use Case(s) Reliability Testing

**Repetitive HV Spikes**

- Silicon → avalanche
- GaN → No avalanche
- 85°C
- 650 V
- 700 V GaN → 900 V
- More voltage margin mandatory for GaN
- Adjustable overshoot from 40 V to 900 V
- 50..150 V/ns
- 0..350 V
- Leakage monitoring (Cp/Cpk) > 10 M spikes

**Repetitive hard switching**

- Voltage
- DUT
- 22 μH
- 400 to 650 V
- 1 to Max DC Amp.
- 25°C & 150°C

**Buck/Boost Converter**

- Switching/Locus modes
- Different magnetizing energies
- Monitoring Tcase switches/Efficiencies

**Device:** EXA06C190LDS0
Exagan’s Product Portfolio,

**G-FET™**
650V Transistor
Safe and Powerful Switching

**G-DRIVE™**
650 V Transistor + Driver
Intelligent and Fast Switching

<table>
<thead>
<tr>
<th>Technology</th>
<th>TRANSISTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaN MIS Transistor</td>
<td></td>
</tr>
<tr>
<td>Standard analog gate control</td>
<td></td>
</tr>
<tr>
<td>&lt; 500 kHz switching</td>
<td></td>
</tr>
<tr>
<td>&lt;10 up to 75 A capability</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Features</th>
<th>+ DRIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on G-FET with embedded intelligent driver</td>
<td></td>
</tr>
<tr>
<td>Digital Control (MCU)</td>
<td></td>
</tr>
<tr>
<td>Up to 3 MHz switching</td>
<td></td>
</tr>
<tr>
<td>Integrated protection &amp; diagnostic</td>
<td></td>
</tr>
<tr>
<td>High speed current monitoring capability</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Applications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer power supply</td>
<td></td>
</tr>
<tr>
<td>(Cost competitiveness, &lt; 100 W)</td>
<td></td>
</tr>
<tr>
<td>Automotive Charger (On/Off board)</td>
<td></td>
</tr>
<tr>
<td>(High Reliability, 3-20 KW)</td>
<td></td>
</tr>
<tr>
<td>High end consumer power supply</td>
<td></td>
</tr>
<tr>
<td>(&gt; 100 W)</td>
<td></td>
</tr>
<tr>
<td>Datacenter power supply (KW)</td>
<td></td>
</tr>
<tr>
<td>Industrial motor control</td>
<td></td>
</tr>
<tr>
<td>Automotive DC/DC (1.5 KW)</td>
<td></td>
</tr>
</tbody>
</table>

**Product roadmap**

- **2019**: Generic product portfolio
- **2020**: Application specific standardized products
- **2021**: Automotive qualified products

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GaN Discrete to Smart Power Integration Solution

- **Power Discrete**
  - G-FET™
  - Switches

- **Discretes Integrated**
  - Driver + Switches

- **Smart HV Power Integration**
  - G-Drive™
  - Driver + Switch(es) + Protections
  - Diag. + Syst. Features + ...

System Integration
G-FET™ Series

G-FET™
Safe and Powerful

- Broad power range
- Easy system implementation
- Rugged gate

Product features

<table>
<thead>
<tr>
<th>System design</th>
<th>Analog power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving</td>
<td>+/- 20V analog</td>
</tr>
</tbody>
</table>

Benefits for power-conversion designers include:
- Compatibility with standard silicon drivers
  - 10-volt analog signal to control the gate
  - Robust gate with a maximum rating of ± 20 V
  - No gate leakage
  - No negative voltage to force in off-state
- Gate return pin to reduce the switching inductance loop

650 V products portfolio

<table>
<thead>
<tr>
<th>Part number</th>
<th>$R_{DS(on)}$ (mΩ)$^2$</th>
<th>$I_{OSS}$ (A)$^3$</th>
<th>$I_{DM}$ (A)$^3$</th>
<th>$C_{oss}$ (pF)$^3$</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXA06C190LDS0</td>
<td>190</td>
<td>10</td>
<td>30</td>
<td>45</td>
<td>PQFN8x8</td>
</tr>
<tr>
<td>EXA06C135LDS0</td>
<td>135</td>
<td>25</td>
<td>75</td>
<td>65</td>
<td>PQFN8x8</td>
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<tr>
<td>EXA06C075LDS0</td>
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<td>30</td>
<td>90</td>
<td>110</td>
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<tr>
<td>EXA06C050XDS0</td>
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<td>40</td>
<td>120</td>
<td>145</td>
<td>TO247-4L</td>
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<td>EXA06C030HSS0</td>
<td>30</td>
<td>75</td>
<td>225</td>
<td>240</td>
<td>PQFN15x15</td>
</tr>
</tbody>
</table>

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Exagan GaN technology

650 V Optimized soft breakdown

< 100 µA @ 900 V

650 V/ 135 mΩ

100 nA @ 650 V
G-FET™ 650 V / 75 mOhm

Eon+Eoff ~ 65 μJ @ 20 A @ 25°C

Eon+Eoff ~ 54 μJ @ 20 A @ 25°C
G-DRIVE™ Series

G-DRIVE™
Intelligent and fast

- Embedded GaN gate driver
- Fast switching capability (MHz)
- Integrated protection and diagnostic
- Slew rate control capability
- Peak current monitoring

Product features

<table>
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<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>System design</td>
<td>Digital power</td>
</tr>
<tr>
<td>Driving</td>
<td>3.3V to 5V CMOS</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>UVLO, OCP, TSD^2</td>
</tr>
<tr>
<td>Self protected</td>
<td>State machine</td>
</tr>
<tr>
<td>Current sensing</td>
<td>Adjustable, SFB^2</td>
</tr>
<tr>
<td>EMI</td>
<td>Slew rate control</td>
</tr>
</tbody>
</table>

2. Under Voltage Look-At, Over Current Protection, Thermal Shut Downs, Sense Feedback

Benefits for power-conversion designers include:

- Control of the load current without complex software
  - CMOS digital control and diagnostics
  - Current loop regulation using Sense Feedback (SFB)
  - Embedded state machine for protection
- Self-protection thanks to an embedded state machine
- EMI optimization using slew rate adjustment

650 V product portfolio

<table>
<thead>
<tr>
<th>Part number</th>
<th>R_{on} (mΩ)^2</th>
<th>I_{on} (A)^2</th>
<th>I_{off} (A)^2</th>
<th>C_{SS} (pF)^2</th>
<th>Package</th>
</tr>
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<tbody>
<tr>
<td>EXA06G0150M550</td>
<td>190</td>
<td>10</td>
<td>30</td>
<td>30</td>
<td>PQFN8x8</td>
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<tr>
<td>EXA06G0151M550</td>
<td>115</td>
<td>25</td>
<td>75</td>
<td>35</td>
<td>PQFN8x8</td>
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<tr>
<td>EXA06G0065M550</td>
<td>65</td>
<td>35</td>
<td>100</td>
<td>80</td>
<td>PQFN8x8</td>
</tr>
</tbody>
</table>

^2 2.5°C typical values

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G-DRIVE™ GaN Solutions

- GaN-Si Power
- Dedicated Driver
- Built-In Protected (Current, Temp...,)
- Current sensing (Loss less)
- Very fast resp. time (SC < 40 ns)
- Very fast switching time (< 5 ns)
G-DRIVE™ Implementation

**Simplified Application Diagram:**

- **MCU**
  - Computes Current Targeted
  - Generates PWM signal (« IN »)
  - Sets current peak (« IPK_CTRL »)
- **G-DRIVE**
  - Reports Peak Current Detected (« IPK » signal)
  - Reports Fault (Fault Report)
- **PWM Output**
- **IN**
- **AN0**
- **IPK_CTRL** (Current peak setting)
- **Input Capture** (Detection Report)
- **I/O**
- **FAULT**
- **400 V**
- **Drain**
- **Source**
- **GND**
- **PGND**

Current Regulation Loop Cycle by Cycle

*MCU Computes Current Targeted*

*MCU sets current peak (« IPK_CTRL »)*

*MCU Generates PWM (« IN » signal)*

*G-DRIVE Reports Peak Current Detected (« IPK » signal)*

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G-DRIVE™ EXA06D190LDS0

400 Volts

Fall < 7ns

~ 25V ripple

~ 3 Amps

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G-DRIVE™ at a Glance

- **Up to 3 Mhz**
- **Propagation Time (10 to 20 ns)**
- **Switching Time (< 5 ns)**

**Peak Current Accuracy < 5% @ 250 mA (0 to 150°C)**

**Slew Rate Control**
Current Peak & Over Current Detections (EXA06D190MSS0)

example

- Current Threshold set @ 10 A
- Over Current Protection set @ 12 A

Peak Current Threshold detected

Ipk digital signal
(Blanking ~ 200ns, prog. fuse)

Over Current Protection (OCP) detected
(Prog. fuse)

OCP digital signal
(Resp. time < 40ns)
G-FET™ & G-DRIVE™ Evaluation Modules

4 layers PCBs
Switching node capacitance & Power loop Inductance optimized

HS 400 V / 12 A ➔ 25 V Ripple

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G_FET™ Solutions for PFC Totem Pole

GaNDalf

- Specifications:
  - 85Vac to 265Vac input
  - 400Vdc out
  - <10% THD, >0.98 PF
  - 99% efficiency target

650 V/ 30m
- PQFN 15*15

650 V/ 190m
- PQFN 8*8

650 V/ 50m
- TO247-4L
Thank you