TRANSFORMING THE WORLD

WITH SMALLER, LOWER COST, MORE EFFICIENT POWER ELECTRONICS

Adapting GaN into products we use everyday
Semicon Taiwan 2019
Market leader for GaN power transistors

- GaN-on-Silicon transistors for power conversion
- Industrial most extensive & highest-performance products
  - 100V & 650V devices; industry-best performance
  - Applications from 25W to 225,000W
  - $10B SAM with existing products

Global company, decades of GaN experience

- Parts shipping to >2000 customers since 2014
- World-class fabless manufacturing and packaging
- HQ and R&D in Ottawa, Canada
- Global Sales & Application Engineering
GaN Advantages

**GaN Material advantages**

- High frequency – 100MHz
- Best FOM – 40x better
- Lower specific $R_{\text{ON}}$ – up to 10x smaller size

**System Advantages**

- Higher Efficiency – cuts losses 50%-90%
- Smaller size, higher density – 1/4 the size
- Lower BOM cost – smaller passives, thermal
- Enable new topologies – VHF, wireless power

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**Key Figure of Merit ($R_{\text{on}} \times Q_g$) [$\Omega \times nC$]**

- MOSFET
- SiC
- Infineon C3
- Infineon CP
- STMicro MS
- Other GaN
- Super Junction MOSFET

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**Power Supply with Si**

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**Same PSU with GaN**
GaN HEMT Fundamentals

GaN High Electron Mobility Transistor (HEMT)

- Lateral structure vs vertical
- Epi-growth of GaN on standard silicon wafer, 2-Dimensional Electron Gas (2DEG) is formed at the hetero-interface between GaN and AlGaN
- 2DEG has very high charge density and mobility – Excellent device performance
- The result: very low $R_{\text{ON}}$ and high speed device
- However, 2DEG after it is formed is intrinsically D-mode (normally on), industry needs normally off

Vertical Power MOS

Lateral GaN HEMT

Si substrate
2DEG Channel
GaN Buffer Layers
AlGaN Barrier Layer
Main current path
GaN Source
GaN Drain
Gate
Main current path
No main current flowing in Si substrate, tied to Source potential for optimum performance
Achieving Normally Off GaN– E-mode

GaN Systems E-Mode

- P-type GaN depletes 2DEG channel underneath, a positive gate bias turns on the 2DEG – Normally off e-mode
- Voltage driven like Si MOSFET
- No Gate Oxide: high gate reliability
- $V_{GS}$ rating higher than other E-mode GaN: +7/-10V
Island Technology®

- More reliable
- Higher current
- Lower cost

- Scalability for flexible and compact layout
- Enables higher current GaN die
- Island isolation for defects, higher yields

![Diagram of Island Technology](image)

![Graph showing die yield probability vs. current](image)
Innovative packaging for high speed GaN device:

- Extremely low inductance: high frequency switching
- Near Chip Scale embedded Packaging
- No wire bonding: high reliability
- Better CTE match to PCB: Temp cycle reliability*
- Lower thermal resistance $R_{\text{thJC}}$

[*) GaNPx passed 1000hr IPC9701 solder joint reliability test, condition: 12-Layer 2.5mm PCB, 5oz inner copper and 2oz outer copper.]
GaN Is Maturing In These Markets

**DATA CENTERS**
Inefficient and approaching 5% of global power usage

**RENEWABLE ENERGY**
Storage needed for Distributed Energy (ESS)

**INDUSTRIAL**
Inefficient and 30% of worldwide electricity usage

**ELECTRIC VEHICLES**
Government reduced CO2 & high MPG regulations

**CONSUMER**
Large, heavy, and Ecodesign directive for higher efficiency
Next generation power supply with GaN

High Frequency
- Controller IC
- High-frequency magnetic material

Packaging and Integration
- Embedded packaging
- System assembly
- Thermal design

New Control Topologies
- CRM soft switch
- VHF DC/DC

System optimization
- Reduce passive size

Control optimization

High performance power supply

GaN Advantages
Fast growing customer base

Computer charger
- 4x smaller
- 3x lighter
- 40 W/in$^3$

AC/DC Converter
- 2x smaller
- 3x more power
- 6x density increase

Solar ESS
- 2x smaller
- 3x lighter
- Eliminated fan

Data Center server power supply
- 50% higher power density
- 20% lower $P_{loss}$

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- 4x smaller
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GaN Adapters in the Market

- Apple Store

- Amazon Prime Day

- Double Eleven Day
EZDrive™ makes it easy

The GaN Systems EZDrive circuit is a low cost, easy way to implement a GaN driving circuit.

The EZDrive circuit utilizes the standard controller with integrated driver to drive GaN Systems’ devices, eliminating the need for an extra driver.

<table>
<thead>
<tr>
<th>Application Considerations</th>
<th>Silicon MOSFETs</th>
<th>GaN Systems EZDrive</th>
<th>Monolithic-integrated GaN driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total BoM Cost</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
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<tr>
<td>Choice of devices to optimize design</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
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<tr>
<td>Use controller driver, eliminate redundancy</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
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<tr>
<td>EMI control</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Power density</td>
<td>✗</td>
<td>✓</td>
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</table>

Adapter performance is better with GaN Systems
What is the **EZDrive** Solution?

- Enables controller to drive GaN device with a small number of external components
- Turn ON / OFF slew rate is controllable with external resistors to optimize EMI
- Applies to any controllers with single, dual, or high-side/low-side drivers
“... the known technological benefits of GaN combined with widespread industry interest in developing GaN-based solutions will result in market success for GaN in the AC adapter market.”

“We expect to find GaN more often in high efficiency, small form factor, higher power AC adapters.”

“... we expect to see incremental innovations moving forward that make GaN a bigger player in the adapter space.”
Summary – GaN Systems’ EZDrive Solution

• Universally converts any IC controller/driver to properly drive GaN Systems E-HEMTs
• Eliminates redundant GaN drivers & LDOs of a monolithic integrated driver GaN device
• Turn On/Off slew rate is controllable with external resistors for complete EMI control
• Applies to single, dual, or half-bridge controllers with Si MOSFET drivers

![Diagram of EZDrive Solution](image)

- Simple
- Eliminates drivers
- Higher power density
- Lower Cost
**Join the wave - revolutionize your power system**

**Broader line of Products**

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Current (A)</th>
<th>Resistance (mΩ)</th>
<th>Dimensions</th>
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<td>200</td>
<td>6.6 x 5.0 mm</td>
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<td>GS61008T</td>
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<tr>
<td>GS-010-120-1-P</td>
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<td>7.6 x 4.6 mm</td>
</tr>
</tbody>
</table>

**Many Eval Kits & Reference Designs**

- **Half bridge power stage**
  - 650 V test kit
- **High power Paralleling**
  - 1.5 kW bridgeless totem pole PFC
- **3 kW bridgeless totem pole PFC**
- **650 V test kit**
- **300 W wireless power transfer**
- **EZDrive™ Eval Kit**
- **Full Bridge Class D Amplifier**

**Learn more at gansystems.com**