TRANSFORMING THE WORLD
WITH SMALLER, LOWER COST, MORE EFFICIENT POWER ELECTRONICS

Power Electronics Conference
December 3, 2019
OBJECTIVES

• Introduction
• GaN’s Role in Power Electronics
• Improving Customers’ Financial Performance
• Increasing Business Competitiveness
• Addressing Customer Challenges
• Tools & Solutions
• Conclusion
**GaN Systems company overview**

**Market leader for GaN power transistors**
- GaN-on-Silicon transistors for the power conversion market
- Industry’s most extensive & highest-performance products
  - Enhancement mode devices
  - 100V & 650V devices; industry-best performance

**Global company with decades of experience in GaN**
- Parts shipping to >2000 customers since 2014
- World-class fabless manufacturing and advanced packaging
- HQ and R&D in Ottawa, Canada. Ops HQ in Taiwan.
- Sales & App. Eng. in Germany, Japan, China, Taiwan, Korea, USA
GaN value proposition

GaN SYSTEMS OUTPERFORMS OTHER TRANSISTORS

- 13X better than best Silicon
- 6X better than best SiC
- 3X better than other GaN

CUSTOMERS ACHIEVE IMPROVED SYSTEMS

- Efficiency: 4x lower losses
- Size: 4x smaller
- Weight: 4x lighter
- Lower system cost: 10% to 20%
**Product Portfolio**

### 650 V GaN POWER TRANSISTORS

- **“T” Top-side Cooling**
  Simpler thermal design for hard-switching applications

- **“B” & “P” Bottom-side Cooling**
  Compact solution for lower power designs

- **“D” Die**
  Optimized for wire bonding. Suitable for power module applications

- **“L” 5x6 PDFN**
  A cost effective solution for low power designs

### 100 V GaN POWER TRANSISTORS

- **GS61004B**
  45 A, 15 mΩ
  4.6 x 4.4 mm

- **GS61008B**
  90 A, 7 mΩ
  7.6 x 4.6 mm

- **GS61008T**
  90 A, 7 mΩ
  7.0 x 4.0 mm
GaN is growing across many markets

**CONSUMER**
Large, heavy, and Ecodesign directive for higher efficiency

**ENTERPRISE**
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 CO$_2$ & high MPG regulations
GaN Adapters in the Market

- Apple Store

- Amazon Prime Day

- Double Eleven Day
GaN POWER SUPPLIES

AC/DC Power Supply Unit in the Rack

• GaN outperforms Silicon
• Efficiency 98% vs 96%
• Power density 100 W/in\(^3\) vs 67

DC/DC Power Supply Unit in the Server

• GaN outperforms Silicon
• Power Loss 50% reduction
• Power density 2X increase
40% of Data Center Operating Cost is Energy

GaN based PSU in the Data Center

Higher energy efficiency
- $461M lower energy bill
- 10% more servers per rack
  - $1.4B additional revenue
A 1.5KW Totem Pole PFC Loss Breakdown – SiC and GaN

1.5KW BRIDGELESS TOTEM POLE PFC SWITCHING
POWER DEVICE LOSSES BREAKDOWN

NORMALIZED EFFICIENCY IMPROVEMENT (ΔEFF)

POWER LOSS (W)

100 KHz 200 KHz 300 KHz 400 KHz 500 KHz

GaN E-HEMT
SiC MOSFET

NORMALIZED EFFICIENCY IMPROVEMENT (ΔEFF)

0,0% 0,5% 1,0% 1,5% 2,0% 2,5%

Δ0.3% 60.8% Δ2.2%

Conditions:
- Vin=180Vac~264Vac
- Vo=400V
- Po=1500W at full load

One fast switching transistor (GaN or SiC) per totem pole’s switch
Switching Frequency: 100KHz~500KHZ as calculation condition
1.5kW CCM BTP PFCs peak efficiency and power density GaN & SJMOS

GaN-based PFC

Si-based PFC

Efficiency and Power Density Curve

Optimal range for GaN

GaN-based PFC

Si-based PFC

Peak Efficiency

Frequency

Power Density (w/in³)

Efficiency and Power Density Curve

65KHz 100KHz 200KHz 300KHz 400KHz
Renewable Energy

APPLICATION: ENERGY STORAGE SYSTEM DC/DC INVERTER

SOLAR ENERGY STORAGE SYSTEM
• 4% round-trip efficiency increase
• 30% smaller in size
• 8% BoM cost savings

• Better Power Conversion
• Better Financials
• Better Market Differentiators
Benefits of gan vs IGBT Motor drives

**• IGBT-based Motor Drives**

- Large Sine Wave Filter
- SINE WAVE FILTER or SHIELDED CABLE

**• GaN-based Motor Drives**

- 2x smaller MOTOR DRIVE with built-in FILTER

**Lower Losses**
- Smaller Heatsink. ½, ¼ the size OR even NO HEATSINK
- Higher power density. 2x OR MORE

**Higher Switching Frequency**
- No acoustic noise

**Sinusoidal Output Filter Built In**
- Use of low-cost unshielded, long length cables
- Increased system efficiency
- Easy to use inverter & increased motor lifetime

**Active Infeed**
- Smaller, cheaper filters and no braking chopper
- Meet harmonics requirements with regeneration

Huge BENEFITS with GaN
GaN in Automotive

- Wireless phone charging
- 48V BSG/ISG Inverter (ICE)
- LiDAR sensor
- On-Board Charger
- Wireless battery charging
- DC/DC Converter
- Traction Inverter
- V2G and ESS inverter battery reuse
- Datacenter Server
On-Board Charger (OBC)

- 5X size reduction
- >3X loss reduction
EV DC/DC and Inverter examples

DC/DC Converter

- 1 kW/L
  - 93% Efficient
  - Water-cooled

- 2 kW/L
  - 98% Efficient
  - Air-cooled
  - Lower Cost

100% better Power Density

Inverter

- 8% Cost Reduction
- 93% Efficient
- Water-cooled
- 98% Efficient
- Air-cooled
- Lower Cost
Take full advantage of GaN – Tools and Resources

www.gansystems.com

Application Notes

<table>
<thead>
<tr>
<th>Document #</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>GN001</td>
<td>Design with GaN Enhancement mode HEMT</td>
</tr>
<tr>
<td>GN001 日本語</td>
<td>エンハンシメントモード GaN-HEMT を用いたデザイン</td>
</tr>
<tr>
<td>GN002</td>
<td>Thermal Design for Top-Side Cooled GaNnx® packaged Devices</td>
</tr>
<tr>
<td>GN003</td>
<td>Measurement Techniques for High-Speed GaN E-HEMTs</td>
</tr>
<tr>
<td>GN004</td>
<td>Design considerations of paralleled GaN HEMT</td>
</tr>
<tr>
<td>GN005</td>
<td>PCB Thermal Design Guide for GaN Enhancement Mode Power Transistors</td>
</tr>
<tr>
<td>GN006</td>
<td>SPICE model for GaN HEMT usage guidelines and example</td>
</tr>
<tr>
<td>GN007</td>
<td>Modeling Thermal Behavior of GaNnx® packages Using RC Thermal SPICE Models</td>
</tr>
<tr>
<td>GN008</td>
<td>GaN Switching Loss Simulation Using LTSpice</td>
</tr>
<tr>
<td>GN009</td>
<td>PCB Layout Considerations with GaN E-HEMTs</td>
</tr>
<tr>
<td>GN010</td>
<td>EZDrive™ Solution for GaN Systems E-HEMTs</td>
</tr>
<tr>
<td>GN011</td>
<td>Soldering Recommendations for GaNPX® Packaged Devices</td>
</tr>
</tbody>
</table>

Papers, Articles and Presentations

Learn from our experts how to use and take advantage of GaN transistors in your systems.

- Datasheets
- Application Notes
- Reference designs
- Simulation models
- CAD symbols
- STP files
- FAQs

Document Details

- The Value of GaN HEMTs in 800V and Above Applications
- Why GaN E-HEMTs are a Power Designer’s Transistor of Choice
- Power Amplifier and Cell Design Optimization for Large Air Gap Applications
- Parasitics Optimization for GaN HEMTs in Conventional Housing Type Power Modules
- Getting Started with GaN
- Parasitic Capacitance Effects Loss Mechanism, Calculation, and Measurement in Hard-Switching for GaN HEMTs – Available with IEEE membership
- Parasitic Capacitance Effects Loss Mechanism Calculations and Measurement in Hard Switching with GaN HEMTs – Available with IEEE membership
- A Full Power Simulation Platform for Evaluating Power Semiconductors – Available with IEEE membership
- Opportunities and Challenges of GaN HEMTs in ZVS Applications – Available with IEEE membership
- A Mathematical Guideline for Designing an AC-DC LLC Converter with Dual – Available with IEEE membership
- High-Power-Density 400VDC to 48VDC LLC Solution with GaN HEMTs
- Loss Distribution among Paralleled GaN HEMTs
- High power constant Current Class EF2 GaN Power Amplifier for AirFuel Magnetic Resonance Wire-less Power Transfer Systems
- System-level Considerations with GaN Power Switching
- Opportunities and Design Considerations of GaN HEMTs in ZVS Applications
Take full advantage of GaN - Evaluation Boards

**GS665MB-EVB Motherboard**
+ **GS665xxDB-EVB Daughterboard**
Half bridge power stage

**GSP65MB-EVB**
+ **GSP65RxxHB-EVB**
2-7 kW Insulated Metal Substrate
Configurable Full/Half Bridge Evaluation kit

**GS665x-EVBIMS2**
NEW
2-6 kW Insulated Metal Substrate
Configurable Full/Half Bridge Evaluation kit

**GS1200BTP-EVB**
NEW
1.2kW Bridgeless Totem Pole Power Factor Correction Evaluation Board

**GSWP050W-EVBPA**
**GSWP100W-EVBPA**
**GSWP300W-EVBPA**
50W, 100W to 300W+ Wireless Power Transfer Power Amplifier Evaluation Kits

**GS61008P-EVBHF**
Buck Converter with 40MHz GaN Driver

**GSWP-EVBSKY**
NEW
Dual-mode wireless charging pad supporting AirFuel’s Magnetic Resonant MR and WPC’s Qi charging standards. Fully documented reference design.

**GS65011-EVBEZ**
NEW
EZDrive™ open loop boost evaluation board
**Features and Benefits**

- 650V high-side and low-side GaN Gate Driver
- CMTI Rating 200 V/ns for SW and PGND nodes
- Independent Source/Sink for EMI dV/dt Adjust
- Integrated $V_{GS}$ regulation and 1MHz+ range
- Ultra-small 650V GaN gate drive PCB layout
- Reduced schematic part count & BOM Cost

**Applications**

- AC-DC Adapters for Mobile, OLED TV, Gaming
- Enterprise: 1U Power Supplies to 3kW range
- Industrial: PV Inverters/ESS and Motor Drives
- Totem Pole Bridgeless PFC, LLC, ACF, ZVS

Created in partnership with ON Semiconductor, featuring NCP51820, a high voltage Half-Bridge gate driver
WEBINAR: Simple Layout Steps for Maximizing GaN Design Performance

• Designing with GaN is not difficult
  - Many similarities to MOSFET
  - Differences require attention to detail but no new concepts

• Common “first-time” mistakes
  - Missing Kelvin source
  - Absence of power loop flux cancellation
  - Poor gate loop

• Many resources available
  - Easy to find
  - Easy to use
  - GaN Systems application engineering team to help

Thank you for joining us. Please visit GaNSystems.com for more information
Growing list of Companies show GaN advantage

• Discover companies like yours who have demonstrated success with GaN Systems.

https://gansystems.com/gan-application-examples/
• GaN is the dominant reason for increases in efficiency and density in power electronics today
• Improving Customers’ Financial Performance
  ▪ Lower System Costs
  ▪ Lower Operating Costs
  ▪ More Opportunities for Revenue
• Increasing Business Competitiveness
  ▪ Faster time to market
• Addressing Customer Challenges
  ▪ Efficiency, Size, Weight and Cost
• Tools & Solutions
  ▪ SPICE & PLECS, EVBs, Reference Designs & Webinars

Many Customers in Many Applications Reaping the Benefits of GaN
CONSUMER

Highest current; broadest voltages
Best electrical performance
Best die & best package
Most widely used by customers

Shipping since 2014
Offices in 7 countries
Worldwide distribution & direct sales

Customer Successes
Solar Inverter and ESS
Motor Drives
Wireless Power and Charging
AC Adapters
Datacenter Server and Rack Power
Automotive Onboard Charger

DATACENTER

INDUSTRIAL

TRANSPORTATION
Abstract

Transforming the World

• The role of power greatly impacts company financial performance, business competitiveness and the health of our planet. GaN power transistors play a central role in the revolution of these power systems. This session reviews how GaN Systems addresses customer challenges, provides the right solutions and tools and delivers maximum benefit.