TRANSFORMING THE WORLD

GaN Systems Performance & Reliability in Industry’s Most Demanding Applications

APEC 2021
### BIG TRANSFORMATION

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecosystem</strong></td>
<td>Limited</td>
<td>Standard Products</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>Too expensive</td>
<td>Cost saving today “GaN under $100”</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Unknown</td>
<td>Proven, FIT &lt; 1</td>
</tr>
<tr>
<td><strong>Customers</strong></td>
<td>Niche</td>
<td>Mainstream Pervasive, Widespread, Global</td>
</tr>
</tbody>
</table>
GaN Systems products and design tools

<table>
<thead>
<tr>
<th>Broadest line of Transistors</th>
<th>Many Eval Kits &amp; Reference Designs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>650 V GaN</strong></td>
<td></td>
</tr>
<tr>
<td>GS66502B 7.5 A, 200 mΩ</td>
<td>65W PD QR &amp; ACF Chargers</td>
</tr>
<tr>
<td>6.6 x 5.0 mm</td>
<td></td>
</tr>
<tr>
<td>GS66504B 15 A, 100 mΩ</td>
<td>170W PFC/LLC AC/DC Charger</td>
</tr>
<tr>
<td>6.6 x 5.0 mm</td>
<td></td>
</tr>
<tr>
<td>GS66506T 22 A, 67 mΩ</td>
<td>300W PFC/LLC AC/DC Charger</td>
</tr>
<tr>
<td>5.6 x 4.5 mm</td>
<td></td>
</tr>
<tr>
<td>GS66508T 30 A, 50 mΩ</td>
<td>400W Class D Audio Amp+SMPS Eval Kit</td>
</tr>
<tr>
<td>7.0 x 4.5 mm</td>
<td></td>
</tr>
<tr>
<td>GS66508B 30 A, 50 mΩ</td>
<td></td>
</tr>
<tr>
<td>8.4 x 7.0 mm</td>
<td></td>
</tr>
<tr>
<td>GS66516B 60 A, 25 mΩ</td>
<td></td>
</tr>
<tr>
<td>9.0 x 7.6 mm</td>
<td>800W Half Bridge with Controller IC</td>
</tr>
<tr>
<td>GS66516A 60 A, 25 mΩ</td>
<td></td>
</tr>
<tr>
<td>12.7 x 5.6 mm</td>
<td></td>
</tr>
<tr>
<td>GS-065-004-1-L 4 A, 450 mΩ</td>
<td>DrGaN Half Bridge DC/DC power stage</td>
</tr>
<tr>
<td>5.0 x 6.0 mm</td>
<td></td>
</tr>
<tr>
<td>GS-065-008-1-L 8 A, 225 mΩ</td>
<td>650V 150A FB &amp; HB Modules</td>
</tr>
<tr>
<td>5.0 x 6.0 mm</td>
<td></td>
</tr>
<tr>
<td>GS-065-011-1-L 11 A, 150 mΩ</td>
<td>65V 300A 3-Phase Power Module</td>
</tr>
<tr>
<td>5.0 x 6.0 mm</td>
<td></td>
</tr>
<tr>
<td><strong>100 V GaN</strong></td>
<td></td>
</tr>
<tr>
<td>GS61004B 38 A, 16 mΩ</td>
<td>1.2kW bridgeless totem pole PFC</td>
</tr>
<tr>
<td>4.6 x 4.4 mm</td>
<td></td>
</tr>
<tr>
<td>GS61008P 90 A, 7 mΩ</td>
<td>3kW bridgeless totem pole PFC</td>
</tr>
<tr>
<td>7.6 x 4.6 mm</td>
<td></td>
</tr>
<tr>
<td>GS61008T 90 A, 7 mΩ</td>
<td>6kW Full Bridge, Dual Half Bridge</td>
</tr>
<tr>
<td>7.0 x 4.0 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14kW IMS Half Bridge</td>
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</tbody>
</table>
Market leaders confirm GaN value

#1 Worldwide in Energy Storage

#2 Worldwide in Automotive

#4 Worldwide in Data Center Servers

Advantage with GaN Systems

- GaN Systems’ technology gives us improved design freedom
  - Higher Efficiencies: 4% round-trip efficiency increase
  - Normalized Efficiencies: at low and high power
  - Reduction in Material Cost: 8% BoM cost savings
  - Reduction in Size: 30% smaller

- GaN provides an improved value-stack at a competitive cost position
  - Extending the value of the battery usable capacity by improving directional efficiencies
  - Allow us to design more integrated solutions

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Improved data center power efficiency

- Supermicro high-density, high-efficiency cost effective solutions save space, money and reduce our imprint on the environment.

- GaN-based power supplies provide the leap in efficiency and power density.

Source: APEC Conference 2019
High Reliability Electronics

• Comprehensive portfolio of highly engineered solutions
• Meet the most demanding requirements in the harshest environments
• Manufacturing both custom and off-the-shelf product offerings
• Meet emerging needs for avionics, radar, satcom, space, and test and measurement

Radiation Tolerant Power

Radiation Tolerant RF

Digital Processing

Integrated Solutions / Microelectronics
Meeting the Space Industry Needs

• Key performance criteria of Teledyne’s customers
  ➢ Radiation Performance
  ➢ High Efficiency
  ➢ Small Size & Low Weight
  ➢ High Reliability
  ➢ Long Lifetime
  ➢ Low Qualification Cost
Meeting the Space Industry Needs

- GaN features that enable requirements to be met
  - Radiation Performance (100 KRAD, 60Mev)
  - Higher Efficiency simplifies cooling requirements by saving weight and payload cost
  - Package
  - High frequency operation reduces system size and weight by factor of 3
  - Energy Density
  - Robust Transistor Gate Performance simplifies the driver circuitry
  - Scalability by using parallel GaN devices to reduce losses or increase power
  - Breadth of use in low and high-speed applications from 20Khz to 15Mhz reduces system qualification cost
  - High Reliability Qualification
GaN Advantage in Class D Audio

Skip Taylor
Elegant Audio Solutions
Goal: Maximize Performance **AND** Efficiency

- **Class A**
- **Class AB**
- **Class G**
- **Class H**
- **Silicon FET Class D**
- **“Original” Class D**
- **GaN FET Class D**

**GaN Class-D** Achieves The Goal
GaN transistors provide huge advantage in Audio

<table>
<thead>
<tr>
<th>GaN Transistors</th>
<th>Silicon Transistors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FET</strong></td>
<td><strong>FET</strong></td>
</tr>
<tr>
<td><strong>Perf. Trade-Off</strong></td>
<td><strong>Higher Switching Frequency</strong></td>
</tr>
<tr>
<td><strong>Audio Performance</strong></td>
<td>🔺🔺</td>
</tr>
<tr>
<td><strong>Audio Bandwidth</strong></td>
<td>🔺🔺</td>
</tr>
<tr>
<td><strong>Idle Power Dissipation</strong></td>
<td>🔻</td>
</tr>
<tr>
<td><strong>System Size</strong></td>
<td>🔻</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>🔻</td>
</tr>
</tbody>
</table>

- **Higher switching frequency** → better performance, better efficiency, increased bandwidth
- **Reduced Rdson** → better audio performance through reduced THD and increased bandwidth
- **Lower System Cost** → Eliminate heat sinks and more efficient EMI/EMC compliance
GaN versus Silicon switching

GaN transistor’s much lower switching losses and ‘stored charge’ result in near-ideal performance.
GaN Class D Amplifier Performance

### THD+N (1kHz)
- **@ 1/10 Power**: 0.004% vs. 0.015%
- **@ Full Power**: 0.018% vs. 0.020%

### THD+N (-9dBFS)
- **@ 100Hz**: 0.002% vs. 0.003%
- **@ 6.7kHz**: 0.030% vs. 0.040%

### SNR/DNR
- **Typ. Consumer Product**: > 108dB
- **Typ. Professional Product**: > 110dB

### Efficiency
- **@ 8 ohms**: 94% vs. 90%
- **@ 4 ohms**: 92% vs. 85%

### Freq. Response
- **20Hz ~ 20kHz**

### GaN Systems Class D Amplifier
- Up to 10dB better SNR
- 6dB better THD vs. Frequency
- Reduce power losses by as much as 50%
GaN Advantage in Class D Audio

• GaN transistors have lower conduction and switching losses resulting in near-ideal switching output
• Performance data demonstrate GaN has superior performance to silicon transistors
• GaN Class D Amplifiers provide the best efficiency and performance
A MISSION to revolutionize wireless energy for industrial & automotive mobility, that scales across the power curve.

- Automotive
- Power Tools
- Industrial

We are a company focused on using wireless energy to enable a more wire free future. GaN Systems helps take us there.
Wireless Power advanced with Power Electronics

GaN devices play a critical role in opening new doors for wireless power applications that are impossible for traditional silicon devices. GaN offers several benefits:

- **Power Transfer**
  - 3x Higher power density compared to silicon devices
  - Over 50x higher power transfer capability for wireless energy

- **Efficiency**
  - Higher voltage devices
  - Higher frequencies
  - Less lossy in a wider range of applications – up to 50% reduced loss

- **Thermal**
  - Reduced current systems – operates cooler
  - Numerous cool options – packages to choose from
  - GaN Systems offers a wide variety of devices for any application/power level

- **Cost**
  - 10-20% Reduced Cost
  - Less Copper
AUTOMOTIVE MOBILITY
IN COCKPIT & AUTOMOTIVE UTILITY

Power
30-350 Watts

Z-Distance
Up to 15cm

Spatial Freedom
X, Y and Z

Better EMI
No Interference with keyless entry
Coins and Keys are okay

Multi-Device Charging
Better handling of Load Variation

faurecia
POWERSPHYR
POWER TOOL CHARGING
HIGH POWER, SPATIAL FREEDOM & MULTI-DEVICE

Power
30-400 Watts

Larger Charging Areas
Flexible & Safe

Rugged Applications
Vehicle, Benchtop, Mobile Cargo Boxes

Multi-Device Charging Flexibility
Handles many devices of all shapes and sizes

Multiple Batteries Charge Simultaneously

info@powersphyr.com
WIRELESS POWER: MOBILITY & FLEXIBLE FORM FACTORS
FOR MISSION CRITICAL DEVICES - FIRST RESPONDERS AND MILITARY APPLICATIONS

12-Watt Devices
Multiple devices per source

Power
30-120 Watts

Larger Charging Areas
20x20cm

15 Watts
Critical Equipment & Devices

Multi-Device Charging Flexibility
Handles many devices of all shapes and sizes

20 Watts
Portable Power Flashlights

High Efficiency – Low Charging Temperature
Charge area remains cool, even with wearables

15 Watts x 6
Emergency Radios
VEHICLES
FOR FIRST RESPONDERS AND MILITARY APPLICATIONS

Power
10 - 250 Watts

Z-Distance
Up to 15cm

GAN ADVANTAGE

High Power
Emergency equipment & Tools

Aggressive & Extreme Environments
- Better Load Variation Handling
- Great thermal for 24/hour use cases and
- Handles Aggressive recharging

POWERSPHYR
PowerSphyr and GaN Systems achieve:

- High efficiency at high power levels
- Spatial Freedom required by today’s users
- Multi-device charging needed in most applications
- Reduced Cost & Thermal
- Reduced EMI

We deliver power wirelessly and without limitations
GaN Systems PERFORMANCE, VALUE and RELIABILITY....

Fast Charge, Lightweight All-in-One Charger

“Breakthrough in drive technology”

....have established GaN in the power electronics foundation

See more at www.gansystems.com