CREATING A TECHNOLOGY LEGACY

GaN Systems’ Firsts in the Power Semiconductor Industry

GaN Systems Design Support and Complete Product Offering Available from:
What does it mean to lead in an industry?

And when do technology ‘firsts’ matter in demonstrating leadership that enables others in the industry – partners and customers – to succeed?

These are important questions in industries that have recently moved from trials with early adopters – to – acceptance and engagement with mainstream customers. And that is certainly the case for GaN power semiconductors today.

We see industry leadership as built on a strategic perspective of knowing what innovation is needed, along with the ability to credibly deliver on the promise of GaN for significant global impact. Leaders look for ways to address industry challenges – not just their own – and seize on those opportunities even before the market asks for a solution.

Leaders need to take risks and deliver on the ‘firsts‘ that become the building blocks of the industry – enabling customers to create products and systems of significant differentiation and impact.

We all want technology and processes that enable the creation of more innovative products that enhance the bottom line. But we are also intensely aware of the positive impact our industry can have on the world in terms of how we more wisely use natural resources in manufacturing products and in the creation of power systems that deliver greater energy efficiency. We have the unique opportunity to simultaneously drive new business growth and global sustainability efforts.
FIVE FIRSTS FROM GaN SYSTEMS

Here are five ‘firsts’ from GaN Systems that are driving change not only for our customers, but also the semiconductor industry.

1. High Power Applications
   Delivering High-Power Capabilities for the Most Compact and Elegant Designs

2. Product Breadth
   Maximizing Choice. Minimizing Qualification Time.

3. Reliability
   Performing with Confidence in the Most Demanding Environments

4. Packaging
   Overcoming the Heat Challenge Through Packaging Innovation

5. Supply Chain
   Building a Resilient Global Supply Chain

INDUSTRY LEADERSHIP COMES FROM

LISTENING AND EXECUTING
ACTIVELY COLLABORATING
DELIVERING ON OPERATIONAL EXCELLENCE

GaN Systems Design Support and Complete Product Offering Available from:
DELIVERING HIGH-POWER CAPABILITIES FOR THE MOST COMPACT AND ELEGANT DESIGNS

As the world becomes increasingly electrified – from our homes to our factories to our transportation systems – our demands for electricity are growing at unprecedented rates.

In Data Centers
With the creation of more and more data, data centers face growing pressure to expand or increase data density and power handling capabilities in existing physical footprints. The use of GaN transistors in higher-power power supplies for servers and power shelves enables this greater data density within an existing data center.

In Electric Vehicles
Both consumer interest and government policies have focused more attention on the mainstreaming of EVs – along with heightened expectations to deliver driving ranges equal to gas-powered cars. Greater power efficiency through the use of GaN transistors in a vehicle's applications that require higher power such as onboard chargers and inverters are an essential part of this equation, along with new battery technology.

USE CASE: DATA CENTERS

xFusion

Challenge: High power with high efficiency in a small form factor to enable greater data and energy density

GaN Systems Product: 60A GaN transistors

Impact: 3000W power supply delivers very high efficiency (96%) and very high-power density (100W/in³)

“Global digitalization and increased energy usage is forcing industry to reduce power losses and the size of power supplies. We are proud to be one of the first companies to commercialize PSUs with 100W/in³ and Titanium efficiency in a 1U, 185mm CRPS form factor.”

— xFusion Program Manager
The growing demand of power among all markets at higher levels requires high power solutions. GaN Systems uniquely delivers solutions to address these trends.

1. High-power transistors

GaN Systems is the first company to offer GaN transistor products with current ratings of 60A, 80A, 90A, 120A, 150A – that deliver power levels from 1kW to more than 100kW. Other GaN companies are limited to only 5-30A, significantly limiting their applications.

A single high-power transistor can eliminate the need for paralleling multiple transistors to achieve a higher power level and thereby reduces a system’s complexity and validation time.

Only GaN Systems has the high-power transistors for the automotive industry that can deliver on the multi-kilowatt solutions needed for an EV’s OBC and traction inverter. For another GaN company to deliver on the same power need, five times the number of transistors would be required and would result in an overly complex power design.

2. Effective paralleling of several high-power transistors

In very high-power applications, paralleling of transistors is needed to meet output power requirements. GaN Systems’ transistors are designed to easily enable paralleling of several transistors that yields the sum of their individual power ratings.

In a 75-kilowatt traction inverter power module, only two 150 amp GaN Systems transistors are paralleled on each branch of a half-bridge circuit to create a compact, efficient, and reliable design. Using another GaN transistor brand would mean creating a complex and overly large design with ten 30 amp transistors paralleled together.
MAXIMIZING CHOICE. MINIMIZING QUALIFICATION TIME.

Many industries that have a variety of power system needs in their products benefit from working with a single supplier. Identifying, auditing, negotiating, and finally qualifying a supplier for each semiconductor in a system design is expensive and time-consuming. For that reason, finding and establishing a confident relationship with a supplier for multiple needs streamlines a business’ engineering design and production processes.

**GaN Systems provides a Full Breadth of Power Solutions**

<table>
<thead>
<tr>
<th>MARKET</th>
<th>LOWER POWER</th>
<th>HIGHER POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Vehicles</td>
<td>48V for DC/DC accessory power conversion</td>
<td>400V &amp; 800V for onboard charger and traction inverter</td>
</tr>
<tr>
<td>Data Center</td>
<td>48V for Point of Load</td>
<td>240V for server and power shelf power supplies</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>48V for BESS battery storage</td>
<td>400V for DC to DC and inverter power conversion</td>
</tr>
<tr>
<td>Consumer Electronics Chargers</td>
<td>65W for laptops and fast charging smartphones</td>
<td>330W for gaming laptops and all-in-one PCs</td>
</tr>
<tr>
<td>Audio Amplifiers &amp; Speakers</td>
<td>50W for consumer speakers</td>
<td>1000W for professional amplifiers</td>
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**USE CASE: AUTOMOTIVE**

**Vitesco**

**Challenge:** Small size, low weight, maximized efficiency and power density are all critical for EV performance. EV applications range from 12V to 800V operating voltages in a variety of power levels.

**GaN Systems Products:**
- DCDC: 48V applications using the 100V product line
- OBC: 400V and 800V applications using the 650V product line
- Traction: 400V and 800V applications using the 650V product line

**Impact:**
- 2-4X size reduction of the charger, inverter, and converter systems
- 30-50% reduction in power loss, increasing efficiency resulting in overall cost savings of 5-15%
- 5-10% increase in driving range of the vehicle

“Together with GaN Systems we will be able to develop a platform for even more efficient automotive-grade solutions from 48 V to 400 V to 800 V applications in DC/DC conversion, for onboard chargers and in the future also for inverters.”

— Dr. Gerd Rösel, Head of Innovation in the Electrification Technology Business Unit Vitesco Technologies
PERFORMING WITH CONFIDENCE IN THE MOST DEMANDING ENVIRONMENTS

Over the past several years, GaN transistors have demonstrated that they increase the performance and reduce the cost of power electronics systems in comparison to Silicon and SiC-based approaches. But there has been a once nagging but now resolved question in the industry about GaN reliability and the expected lifetime of systems that use GaN power semiconductors.

As in the case of new materials in any industry, how do you evaluate and set rules and benchmarks for relatively new technologies and materials like GaN? This is particularly critical in industries including EVs and space, where expectations for flawless performance are high.

GaN Power Semiconductors Qualification and Reliability

To demonstrate the GaN Systems transistor design margin beyond JEDEC qualification requirements, testing was extended beyond the standard JEDEC time durations. The “Extended” column illustrates the multiple of the required test that the GaN Systems devices have been tested.

<table>
<thead>
<tr>
<th>TEST</th>
<th>STATUS</th>
<th>EXTENDED*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTRB</td>
<td>36,000 hrs (&gt;4 yrs!)</td>
<td>36x</td>
</tr>
<tr>
<td>LTRB</td>
<td>3,000 hrs</td>
<td>3x</td>
</tr>
<tr>
<td>HTGB</td>
<td>8,000 hrs</td>
<td>8x</td>
</tr>
<tr>
<td>DHTOL</td>
<td>5,000 hrs</td>
<td>5x</td>
</tr>
<tr>
<td>H3TRB</td>
<td>5,000 hrs</td>
<td>5x</td>
</tr>
<tr>
<td>TC</td>
<td>6,000 cycles</td>
<td>6x</td>
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<tr>
<td>LTS</td>
<td>6,000 hrs</td>
<td>6x</td>
</tr>
<tr>
<td>HTS</td>
<td>7,000 hrs</td>
<td>7x</td>
</tr>
<tr>
<td>IOL</td>
<td>70,000 cycles</td>
<td>14x</td>
</tr>
</tbody>
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Challenge: Need for highly ruggedized and reliable systems that can deliver on long lifetime expectations.

GaN Systems Products:
- 100V and 650V GaN transistors

Impact:
- Reduce size and weight of systems by more than 25%
- Proven performance in space

USE CASE: HIREL

Teledyne

“High reliability, or hi-rel, semiconductors are critical for space, avionics, radar, and satcom applications. We are confident that, with GaN Systems’ transistors, our solutions will function at the most critical moments, under the worst radiation bombardment, widest extremes of temperature, most violent mechanical shock and the highest altitudes.”

— Mont Taylor, VP of Business Development Teledyne e2v HiRel
GaN Systems’ leadership role in GaN product reliability.

GaN Systems has continued active participation and leadership in the JEDEC JC70 industry group chartered to create a robust standard for a set of tests, conditions, and pass/fail criteria for GaN power transistors to ensure the reliability of customer systems under required mission profiles.

Additionally, to ensure customer acceptance in the very high reliability applications, GaN Systems collaborated directly with customers in the automotive, industrial, and high-reliability (HiRel) industries to develop the very first qualification strategy and process for GaN power semiconductors, named the AutoQual+™ qualification criterion. Methodology and results were published in the “GaN Power Semiconductors - Qualification and Reliability” report.
OVERCOMING THE HEAT CHALLENGE THROUGH PACKAGING INNOVATION

The performance of a power application is dependent on the ability of its thermal management system to dissipate heat. When a system such as an EV’s onboard charger or a data center server PSU is in use – semiconductors, transformers, and inductors heat up.

Efficiency is a measure of the output power of a system compared to input power – with the power lost in the form of heat as the difference.

**Thermal management is important in two cases:**

1. Transferring heat from the GaN transistor die to its packaging.
2. Managing the heat transfer between the GaN package through an interface material and then to the heatsink

In both cases the reduction of thermal resistance directly translates to higher power efficiency and less power loss as heat. GaN Systems designed a proprietary embedded packaging solution – GaNPx – to address the thermal challenge in medium and high-power applications.

GaNPx embedded packaging uniquely addresses thermal management challenges through the reduction of thermal resistance. This technology is available in bottom-side cooled and top-side cooled form factors that deliver even higher power capabilities by minimizing thermal resistance.

**GaNPx embedded packaging delivers up to 70% lower thermal resistance.**

GaN Systems is the Leader in Thermal Management Solutions for GaN Power Transistors

“High power density, high efficiency, heatsinkless designs are a power designer’s nirvana. With the GaN Systems transistors in their GaNPx embedded packaging, achieving these design goals becomes a lot easier.”

— Skip Taylor, EAS
BUILDING A RESILIENT GLOBAL SUPPLY CHAIN

Companies and industries have become increasingly alert to supply chain fragilities – from geopolitical trade wars, raw materials shortages, or natural disasters. For the growing number of industries in which semiconductors are a key product component - the severity of the impact of supply chain disruption has been increasingly clear in recent years. Given the extent of the integration of semiconductors into everyday products from cars to consumer electronics to industrial equipment, what might have been viewed as a supply chain hiccup years ago, now has long lasting and far reaching impacts.

**An efficient and reliable global supply of semiconductors that can scale on demand is one of the important keys to business resiliency and success.**

GaN Systems has prioritized the creation of a robust and resilient supply chain for its products through partnerships and co-location decisions with leading global chip manufacturers and foundries SMC, USI, and ASE.

TSMC is the top-ranked pure-play foundry in the world with notable brands as customers including Apple, Intel, AMD, Nvidia, and Qualcomm. It is also the first foundry to offer GaN production – in partnership with GaN Systems. This unique partnership has yielded advanced learning and practices in meeting market quality and cost expectations, market demand trends, continual process innovation, and multiple generations of technology development.

GaN Systems was the first GaN power semiconductor company to co-locate in Taiwan with TSMC, USI, and ASE. The close, trusting relationships between GaN Systems and its supply chain partners has led to partner confidence and the buildout of the capacity required for future growth for GaN.

**GaN Systems now benefits with lead times much shorter than the rest of the industry.**

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Leadership and Action Matter in the World of GaN technology

At GaN Systems, we believe in:

- Embracing a strategic perspective on innovation,
- Investing in areas such as reliability that benefit the entire industry,
- Nurturing a strong global chain, and
- Delivering the depth and breadth of products that enable our customers and partners to create systems of significant differentiation and impact

We’re dedicated to continue to deliver on the ‘firsts’ that matter for both economic and environmental impact.

We are inspired every day by the opportunity within the GaN industry to make a positive impact in the world from the ways that we use our natural resources and bring greater energy efficiency into an increasingly electrified world.

It’s great to have you on that journey with us.
ABOUT GaN SYSTEMS

GaN Systems is the global leader in GaN power semiconductors with the most extensive transistors portfolio that uniquely addresses the needs of today’s most demanding industries, including consumer electronics, data center servers, and power supplies, renewable energy systems, industrial motors, and automotive electronics.

As an industry-leading innovator, GaN Systems makes it possible to design smaller, lower cost, more efficient power systems. The company’s award-winning products provide system design opportunities free from the limitations of yesterday’s silicon.

GaN plays an important role in effectively enabling the increasing electrification of the world across important industries:

- Transportation with EVs going mainstream and demanding driving ranges similar to internal combustion engine vehicles
- Data centers with growing data density and energy demands
- Industrial factories as automation and intelligence make Industry 4.0 a reality
- Renewable energy systems finally delivering on the quest for a 24/7 renewable energy world
- Consumer electronics with higher-performing, more aesthetically appealing, and less natural resource-intensive designs

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