Beyond Simply Replacing Silicon – System Level Impact of GaN Power ICs in Key Applications

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Senior Director Industrial & Consumer
Beyond Simply Replacing Silicon –
System Level Impact of GaN Power ICs in Key Applications

• Navitas Semiconductor

• Performance implications of GaN power ICs
• Reliability implications of GaN power ICs
• Application example: High density mobile phone charger
• Application example: High performance motor drive
• Application example: High power SMPS
• Conclusion
August 15th, 2022: Navitas Semiconductor, industry-leader in gallium nitride power ICs, acquired GeneSiC Semiconductor, silicon carbide pioneer and industry leader
Navitas Fundamentals

• Industry’s only pure-play next-gen power semi company, $23B/yr market
  • Founded 2014, 220+ employees
  • Nasdaq: NVTS (IPO October 2021)
• Leading power GaN IC and power SiC technology, 185+ patents
  • >75M GaN, >9M SiC Shipped
  • 3x (GaN), 5x (SiC) capacity expansion starting in 2023
  • Major diversification in markets, regions
• Mission to Electrify Our World™
  • Industry leader in mobile fast, ultra-fast chargers
  • Market expansion on track / accelerated into data center, solar, EV

(1) See Navitas New York Investor Meeting September 13th, 2022, and Navitas’ Q3’22 earnings November 9th, 2022, for details
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**Accelerating Growth**

- **World's Smallest 27W USB-PD**
- **World's Smallest 25W USB-A**
- **World's Smallest 65W USB-PD**
- **30+ Patents**
- **Mass Production**
- **World's Smallest 45W USB-PD**
- **World's Smallest 150W**
- **World's Smallest 65W USB-PD**
- **World's Smallest 27W USB-PD**
- **World's Smallest 300W**
- **World's Smallest 65W**
- **100+ Patents**
- **World's Smallest 250W**
- **3kW EV Prototype**
- **World's Smallest 300W**
- **20M Shipped**
- **Data Center**
- **EV Design Center**
- **3.2kW Data Center Prototype**
- **World's 1st GaN Half-Bridge Prototype**
- **World's 1st GaN Power IC Prototype**
- **Founded**
- **30+ Patents**
- **120+ Patents**
- **150+ Patents**
- **Data Center Design Center**
- **EV Design Center**
- **Data Center, Solar, EV Validation**
- **120+ Patents**
- **20M Shipped**
- **Industry-First GaNSense Half-Bridge**
- **40M Shipped**
- **75M Shipped**
- **IPO: NVTS**
- **World's 1st GaN Sense Half-Bridge**

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Benefits of Integration – what is a GaN power IC?

**GaNFast plus:**
- Autonomous Standby
- Autonomous Protection
- Loss-less Current Sensing
- High Precision
- High Efficiency

**GaNFast:**
- Internal Gate
- Integrated Gate Drive
- dV/dt Immunity
- Layout Insensitive
- 2 kV ESD rating
- Proven Reliability
- Proven Robustness

- Exposed gate
- External gate drive
- dV/dt sensitivity
- Layout sensitivity
- ESD sensitivity
- Unknown reliability
- Unknown robustness

**GaNSense plus:**
- Highest integration
- integrated HS and LS FETs
- Integrated level-shift isolation
- integrated boot-strap
- Shoot-through protection
- Enlarged cooling pads

- Fastest switching
- Highest efficiency

**GaNFast vs Discrete GaN:**
- Old, slow
- High Qg
- High COSS
- Fsw < 100 kHz
- Exposed gate
- External gate drive
- dV/dt sensitivity
- Layout sensitivity
- ESD sensitivity
- Unknown reliability
- Unknown robustness

**GaNSense vs GaNFast:**
- Highest integration
- Integrated level-shift isolation
- Integrated boot-strap
- Shoot-through protection
- Enlarged cooling pads

- Fastest switching
- Highest efficiency
GaN Integration Drives Speed, Efficiency, Stability

Discrete GaN Half-Bridge
- 33 components
- 250 mm² footprint
- External HB driver HVIC
- External HV bootstrap
- 2x HV bypass diodes
- 2x external gate drives
- Exposed gates

GaNSense Half-Bridge IC
- 61% fewer components
- 64% smaller footprint
- Complete integration
- 13 components
- 90 mm² footprint
- Level shifters
- Bootstrap
- Gate drivers
- No exposed gates

Severe Ringing & Glitching!

No Ringing, No Glitching!
GaNSense™ Control: Ultimate Integration
Navitas GaN IC: Smaller, Faster, Robust

Discrete dMode GaN

- dMode GaN Discrete (3.7mm²)
- Silicon FET Discrete (3.8mm²)

Discrete eMode GaN

- eMode GaN Discrete (4.5mm²)

Navitas eMode GaN IC

- Integrates drive circuit & more
- Monolithic GaN IC (1.4mm²)

• No extra circuits
• No parasitics & delay
• Drive & power matched in GaN
• Integrated features, functions
• Highest speed & efficiency
• Highest robustness and reliability
• Simple customer design
• 50-80% smaller chip

Extra Si FET + other

- Cost & complexity
- Adds parasitics & delay
- Limits speed & efficiency

Extra Si driver circuit

(1) ‘dMode’ = depletion mode = ‘normally on’ transistor, causes short circuit unless additional transistor added.
(2) ‘eMode’ = enhancement mode = ‘normally off’ transistor.
Leader in Sustainability: 150,000+ tons CO₂ Saved! (1)

Every GaNFast™ IC saves 4 kg CO₂

4x-10x lower component CO₂ footprint than silicon

28% lower lifetime CO₂ footprint for chargers / adapters

Accelerates transition from ICE to EV by 3 years, saving 20%/yr of road-sector emissions by 2050

GaN + SiC save up to 6 Gton / year by 2050

February '22 First GaN sustainability report based on global standards.

May '22 World’s first semiconductor company CarbonNeutral® certified

August '22 First 100,000 tons CO₂ saved

October '22 Recognized for industry-leading sustainability reporting

(1) Navitas estimates based on Earth-Shift Global, DNV life-cycle analysis, market growth. See 2021 Sustainability Report for more details. CO₂ saved as of March 2023
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Motor Drive: 70%+ Reduction in Loss vs. Silicon

Application case:
- Bus voltage 400 V
- Current 7 A RMS
- Motor power 2 kW
- Switching 6 V/ns
- GaN and MOSFET same conduction losses

Using GaN FETs, the inverter efficiency increases by 2.5% (96% → 98.5%) and total losses are halved (15 W → 6-8 W)

→ Significant reduction in cost, weight and size of thermal management (heatsink, fans, etc.)
→ Benefit even larger at higher switching frequency
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Foundational Reliability – driver integration is key

**Design** for Reliability
- Integrated drive, sensing and protection
- Component reliability, and **system** reliability

**Testing** for Reliability:
- Proprietary production test methods
- GaN ICs tested 400% (multi-temp, high-frequency)

**Characterization** for Reliability
- Exhaustive, proactive, and unique Navitas reliability program
- 5.8 B equivalent device hours tested\(^{(1)}\)
- Proprietary, highly-accelerated Op-Life, plus JEDEC, plus ELFR monitoring
- Founder member of JEDEC JC70.1

\(^{(1)}\) As of September 2022
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### 100% Tier 1 Mobile OEMs Adopting Navitas

**Tier 1 OEMs**

<table>
<thead>
<tr>
<th>Brand</th>
<th>GaN Chargers</th>
<th>In Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>125W</td>
<td></td>
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<tr>
<td>moto X30 Pro</td>
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<td>LG Electronics</td>
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<td>OPPO</td>
<td>135W</td>
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<td>Xiaomi</td>
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<tr>
<td>realme</td>
<td>150W</td>
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</tbody>
</table>

**Aftermarket Examples**

<table>
<thead>
<tr>
<th>Brand</th>
<th>GaN Chargers</th>
<th>In Development</th>
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<tbody>
<tr>
<td>Amazon</td>
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<td>F-SERIES</td>
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</tbody>
</table>

(1) as of Q4'22 report (2) as of March '23
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- 240+ GaN Chargers Mass Production
- 250+ GaN Chargers In Development
- 100% Mobile OEMs Designing With Navitas GaN ICs
- 75M+ GaN ICs Shipped

Navitas

Navitas Semiconductor
Now Ultra-Fast Chargers

- New, fast-growth market: $1B opportunity by 2025\(^1\)
- Full charge in <10 mins (200W)
- Increased GaN content per charger
- World’s highest power density 120W, 150W, 200W

Key value drivers:
- Lowest losses $\rightarrow$ High power density
- No big penalty for high switching frequency $\rightarrow$ Smaller components

\(^1\) Navitas estimate
Powering the World’s Fastest-Charging Smartphone

realme GT3 Global Launch Event
February 28, at 6:00 p.m. (UTC+8)

Max Charging Power of Type-C

*The charging dock shown in the video is a special 240W SuperVOOC charging dock, which changes the camera's perspective and the charging dock's angle positions for clarity.

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High Speed Shrinks Passive Components

Typically, slow-speed designs have ~70% of volume used by transformer, capacitors, EMI filter, etc.

High-speed GaN IC designs shrink ‘passive’ components by ~50%(1)

Half-Bridge IC delivers ~2x the power, or ~2x faster charging in the same size(1)

~65 kHz Silicon
65 W 43 cc

~75 kHz GaN Discrete / MCM
65 W, 46 cc

~400 kHz GaN IC
65 W, 31 cc

~750 kHz peak Half-Bridge GaN IC
120 W, 44 cc

~2x faster charging!

(1) Sep’22 Navitas survey of 20 publicly-available Navitas and MCM example chargers and reference designs 65W - 200W. Nominal 100 cc charger size selected, power capability determines charging speed
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Reference design high power 6-in-1 inverter

Efficiency >99% at 500 W, using NV6138

Board size 74 x 62 mm

Thermal scan @ 500 W, 20 kHz ($R_{THCA} \sim 20$ K/W), $T_{amb} = 25^\circ$C

No heatsink used
Reference design 1kW motor inverter

Max temperatures with / without heatsink

Motor Drive Inverter Max temperatures without heatsink

$V_{bus}=300V$

Output (Phase) Current [A] vs. Case Temperature [°C] graph for two conditions:
- With heatsink, $RDDL=RDDH=47\Omega$
- Without heatsink, $RDDL=RDDH=47\Omega$
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GaNFast Exceeds “Titanium” with >2x Power Density

- Euro ‘Titanium plus’ standard from January 1st, 2023\(^{(1)}\)
- System Design Center: 4 platforms: 1.3 kW, 1.6 kW, 2.7 kW, 3.2 kW CRPS\(^{(2)}\)
- GaN can reduce electricity use by up to 10%, save >15 TWh or $1.9B/yr \(^{(3)}\)

\(\text{Slow Silicon AC-DC 3,200W}\)

47 kHz
325 x 107 x 41 mm
2.2 W/cc

\(\text{GaNFast AC-DC 2,700W}\)

300-500 kHz
185 x 73.5 x 39 mm
5.1 W/cc

>2x higher power density
>30% reduction in energy loss

“GaN is a breakthrough new technology that is enabling dramatic reductions in size, energy savings and power density”

“Navitas is an excellent partner with industry-leading GaN ICs”

Robin Cheng, VP R&D

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\(^{(1)}\) European Union 'Directive 2009/125/EC, 2019 Annex', power supplies must be >96% efficiency peak.

\(^{(2)}\) CRPS = Common Redundant Power Supply standard, defined by Intel for standardized mechanical form-factors, targets hyper-converged compute, storage and networking eqpt.

\(^{(3)}\) Navitas est. based on a) Navitas server/datacom forecast & AAAS data, b) $0.12/kWhr, c) Si vs. GaN $/W and d) data-center loading profile. Estimated based on known existing Si-based solutions to deliver >500A next-generation data processors to Navitas targets for new GaN-based AC/DC and DC/DC for these same next-generation data processors.
GaNFast™ Server power supply 2.7kW
Titanium+

- Output power 2.7kW
- Peak efficiency 96.34%
- Power density 5.1W/cc
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**Conclusion – The time is now**

- Through GaNFast / GaNSense integration, GaN power ICs are ready now
  - Reliable and repeatable performance of e-mode GaN power transistors
  - Smallest form factor and lowest losses
  - Easy to use digital power stage
- Massive performance improvement over silicon alternatives
- Immediate availability
  - 16 week leadtime
  - 3x capacity increase
  - Re-using older silicon fabs with little additional expense and waste

_GaN power ICs enable the next level of performance, reliability and robustness in power electronics applications_
Thank you!

Contact: alfred.hesener@navitassemi.com