Pure-Play, High-Speed
GaNFast and GeneSiC:
The Leading Edge of Next-Gen Power Semiconductors

Stephen Oliver
VP Corp. Mktg. & IR

Navitas
Energy • Efficiency • Sustainability
August 15th, 2022: Navitas Semiconductor, industry-leader in gallium nitride power ICs, acquired GeneSiC Semiconductor, silicon carbide pioneer and industry leader.
$22B ‘Pure-Play’ Market Opportunity

1) 2026E potential, Source: Yole, DNV, IRENA, Fraunhofer ISE, IHS, Cisco, Hyperscale, Peer annual reports, Wall Street research.
The GaN Revolution: Critical Integration

200-300 kHz

- Old, slow
- High Q_g
- High C_OSS
- FSW < 100 kHz

500 kHz

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

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

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

SiFET

Discrete GaN

SiC FET

GaNFast™

GaNSense™

GaNFast plus:

GaNSense plus:

Navitas Semiconductor 2023
### Discrete GaN vs. GaNSense Control IC

<table>
<thead>
<tr>
<th></th>
<th>Discrete GaN</th>
<th>GaNSense Control IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Frequency (kHz)</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>Peak Efficiency (%)</td>
<td>90.3</td>
<td>94.3</td>
</tr>
<tr>
<td>Dimension: x,y,z (mm)</td>
<td>33 x 33 x 60</td>
<td>50 x 30 x 20</td>
</tr>
<tr>
<td>Power Density (W/CC) cased</td>
<td>1.03</td>
<td>1.50</td>
</tr>
</tbody>
</table>

**Typical 65W Application Circuit**

**GaN Sense Control**
## More Efficient, Smaller than GaN Discrete MCMs

<table>
<thead>
<tr>
<th>Feature</th>
<th>Competitor A</th>
<th>Competitor B</th>
<th>Navitas</th>
<th>Navitas Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Frequency (kHz)</td>
<td>175</td>
<td>150</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Package</td>
<td>PQFN 6x8</td>
<td>InSOP 10x14</td>
<td>PQFN 5x6</td>
<td></td>
</tr>
<tr>
<td>HV Startup</td>
<td>Internal</td>
<td>Internal</td>
<td>Internal</td>
<td></td>
</tr>
<tr>
<td>Lossless Current Sensing</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>V_{DS} Range (V)</td>
<td>7.9 - 40</td>
<td>4 - 6</td>
<td>6.2 - 80</td>
<td>Higher Efficiency, Power Density</td>
</tr>
<tr>
<td>External V_{DS} Regulator</td>
<td>Boost</td>
<td>Linear</td>
<td>Not Required</td>
<td></td>
</tr>
<tr>
<td>External Components</td>
<td>+11</td>
<td>+18</td>
<td>+9</td>
<td></td>
</tr>
<tr>
<td>PCB Footprint (mm²)</td>
<td>85</td>
<td>90</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Thermal Pad</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Standby Loss (mW)</td>
<td>50</td>
<td>&lt;30</td>
<td>&lt;20</td>
<td>Higher Reliability</td>
</tr>
<tr>
<td>Hotspot</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>V_{DS} (cont/trans.)</td>
<td>650 / 750</td>
<td>650 / 750</td>
<td>700 / 800</td>
<td></td>
</tr>
</tbody>
</table>
Navitas GaN IC: Smaller, Faster, Robust

Discrete dMode GaN
- dMode GaN Discrete (3.7mm²)
- Silicon FET (3.8mm²)
- Extra Si FET + other

Discrete eMode GaN
- eMode GaN Discrete (4.5mm²)
- Drive Circuit (in Silicon)

Navitas eMode GaN IC
- Integertes 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

(1) ‘dMode’ = depletion mode = ‘normally on’ transistor, causes short circuit unless additional transistor added.
(2) ‘eMode’ = enhancement mode = ‘normally off’ transistor.
Foundational Reliability

**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

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\(^{(1)}\) As of September 2022
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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

61% fewer components

Severe Ringing & Glitching!

GaNSense Half-Bridge IC

- 13 components
- 90 mm² footprint
- Level shifters
- Bootstrap
- Gate drivers
- No exposed gates

64% smaller footprint

Complete integration

No Ringing, No Glitching!

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### 100% Tier 1 Mobile OEMs Adopting Navitas

#### Tier 1 OEMs

<table>
<thead>
<tr>
<th>Tier 1 OEMs</th>
<th>Aftermarket Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>Amazon</td>
</tr>
<tr>
<td>Moto X30 Pro</td>
<td>Baseus</td>
</tr>
<tr>
<td>LG Electronics</td>
<td>Navitas</td>
</tr>
<tr>
<td>Oppo</td>
<td>Lenovo Legion</td>
</tr>
<tr>
<td>Dell</td>
<td>ANKER</td>
</tr>
<tr>
<td>Xiaomi</td>
<td>UGREEN</td>
</tr>
<tr>
<td>Redmi Note</td>
<td>Satechi</td>
</tr>
<tr>
<td>Redmi Book Pro 2</td>
<td>belkin</td>
</tr>
<tr>
<td>realme</td>
<td>Navitas</td>
</tr>
</tbody>
</table>

#### GaN Chargers

- **240+** GaN Chargers in Mass Production\(^{(1)}\)
- **250+** GaN Chargers in Development\(^{(1)}\)
- **100%** Mobile OEMs Designing With Navitas GaN ICs
- **70M+** GaN ICs Shipped\(^{(2)}\)

\(^{(1)}\) as of Q4’22 report  
\(^{(2)}\) as of Q4’22 report  
© Navitas Semiconductor 2023
Now Ultra-Fast Chargers

- Major trend
- New, fast-growth market: $1B opportunity by 2025\(^{(1)}\)
- Full charge in <10 mins (200W)
- Increased GaN$ per charger
- World’s highest power density 120W, 150W, 200W, 240W

\(^{(1)}\) Navitas estimate

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RedMi (Xiaomi) F1 Mercedes 120W
Realme (OPPO) GT Neo 3 150W
iQOO (vivo) 10 Pro, 200W
Powering the World’s Fastest-Charging Smartphone

realme GT3 — Global Launch Event
February 28, at 4:00 pm, UTC+1

Max Charging Power of Type-C

The charging dock shown in the video is a sample of 240W SuperVOOC charging dock, which charges the smartphone using wireless charging technology. A fast charger is required for units.
GaNFast Exceeds “Titanium”, >2x Power Density

- Euro ‘Titanium plus’ standard from January 1st, 2023\(^{(1)}\)
- Design Center: 4 platforms, 10 customer projects (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 \(^{(3)}\)

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**Slow Silicon AC-DC 3,200W**

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

**GaNFast AC-DC 2,700W**

- >2x higher power density
- >30% reduction in energy loss
- 300-500 kHz
- 185 x 73.5 x 39 mm
- 5.1 W/cc

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**“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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\(^{(2)}\) 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.
Largest range of SiC FETs & diodes (650 V to 6.5 kV)

Lowest RDS(on) at high temperature (25% lower than industry typical)

World-class survival duration in fault condition

Based on Navitas testing of 1200V SiC MOSFETs vs. competitor products

Matching currents (Stable Vth)

Highest published capability to handle excess energy in fault condition

**GaN + SiC for Solar & Energy Storage**

**Market Potential (2)**
- Residential Micro  >$1.4B (GaN)
- Residential String  >$1.0B (SiC)
- Commercial String >$1.0B (SiC)
- Energy Storage       >$1.25B (SiC) (50% attach rate)

Total =               >$4.65B

**Navitas Strength & Opportunities**
- Solar up 3x 2022-2027, more capacity than natural gas by 2026, coal by 2027
- Inflation Reduction Act: >$50B to solar, storage and wind
- Bus voltages rising to 1,500V – matches GeneSiC 3,300V capability

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(1) Navitas est. 6.2 kW residential installation with silicon inverter at 97.5%, GaN at 98.5% efficiency.
(2) Market estimates for 2030, based on DNV and Navitas analysis.
Pure-Play EV: The Largest Opportunity

>$11B/year Opportunity\textsuperscript{(1)}
(On-board >$10B/yr + Roadside >$1B/yr)

Navitas EV System Design Center

- 5 platforms including 400V, 800V and 6.6-22 kW
- Bi-di charger (2-in-1), bi-di + DC-DC (3-in-1)
- Increasing bus voltages play to GeneSiC 3,300 V strength

Navitas + Geely Joint EV Design Center

Customers in Production, Development

- AMG
- BYD
- INOVANCE
- EVTECH
- LG
- MAGNA
- JAGUAR
- Land Rover
- BRUSA

Customers in Production,
Development

VP Power Products

“10-80% charge in only
18 minutes!”\textsuperscript{(2)}
Home Appliance & Industrial

Legacy Si-Based Brush-less DC (BLDC) Motor & Inverter for Washing Machine (~80% efficiency)

Navitas 300W 3-phase Platform for Inverter-Motor Integration

- 2x higher frequency
- >60% fewer components, PCB area
- 95-97% efficiency
- 80% energy savings vs Silicon BLDC
- 90% energy savings vs AC motors
- High reliability
- Fast time to market

>$1.5B/year Opportunity for 50-300W Motors

Inflation Reduction Act: $9B to upgrade US home appliance efficiencies

(1) Navitas estimate 50-300W motors, including circulators, hydronic pumps, aircon IDU/ODU fans, HVAC, air purifiers, hair dryers, refrigerator compressors, dishwashers, washing machines.
• Tier-1 foundry partners, excellent manufacturing support
• High yields, low costs, flexible supply chains
• Long-term capacity agreements: GaN up 3x, SiC up 5x starting in 2023
• 50% shorter lead-times than industry typical

1) Industry lead-times per Jefferies Equity Research, August ’22
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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
Mission: Electrify Our World™

Energy sources and uses are being electrified...

...creating a $40B GaN + SiC opportunity by 2050

Fossil-fuel vs renewable ratios adapted from IRENA 2020 “Global Renewables Outlook”. Shift required to meet “Transforming Energy Scenario, 9.5 Gton target in 2050”, per Paris Agreement’s 1.5°C rise. Market opportunity $ from Yole Développement, 2020 and Navitas analysis.
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