GaN Power IC Adoption Takes Off in Fast Charging Market

APEC 2019 PowerAmerica IS19, March 21, 2019

“Advances in the Adoption of Wide Bandgap Semiconductors in Commercial and Industrial Applications"

Dan Kinzer, COO/CTO Navitas

Dan.kinzer@navitassemi.com
Navitas Semiconductor

- World’s first GaN power IC company
  - JEDEC qualified
  - Volume production with fast ramp
- Navitas: Latin for Energy
  - Bringing a new energy to power electronics
- Founded 2014 with HQ in El Segundo, CA
- Proven management team
  - 60+ employees
- Tier 1 manufacturing partners
  - TSMC wafer foundry, Amkor packaging
- Strong financial investors
  - Over $1B capital under management
World’s First GaNFast™ Power ICs

Fastest, most efficient GaN Power FETs
- >20x faster than silicon
- >5x faster than cascoded GaN
- Proprietary design
- Gate is fragile and sensitive to noise

First & Fastest Integrated GaN Gate Drivers
- >3x faster than any other gate driver
- Proprietary design
- 30+ patents granted
- Fast, protected gate, no need for negative drive

World’s First Power ICs
- Simple, fast and reliable
- Easy to use and package

Up to 40MHz switching, 5x higher density & 20% lower system cost
Navitas eMode Power FET Technology

- Lateral device technology → Convenient isolation and easy voltage scaling
- High breakdown field (10X) and high mobility (2X) → Low $R_{DS(ON)}$, Low $Q_{OSS}$
- Lateral device technology → Low $Q_G$, easy to drive, easy to integrate
- Processed in established CMOS line → High yield, high capacity
- Multiple metal technology using standard CMOS processing equipment
Single Switch GaN Power IC

Monolithic integration at 650V

- GaN FET *(range 120-300 mΩ)*
- GaN gate driver (fast, no overshoot)
- Wide input voltage range (10-30V)
- GaN regulator (well controlled gate voltage)
- dV/dt control (programmable 10-100V/nsec)
- Hysteretic input, ESD, fault protection
- Fast and controlled start-up

5 x 6 mm QFN
Monolithic integration at 650V

- 2x 650V eMode GaN FETs (a/symmetrical range 120-600 mΩ)
- 2x 6V GaN gate drivers
- 2x 30V to 6V GaN regulators and UVLO circuits
- 650V GaN level-shifters and bootstrap drivers
- GaN Logic (shoot-through protection, fault mgmt, ESD, etc...)
Complex Design ➔ Made Simple

Half-Bridge Discrete GaN

- 20x smaller PCB area
- 40+ fewer components
- Lower cost
- Robust & protected
- Simple
- Easy layout

Half-Bridge NV6252 GaN Power IC

Half-Bridge NV6115 GaN Power ICs + isolator and bootstrap diode

PCB Area: 24 x 42 ~ 1,000 mm²
PCB Area: 18 x 20 = 360 mm²
PCB Area: 6 x 8 = 48 mm²
Application Profile for ACF Charger

**Full Power (TDUT = 100°C)**

- Voltage
- Current

1 us/div

**Light Load (TDUT = 50°C)**

- Voltage
- Current

5 us/div

**Burst Mode (TDUT = 25°C) (No Load)**

- Voltage
- Current

500 us/div
Mission Profile Driven HTOL (ZVS)

Full Power ($T_{DUT} = 100^\circ$C)

1 us/div

ZVS test bench replicates stresses seen in ACF application
Significant built-in reliability margin → even at worst case conditions (exceeds 10+ year lifetime requirement)
Reliability → Qualification → Release

Reliability models on IC building blocks = Robust design

Mission profile driven reliability = Protected Customer

Comprehensive reliability monitoring

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### Power ICs

**Quality**

**Speed**

**Efficiency**

Now in high volume production!

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#### Metric Results

<table>
<thead>
<tr>
<th>Reference</th>
<th>Test Conditions</th>
<th>Duration</th>
<th>Lots</th>
<th>S.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>JESD22-A113 J-STD-020</td>
<td>Preconditioning (MSL1); Moisture Preconditioning + 3x reflow; HAST, UHAST, TC &amp; PC</td>
<td>N/A</td>
<td>3</td>
<td>308 PASS (0/308)</td>
</tr>
<tr>
<td>JESD22-A104</td>
<td>Temperature Cycle: -55°C / 150°C</td>
<td>1,000by</td>
<td>3</td>
<td>77 PASS (0/231)</td>
</tr>
<tr>
<td>JESD22-A122</td>
<td>Power Cycle; Delta TJ = 100°C</td>
<td>10,000by</td>
<td>3</td>
<td>77 PASS (0/231)</td>
</tr>
<tr>
<td>JESD22-A110</td>
<td>Highly Accelerated Stress Test 130°C / 89%RH / 100V VGS</td>
<td>98hrs</td>
<td>3</td>
<td>77 PASS (0/231)</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Reverse Bias: 150°C / 520V VDS</td>
<td>1,000hrs</td>
<td>3</td>
<td>77 PASS (0/231)</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Gate Bias: 150°C / 6V VDS</td>
<td>1,000hrs</td>
<td>3</td>
<td>77 PASS (0/231)</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Operating Life</td>
<td>1,000hrs</td>
<td>3</td>
<td>77 PASS (0/231)</td>
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<tr>
<td>JESD22-A108</td>
<td>Early Life Failure Rate</td>
<td>24 hrs</td>
<td>3</td>
<td>1,000 PASS (0/9,000)</td>
</tr>
<tr>
<td>JIS-001-2014</td>
<td>Human Body Model ESD</td>
<td>N/A</td>
<td>1</td>
<td>3 PASS (0/3)</td>
</tr>
<tr>
<td>JIS-002-2014</td>
<td>Charged Device Model ESD</td>
<td>N/A</td>
<td>1</td>
<td>3 PASS (0/3)</td>
</tr>
</tbody>
</table>

#### Metric Results

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<tbody>
<tr>
<td>Equivalent device hours tested*</td>
<td>1.5 billion hours</td>
</tr>
<tr>
<td>FIT*</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Statistics calculated from HTOL tests
**Project Title:**
65W High-Efficiency High-Density Adapter with Improved Manufacturability

**Objectives:**
Create a commercially compelling platform that sets an industry standard in energy efficiency, power density & is manufacturing proven & volume ready (TRL≥8) for US OEMs.

**Major Milestones:**
Aug 2017 – 1st proto
Nov 2017 – eval & optimization
Feb – final design
May – manufacturing validation

**Deliverables:**
30 adapter ref designs

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1. Advances over silicon or conventional approaches: *Advancement & commercialization of Navitas GaN power ICs*

2. Markets impacts: *mobile chargers, travel adapters (consumer electronics)*

3. Timeframe for commercialization: *Q3 2018*

4. Quantitative benefits over state-of-the-art: *50% higher density, 30% improved energy efficiencies, improved manufacturability at a lower cost per watt*

5. Impact on the cost of WBG compared to Silicon: *A high-volume platform that demonstrates WBG superiority over silicon in performance and cost*

6. Potential for Job Creation Economic impact: *Significant job creation for US manufacturing partner(s) & US OEMs*

7. Workforce Development and Education: *All R&D and manufacturing is 100% based in the US with significant workforce development and education with Navitas, suppliers, partners and customers*
Key Elements For New Adaptors

High Power Density Adaptors Needs
- GaN Power Device
- Higher Integration
- Advanced Magnetics
- High Frequency Controllers
- Soft Switching Topologies

Higher Integration

GaN Power Device

New Magnetics

New Control IC

>500Khz controllers are ready!
World’s Smallest 65W USB-PD

Power, Output: 65 W USB-PD

Topology: ACF with NV6115, NV6117 GaNFast Power ICs

Frequency: 600 kHz

Size: 27 cc (45 cc with case)

Density: 2.4 W/cc (39 W/in³) uncased
1.5 W/cc (24 W/in³) cased

Efficiency:
- 93.3% peak (115 VAC)
- 93.2% at 90 VAC, full load
- DoE Level VI, Euro CoC (EuP) Tier 2

Conducted Average at 230 VAC

115 VAC, 20 V / 3.25 A, 25°C ambient, no case, no airflow, no heatsink
20mins steady state operation. Maximum case <70°C

4-Point Average Efficiency

- 115 VAC
- 230 VAC
- CoC Tier 2

EN55032

QP_Limit
Avg_Limit
QP_test
Avg_test
• SR on secondary winding, minimized $L_k$ & $R_{ac}$
• Shielding integrated as primary winding
• Safety rule compliance
Design Details & Thermal Performance

65W/90Vac

Component max temperature is 90°C
• Accomplishments
  • Completed 65W design
    • Verified efficiency, density, thermal, EMI, etc.
  • Technology platform adopted and released to production
    • World’s thinnest universal 45W adapter (Mu One)

• US Manufacturing Impact
  • Reduced labor content, costs
    • Fully automated transformer, reduced component count
  • Reduced manufacturing costs
    • Improved manufacturing quality & consistency (yield)
      • Automated transformer assembly
      • Reduced re-work
  • Significant US OEM interest to drive global adoption

PowerAmerica Project:
65W USB-PD 3.0, 27 cc, 2.4 W/cc (39 W/in³)

Commercial realization: Mu One
45W USB-PD 3.0, only 14 mm thin cased
Existing: “The Mu”

- 14 mm profile
- CE, UL, etc.

- 90-264 V$_{AC}$ input
- 2 x 6 W = 12 W (Type A)

Images courtesy Made-in-Mind
Challenge: Fast Charging “Mu One”

- 14 mm profile
- CE, UL, etc.

- 90-264 V\textsubscript{AC} input
- \(2 \times 6 \text{ W} = 12 \text{ W} \) (Type A)
- 45 W (USB-PD Type C)

Images courtesy Made-in-Mind
45 W in 11 mm = HF Planar ACF

- Planar Transformer
- NV611x Power ICs
- ACF IC UCC28780
- Type-C Receptacle
- AC Bridge
- PD IC
- SR FET
- EMI Filter
- Bulk Caps

Proprietary; Authorized Use with Navitas License
Cool Operation

90 V_{AC}, 45 W, 25 °C, uncased, no airflow, no thermal compound / heatsinking
High Efficiency Across Line, Load, Output Voltage

- Full Load, 20V
- 4-Point Average

Input VAC (V)

90 VAC
115 VAC
230 VAC
90.0%
91.0%
92.0%
93.0%
94.0%
95.0%
96.0%
97.0%
98.0%
99.0%
100.0%

Output Voltage

5 V
9 V
15 V
20 VOUT

CoC Tier 2
Quiet EMI (Conducted, Radiated)

CE: 115Vac 20V/2.25A
CE: 230Vac 20V/2.25A

RE: 230Vac 20V/2.25A
Horizontal

RE: 230Vac 20V/2.25A
Vertical
Thanks to Matt Judkins, CEO of Made-in-Mind (Mu One)

Available via [www.kickstarter.com](http://www.kickstarter.com) and [www.amazon.com](http://www.amazon.com) and airport stores

Images courtesy Made-in-Mind
RAVPower 45W: Same Platform

45W Power Delivery
2.5X Faster

Macbook 12”
2.0 hrs

iPhone XS Max
1.8 hrs

Available now on www.amazon.com

Images courtesy RAVPower
AUKEY USB-C GaNFast Chargers

Available now on www.amazon.com

Images courtesy AUKEY
GaNFast Design Support

- Global technical support
  - Direct support
  - Partner support (VAR)

- Strong AE team

- Strong FAE team

- GaNFast Design Support Program
  - From schematic to EMI
  - Components, magnetics, PCB
  - Critical component support
  - System reliability support