Delivering Performance, Let’s Go GaNFast™

Stephen Oliver, VP Sales & Marketing, stephen.oliver@navitassemi.com
Navitas Semiconductor Inc.

- World’s first & only GaN power IC company
  - Production released with fast revenue ramp
- Navitas: Latin for Energy
  - Energy savings
  - Bringing a new Energy to power electronics
- Founded January 2014, HQ El Segundo, CA
- Proven management team, 60+ employees
- Tier 1 manufacturing partners
  - Wafer foundry, packaging
- Strong financial investors ($1B+ managed capital)
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
Fastest, most efficient GaN Power FETs

>20x faster than silicon
>5x faster than cascoded GaN
Proprietary design

First & Fastest Integrated GaN Gate Drivers

>3x faster than any other gate driver
Proprietary design
30+ patents granted/applied

Up to 40MHz switching, 5x higher density & 20% lower system cost
**Single GaNFast Power IC**

- Monolithic integration, 650V
  - GaN FET
  - GaN Driver
  - GaN Logic

- “Digital In, Power Out”
Half-Bridge GaNFast Power IC

- Monolithic integration, 650V
  - 2x GaN FETs
  - 2x GaN drivers
  - GaN Logic (level-shift, bootstrap, UVLO, shoot-through, ESD)
- “Digital In, Power Out”
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 V_{ac})
93.2% at 90 V_{ac}, full load
DoE Level VI, Euro CoC (EuP) Tier 2

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

Conducted Average at 230 V_{ac}

EN55032
World’s Smallest 65W USB-PD

Demo Boards Are HISTORY

<table>
<thead>
<tr>
<th>Power Output</th>
<th>65 W USB-PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology</td>
<td>ACF with NV5115, 8117 GaNFast I C's</td>
</tr>
<tr>
<td>Frequency</td>
<td>600 KHz</td>
</tr>
<tr>
<td>Size</td>
<td>27 cc (63 cc with case)</td>
</tr>
<tr>
<td>Density</td>
<td>2.4 W/cc (38 W/in³) uncased</td>
</tr>
<tr>
<td></td>
<td>1.5 W/cc (36 W/in³) cased</td>
</tr>
<tr>
<td>Efficiency</td>
<td>95.3% peak (115 V_ac)</td>
</tr>
<tr>
<td></td>
<td>93.2% at 90 V_ac, full load</td>
</tr>
<tr>
<td></td>
<td>DoE Level VI, Euro CoC (EU) Tier 2</td>
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</table>

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

Conducted Average at 230 V_ac

EN 55032

QP_Limit
Avg_Limit
QP_test
Avg_test
• GaNFast power ICs:
  • Capability
    • Voltage, power, system performance
  • Reliability
    • ‘Time-zero’, lifetime
  • Availability
    • Capacity (M’s/month), leadtime (12 weeks)
  • Cost-competitive
**GaN-Based Qual Plan**

<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</td>
<td>Preconditioning (MSL1): Moisture Preconditioning + 3x reflow: HAST, UHAST, TC &amp; PC</td>
<td>N/A</td>
<td>3</td>
<td>308</td>
</tr>
<tr>
<td>JESD22-A104</td>
<td>Temperature Cycle: -55°C / 150°C</td>
<td>1,000cy</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JESD22-A122</td>
<td>Power Cycle: Delta Tj = 100°C</td>
<td>10,000cy</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JESD22-A110</td>
<td>Highly Accelerated Stress Test: 130°C / 85%RH / 100V V&lt;sub&gt;DS&lt;/sub&gt;</td>
<td>96hrs</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Reverse Bias: 150°C / 520V V&lt;sub&gt;DS&lt;/sub&gt;</td>
<td>1,000hrs</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Gate Bias: 150°C / 6V V&lt;sub&gt;GS&lt;/sub&gt;</td>
<td>1,000hrs</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JESD22-A108</td>
<td>High Temperature Operating Life</td>
<td>1,000hrs</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>JS-001-2014</td>
<td>Human Body Model ESD</td>
<td>N/A</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>JS-002-2014</td>
<td>Charged Device Model ESD</td>
<td>N/A</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

**Lifetime Models** (HTOL, HTRB)

**Failure Modes Established**

**Application Specific HTOL Test Bench**
• Matches all elements of application profile
  • FET & IC
• Many cells in parallel
  • Statistical sample sizes
• Low total power consumption
• Conditions changeable to develop lifetime and acceleration models

HTOL Mother Board

Qualification
3 Lots x 77

Lifetime Models
Voltage Current Frequency Temperature

Early Life Failure Rate
3 Lots x 1,000
HTOL-based Lifetime Model

<table>
<thead>
<tr>
<th>Voltage/Temperature</th>
<th>100</th>
<th>125</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>575</td>
<td></td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>✅</td>
<td></td>
<td></td>
</tr>
<tr>
<td>625</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>650</td>
<td></td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>

For $T = 150 \, ^\circ C$, Voltage Acceleration

$$\text{Time to Fail (hrs)} \propto \frac{1}{(\text{Voltage})^{n=17.2}}$$

For $V = 650 \, V$, Temperature Acceleration

$$\text{Time to Fail (hrs)} \propto e^{\frac{E_a}{kT}}$$
Lifetime Estimation: ACF Charger

\[
Temperature \text{ Acceleration Factor (AF}_{\text{temp}}) = e^{\frac{E_a}{k} \left( \frac{1}{T_{\text{application}}} - \frac{1}{T_{\text{ambient}}} \right)}
\]

\[
Voltage \text{ Acceleration Factor (AF}_{\text{voltage}} = \left( \frac{V_{\text{application}}}{V_{\text{ambient}}} \right)^n
\]

\[
Total \text{ Acceleration Factor (AF}_{\text{total}} = AF_{\text{temp}} \times AF_{\text{voltage}}
\]

\[
\text{Lifetime estimate in application} = AF_{\text{total}} \times \text{Time to failure in reliability (TTF}_{\text{reliability}})
\]

<table>
<thead>
<tr>
<th>AC line Voltage (V)</th>
<th>Rectified AC Voltage (V)</th>
<th>Reflected Voltage (V)</th>
<th>Switch Voltage (V)</th>
<th>Full power Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>170</td>
<td>120</td>
<td>290</td>
<td>85</td>
</tr>
<tr>
<td>240</td>
<td>340</td>
<td>120</td>
<td>460</td>
<td>85</td>
</tr>
</tbody>
</table>

\[
\text{Lifetime} = AF_{\text{total}} \times TTF_{\text{reliability}} = 233 \text{ years} @ 240V \text{ AC input}
\]

- Predicted lifetime exceeds 10yr lifetime requirement
Baseline: “The Mu”

- 14 mm profile
- CE, UL, etc.

- 90-264 V<sub>AC</sub> input
- 2 x 6 W = 12 W (Type A)
Challenge: “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
- EMI Filter
- Type-C Receptacle
- Bulk Caps
- AC Bridge
- PD IC
- SR FET

Proprietary; Authorized Use with Navitas License
45 W in 11 mm = HF Planar ACF

- Size: 29 cc (41 cc with case)
- Density: 1.7 W/cc (27 W/in³), 1.1 W/cc (18 W/in³) cased

- Planar Magnetics:
  - Low profile
  - Automated assembly
  - Predictable performance
  - High yield
Cool Operation

90 V$_{AC}$, 45 W, 25 °C, uncased, no airflow, no thermal compound / heatsinking
High Efficiency

Full Load, 20V

Input $V_{AC}$ (V)

4-Point Average

5 V  9 V  15 V  20 V$_{OUT}$

115 $V_{AC}$  90 $V_{AC}$  230 $V_{AC}$

CoC Tier 2

90,0%  90,5%  91,0%  91,5%  92,0%  92,5%  93,0%  93,5%  94,0%  94,5%

90  115  140  165  190  215  240  265
Quiet EMI (Conducted, Radiated)
Thanks to Matt Judkins, CEO of Made-in-Mind (Mu)

Available via [www.kickstarter.com](http://www.kickstarter.com) now, and via [www.amazon.com](http://www.amazon.com) and airport stores in January
RAVPower 45W USB-C PD

45W Power Delivery
2.5X Faster

Macbook 12”
2.0 hrs

iPhone X5 Max
1.8 hrs

Available now on www.amazon.com

Images courtesy RAVPower
AUKEY 24W, 27W, 30W

AUKEY GaNFast™

Up to 3x faster charging with half the size and weight for unparalleled mobility.

- Available now on www.amazon.fr

Images courtesy AUKEY
Let’s go GaNFast™