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
World’s First GaNFast™ Power ICs

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

World’s First Power ICs

Up to 40MHz switching, 5x higher density & 20% lower system cost
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/in^3) uncased
1.5 W/cc (24 W/in^3) 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}

Efficiency

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>5V</td>
<td>0.94</td>
</tr>
<tr>
<td>9V</td>
<td>0.92</td>
</tr>
<tr>
<td>15V</td>
<td>0.90</td>
</tr>
<tr>
<td>20V</td>
<td>0.88</td>
</tr>
</tbody>
</table>

EN55032

QP_Limit
Avg_Limit
QP_test
Avg_test
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, NV6117 GaN Fast Power ICs</td>
</tr>
<tr>
<td>Frequency</td>
<td>600 KHz</td>
</tr>
<tr>
<td>Size</td>
<td>27 cc (65 cc with case)</td>
</tr>
<tr>
<td>Density</td>
<td>2.4 W/cc (38 W/nm) uncased 1.5 W/cc (24 W/nm) cased</td>
</tr>
<tr>
<td>Efficiency</td>
<td>95.3% peak (115 V_ac) 93.2% at 90 V_ac, full load DoE Level VI, Euro CoC (EuP) Tier 2</td>
</tr>
</tbody>
</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

Connected Average at 230 V_ac

Max QP, 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
# ‘Beyond’ JEDEC Qualification

## 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 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</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 VDS</td>
<td>96hrs</td>
<td>3</td>
<td>77</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</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</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

Voltage Current Frequency Temperature

Lifetime Models

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>

### T=150 °C, Voltage Acceleration

The time to failure is given by:

\[
T = \frac{1}{(Voltage)^{n=17.2}}
\]

### V= 650 V, Temperature Acceleration

The time to failure is given by:

\[
Time to Fail (hrs) \propto e^{\frac{E_a=0.71eV}{kT}}
\]
Lifetime Estimation: ACF Charger

**Temperature Acceleration Factor**

\[
AF_{\text{temp}} = e^{\frac{E_a}{k_B \cdot (1/T_{\text{application}} - 1/T_{\text{operation}})}},
\]

\[E_a = 0.71 \text{eV}\]

**Voltage Acceleration Factor**

\[
AF_{\text{voltage}} = \left(\frac{V_{\text{operation}}}{V_{\text{application}}}\right)^n
\]

\[n = 17.2\]

**Total Acceleration Factor**

\[
AF_{\text{Total}} = AF_{\text{temp}} \times AF_{\text{voltage}}
\]

**Lifetime estimate in application** = \(AF_{\text{Total}} \times \text{Time to failure in reliability (TTF_{\text{reliability}})}\)

**ACF Charger Full-Power Profile**

<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>

**Lifetime** = \(AF_{\text{Total}} \times \text{TTF}_{\text{reliability}} = 233 \text{ years} @ 240V \text{ AC input}\)

- 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)

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

- 14 mm profile
- CE, UL, etc.

- 90-264 V<sub>AC</sub> input
- 2 x 6 W = 12 W (Type A)
- 45 W (USB-PD Type C)

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

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

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

80.0% 81.0% 82.0% 83.0% 84.0% 85.0% 86.0% 87.0% 88.0% 89.0% 90.0% 91.0% 92.0%

90.0% 91.0% 92.0% 93.0% 94.0% 95.0% 96.0% 97.0% 98.0% 99.0% 100.0%

$90 \text{ V}_{AC}$ $115 \text{ V}_{AC}$ $230 \text{ V}_{AC}$

CoC Tier 2
Quiet EMI (Conducted, Radiated)
Mu One: From Prototype to Mass Production

Thanks to Matt Judkins, CEO of Made-in-Mind (Mu)

Available via www.kickstarter.com now, and via 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 Xs Max
1.8 hrs

• Available now on www.amazon.com

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

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™