GaN IC Enables Revolution in AC/DC Adaptor

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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, 75+ 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
USB Type C & Power Delivery

All in one: Type C connector

One for all: PD adapter/charger
Mu One 45W PD: World Thinnest Adapter

- 5V/3A, 9V/3A, 12V/3A, 15V/3A, 20V/2.25A
- 14 mm profile
- CE, UL, etc.
- Available now on www.amazon.com

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](http://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.com

Images courtesy AUKEY
How Can We Make It?

A. Select the right semiconductor devices
B. Select the right topology, frequency and control
C. Select the right magnetics and design properly
**World First GaN Power IC**

### Single GaN IC

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

### Half-bridge GaN IC

- **Monolithic integration, 650V**
  - 2x GaN FETs
  - 2x GaN drivers
  - GaN Logic (level-shift, bootstrap, shoot-through)

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**Clean HF waveform**
Active Clamp Flyback with Soft-Switching

Commercial IC Available!!
GaN vs. Si in ACF
2%-3% Higher Efficiency with Low $C_{\text{oss}}$, $Q_g$, $Q_{rr}$, $E_{\text{off}}$

<table>
<thead>
<tr>
<th>Voltage Rating (V)</th>
<th>IPA60R299CP</th>
<th>NV6260 (per FET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R$_{\text{DS(ON)}}$</td>
<td>270</td>
<td>160 (40% ↓)</td>
</tr>
<tr>
<td>C$_{\text{o(tr)}}$ (pF)</td>
<td>120</td>
<td>50 (60% ↓)</td>
</tr>
<tr>
<td>Q$_g$ (nC)</td>
<td>22</td>
<td>2.5 (90% ↓)</td>
</tr>
<tr>
<td>Q$_{rr}$ (nC)</td>
<td>3900</td>
<td>0</td>
</tr>
</tbody>
</table>

650V GaN+ Full ZVS tuning
600V Si + Partial ZVS tuning

Courtesy of Texas Instruments (ACF w/ pri resonance)
Advanced Magnetic Material

\[ F_{3/4} = \frac{B_f^{3/4}}{(T \cdot Hz^{3/4})} \]

\[ F_{3/4} = \frac{B_f^{3/4}}{(T \cdot Hz^{3/4})} \]

ML915 (Hitachi Metal) ~2010s

3C90 (Ferroxcube) ~1990s

3F35 (Ferroxcube) ~2000s

67 (Fair-Rite) ~2015s

Future

Modified Performance factor

(\( P_v = 500 \text{mW/cm}^3 \))


Magnetic: Bulky / Expensive $\rightarrow$ Small / Cheap

<table>
<thead>
<tr>
<th>Vol (mm$^3$)</th>
<th>Freq (kHz)</th>
<th>Size Reduction</th>
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</thead>
<tbody>
<tr>
<td>12000</td>
<td>65kHz</td>
<td>2.5x</td>
</tr>
<tr>
<td>6000</td>
<td>200kHz</td>
<td>1.5x</td>
</tr>
<tr>
<td>4000</td>
<td>400kHz</td>
<td>1.5x</td>
</tr>
<tr>
<td>8000</td>
<td>400kHz</td>
<td>1.5x</td>
</tr>
<tr>
<td>10000</td>
<td>1MHz</td>
<td></td>
</tr>
</tbody>
</table>

Chrome book (65kHz) $\rightarrow$ Innergie (200kHz) $\rightarrow$ Navitas (400kHz) $\rightarrow$ CPES (1MHz)

RM10

~ EQ25

ER25

ER23
Planar Magnetics → Manufacturability

- SR on sec winding, minimized $L_k$ & $R_{ac}$
- Shielding integrated as pri winding
- Safety rule compliance
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
Cool Operation

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

Full Load Efficiency

Efficiency

Vo=5V Vo=9V Vo=15V Vo=20V

115Vac 90Vac 230Vac

4-Point Average Efficiency

Efficiency

Vo=5V Vo=9V Vo=15V Vo=20V

115V_{AC} 230V_{AC} CoC Tier 2

Full Load Efficiency and 4-Point Average Efficiency graphs showing efficiency values for different output voltages and input voltages.
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
Mu One: From Prototype to Mass Production

• Thanks to Matt Judkins, CEO of Made-in-Mind (Mu)
• Available via www.amazon.com and airport stores in NOW!
The New World of Fast Charging

**GaNFast™ Designs**

- 600kHz ACF low profile planar xfrmr
- 500kHz ACF low profile planar xfrmr USB-PD
- 300kHz ACF Wound xfrmr USB-PD
- 300kHz ACF wound xfrmr USB-PD Convention
- 2-stage 200/300kHz CrCM PFC/ACF wound xfrmr USB-PD
- 2-stage 200/500kHz CrCM PFC, plus LLC wound xfrmr

*Power Density (uncased, W/m²)*

<table>
<thead>
<tr>
<th>Power Density</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>27</td>
<td>45</td>
<td>65</td>
<td>100</td>
<td>150</td>
<td></td>
<td></td>
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Conventional Silicon-based Designs

Information available on www.navitassemi.com
Let’s go GaNFast™