GaN Power ICs
Enable 300cc
700kHz 300W
AC-DC Converter

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Presentation Outline

- Mid-Power Applications (100W to 500W)
- Mid-Power AC/DC Adapter Teardowns
- Conventional Input Bridge Rectifier
- Bridgeless PFC Topologies
- 300W TTP+LLC Block Diagram
- 300W TTP PFC & LLC Circuit Stages
- GaNFast Power IC Highlights
- 300W Prototype & Testing Results
- Conclusions, Future Work, Q&A
Mid-Power Applications

- All-in-One PCs
- Flat Screen TVs
- Gaming Consoles
- 5G
- Gaming Laptops
- eMobility
<table>
<thead>
<tr>
<th>Output Specs</th>
<th>Output Power</th>
<th>Size (cased)</th>
<th>Power Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>20V/14A</td>
<td>280W</td>
<td>542cc</td>
<td>0.52 W/cc</td>
</tr>
<tr>
<td>19.5V/16.6A</td>
<td>330W</td>
<td>844cc</td>
<td>0.39 W/cc</td>
</tr>
<tr>
<td>19V/13.2A</td>
<td>250W</td>
<td>332cc</td>
<td>0.75 W/cc</td>
</tr>
</tbody>
</table>

Efficiency @ 90VAC/Full-load:
- 93.3%
- 93.4%
- 90.5%
Rectifier On Fire!

\[ P_{LOSS\_BRIDGE} = 2 \times V_f \times I_{RMS} \]
\[ P_{LOSS\_BRIDGE\_300W\_90VAC} = 6W \]

Input Bridge = 110°C!!

4x Input Bridge Diodes

2x Diodes Always Conducting!
Eliminate the Bridge!

**PLOSS_BRIDGE > 50% of PLOSS_PFC**
(@ 90VAC/300W)

**PLOSS_BRIDGE > 25% of PLOSS_TOTAL**
(@ 90VAC/300W)
Bridgeless PFC Solutions

- **Basic Bridgeless PFC**
  - High CM noise
  - Complex voltage sensing
  - Complex current sensing

- **Semi-Bridgeless PFC**
  - Low CM noise
  - Simple voltage sensing
  - Complex current sensing
  - Requires 2x inductors

- **Bidirectional Bridgeless PFC**
  - Low CM noise
  - Complex voltage sensing
  - Complex current sensing
  - Requires isolated gate drive
  - Requires lower RDSON FETs

- **Bridgeless Totem-pole PFC**
  - Low CM noise
  - Difficult voltage sensing
  - Difficult current sensing

- ✓ Low CM noise
- ✓ Easy voltage sensing
- ✓ Easy current sensing
300W TTP+LLC Block Diagram

- EMI Filter
- TTP PFC
- 2x NV6128
- 2x Si FET
- TTP PFC Controller
- 400V
- Resonant LLC
- 2x NV6127
- LLC Controller
- X’FMR
- Sync Rect
- SR IC
- Vout Reg
- 24V/12.5A Output

Totem-Pole PFC
Half-Bridge LLC
SR Output
TTP PFC Stage = 2x NV6128 (Fast Leg)
Half-Bridge LLC Stage = 2x NV6127
## NV6128 70mΩ GaNFast Power IC

### Features
- Integrated gate drive
- Integrated gate drive regulator
- Programmable turn-on dV/dt
- Wide $V_{CC}$ range (10 to 30 V)
- Source Kelvin GND
- 70 mΩ eMode GaN FET
- 2 KV ESD rating (HBM)
- 800 V transient voltage rating
- 650 V continuous voltage rating
- Zero reverse recovery charge
- 6x8 mm QFN
- Large cooling pad

### Simplified Schematic

![Simplified Schematic](image)

### Package
- PQFN 6x8 mm

### Typical Application Schematic (Boost PFC)

![Typical Application Schematic](image)
Integration Drives Performance

Clean Switching (Boost Circuit)

Integrated Gate Driver
Integrated GaN gate

NV6128

10V to 24V
VCC
PWM
REG
DZ
dV/dt
SK
CP
D
S

V_{PWM}
V_{CC}
V_{DZ, V_{DD}}
V_{DS}
V_{BUS}
I_{DS}
t

12
Simple Layout, Large Cooling Area
GaNFast Power IC = Integrated gate & driver, No gate loop parasitics, No gate voltage spikes!

Discrete GaN FET (exposed gate)

- Turn-on + loop inductance = gate over-shoot & ringing
- Negative dV/dt during turn-on = additional gate over-shoot & ringing
- Turn-off + loop inductance = gate under-shoot & ringing
- Positive dV/dt during turn-off = additional gate under-shoot & ringing
- False turn-on, false turn-off, glitching
- Low reliability and robustness

GaNFast Power IC (integrated gate)

- No loop inductance
- Immune to dV/dt
- Immune to source inductance
- No gate over/under-shooting or ringing
- No false turn-on or turn-off or glitching
- High reliability and robustness
Clean Switching, No Ringing, No Glitching @ 30A

NV6128 GaN Power IC

- Integrated Gate
- Clean Switching
- No Ringing
- No Glitching!

Double Pulsed Test
(Sync Boost Circuit)

Discrete GaN

- Exposed Gate
- Faulty Switching
- Ringing & Glitching!
300W/220cc Prototype (PCBA)

- **VACin**
  - BUS
  - Capacitors
  - EMI Filter
  - Slow Leg
  - PFC
  - Inductor

- **VDCout**
  - Output Capacitors
  - LLC
  - XFMR

- **Top View**
  - LLC GaN Card
  - 2x NV6127

- **Front Side View**
  - TTP GaN Card
  - 2x NV6128 (Fast Leg)

- **Back Side View**
  - SR Card
  - 4x EPC2218

- **Dimensions**
  - 69mm x 127mm x 25mm = 220cc (PCBA)
  - 75mm x 132mm x 30mm = 300cc (Cased est.)
Sinusoidal Inductor Current for High Power Factor

ZVS during Ton and Toff

Fsw=200kHz

VSW (100V/div)

IL (5A/div)
LLC Resonant ZVS Waveforms

Sinusoidal LLC Resonant Tank Current

Smooth & Clean ZVS Half-Bridge Waveforms!

680 kHz
95.75% Peak Efficiency & Low Thermals

94.4% Peak Efficiency @ 90Vac
95.75% Peak Efficiency @ 230Vac
94.1% Efficiency @ 90Vac/100%

1 – 3% higher efficiency vs conventional Si-based designs!

Thermal measurements: 110 VAC / full load (24 V / 12.5 A out)
Conclusions & Future Work

✓ Achieved 200kHz TTP PFC using NV6128 → 2x higher frequency vs Si-based designs
✓ Achieved 700kHz LLC using NV6127 → 7x higher frequency vs Si-based designs
✓ Achieved 95.75% peak efficiency → 1-3% higher efficiency vs Si-based designs
✓ Achieved 220cc PCBA size, est. 300cc cased size → 45-65% smaller size vs Si-based designs
✓ High-frequency off-the-shelf controllers now available
✓ Integrated gate and driver = best reliability & robustness
✓ > 75Mu GaNFast ICs shipped with zero field failures!

➢ EMI compliance in progress
➢ Sample prototype EVBs to customers
Thank you for your attention!

I'm pleased to answer your questions.

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