300W Multi-Mode Totem-pole PFC Using GaN Power ICs

Tom Ribarich
Sr. Dir. Strategic Marketing
Navitas Semiconductor
tom.ribarich@navitassemi.com

Liming Ye
Principal Applications Engineer
Navitas Semiconductor
liming.ye@navitassemi.com
Presentation Outline

- Mid-Power Applications (100W to 500W)
- Mid-Power AC/DC Adapter Teardowns
- Conventional PFC with Bridge Rectifier
- Bridgeless Topologies
- Bridgeless Totem-pole PFC Circuit
- NV6128 GaN Power IC
- NV6128 Daughtercard
- 300W Totem-pole PFC EVB Results
Mid-Power Applications

- All-in-One PCs
- Flat Screen TVs
- Gaming Consoles
- 5G
- Gaming Laptops
- eMobility
ASUS 280W

Output Specs: 20V/14A
Output Power: 280W
Dimensions (cased): 179x85x36mm = 542cc
Power Density: 0.52 W/cc

Efficiency @ 90VAC/Full-load = 93.3%
HP OMEN 330W

Output Specs: 19.5V/16.6A
Output Power: 330W
Dimensions (cased): 150 x 150 x 38mm = 844cc
Power Density: 0.39 W/cc

Efficiency @ 90VAC/Full-load = 93.4%
RAZER BLADE PRO 250W

Output Specs: 19V/13.2A
Output Power: 250W
Dimensions (cased): 194 x 86 x 20mm = 332cc
Power Density: 0.75 W/cc

Efficiency @ 90VAC/Full-load = 90.5%
Rectifier on Fire!

**PLOSS-BRIDGE = 2 x Vf x IRMS**

**PLOSS-BRIDGE-300W-90VAC = 6W**

2x Diodes Always Conducting!

Input Bridge Diodes

**Input Bridge = 110C!!**

ASUS 280W Thermal Image

(PCB in free air, Ta=25C, Vin=90VAC, 100% load)
Eliminate the Bridge!

**$P_{LOSS\_BRIDGE} > 25\% \text{ of } P_{LOSS\_PFC+LLC}$** (@ 90VAC/300W)

**$P_{LOSS\_BRIDGE} > 50\% \text{ of } P_{LOSS\_PFC}$** (@ 90VAC/300W)
Bridgeless Topologies

**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

Some of these topologies exist already at higher powers but are limited to low frequency, and have high cost, high complexity and high losses at light-load.
Totem-pole PFC Simplified Schematic

EMI Filter

Universal Mains Input

FCPF067N65 67m

Polarity Sensing

Boost Inductor

NCP 51530

NCP 1680

NCP 51530

NV6128 GaN IC

To Downstream Converter

RCS+ZCD
# NV6128 70mΩ GaN 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)
Simple and Cool Layout
Clean Switching, No Ringing or 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!
NV6128: “Best GaN We Have Tested!”

NV6128 Testing Feedback:
- Fast and very clean switching
- Easy to control slew rates
- Integrated gate allows for high switching speeds (dV/dt > 200 V/ns, di/dt > 10 A/ns)
- Integrated gate protection eliminates external components without restricting switching speeds
- Minimal ringing and oscillations allowing for EMI optimized designs
- The internal driver realizes the full potential of GaN (no dv/dt and gate-loop induced risks)
- “Outstanding GaN performance, best GaN we have tested!”
300W Totem-pole PFC Evaluation Board

2x NV6128 GaN IC Daughter Card

2x NV6128 GaN ICs

2x Si FETs

Slow Leg
Line Frequency

Fast Leg
PWM Frequency

SRH

SRL

PWMH

PWML

No Input Bridge

Totem-pole Evaluation Board provided by ON Semiconductor
NV6128 Evaluation Daughtercard

- NV6128 High-Side GaN IC
- NV6128 Low-Side GaN IC
- NCP51530 HB Driver IC
Clean Start-up into Full Load

Vin=115Vac
Vo=397V, Io=0.75A
Startup

VBRDG: Fast HB switch node
Vo_pfc: PFC output
Vin_ac: AC line voltage
Iin_ac: AC line current
Clean Steady-State Operation

Vin=115Vac  
Vo=397V, Io=0.75A

VBRDG: Fast HB switch node  
VBRDG2: Slow HB switch node  
Vin_ac: AC line voltage  
lin_ac: AC line current

Ch1: VSWFAST  
100V/div

Ch2: VSWSLOW  
100V/div

Ch3: Vin_ac  
100V/div

Ch4: lin_ac  
2A/div
ZVS & ZCS Switching (Zoomed)

Vin=115Vac
Vo=397V, Io=0.75A

Triggered at Vin_ac=160V
(Rising, at line peak)

Fsw=77.1kHz
(Fsw = 75 - 130 kHz over line/load/line-cycle range)
High Efficiency and Cool Operation

- **Conventional PFC EFF = 96% @ 90VAC/100%**
- **Totem-pole PFC Efficiency = 97.5% @ 90VAC/100%**
- **Totem-pole = +1.5% EFF Increase vs Conventional PFC!**
Acknowledgements & Questions

**Special Thanks To:**
- ON Semiconductor