

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

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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

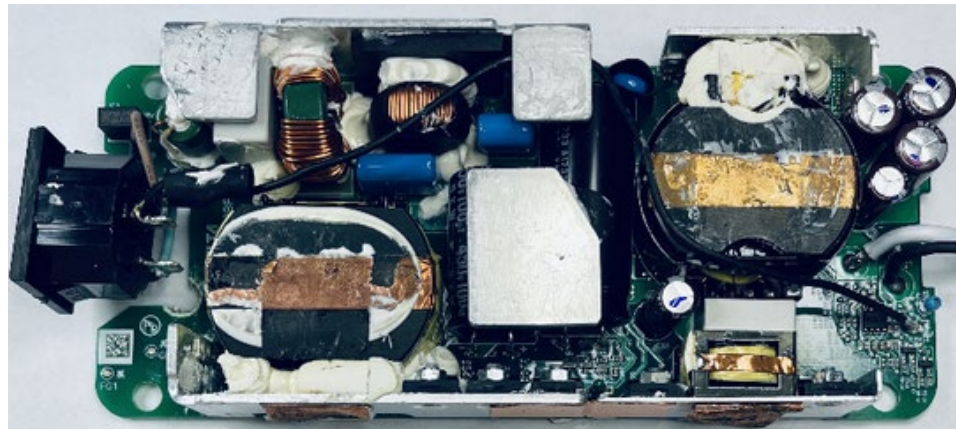
ASUS 280W

Output Specs: 20V/14A

Output Power: 280W

Dimensions (cased): 179x85x36mm = 542cc

Power Density: 0.52 W/cc



Efficiency @ 90VAC/Full-load = 93.3%

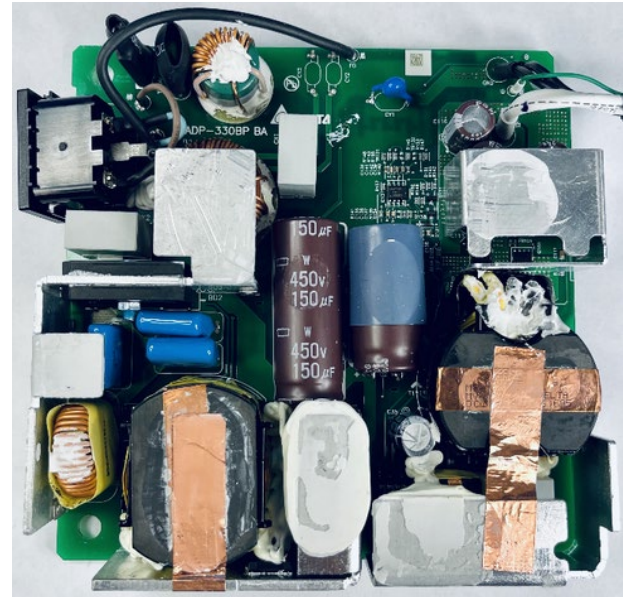
HP OMEN 330W

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%

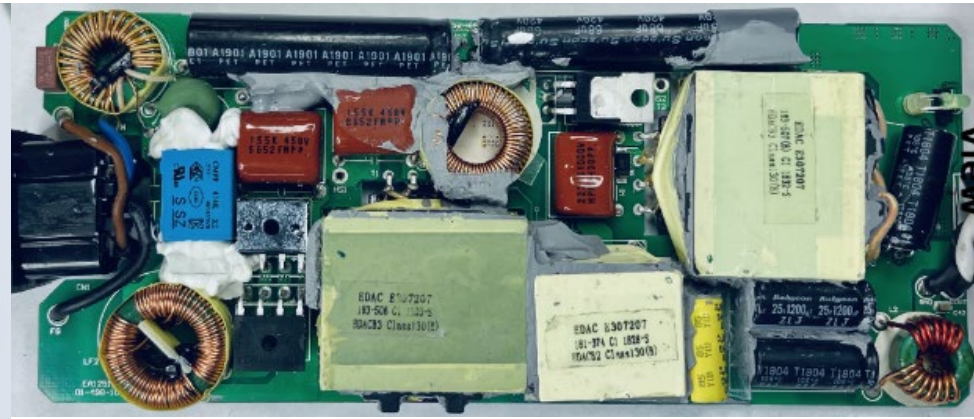
RAZER BLADE PRO 250W

Output Specs: 19V/13.2A

Output Power: 250W

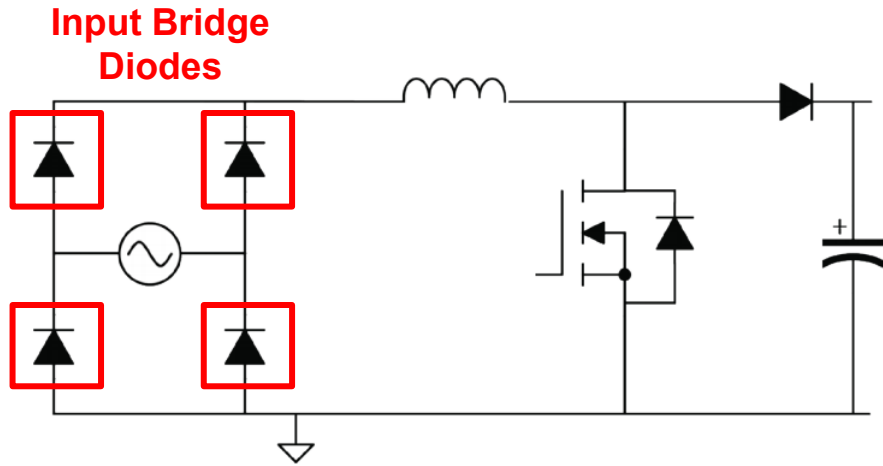
Dimensions (cased): 194 x 86 x 20mm = 332cc

Power Density: 0.75 W/cc

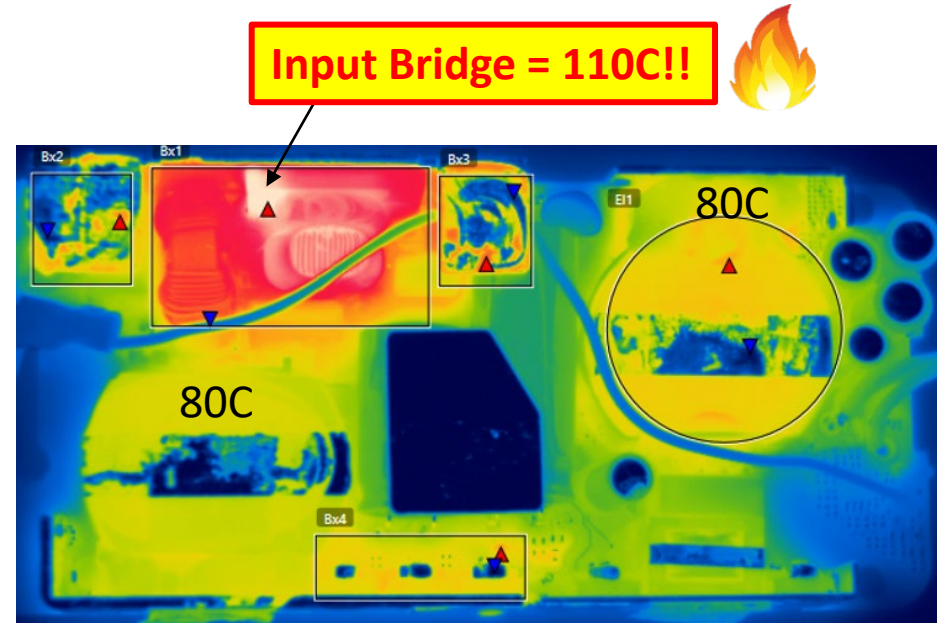


Efficiency @ 90VAC/Full-load = 90.5%

Rectifier on Fire!



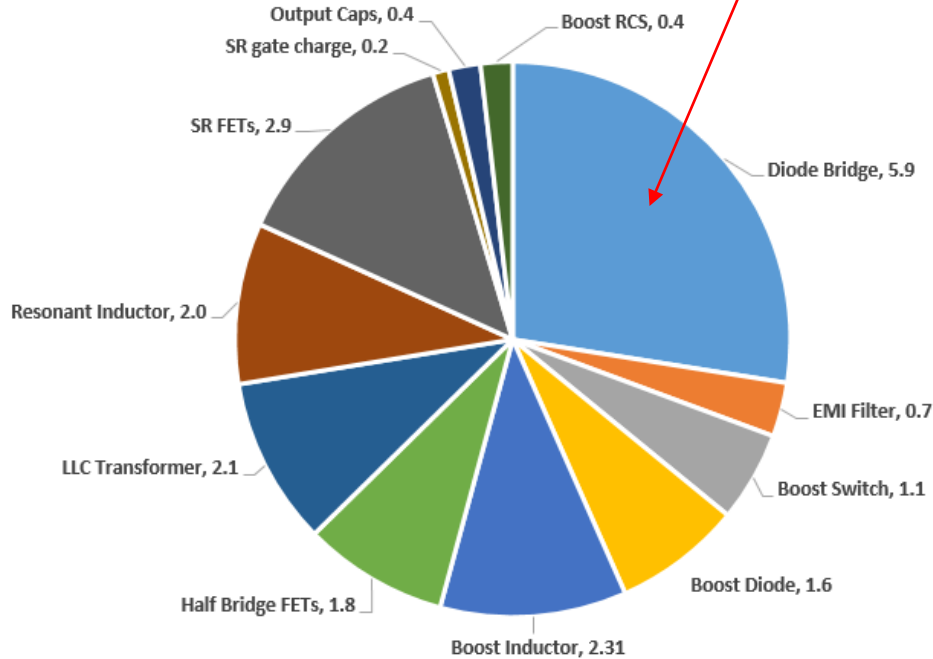
$P_{LOSS-BRIDGE} = 2 \times V_f \times I_{RMS}$
 $P_{LOSS-BRIDGE-300W-90VAC} = 6W$
2x Diodes Always Conducting!



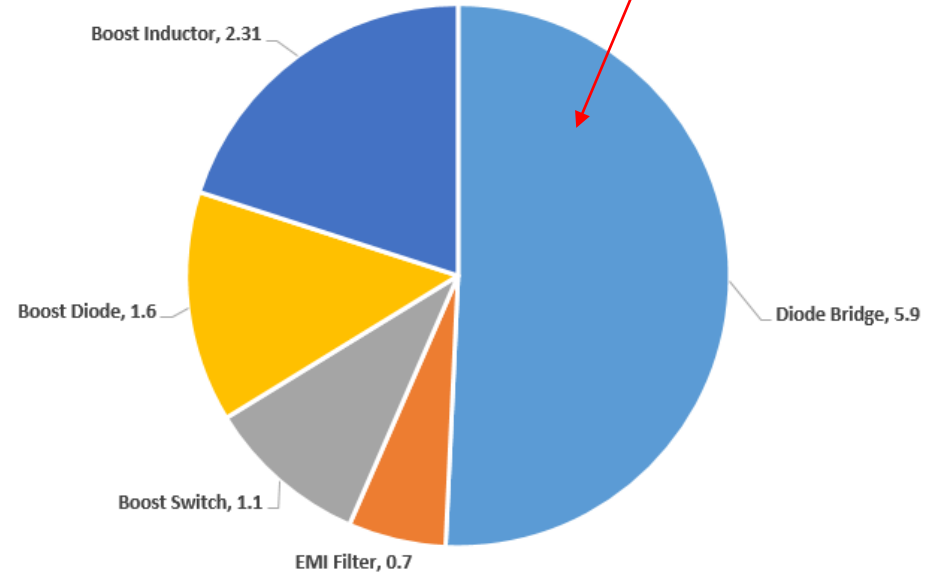
ASUS 280W Thermal Image
(PCB in free air, $T_a=25C$, $V_{in}=90VAC$, 100% load)

Eliminate the Bridge!

**PLOSS_BRIDGE > 25% of PLOSS_PFC+LLC
(@ 90VAC/300W)**

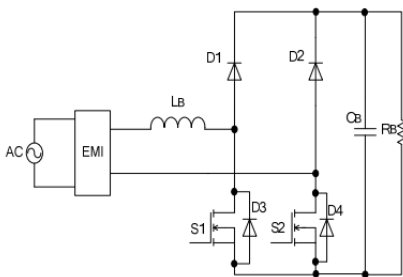


**PLOSS_BRIDGE > 50% of PLOSS_PFC
(@ 90VAC/300W)**



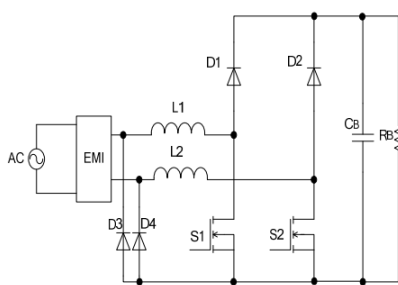
Bridgeless Topologies

Basic Bridgeless PFC



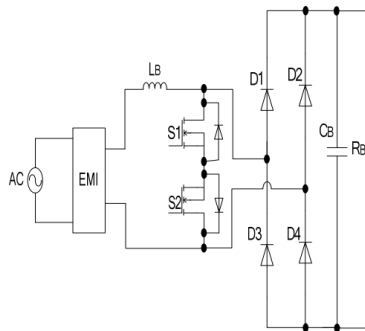
- High CM noise
- Complex voltage sensing
- Complex current sensing

Semi-Bridgeless PFC



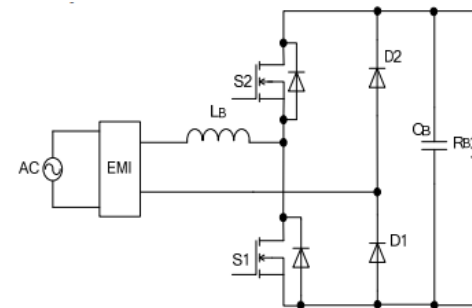
- Low CM noise
- Simple voltage sensing
- Complex current sensing
- Requires 2x inductors

Bidirectional Bridgeless PFC



- Low CM noise
- Complex voltage sensing
- Complex current sensing
- Requires isolated gate drive
- Requires lower $R_{DS(on)}$ FETs

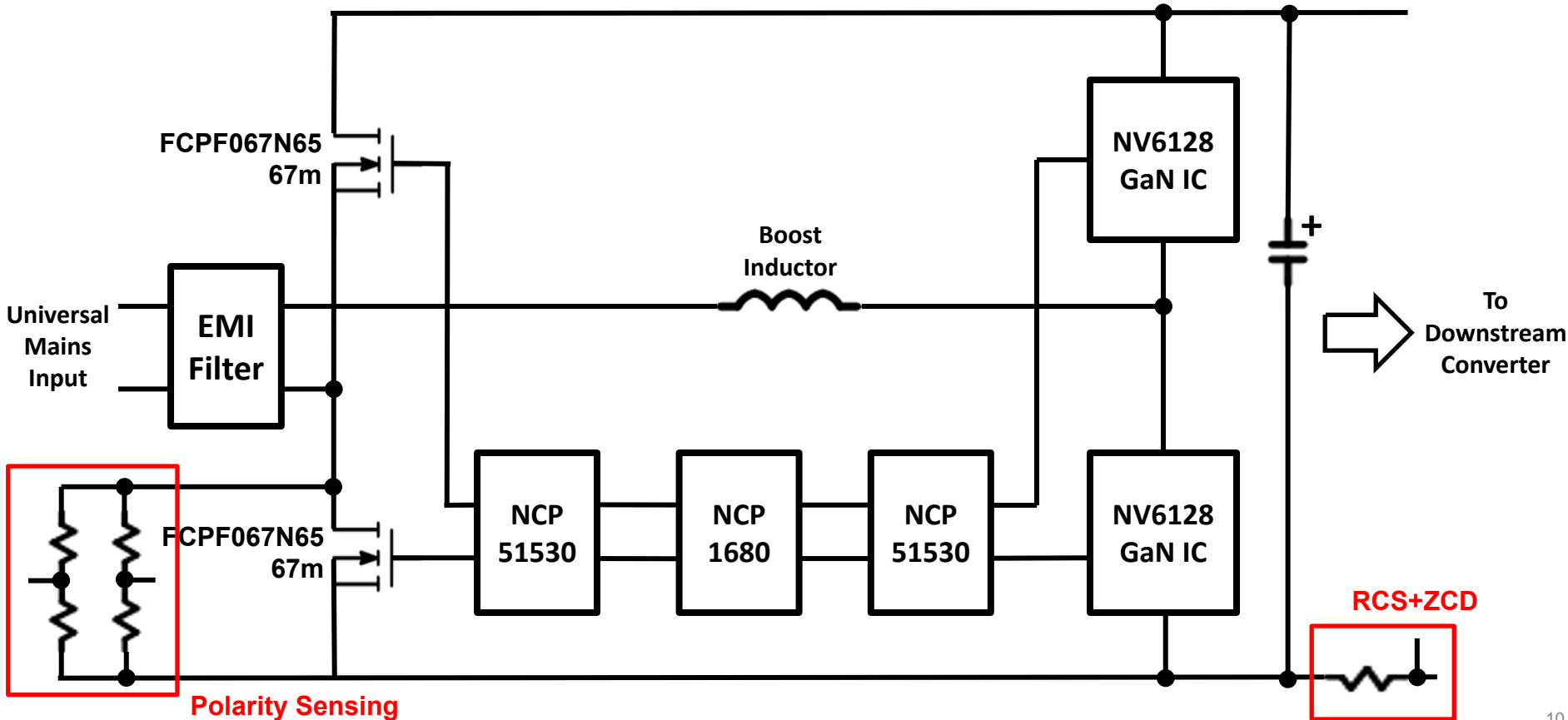
Bridgeless Totem-pole PFC



- 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



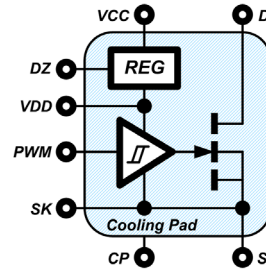
NV6128 70mΩ GaN Power IC

NV6128

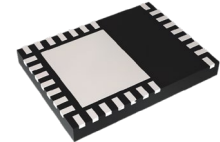
Features

- **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

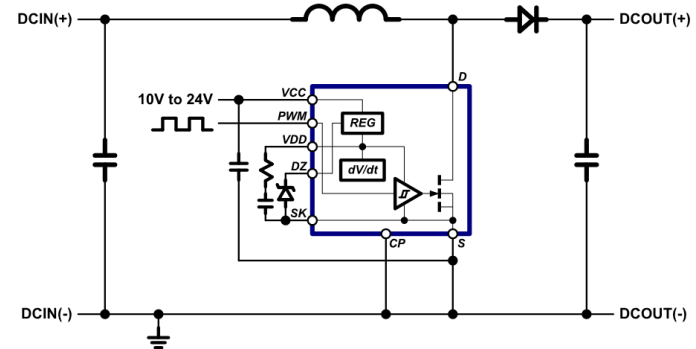


Package



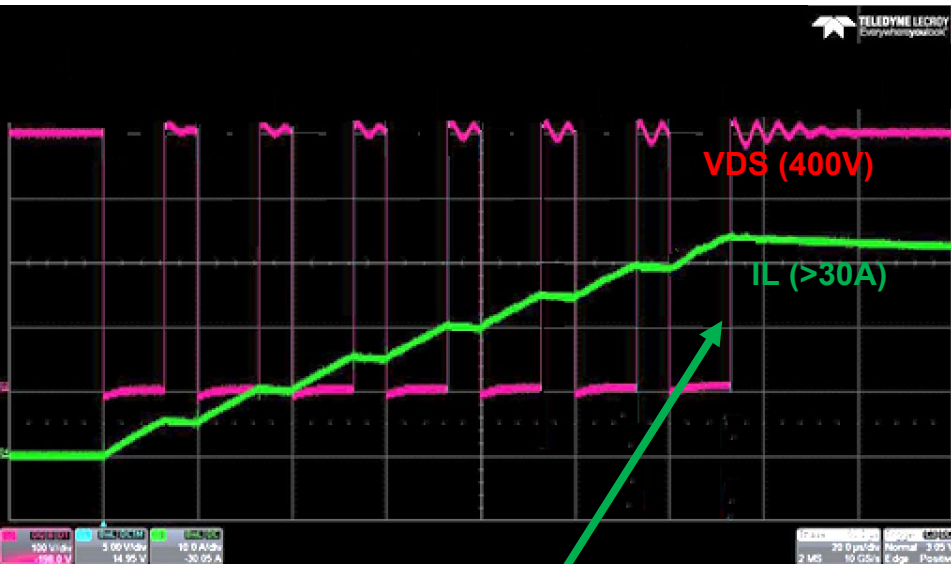
QFN 6x8 mm

Typical Application Schematic (Boost PFC)



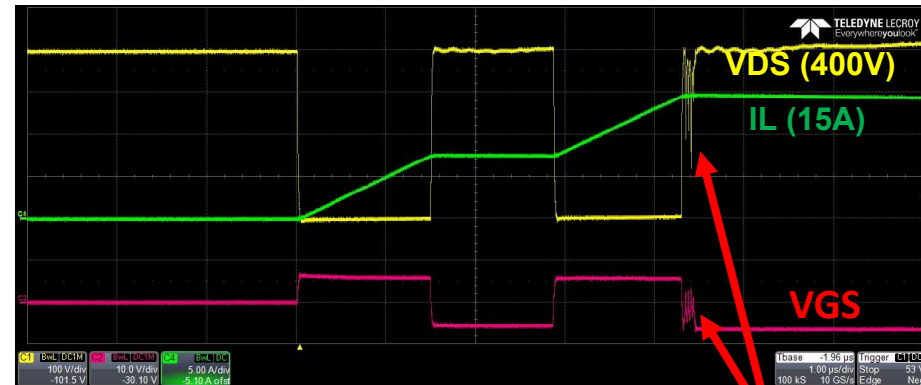
Clean Switching, No Ringing or Glitching @ 30A

NV6128 GaN Power IC



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

Discrete GaN

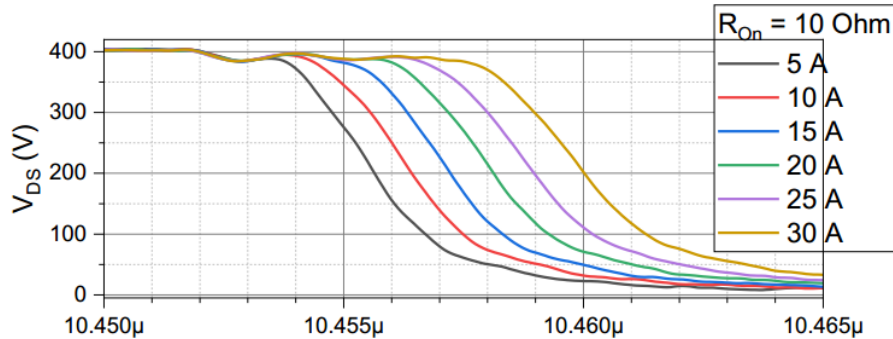


- Exposed Gate
- Faulty Switching
- Ringing & Glitching!

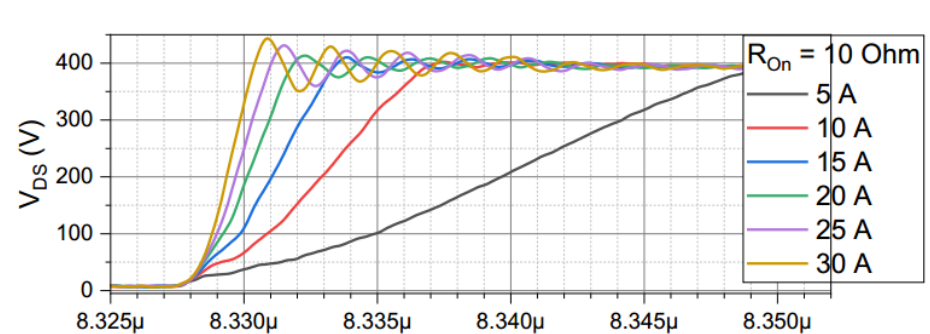
Double Pulsed Test
(Sync Boost Circuit)

NV6128: “Best GaN We Have Tested!”

Turn-on (hard switching)



Turn-off (hard slewing)

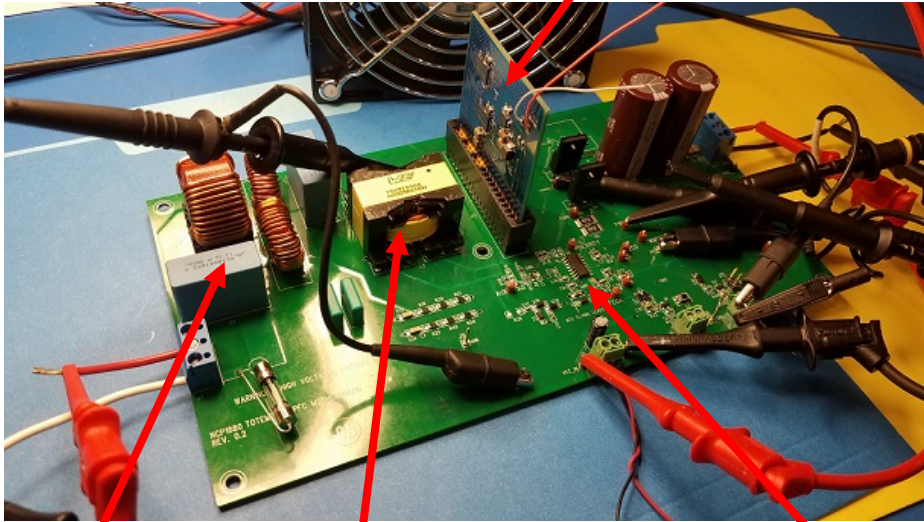


NV6128 Testing Feedback:

- Fast and very clean switching
- Easy to control slew rates
- Integrated gate allows for high switching speeds ($dV/dt > 200 \text{ V/ns}$, $di/dt > 10 \text{ A/ns}$)
- 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

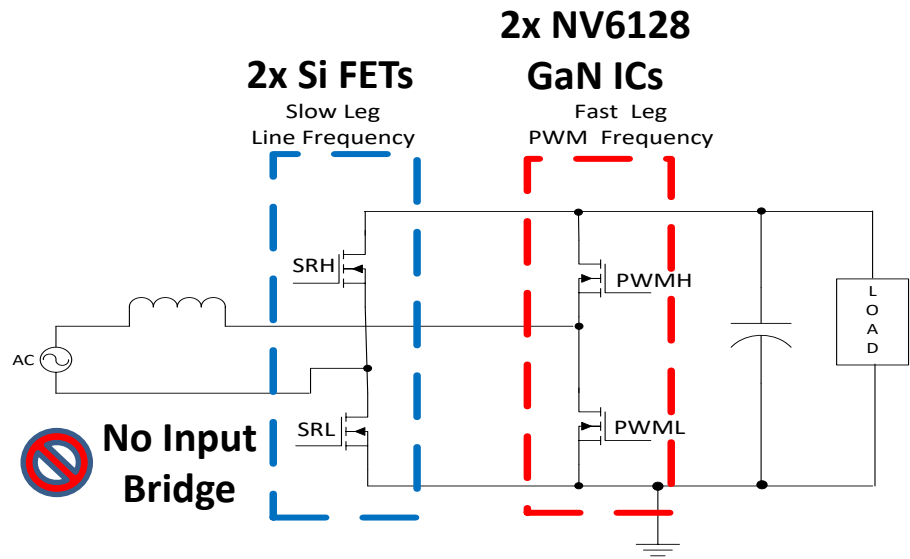
2x NV6128 GaN IC
Daughter Card



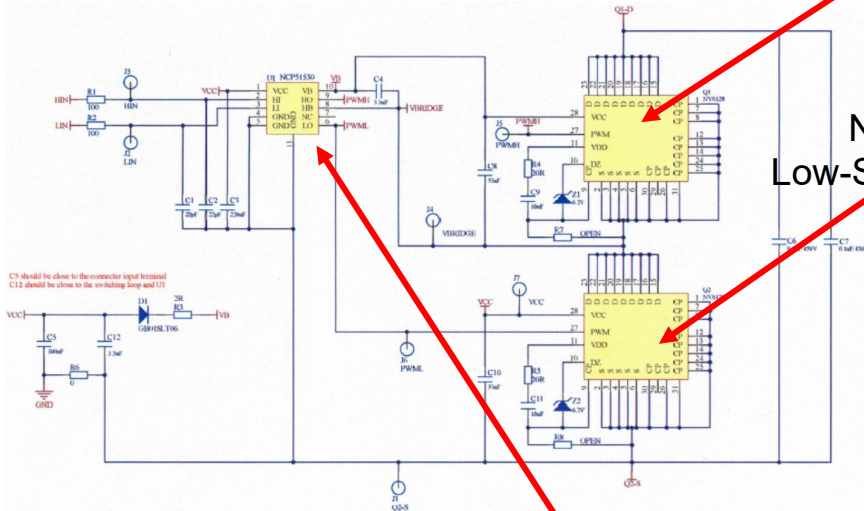
EMI
Filter

PFC
Inductor

NCP1680
Totem-pole Controller



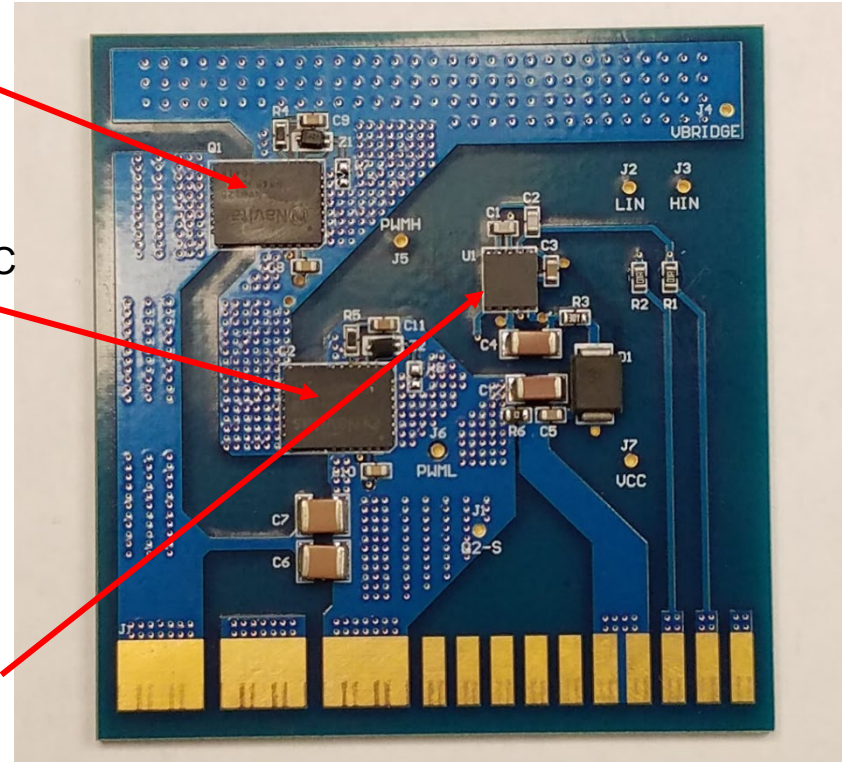
NV6128 Evaluation Daughtercard



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

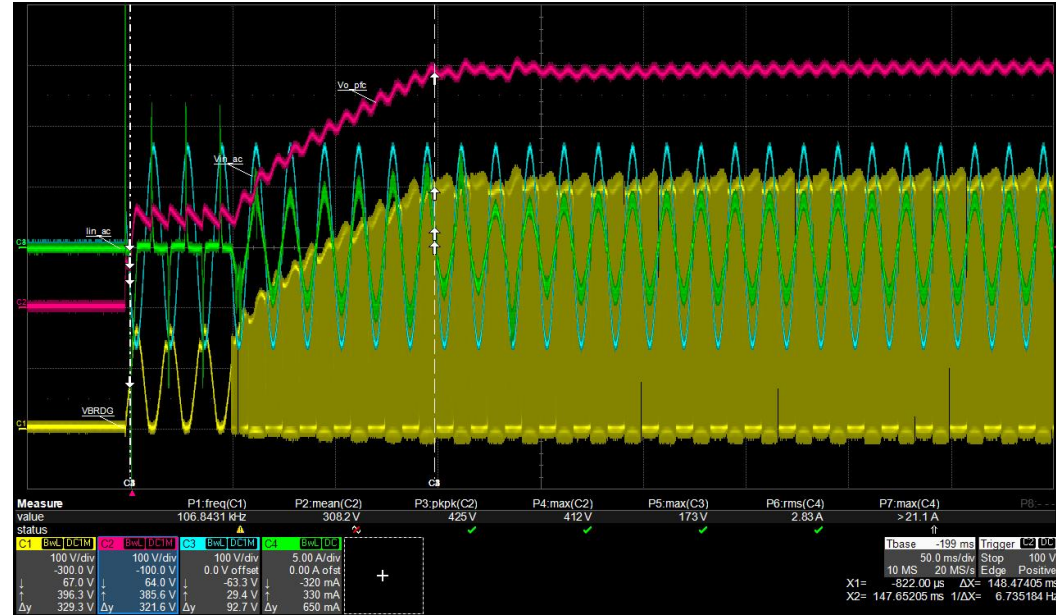
VBRDG: Fast HB switch node
Vo_pfc: PFC output
Vin_ac: AC line voltage
lin_ac: AC line current

Ch1: VSWFAST
100V/div

Ch2: Vo_pfc
100V/div

Ch3: Vin_ac
100V/div

Ch4: lin_ac
5A/div



Clean Steady-State Operation

$V_{in}=115V_{ac}$
 $V_o=397V$, $I_o=0.75A$

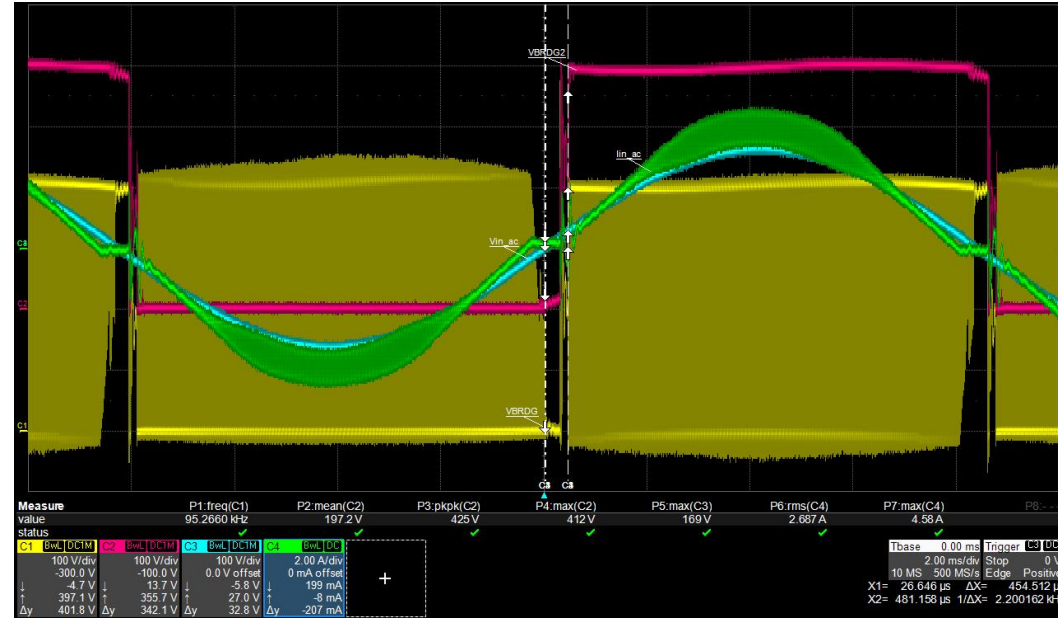
Ch1: VSWFAST
100V/div

Ch2: VSW SLOW
100V/div

Ch3: V_{in_ac}
100V/div

Ch4: I_{in_ac}
2A/div

VBRDG: Fast HB switch node
VBRDG2: Slow HB switch node
 V_{in_ac} : AC line voltage
 I_{in_ac} : AC line current



ZVS & ZCS Switching (Zoomed)

Ch1: VSWFAST
100V/div

Ch2: VSWSLOW
100V/div

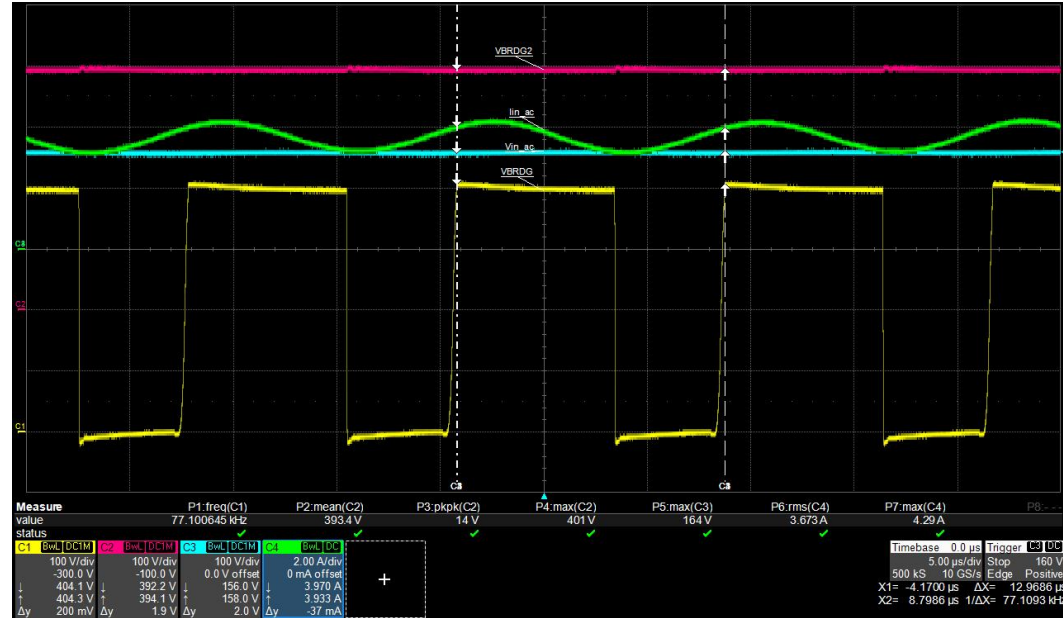
Ch3: Vin_ac
100V/div

Ch4: lin_ac
2A/div

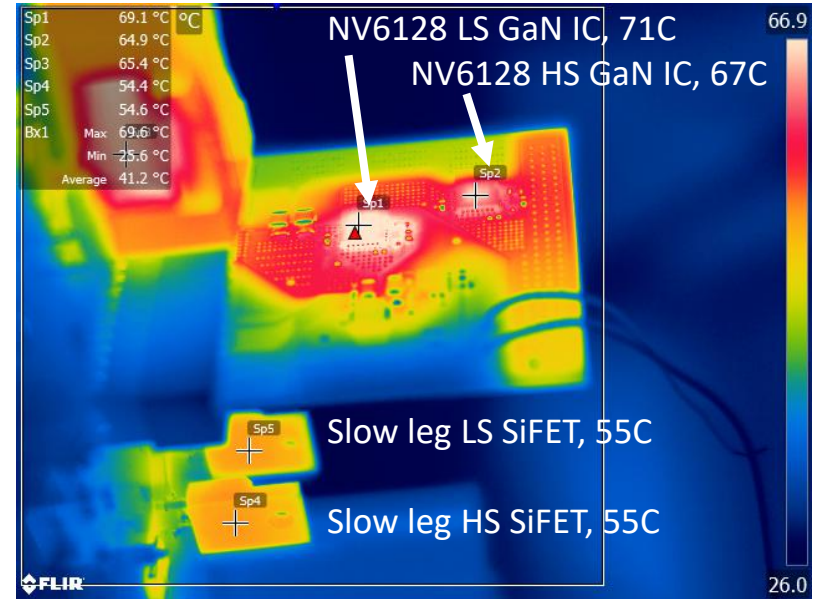
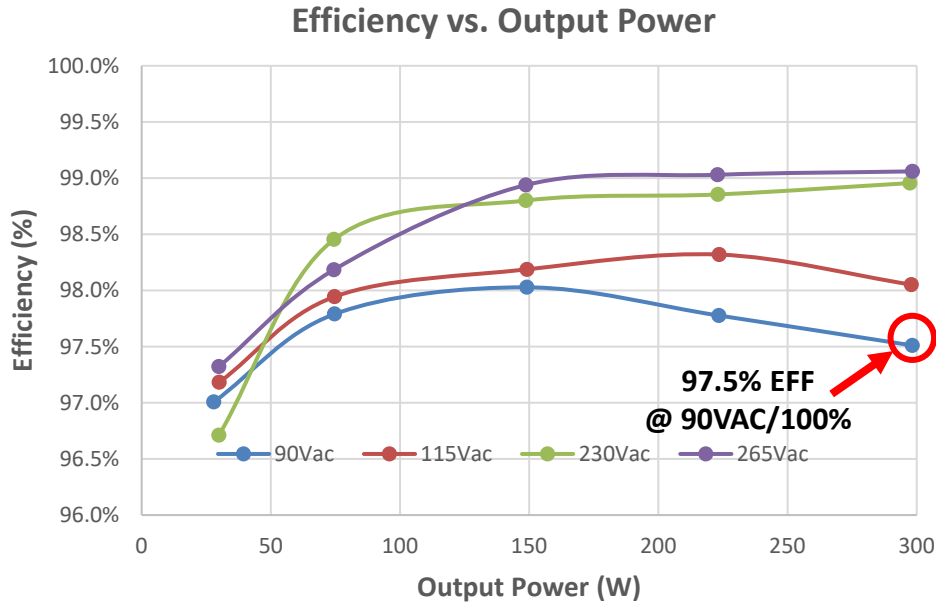
Vin=115Vac
Vo=397V, Io=0.75A

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**



Let's go **GaNFast™**

