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EUROPE

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

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- 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



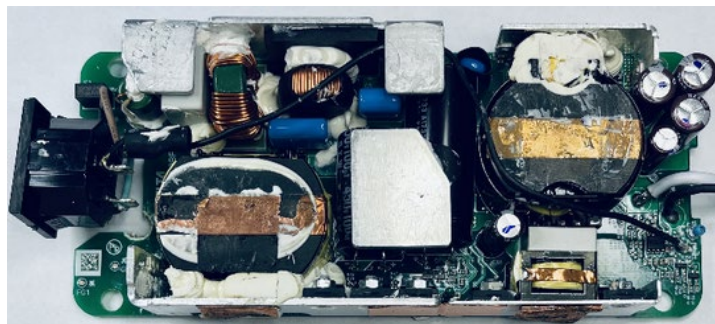
Gaming Laptops



eMobility

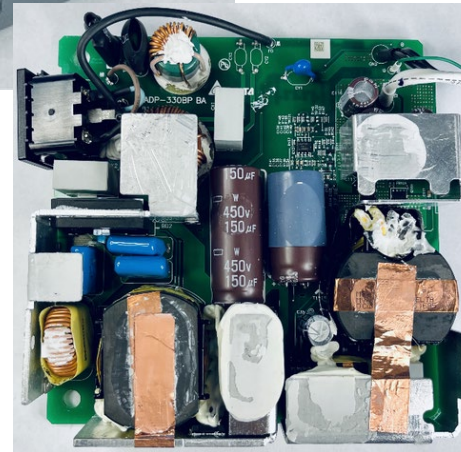
Si-Based Designs = Large Size, Low Power Density & Low Efficiency

Output Specs: 20V/14A
Output Power: 280W
Size (cased): 542cc
Power Density: 0.52 W/cc



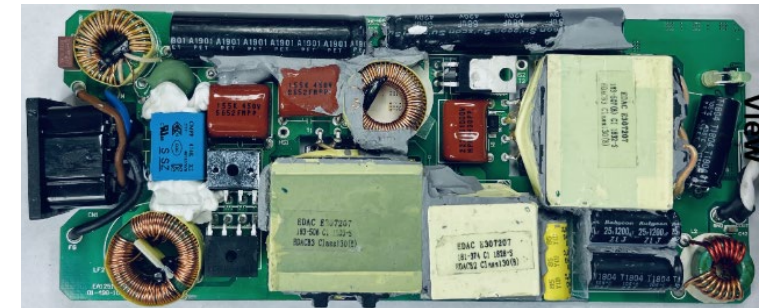
Efficiency @ 90VAC/Full-load = 93.3%

Output Specs: 19.5V/16.6A
Output Power: 330W
Size (cased): 844cc
Power Density: 0.39 W/cc



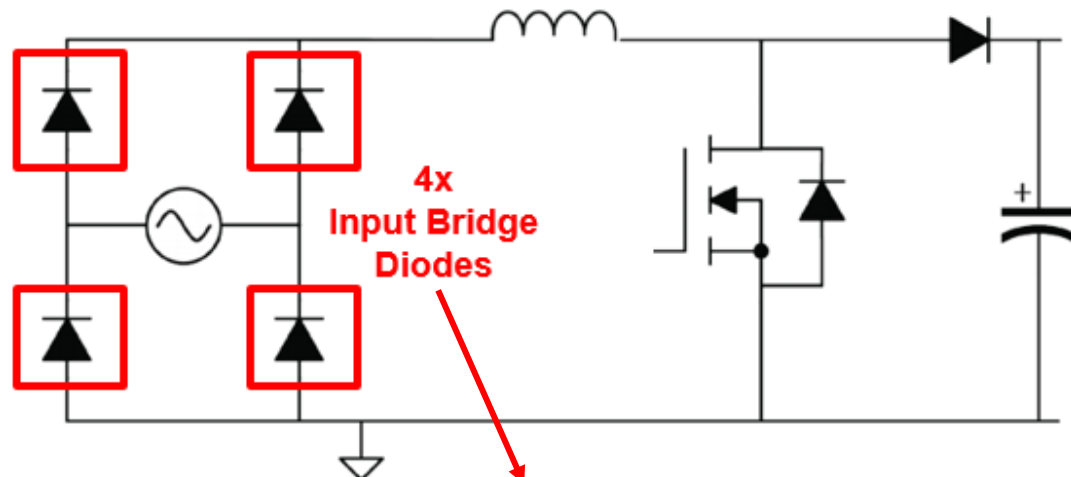
Efficiency @ 90VAC/Full-load = 93.4%

Output Specs: 19V/13.2A
Output Power: 250W
Dimensions (cased): 332cc
Power Density: 0.75 W/cc

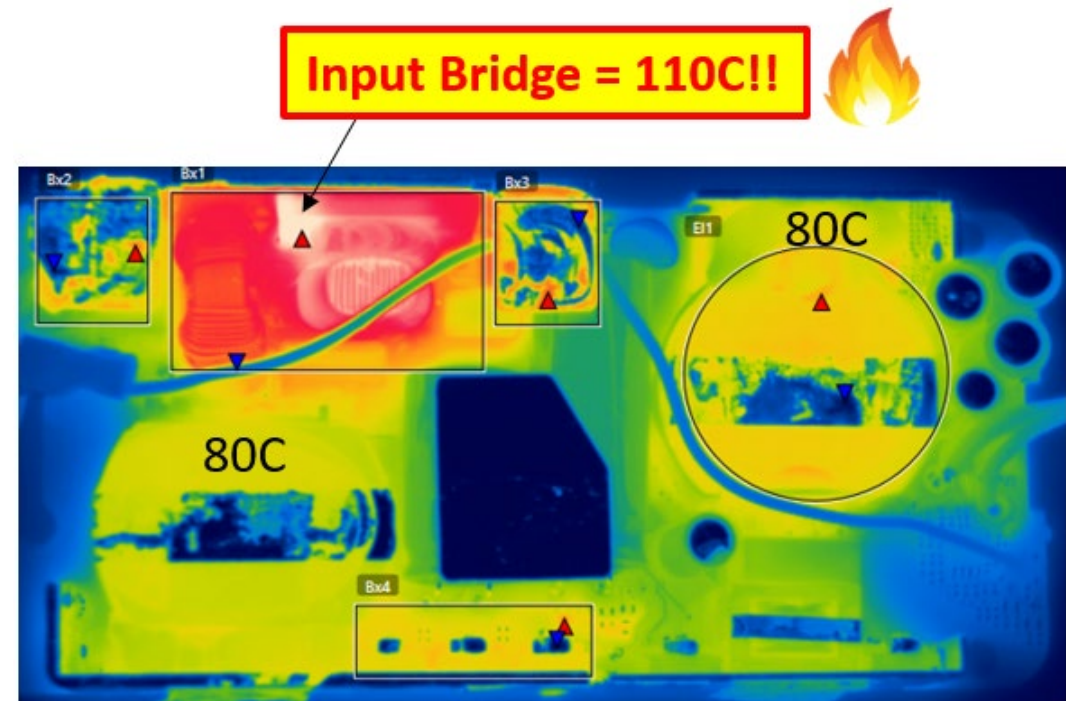


Efficiency @ 90VAC/Full-load = 90.5%

Rectifier On Fire!

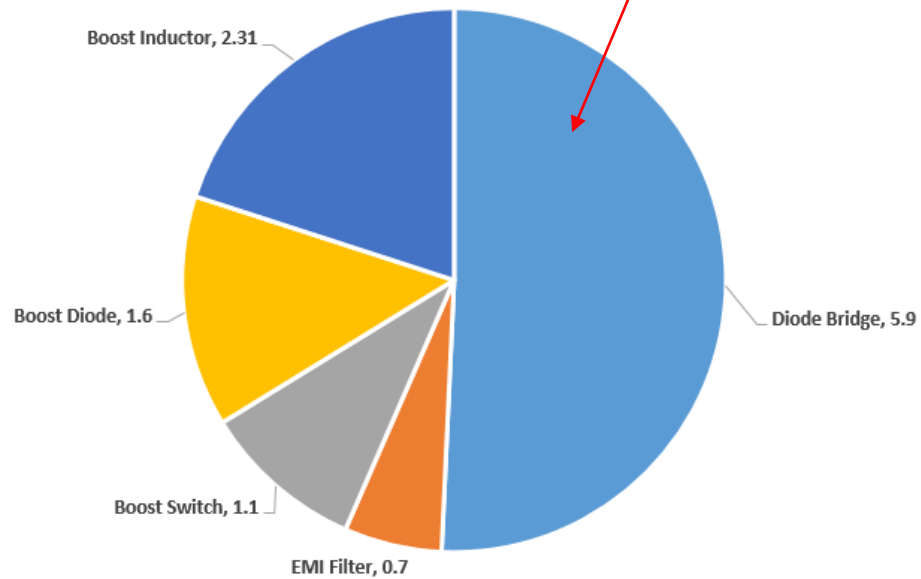


$P_{LOSS_BRIDGE} = 2 \times V_f \times I_{RMS}$
 $P_{LOSS_BRIDGE_300W_90VAC} = 6W$
2x Diodes Always Conducting!

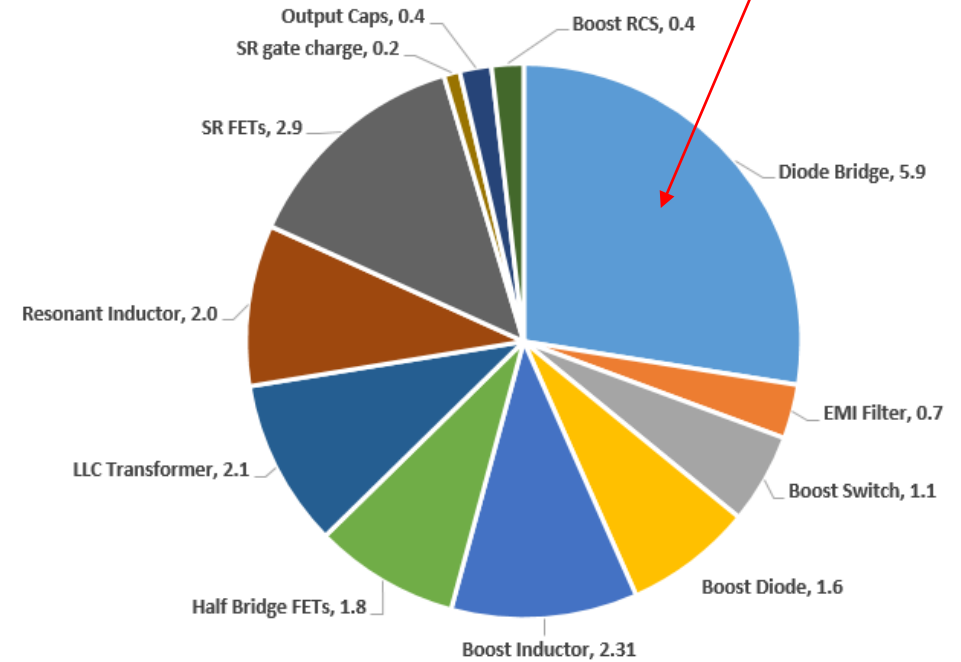


Eliminate the Bridge!

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

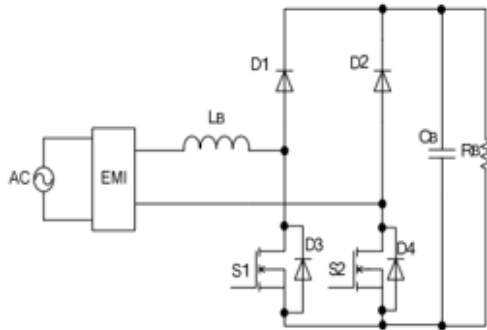


**PLOSS_BRIDGE > 25% of PLOSS_TOTAL
(@ 90VAC/300W)**



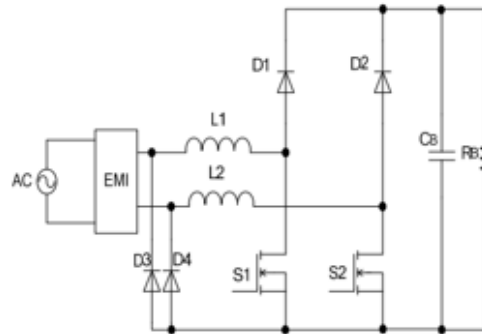
Bridgeless PFC Solutions

Basic Bridgeless PFC



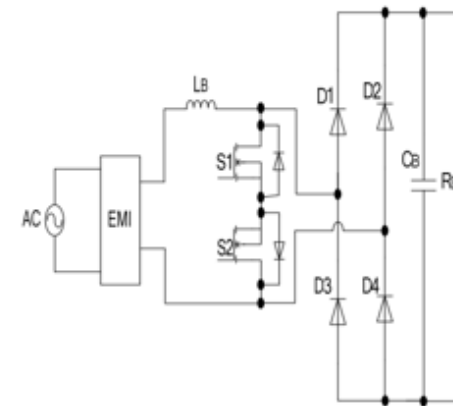
- High CM noise
- Complex voltage sensing
- Complex current sensing

Semi-Bridgeless PFC



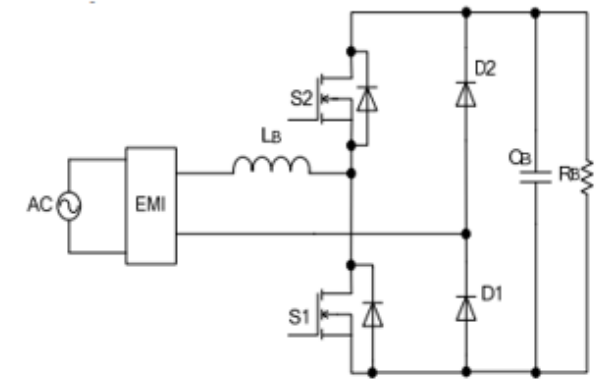
- Low CM noise
- Simple voltage sensing
- Complex current sensing
- Requires 2x inductors

Bidirectional Bridgeless PFC



- Low CM noise
- Complex voltage sensing
- Complex current sensing
- Requires isolated gate drive
- Requires lower R_DS(on) FETs

Bridgeless Totem-pole PFC

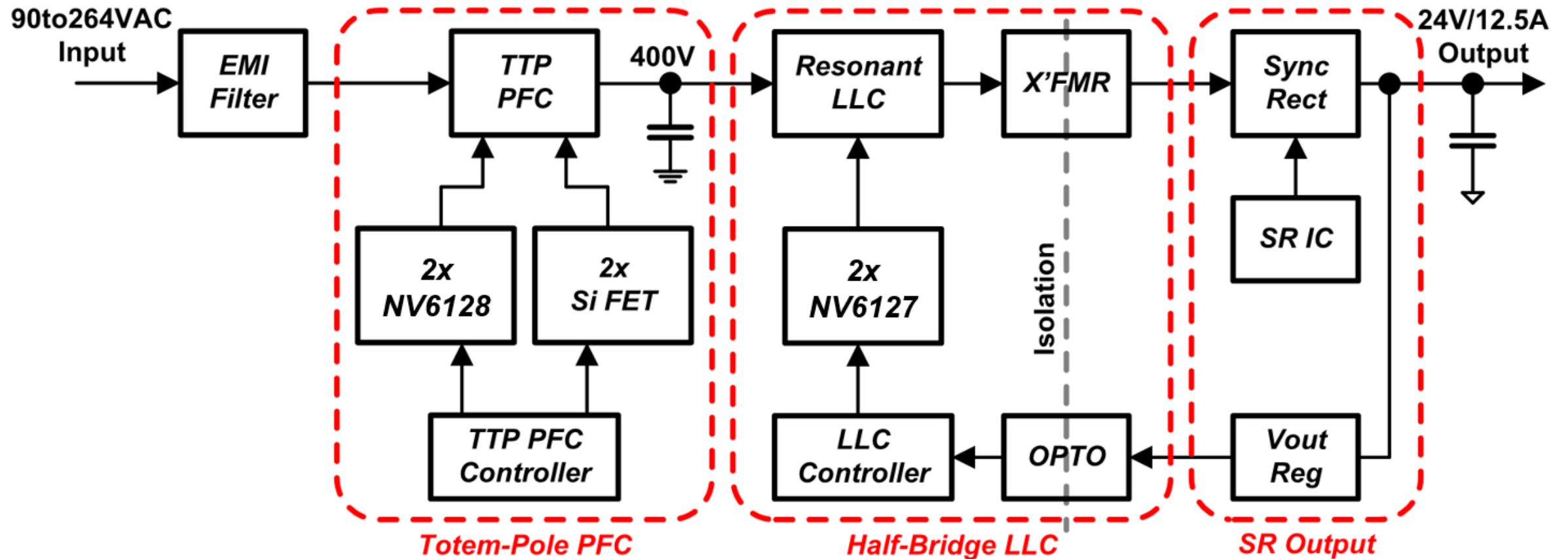


- Low CM noise
- Difficult voltage sensing
- Difficult current sensing

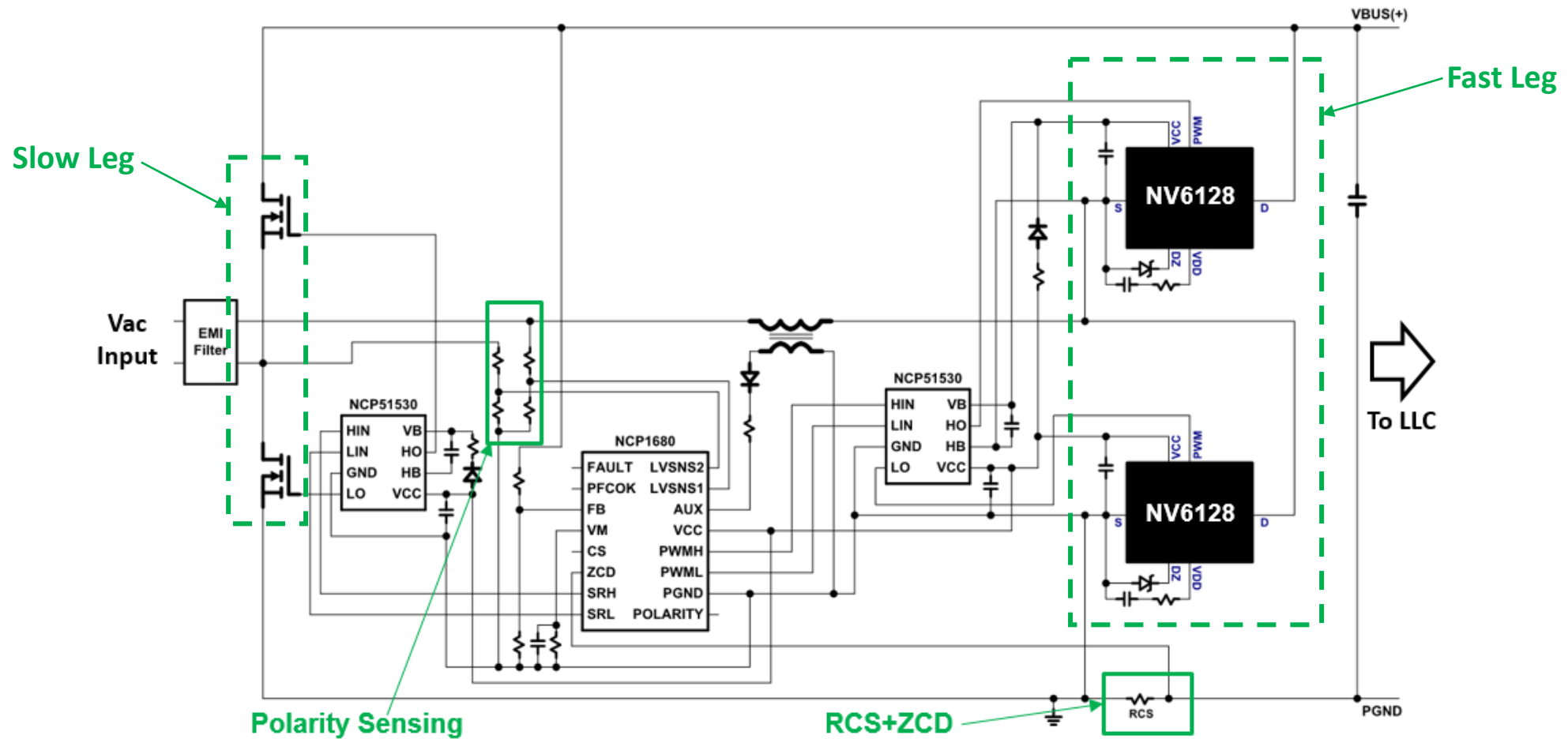


- ✓ Low CM noise
- ✓ Easy voltage sensing
- ✓ Easy current sensing

300W TTP+LLC Block Diagram



TTP PFC Stage = 2x NV6128 (Fast Leg)



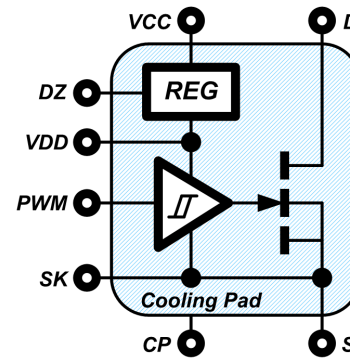
NV6128 70mΩ GaNFast Power IC

NV6128

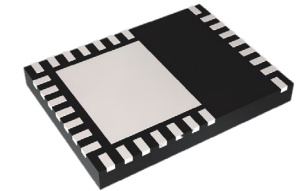
Features

- **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

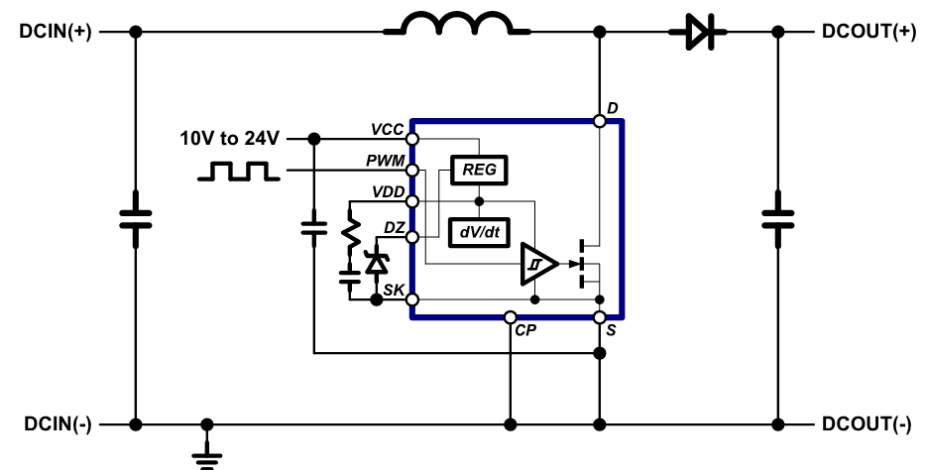


Package

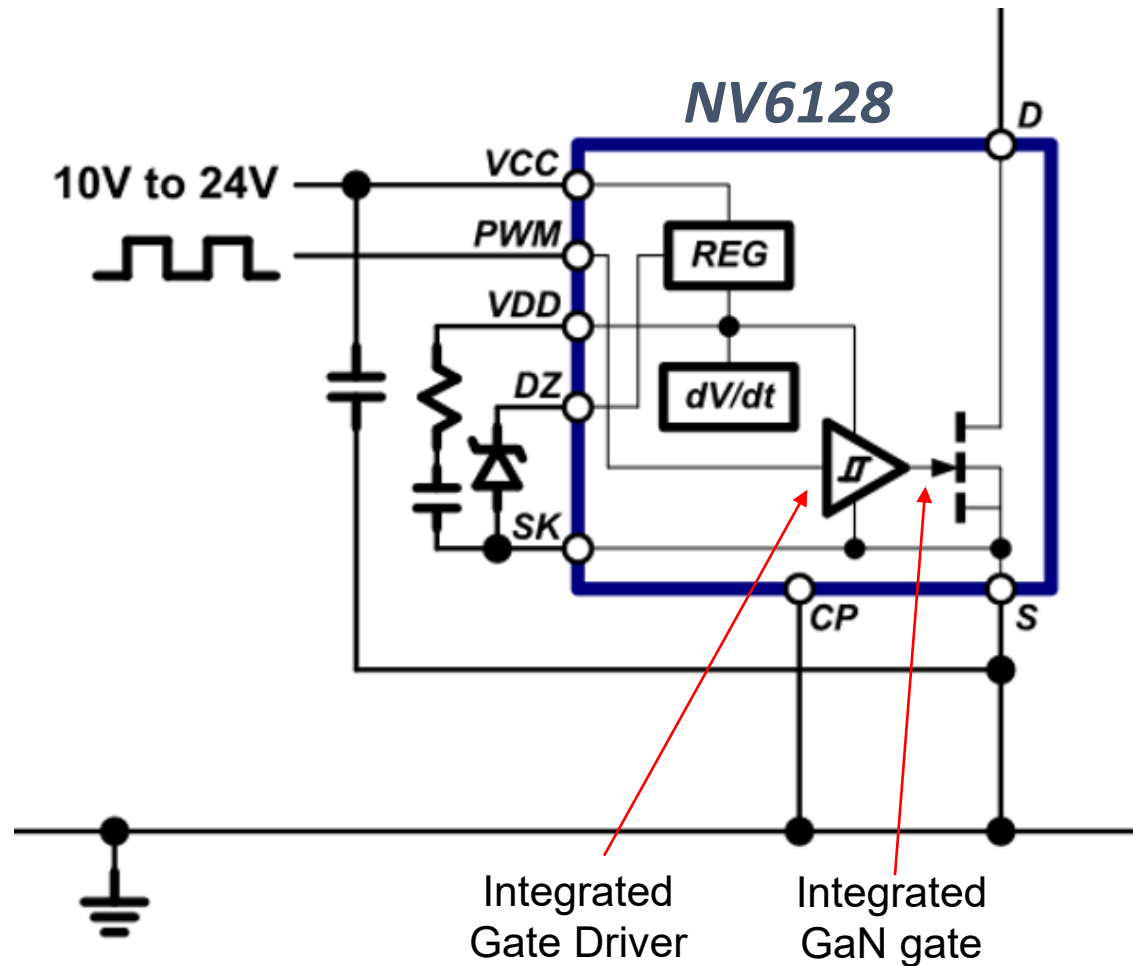


PQFN 6x8 mm

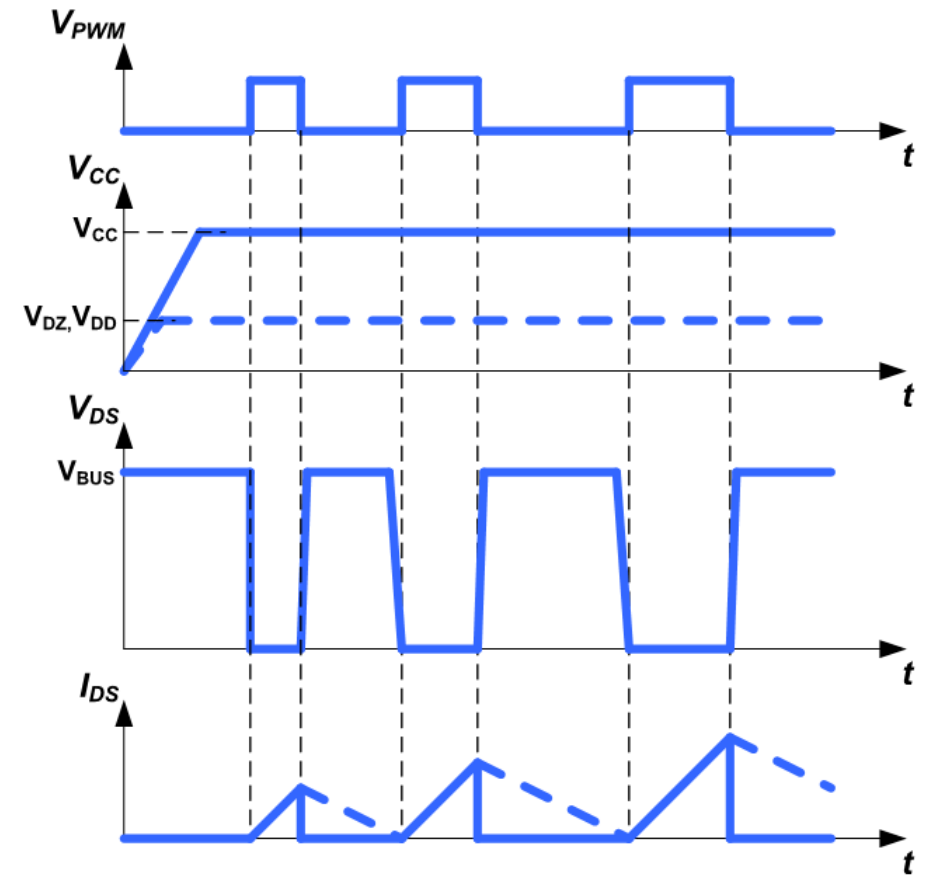
Typical Application Schematic (Boost PFC)



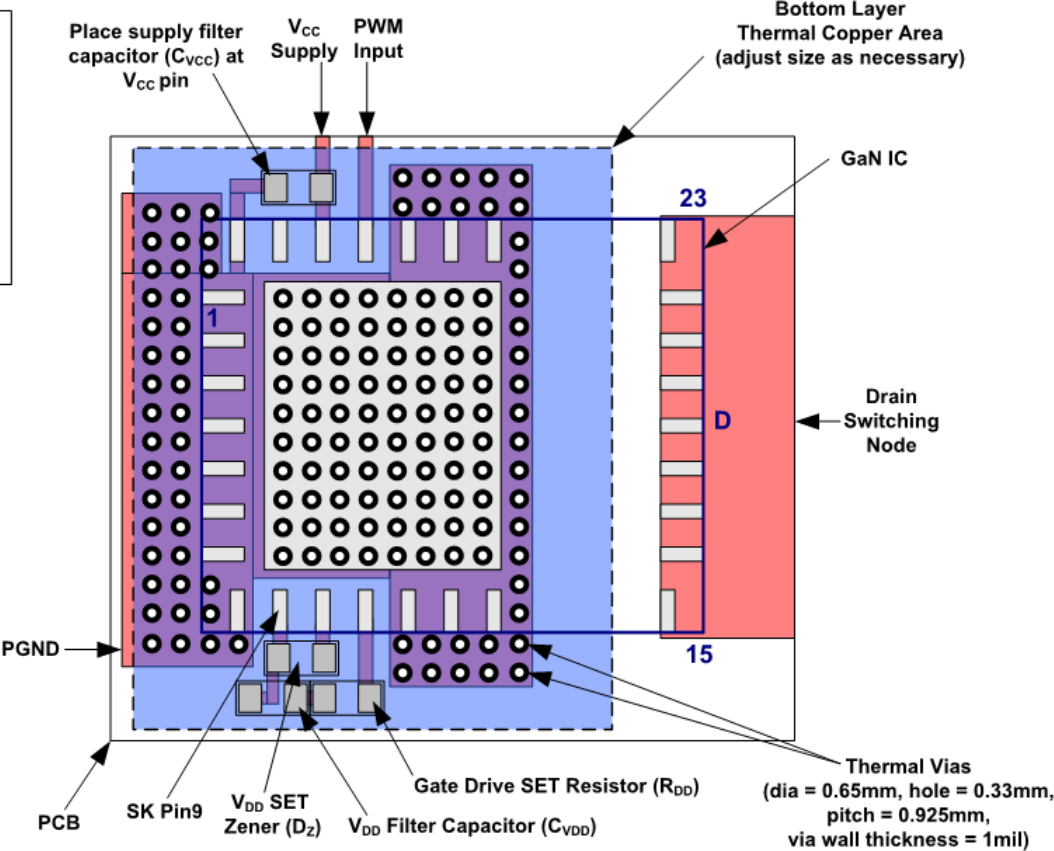
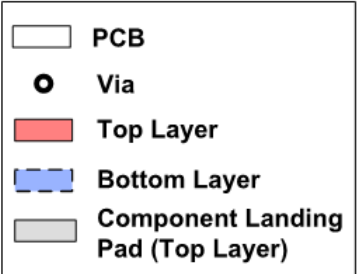
Integration Drives Performance



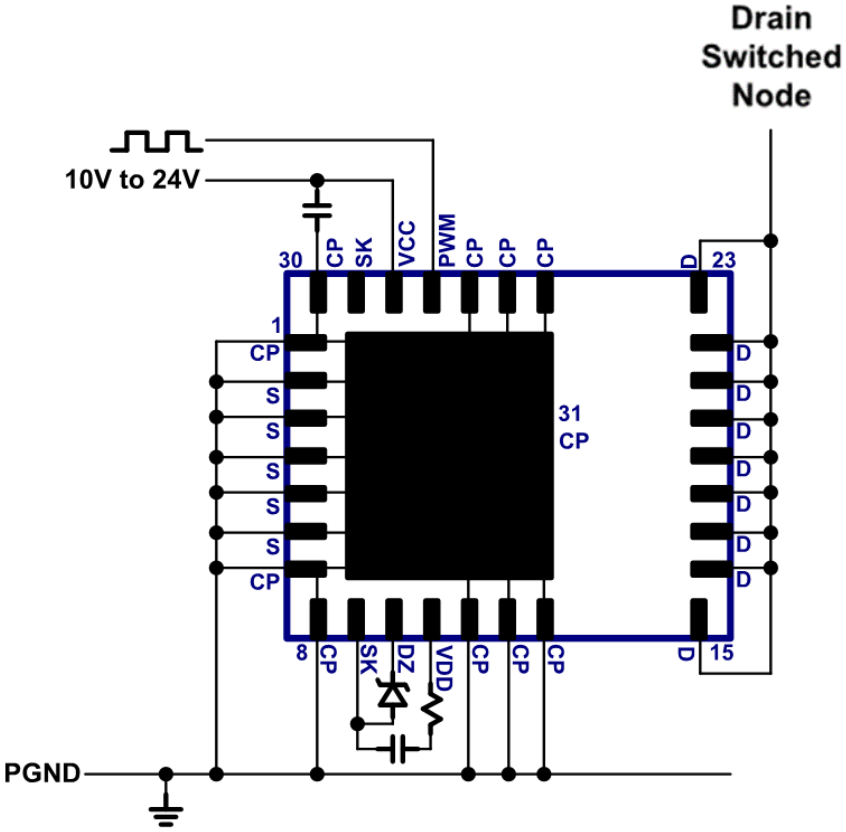
Clean Switching (Boost Circuit)



Simple Layout, Large Cooling Area



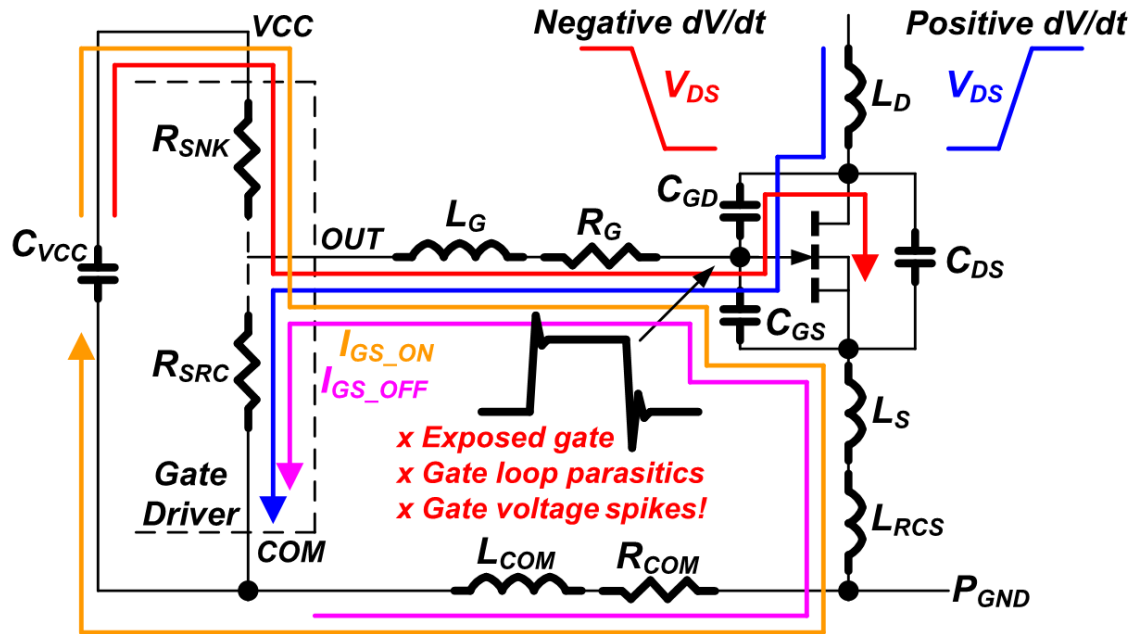
(Top View)



GaNFast Power IC = Integrated gate & driver, No gate loop parasitics, No gate voltage spikes!

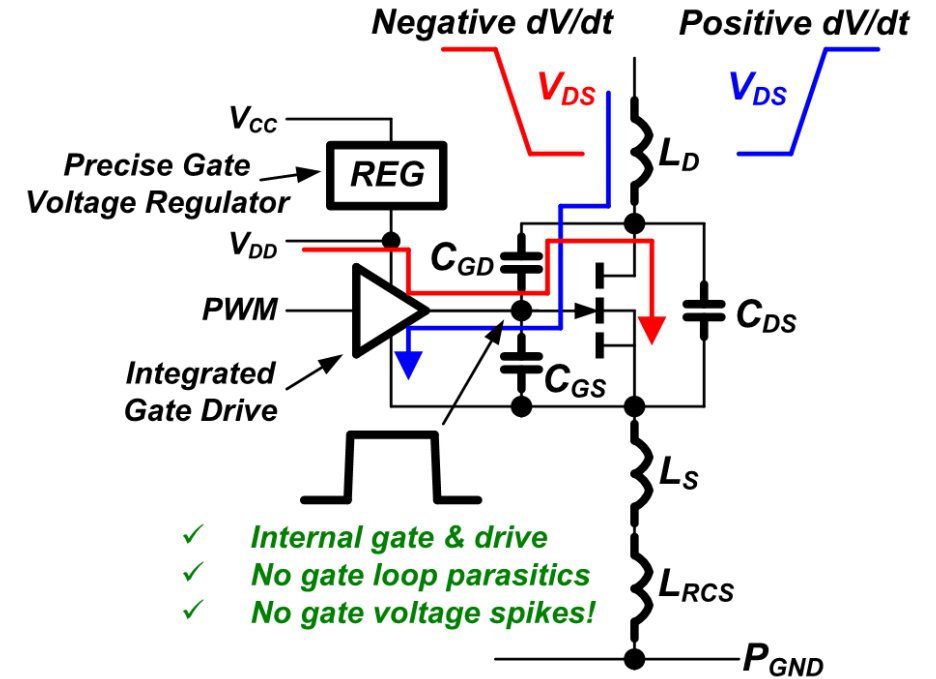


Discrete GaN FET (exposed gate)



- × 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

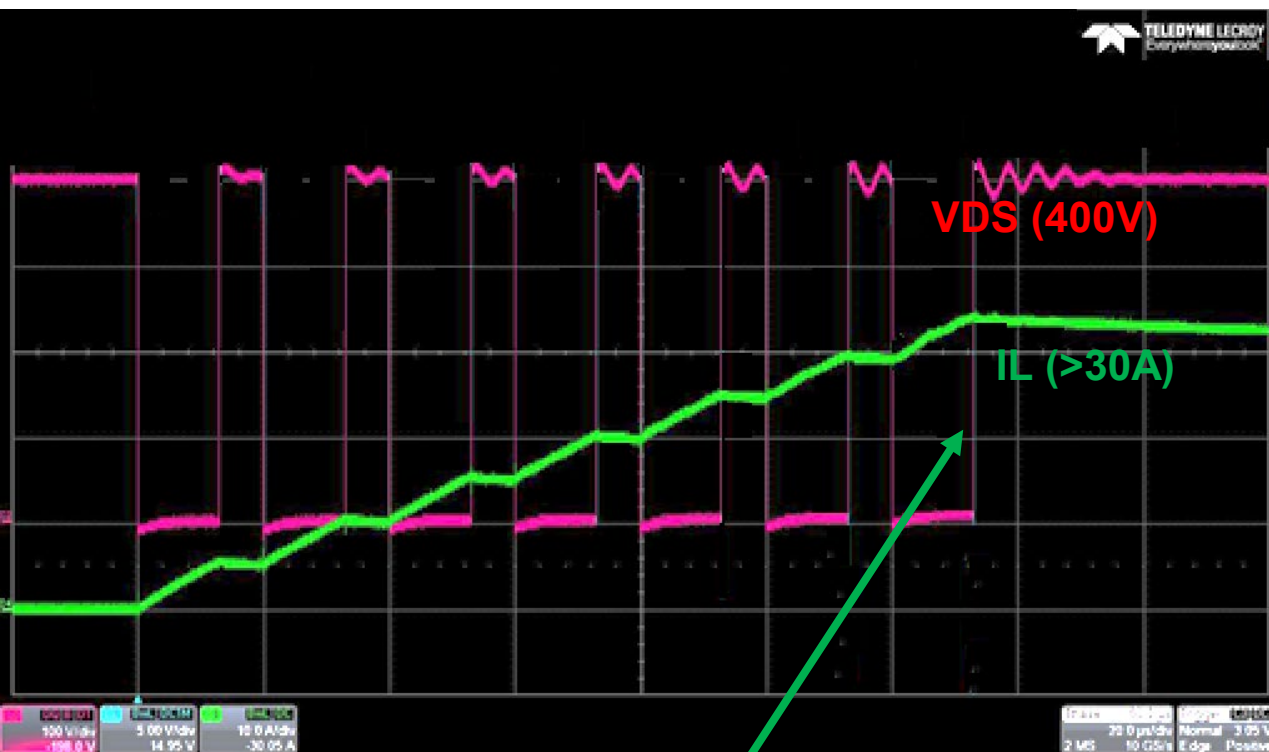
GaNFast Power IC (integrated gate)



- ✓ Internal gate & drive
- ✓ No gate loop parasitics
- ✓ No gate voltage spikes!
- ✓ 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

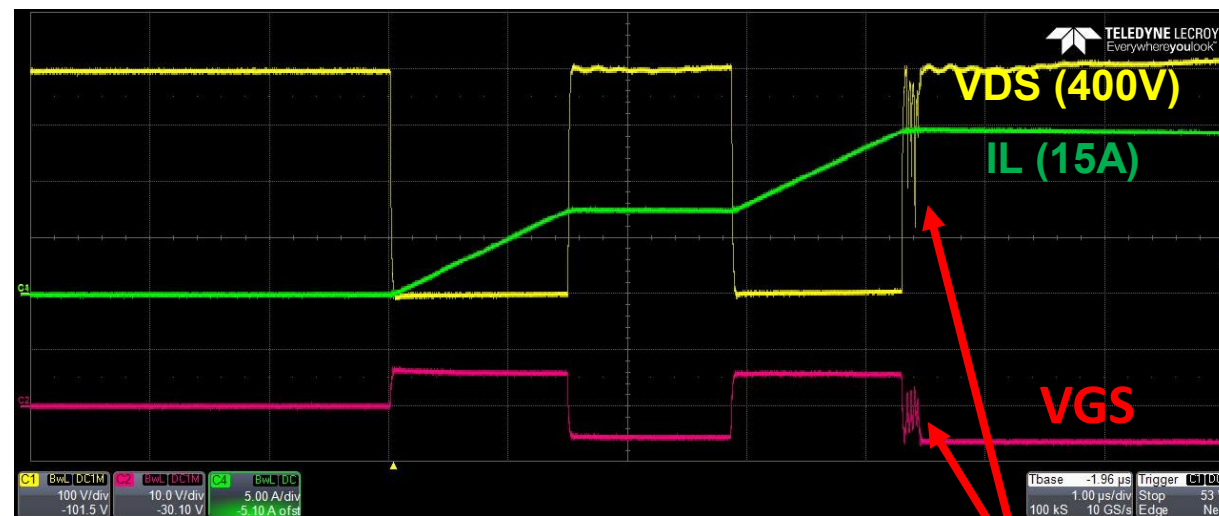
Clean Switching, No Ringing, No Glitching @ 30A

NV6128 GaN Power IC



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

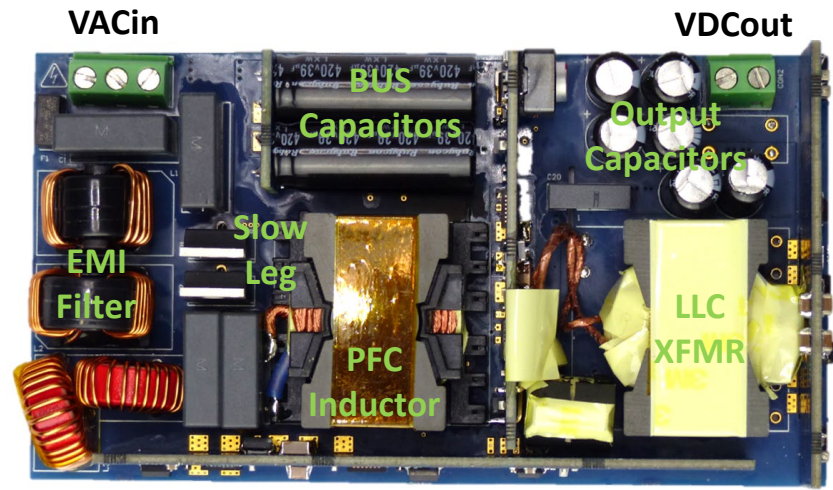
Discrete GaN



- Exposed Gate
- Faulty Switching
- Ringing & Glitching!

Double Pulsed Test
(Sync Boost Circuit)

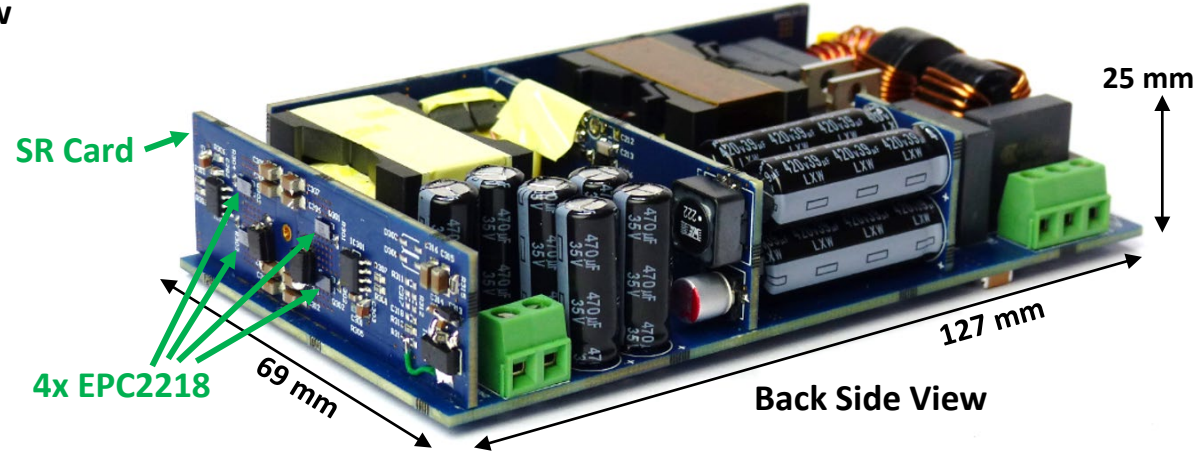
300W/220cc Prototype (PCBA)



Top View



Front Side View

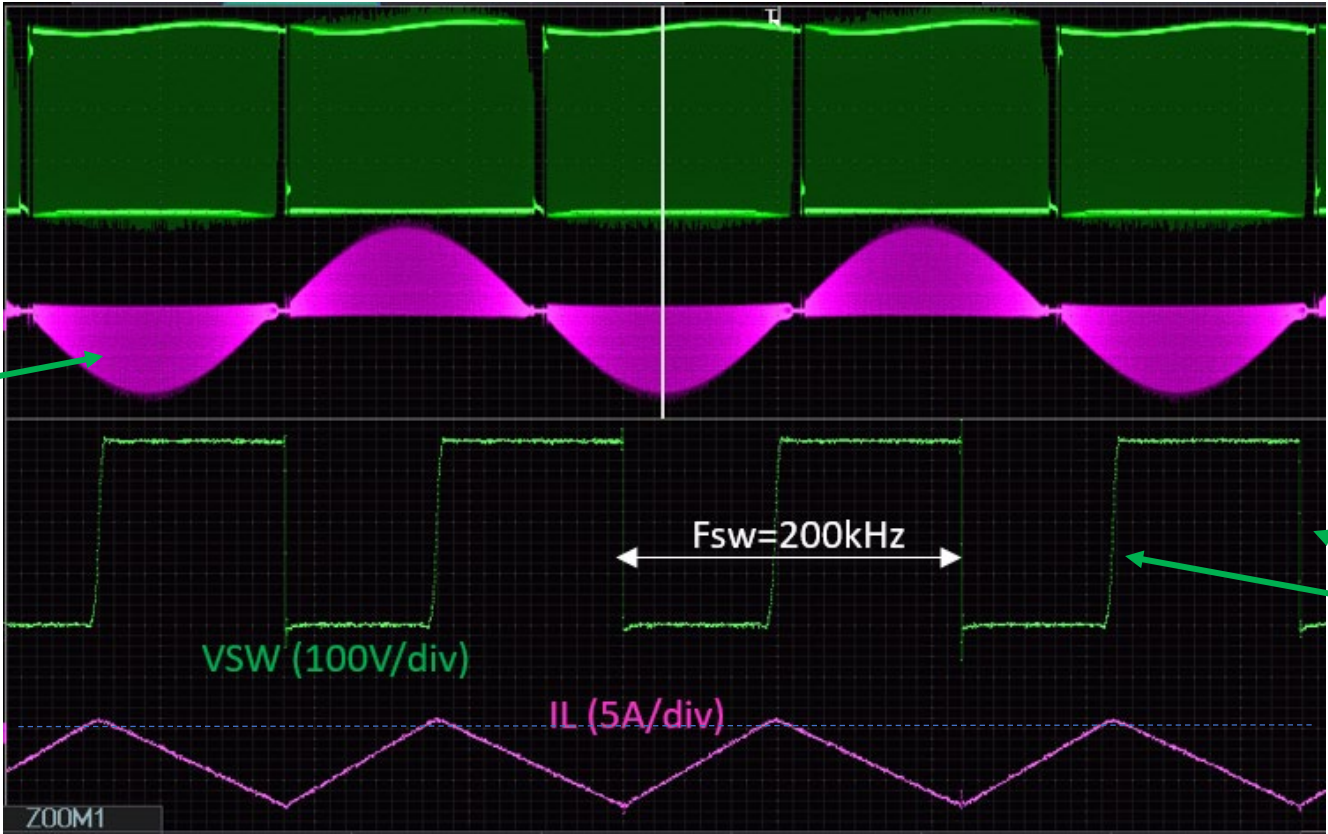


Back Side View

69mm x 127mm x 25mm = 220cc (PCBA)
 75mm x 132mm x 30mm = 300cc (Cased est.)

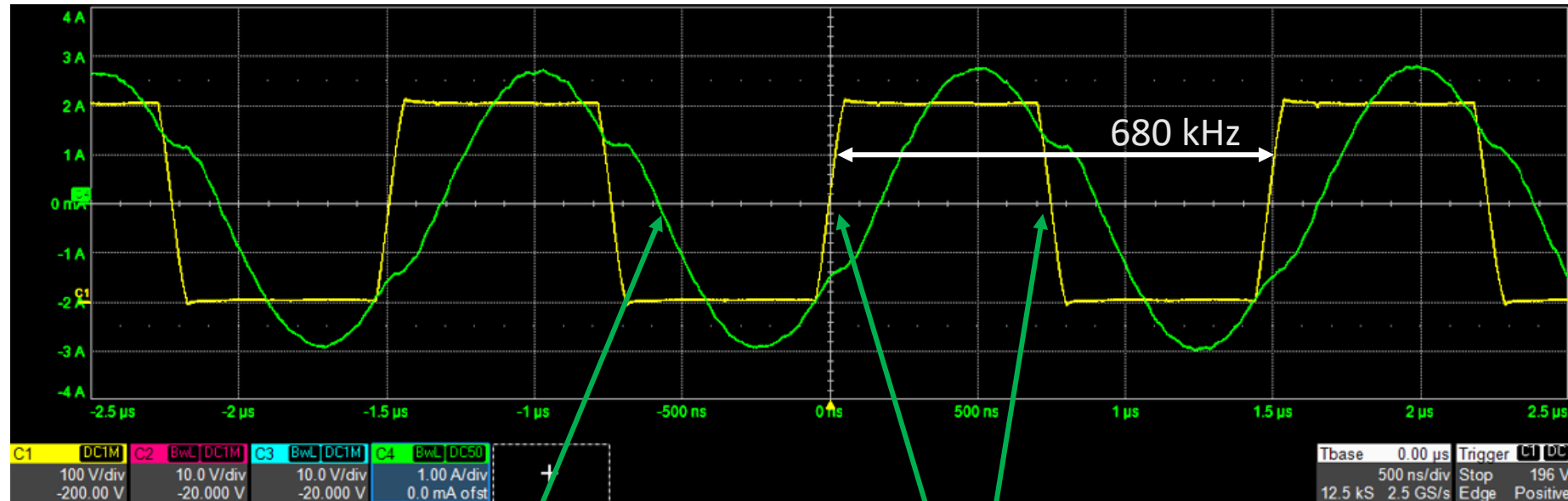
TTP PFC ZVS Waveforms

Sinusoidal Inductor Current for High Power Factor



ZVS during Ton and Toff

LLC Resonant ZVS Waveforms



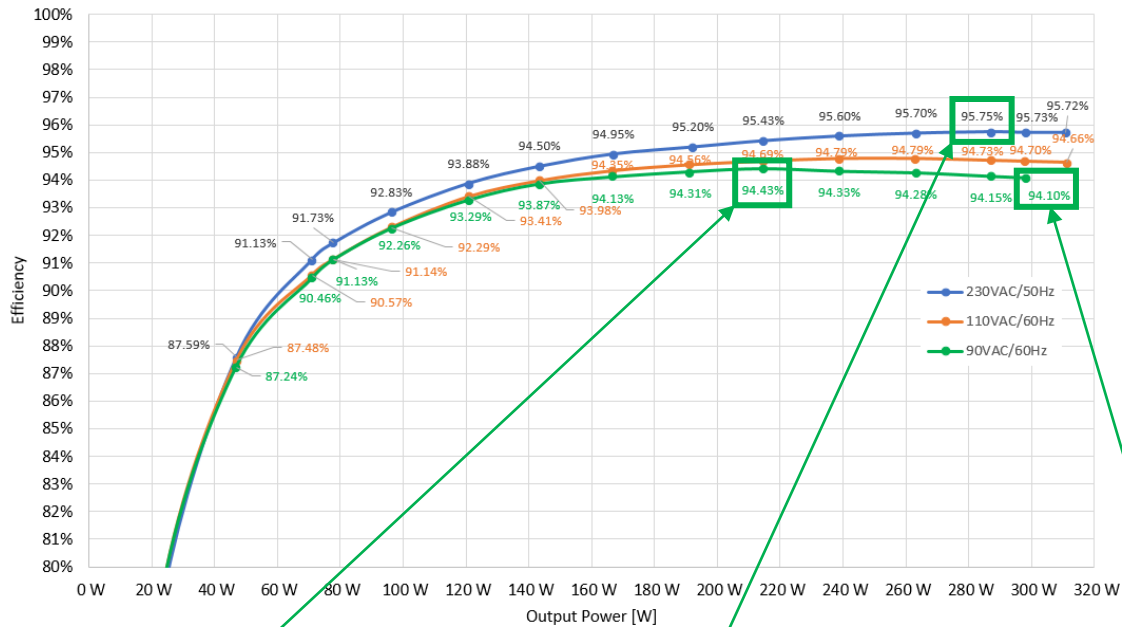
Sinusoidal LLC
Resonant Tank
Current

Smooth & Clean ZVS
Half-Bridge Waveforms!

95.75% Peak Efficiency & Low Thermals

Thermal measurements: 110 VAC / full load (24 V / 12.5 A out)

300W TP-PFC/LLC Power Supply Power Efficiency

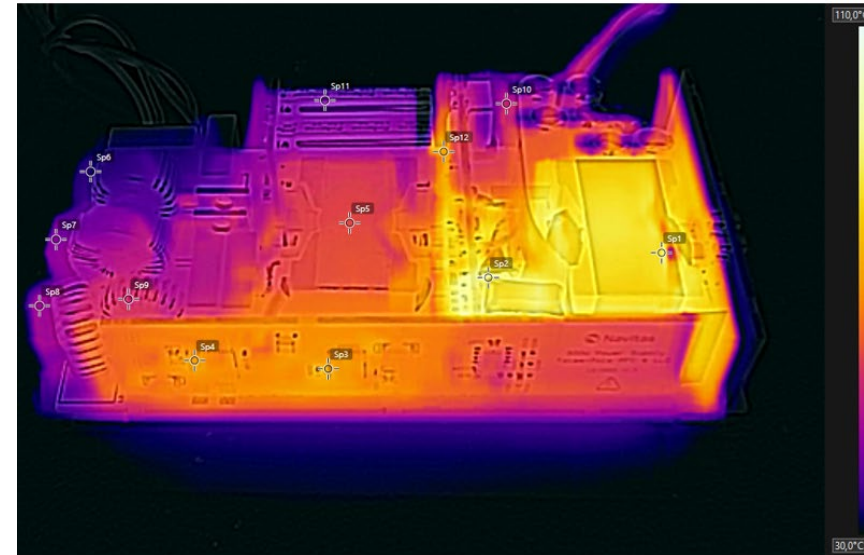


94.4% Peak Efficiency @ 90Vac

95.75% Peak Efficiency @ 230Vac

94.1% Efficiency @ 90Vac/100%

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



Meas. point	Description	Temp
Sp1	LLC Transf.	92.4 °C
Sp2	LLC Lres	94.0 °C
Sp3	PFC GaN HS	77.1 °C
Sp4	PFC GaN LS	75.3 °C
Sp5	PFC L	63.6 °C
Sp6	CM choke 1	35.5 °C
Sp7	CM choke 2	47.3 °C
Sp8	Diff choke 1	50.2 °C
Sp9	Diff choke 2	58.9 °C
Sp10	Output cap	58.5 °C
Sp11	Bus cap	45.6 °C
Sp12	LLC GaN card	76.4 °C

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*

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**Thank you for
your attention!**

I'm pleased to answer your
questions.

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