

DIGITAL WE DAYS

2024



NOVEL TOPOLOGIES AND WBG COMBINE FOR A
COMPACT AND EFFICIENT 1KW POWER SUPPLY

Alessandro Maggioni | onsemi

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Agenda

- AC/DC Power supply landscape
- PFC, Why...?
- Higher Efficiency: Bridgeless vs Bridge
- Onsemi NCP1681 Bridgeless Totem Pole MM/CCM PFC Controller
- 1kW Universal Input 48V Output Power Supply board Data
- Q&A

AC/DC Power supply landscape

AC-DC power supply are extensively used in several verticals market segments



Industrial



Automotive



Medical



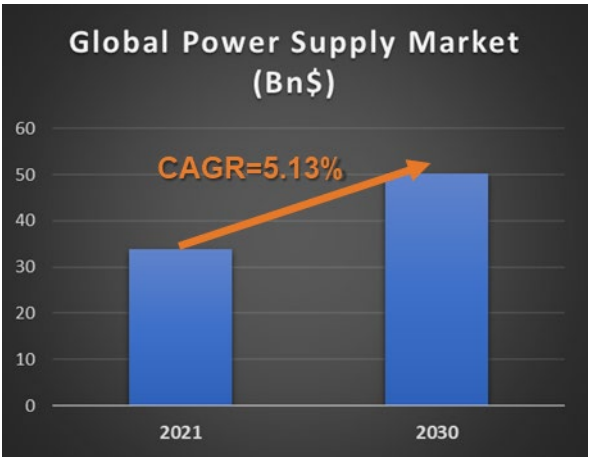
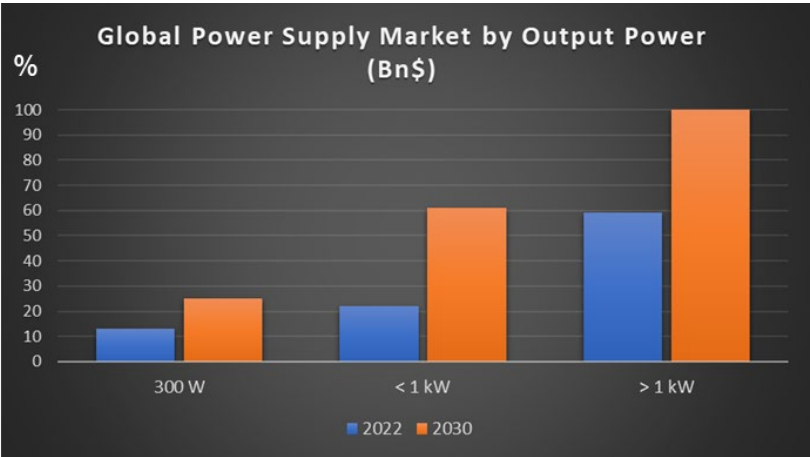
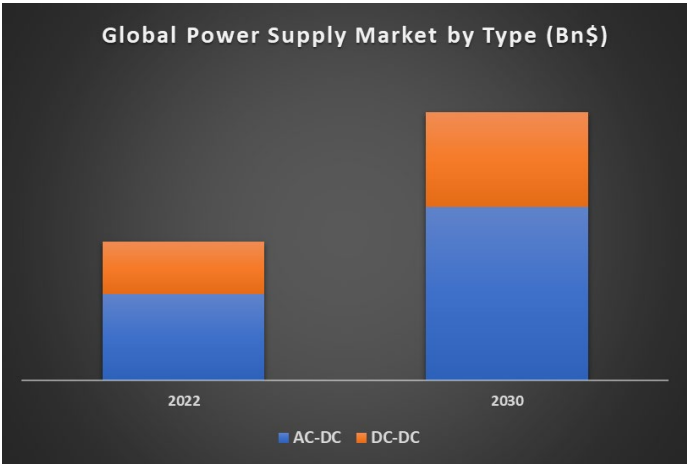
Smart cities



Computing & Clouds

AC-DC power supply are majority of the market

Increasing Demand with constant growth

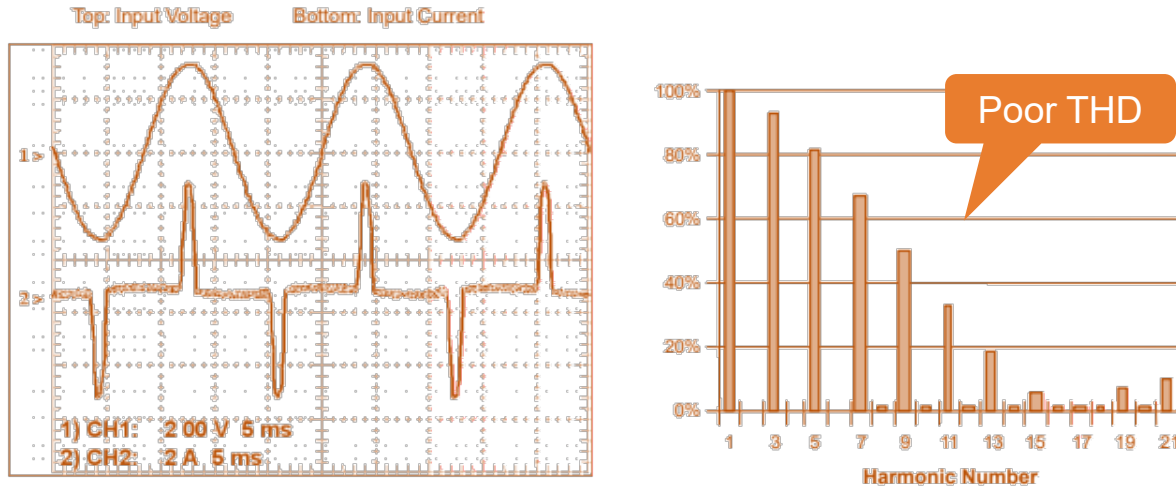


PFC: Why?

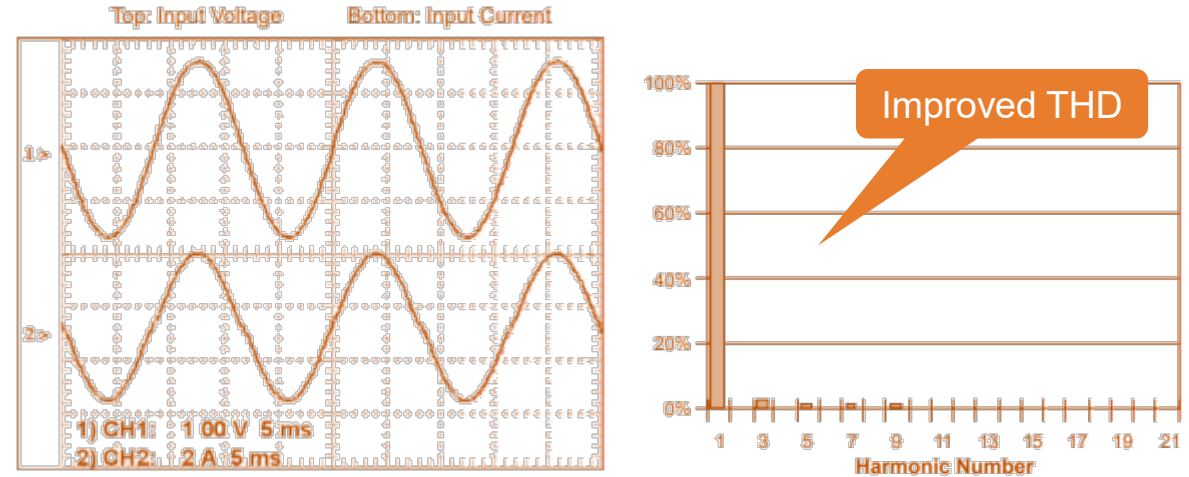
Problem...

When the power factor (load dependent) is not equal to 1, the current waveform does not follow the voltage waveform. This results not only in power losses but may also cause harmonics that travel down the neutral line and disrupt other devices connected to the line. The closer the power factor is to 1, the closer the current harmonics will be to zero since all the power is contained in the fundamental frequency.

SMPS without PFC:



SMPS with PFC:



you need PFC > 75W

Source: PFC Handbook (HBD853/D)

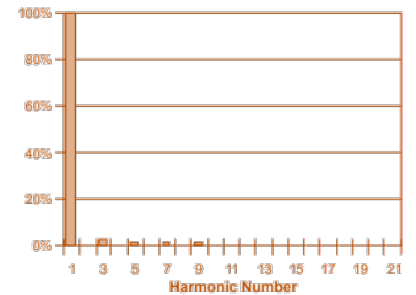
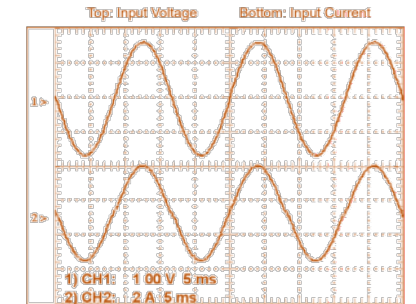
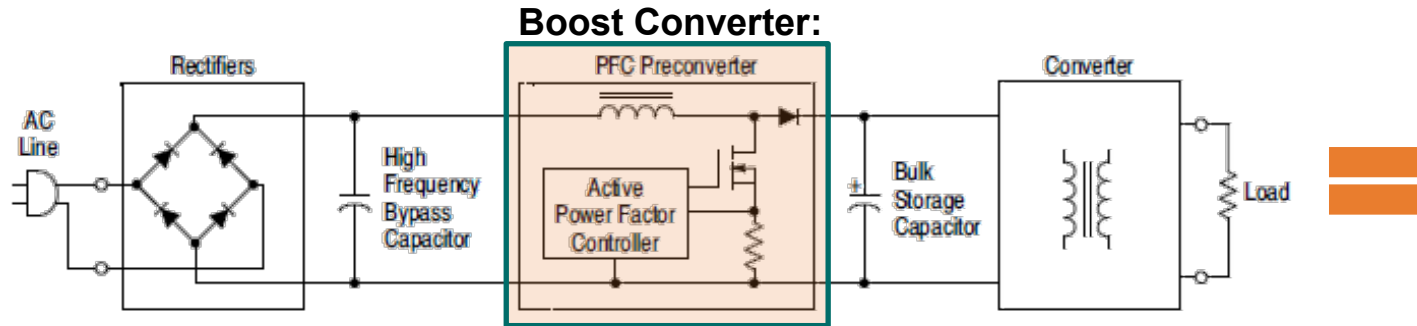
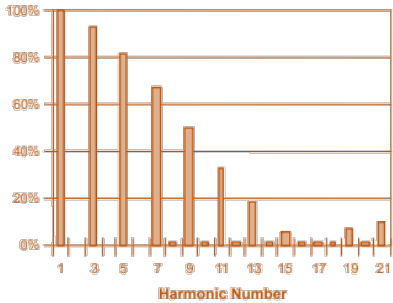
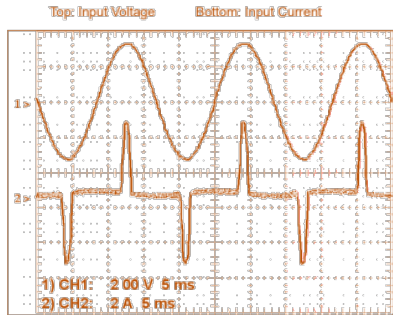
PFC Solution

Solution:

Shape the input current to match the input voltage waveform.

Implementation:

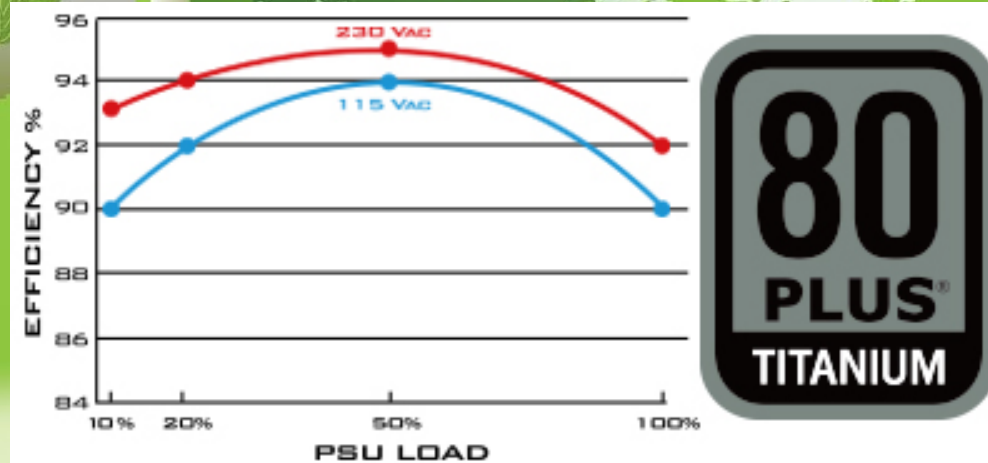
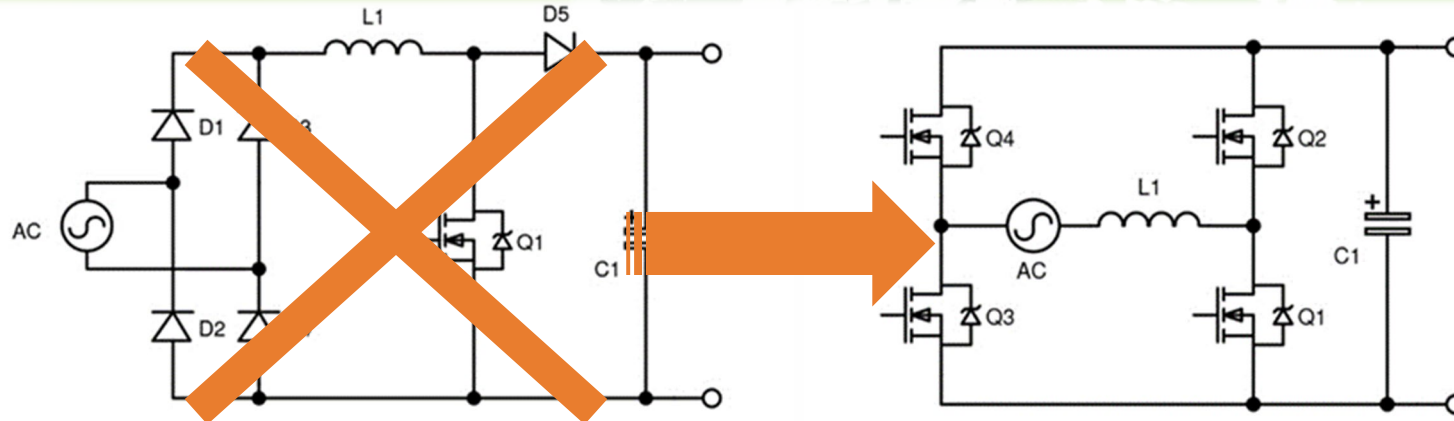
Insert a switched mode boost converter stage between rectifier and bulk storage cap



Source: PFC Handbook (HBD853/D)

High Demand for Energy-efficient Solutions

Typical PFC circuits: Conventional boost to bridgeless Totem Pole



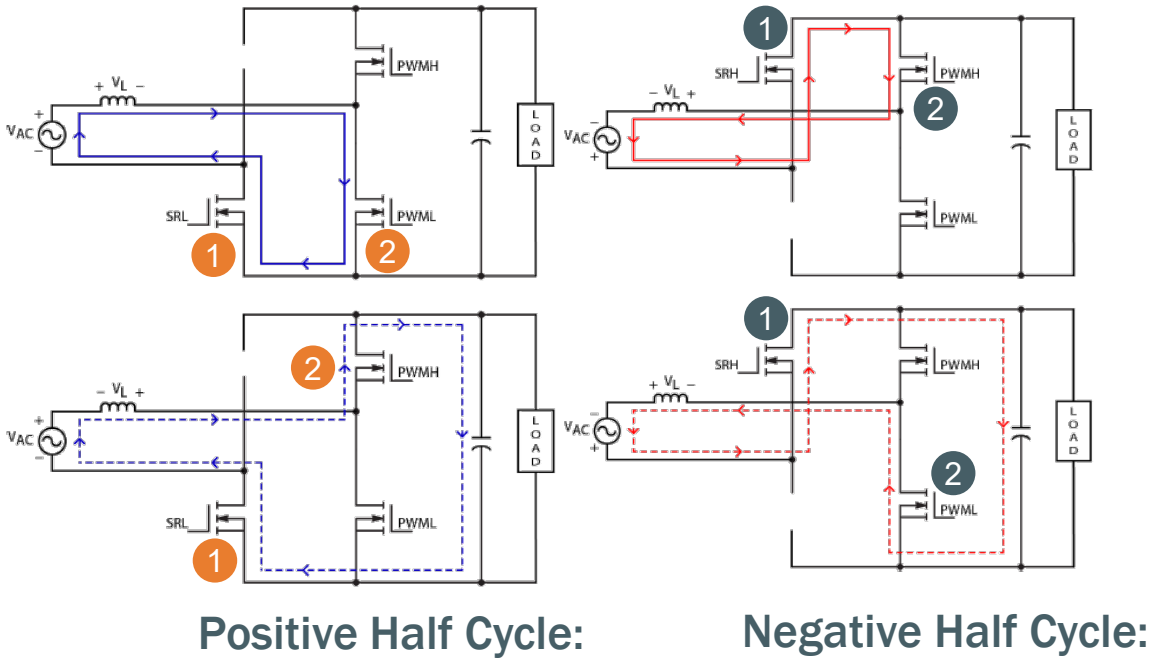
Efficiency: Bridgeless vs Bridge

Elegance = Simplicity
Simplicity = Elegance

Golden Rule: Better Efficiency with fewer devices in the conduction path!!!

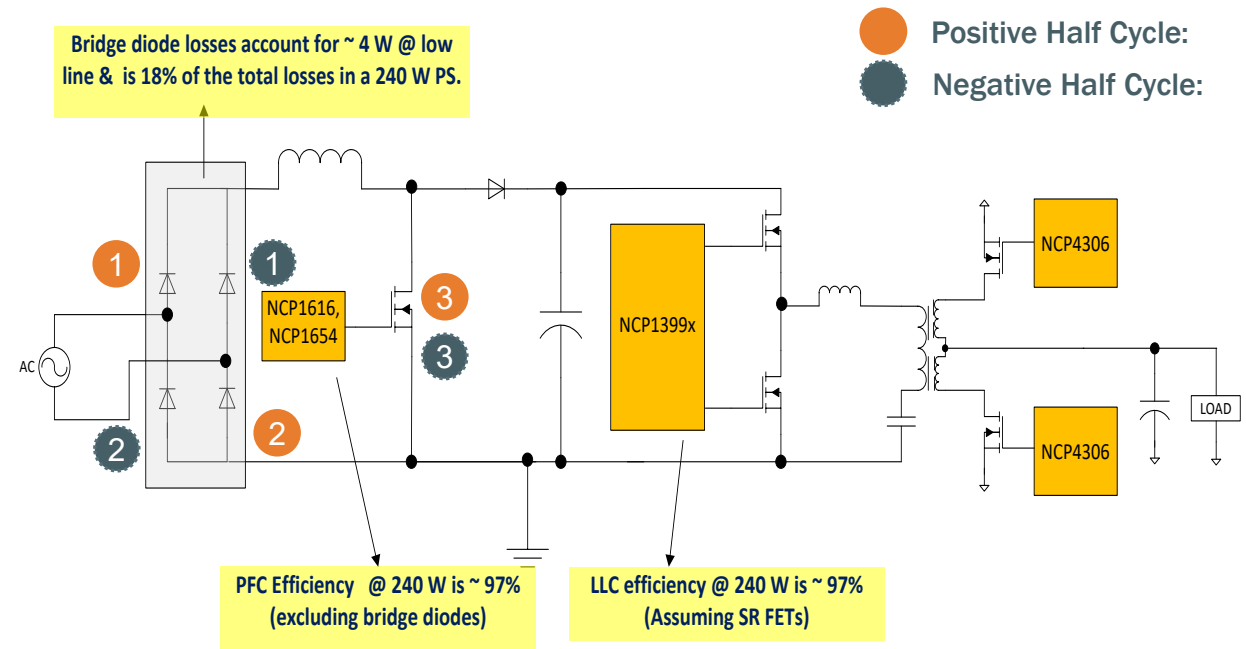
PFC: Bridgeless Totem Pole

Conduction Path: 2 devices

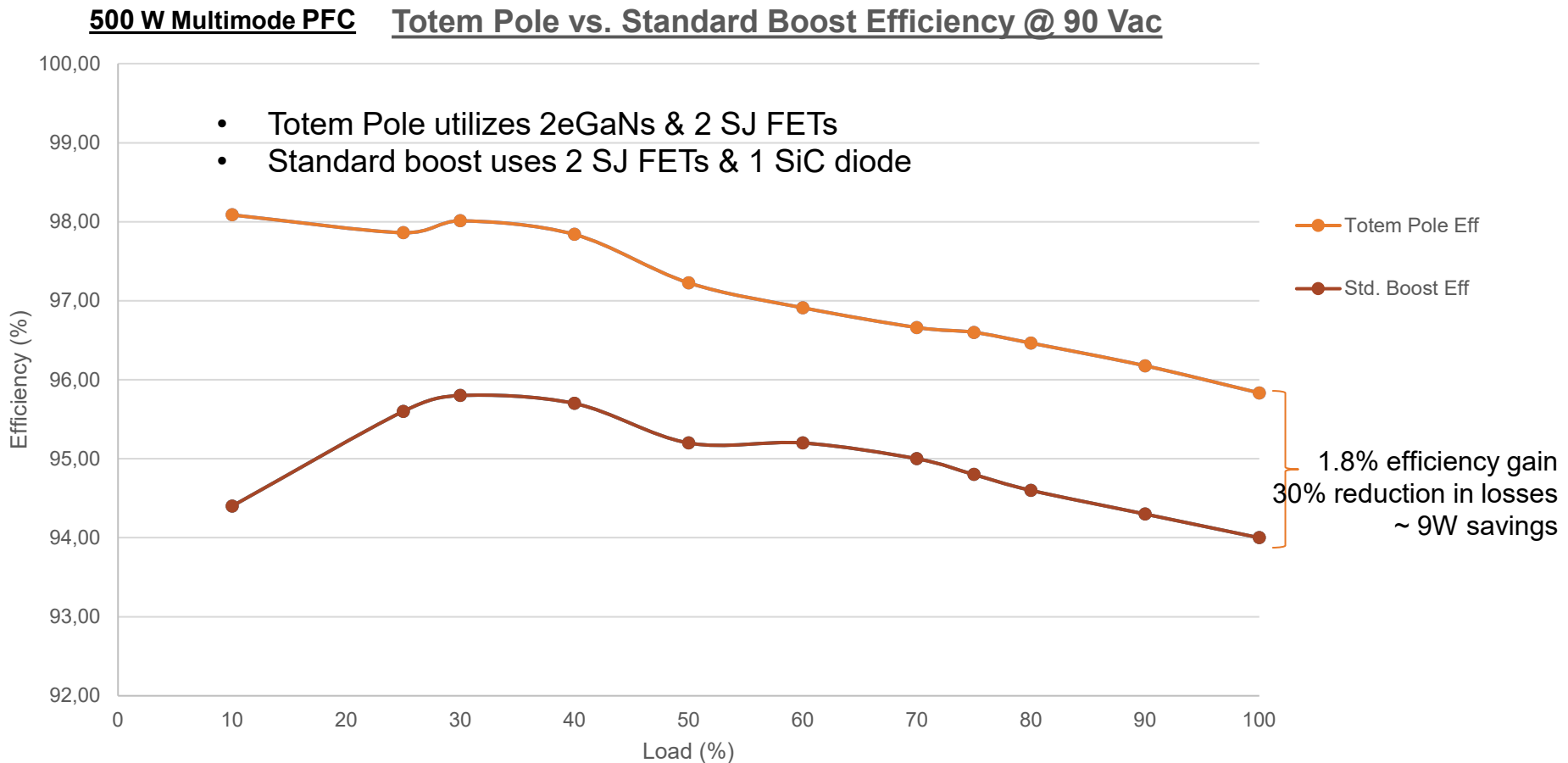


PFC: Bridge Diode

Conduction Path: 3 devices



Totem Pole vs. Standard Boost PFC Efficiency Comparison

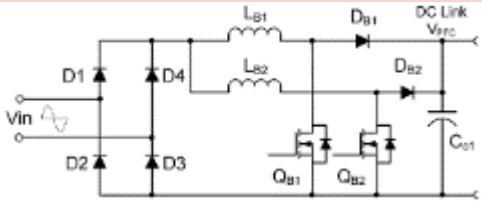
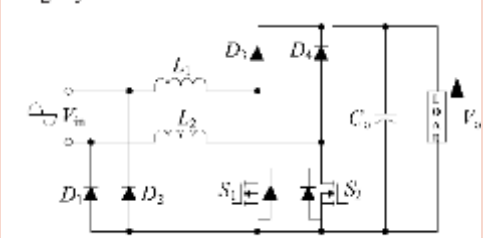
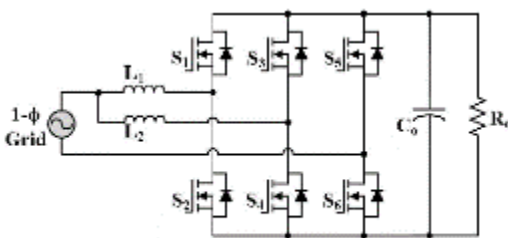
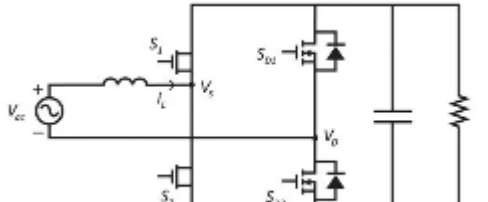


- Bridgeless Totem Pole PFC provides 1.8 % higher efficiency than standard boost PFC at full load, 90 Vac input condition equivalent to 9 W power loss reduction

NCP1681

Bridgeless Totem Pole CCM PFC Controller

Power Factor Correction – Topology overview

Topology	Interleaved Boost	Semi-Bridgeless Boost	Interleaved CrM Totem Pole	Bridgeless Totem Pole
		 <p>Figure 1. Semi-bridgeless boost converter</p>	 <p>(b)</p>	
Modes	CCM or CrM	CCM or CrM	CrM	CrM or CCM
Transistors	Si SJFET	Si SJFET	Si SJFET	Si SJFET, GaN or SiC for CrM Only GaN or SiC for CCM
Fsw	<100kHz	<100kHz	~250kHz	CrM: up to 500kHz (1MHz possible)
Peak eff.	~97%	~98%	~98.5%	>98.8%
Cost	100%	160%	130%	110%
Advantages	<ul style="list-style-type: none"> • Very straightforward • Well-known technology • Many control options 	<ul style="list-style-type: none"> • Simple bridgeless PFC • Good efficiency above 98% 	<ul style="list-style-type: none"> • ZCS mode with soft-switching • Higher efficiency than boost • Interleaved ripple cancellation 	<ul style="list-style-type: none"> • Highest efficiency • Zero Qrr for GaN • Highest power density • Low component count
constrains	<ul style="list-style-type: none"> • Low efficiency • Lower power density 	<ul style="list-style-type: none"> • High BOM cost • V/I sensing more complicated • High CM noise • Two large inductors 	<ul style="list-style-type: none"> • High peak current crossing FETs • <1.5kW output power • Large EMI filter 	<ul style="list-style-type: none"> • THD improvements with Zero current detect and new algorithm • Critical PCB layout • Current sensing critical



BTPPFC Applications



Data Center: rack mounted power supply...



high power LED street light



Industrial: power supply, PSU, UPS...

To match all the applications where efficiency and compactness are critical parameters



high power adapter



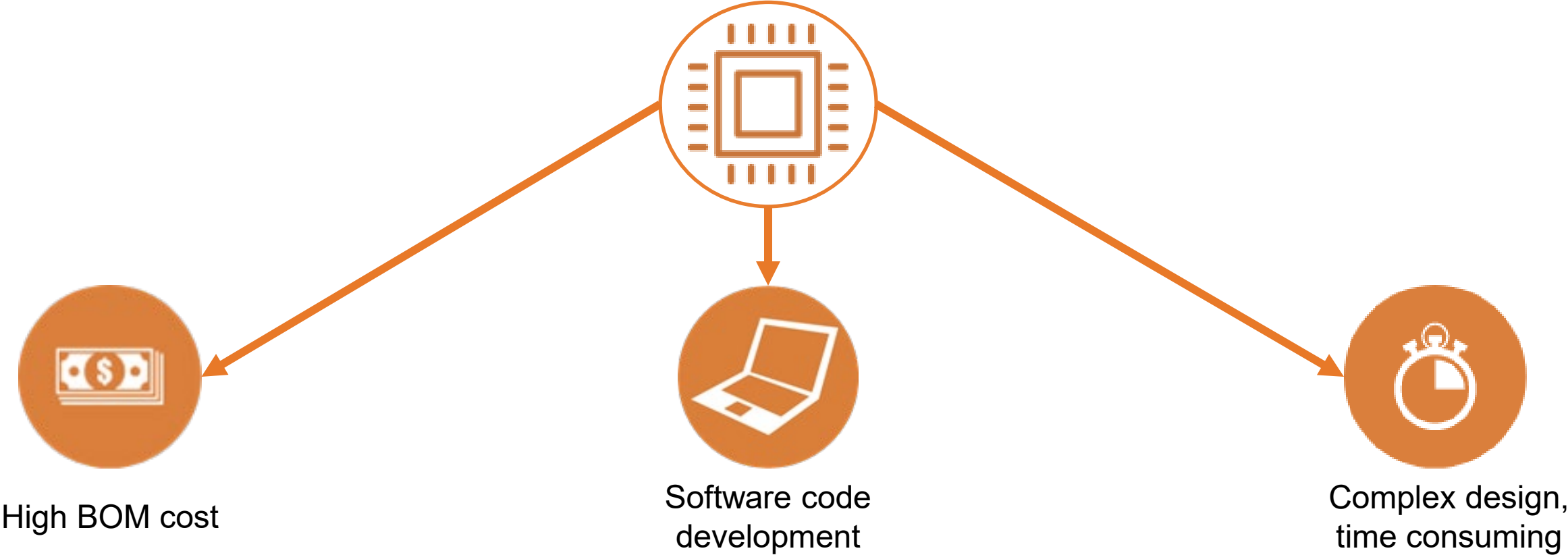
5G telecom power supply



external adapter power supply...

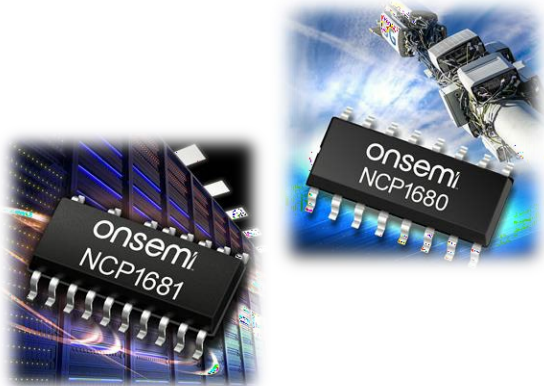
Totem Pole PFC Market Scenario – onsemi’s advantages

Existing solutions on the market MCU based



Totem Pole PFC Market Scenario – onsemi’s advantages

NCP1680/1 Mixed signal



Cost effective



Optimal BOM



Fast Development

NCP1681 – Totem Pole PFC Controller

Value Proposition

The NCP1681 is a multi-mode, or CCM, Totem Pole PFC Controller capable of operating in fixed frequency CCM, constant on-time CrM, and valley synchronized frequency foldback for optimized efficiency across the entire load range. With novel current sensing architectures, proven control algorithms for all operating modes, and a suite of protection features, the NCP1681 allows for a cost-effective solution without jeopardizing performance.

Unique Features

- Fixed frequency CCM w/ Constant on-time CrM and valley switching frequency fold back
- **Novel current sense scheme providing inductor current upslope and downslope sensing**
- Line polarity detection
- Digital loop compensation

Benefits

- Optimized performance across all power levels
- Cycle-by-cycle current limit w/o hall effect sensor
- Reduces external components

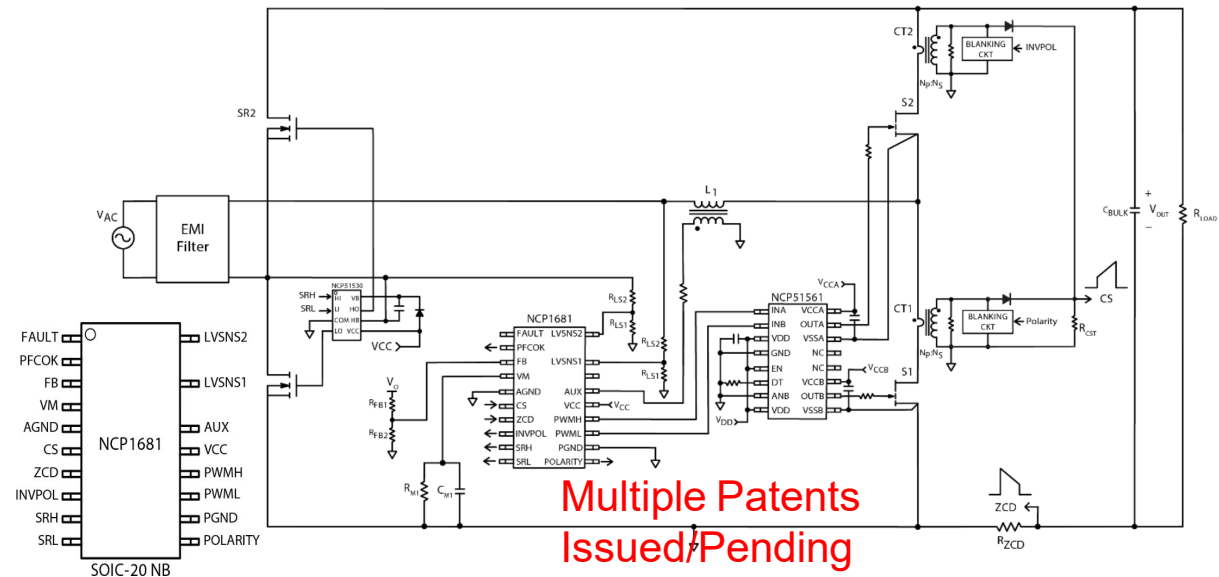
Other Features

- Two low voltage pins for sensing and recreating half-wave sinusoid.
- Fixed frequency pseudo-average current mode control for high performance continuous conduction mode operation
- Constant on-time CrM and valley synchronized frequency foldback at medium and light load
- Skip/Standby mode for optimized light load performance
- PFC OK Indicator

Market & Applications

- Server/Computing PFC
- OBC
- Gaming/TV Power Supplies
- Battery Chargers
- Industrial power supplies
- 5G/Telecom Power

Typical Application Schematic



Ordering & Package information

- SOIC-20 NB

OPN	Operating Mode	F _{CCM} [kHz]	V _{LIM} [V] LL / HL	V _{ZCD(ARM)} [mV]
NCP1681AA	CCM	65	1 / 1	150
NCP1681AB	CCM	95	1 / 1	150
NCP1681BA	Multi-Mode	65	1.4 / 0.84	300

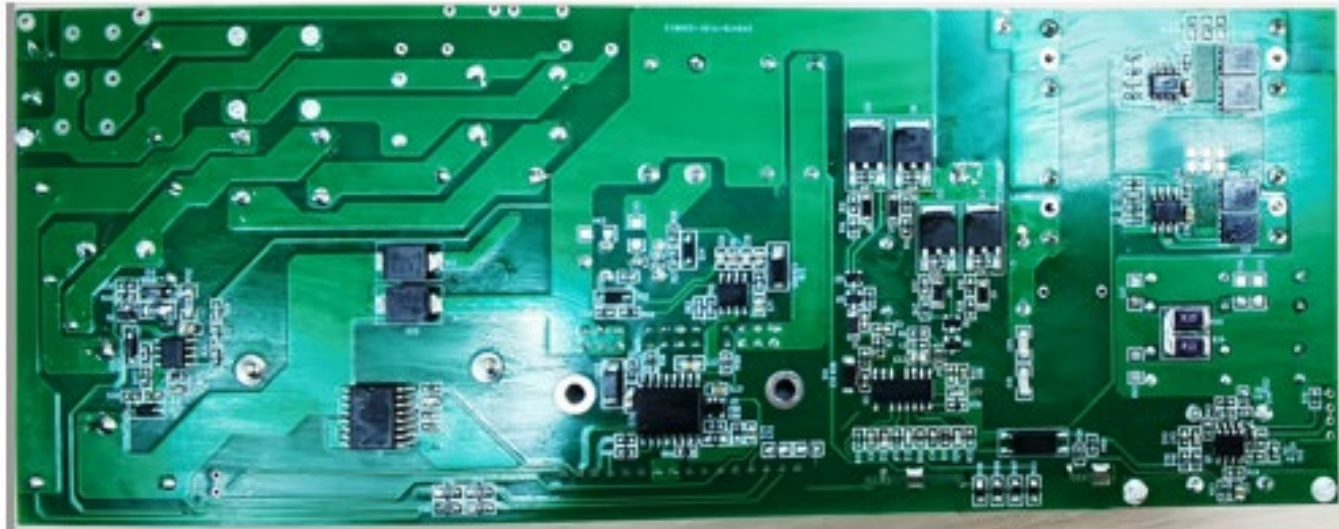
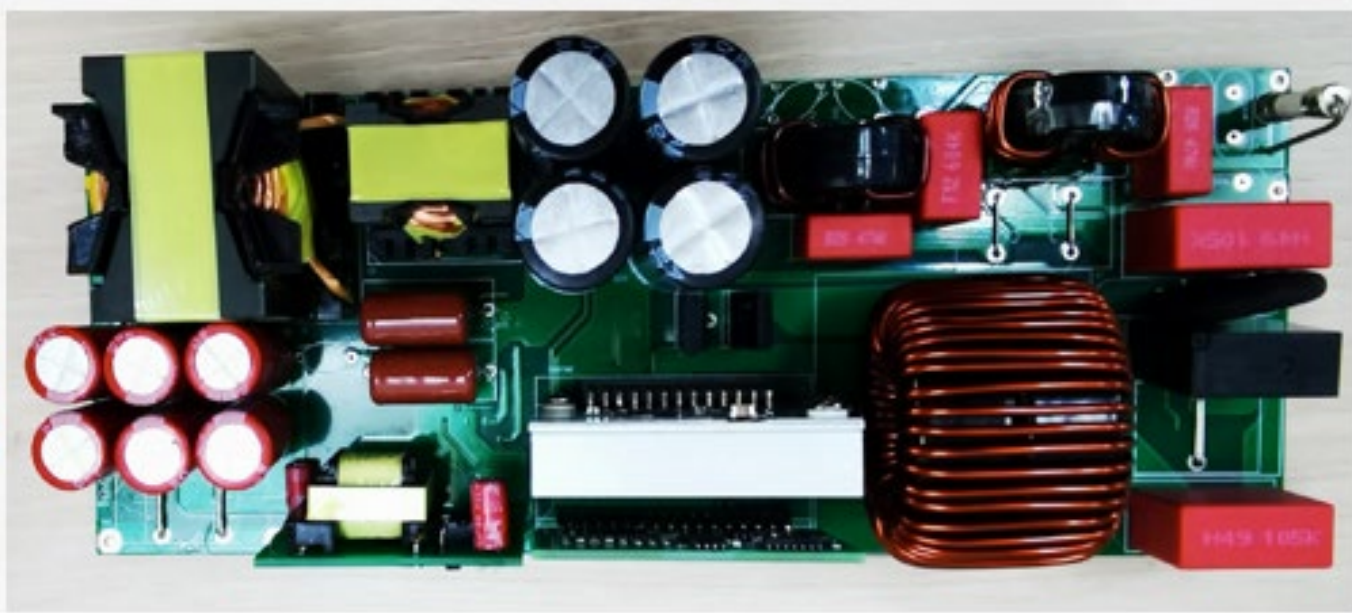
Totem pole PFC mixed signal vs. digital controller

Digital Controller

Mixed Signal Controller (NCP1680 & 1)

1kW Universal Input, 50V Output Power Supply

1kW TP PFC-LLC



This design used onsemi's Totem pole PFC controller **NCP1681** and LLC controller **NCL30159**, with a high PF and low THD performance.

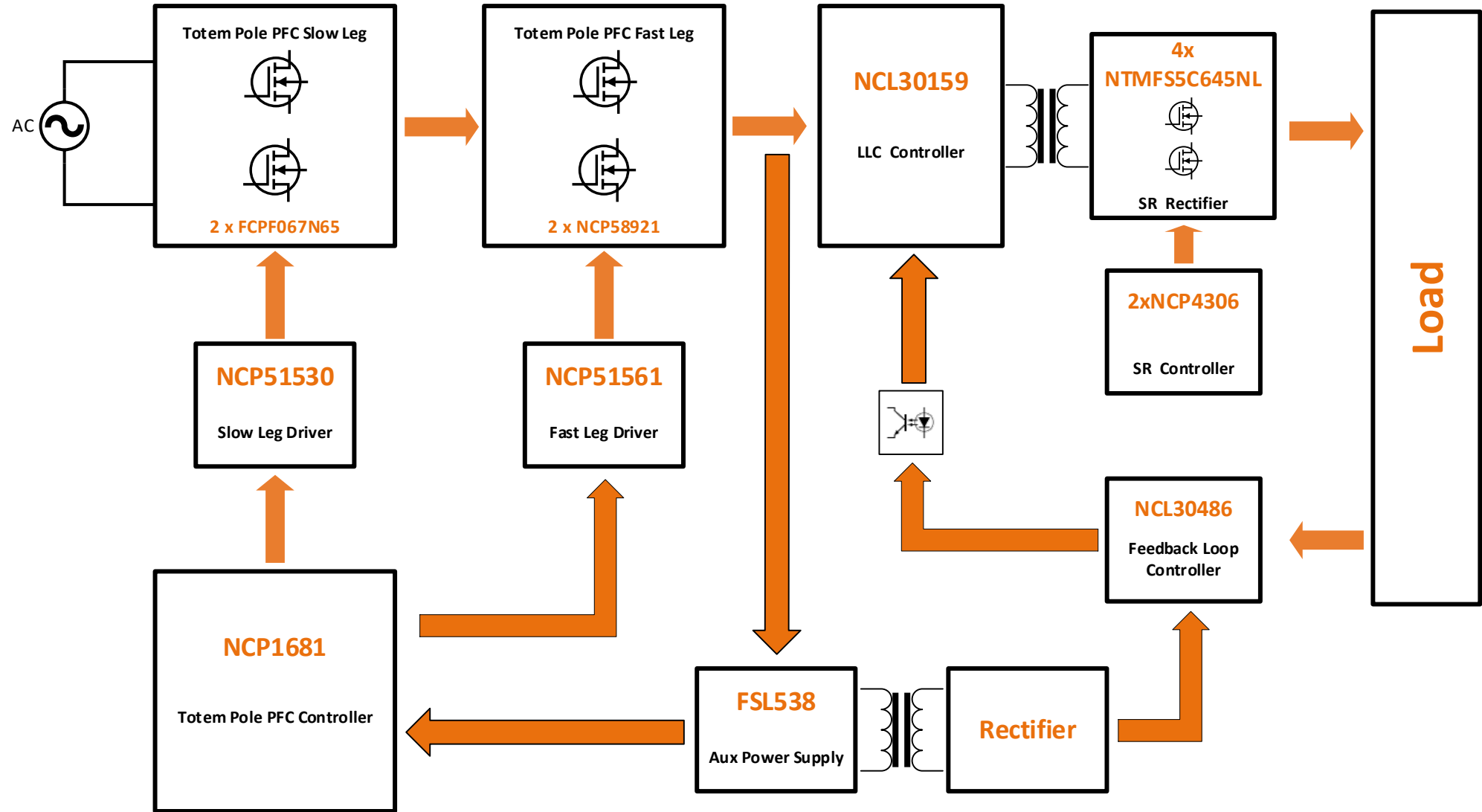
Highlights:

- High efficiency with a Totem pole PFC **NCP1681**
- **NCP58921** integrated driver GaN used for Totem pole PFC fast leg
- Protections: Over voltage protection
 - Over current protection
 - Constant Power protection by **NCL30159** and **NCL38046**
- High PF and low THD

NCP1681 1kW TP PFC-LLC Power Supply

Design Parameter	Performance
Input Voltage	90 VAC to 264 VAC
Output Voltage	50 V
Output Current	20 A (15A @115Vac w/o fan cooling)
Power Factor	> 0.94 @ 20% load – 0.998 @100% load, full input range
Size	220 × 85 × 50 mm
Average Efficiency	<ul style="list-style-type: none">• 94.6% @ 115VAC• 96.1% @ 230VAC
Peak Efficiency	<ul style="list-style-type: none">• 95.4% peak efficiency @ 115VAC• 96.5% peak efficiency @ 230VAC
Construction	4-Layers FR4 PCB with 2-Layers PCB board for LLC and PFC controller

1 kW Totem Pole PFC and LLC Power Supply



Key Components

Controller Devices	Part Numbers
PFC controller	NCP1681
LLC Controller	NCL30519
SR Controller	NCP4306
PFC FL Gate driver	NCP51561
PFC SL Gate Driver	NCP51530
Feedback loop Controller	NCL38046
Aux Power	FSL538
Switching devices	Part Numbers
PFC Fast Leg	NCP58921
PFC Slow Leg	FCPF067N65

Key Components

NCL30159 LLC HB controller

Value Proposition

The NCL30159 is a primary side current mode LLC controller. The controller can also provide wide dimming range operation in wide output condition. This controller allows to implement many features (high efficiency in standby, dedicated startup). And allows to ensure the maximum power limit feature. It enable to design the wide input voltage range converters or the LED drivers with their output matched to different LED strings.

Unique Features

- **Current Mode** Control
- Built-in **700V/0.8A Driver**
- **700V HV start up** with BO
- **Primary Over Power Protection**
- **Advanced Light load mode**
- DIM off **standby** mode

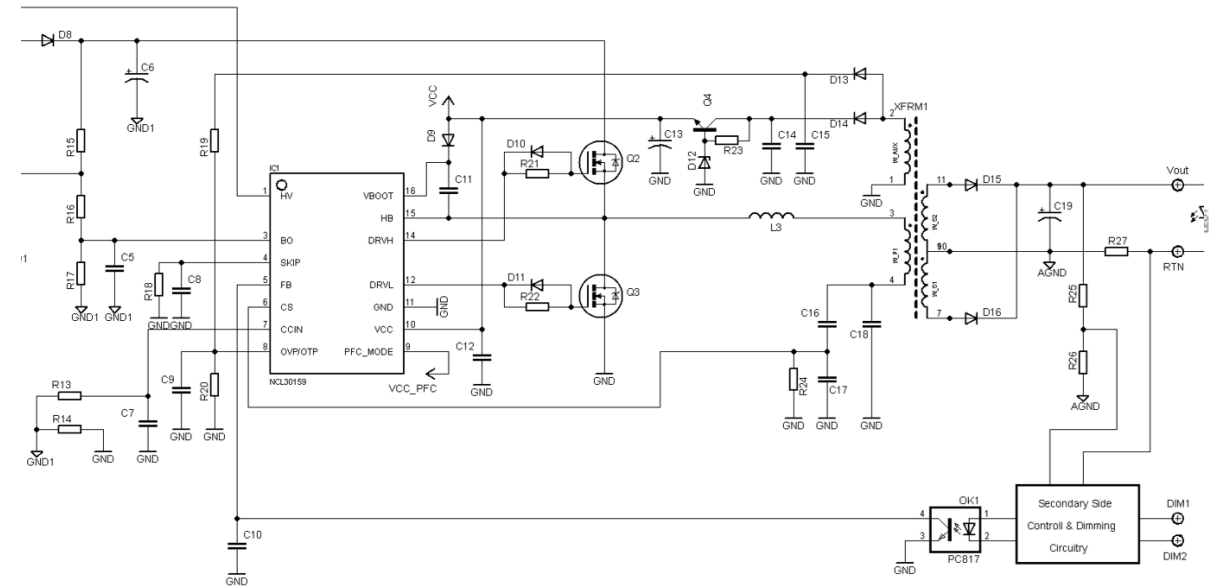
Benefits

- Inherent Anti-Capacitive Switching
- Compact Design
- Low standby power & high reliability
- Provide window driver features
- Low standby power
- High system reliability

Market & Applications

- Industrial Power Supply
- Dimmable LED Drivers

Typical Application Schematic



Ordering & Package information

- NCL30159AADR2G 16SOIC
- NCL30159ABDR2G 16SOIC

NCL30486B Smart-Dimmable CC/CV PSR Controller

Value Proposition

The NCL30486 is a high PF Single stage Constant Current and Constant Voltage PSR PWM controller for Flyback/ Buck-Boost/ Sepic/ Boost. This controller operates in a QR mode to provide high efficiency. Thanks to a novel control method, the device is able to tightly regulate a constant LED current from the primary side. This device is providing very deep analog dimming output current with two dedicated dimming control input pin – ADIM and PDIM.

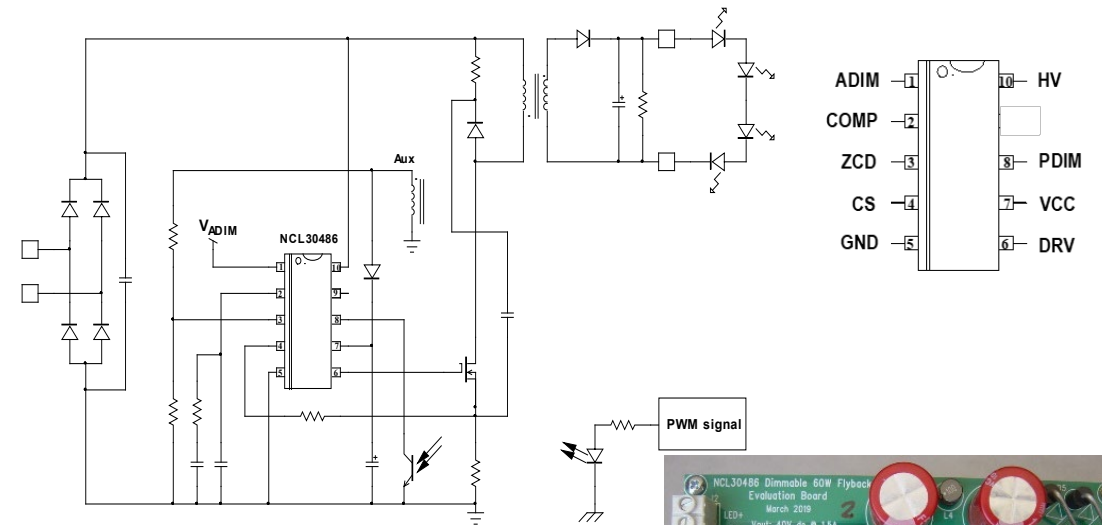
Unique Features

- Integrated **700 V HV Startup**
- Precise **current regulation** accuracy ($< \pm 2\%$ typical)
- Precise **voltage regulation** accuracy ($< \pm 1\%$ typical)
- **PF(>0.95)/THD($<10\%$) @ Univ.**
- **Quasi-resonant** control
- Standby Mode
- Optional **PSR/SSR** mode
- Excellent **Dimming features**
 - Dimming curve: Linear/Logarithmic
 - **ADIM**: Analog I_{OUT} with V_{DC}
PWM I_{OUT} with V_{PWM}
 - **PDIM**: Analog I_{OUT} with PWM duty
 - Optional Min. Dim. Clamping(0/1/5/8%)
 - Deeper dim. w ADIM&PDIM simultaneously
 - DIM CV Mode
- Protections
 - BO/ Line OVP/ V_{CC} OVP
 - LED Open/ short protection
 - Winding / Diode short protection
 - TSD

Benefits

- Fast startup, low Pstdby
- Constant brightness
- Aux. power supply for MCU & cold start up
- Exceeds global standards
- Higher efficiency
- **$P_{IN} < 150$ mW**
- Design flexibility
- Design flexibility
- Supports “Smart” Lighting
- Use opto. Instead of pulse trans.
- Deep dimming features
- Vcc supply for Smart lighting MCU
- High system reliability

Typical Application Schematic



60 W – NCL30486LED2GEVB



Market & Applications

- Analog/PWM Dimmable LED Driver

Ordering & Package information

- NCL30486B1DR2G
- NCL30486B2DR2G

Refer to the slide #4

NCP4306 Secondary Side Synchronous Rectification Driver

Value Proposition

The NCP4306 is high performance driver tailored to control a synchronous rectification MOSFET in switch mode power supplies. Thanks to its high performance drivers and versatility, it can be used in various topologies such as DCM or CCM flyback, quasi resonant flyback, forward and half bridge resonant LLC.

Unique Features

- Operates in CCM, DCM and QR for Flyback or in Forward and LLC
- 15 ns Turn off Delay
- Optional Ultrafast (10.5ns) Trigger Input
- Adjustable Min ON & OFF Time
- dV/dt detection
- 7 A Sink, 2 A Source Drive capability
- GaN Transistor Driving Capability

Other Features

- Operational Voltage up to 36 V
- Precise True Secondary ZCD
- Adjustable Automatic Light Load Disable Mode
- Maximum operation frequency: Up to 1 MHz
- Low Startup and Disable Current Consumption ~ 50mA

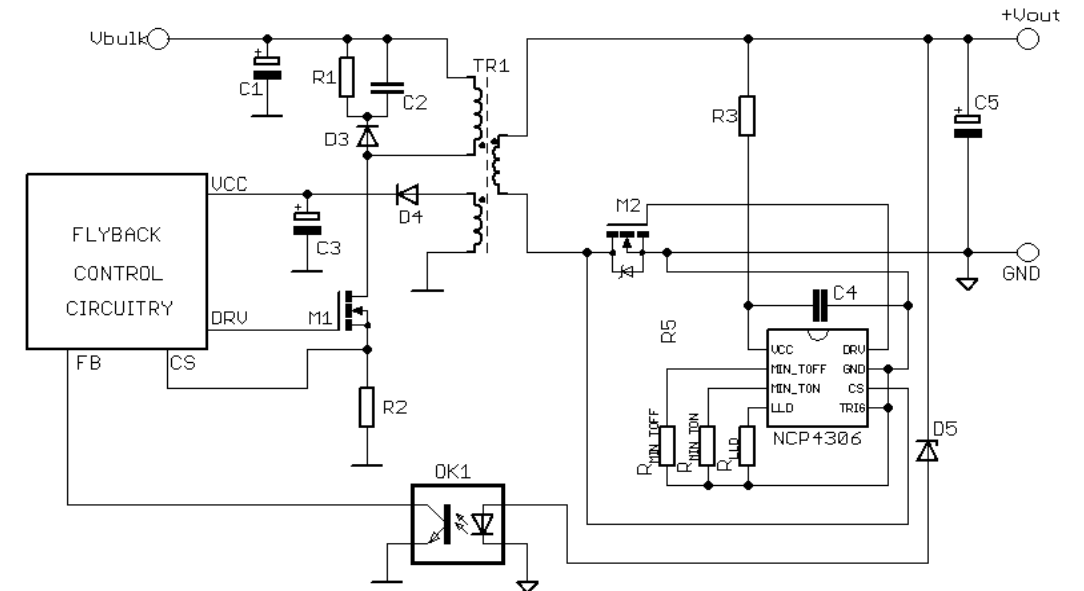
Market & Applications

- Notebook Adapters
- High Power Density AC/DC PS
- USB Wireless Adapters

Benefits

- Flexible solution fits many topologies
- Maximizes conduction time to increase efficiency
- Improves deep CCM performance
- Prevents accidental MOSFET turn on or turn off due to ringing
- Enhanced Operation for USB-PD
- Fast turn off of MOSFET for optimized conduction period

Typical Application Schematic



Package information

- Driver clamp 5 / 10 V
- Flyback, LLC and universal version
- DFN, SOIC8, TSOP6 package variants

NCP5892x 650 V Integrated GaN PQFN

Overview

High performance integrated gate driver with GaN. Built in 6 V clamped gate drive for optimal and robust GaN operation at high switching frequency. Device is available in low inductance PQFN bottom cool package

Key Features

- Integrated gate driver + E-mode GaN
- 50 mOhm, 78 mOhm & 150 mOhm typical $R_{ds(on)}$
- 650 V breakdown voltage rating
- 6 V internal clamped GaN gate drive voltage
- Driver VCC rating 20 Vmax
- 35 ns typical driver propagation delay time
- NCP5892x: Low inductance PQFN 8 x 8 mm BS cool
- 2.75 mm creepage distance

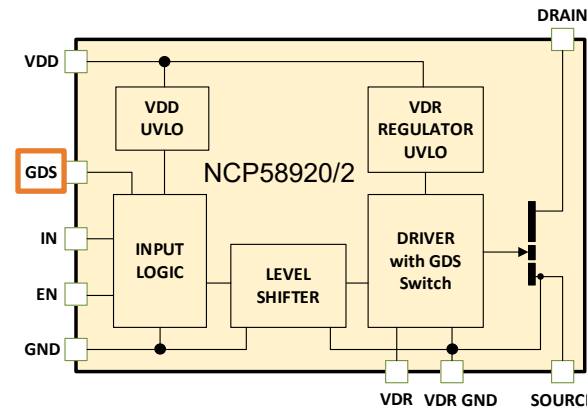
Protections

- UVLO protections for VCC and VDD supplies

Market & Applications

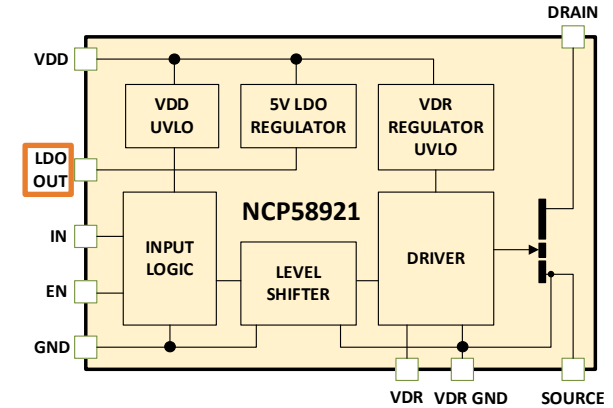
- Cloud-server & 5G Telecom
- High Performance Computing & Industrial
- Totem pole PFC and LLC

Simplified Block Diagram



NCP58920: 150mΩ

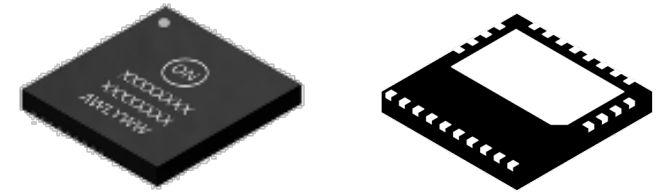
NCP58922: 78mΩ



NCP58921: 50mΩ

Ordering and Packaging

**PQFN 8x8 mm
BS Cool**



NCP51530 – High Performance 3.5A 700V Half-Bridge driver

Value Proposition

The NCP51530 are 700 V high frequency high-side and low-side drivers with very low and matched propagation delays for direct drive of 2 N-channel power MOSFETs in High Performance SMPS & Digital High power converters.

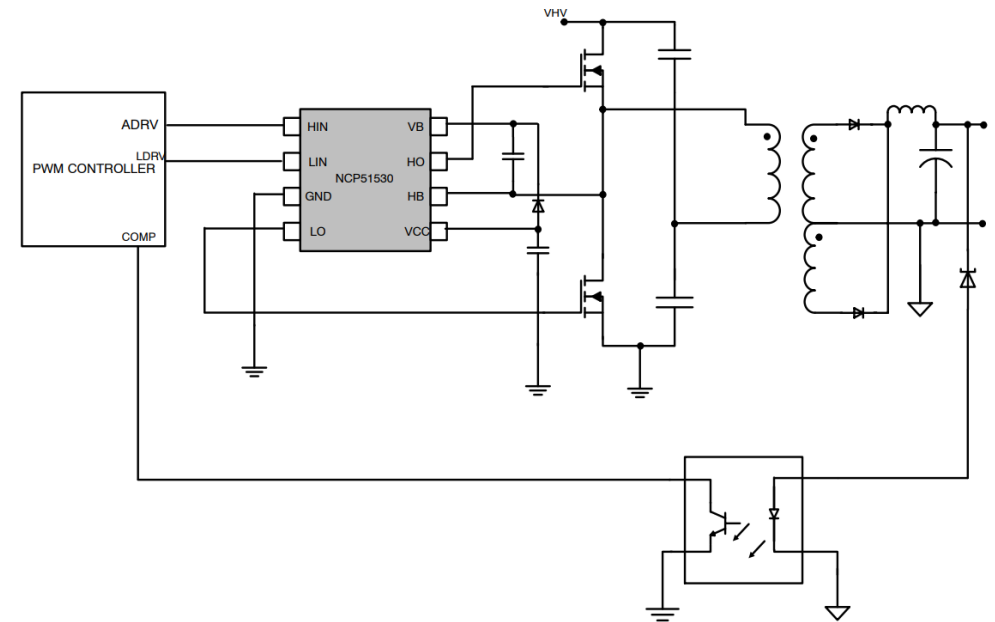
Unique Features

- Excellent dynamic Performance
 - 100 ns Max Prop delay
 - 5 ns Delay matching
 - 15 ns Rise & Fall Times
- Negative bridge voltage to -10V

Benefits

- Off-line applications
- Well suited for high frequency operations
- Robust design

Device Pin-Out



Other Features

- Input range: up to 700 V
- Dual input logic
- 3.5A/3A source/sink currents
- Max Vcc : 20 V
- 100 ns Min pulse width
- Under voltage lockout for both inputs

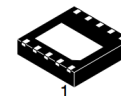
Market & Applications

- Standalone Power Supplies
- Medical Power Supplies
- Server Power Supplies
- Telecom Power Supplies

Ordering & Package information



SOIC-8



DFN10

- NCP51530DR2G: SOIC-8
- NCP51530AMNTWG: DFN10 4*4

NCP51561 – 5kV Isolated High Speed Dual Drivers

Value Proposition

The NCP5156x are isolated dual-channel gate driver with up to 4.5-A/9-A source and sink peak current. It is designed for fast switching to drive power MOSFETs power switches. The NCP5156x offers short and matched propagation delays. Internal functional isolation between the two secondary-side drivers allows a working voltage of up to ~1,200 VDC. The NCP5156x offers other important protection functions such as independent under-voltage lockout for each drivers and disable function.

Unique Features

- Input side isolated from output drivers by 5-kVRMS isolation barrier
- **36 ns Prop Delay & 8 ns Delay Match**
- **>= 200 V/ns dV/dt Immunity**
- 4.5-A/9-A Typical Source/Sink Current Capability

Other Features

- Matched Propagation Delays : Max. 8 ns
- User Programmable Input Logic
 - Single or Dual-input modes via ANB
 - DISABLE or ENABLE mode
- User Programmable Dead-Time Control
- Different UVLO options: 8-V & 17-V (5 & 13 V On demand)

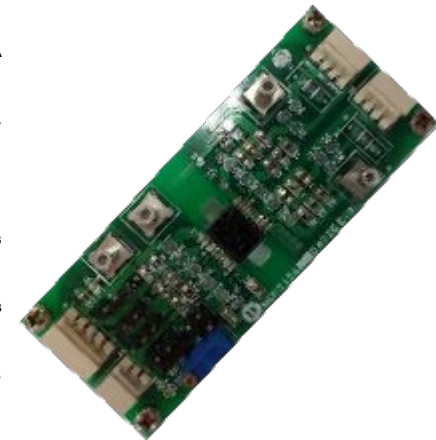
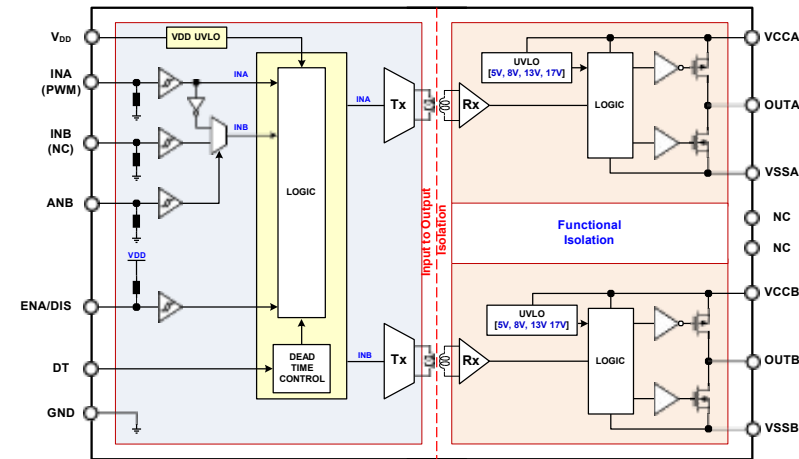
Market & Applications

- Isolated Converters in Offline AC-to-DC Power Supplies
- Motor Drive and DC-to-AC Solar Inverters
- HEV and EV On-Board chargers

Benefits

- Give reliable operation and safety
- Efficient switching
- High Robustness
- Driver to accommodate diff MOS load

Device Pin-Out

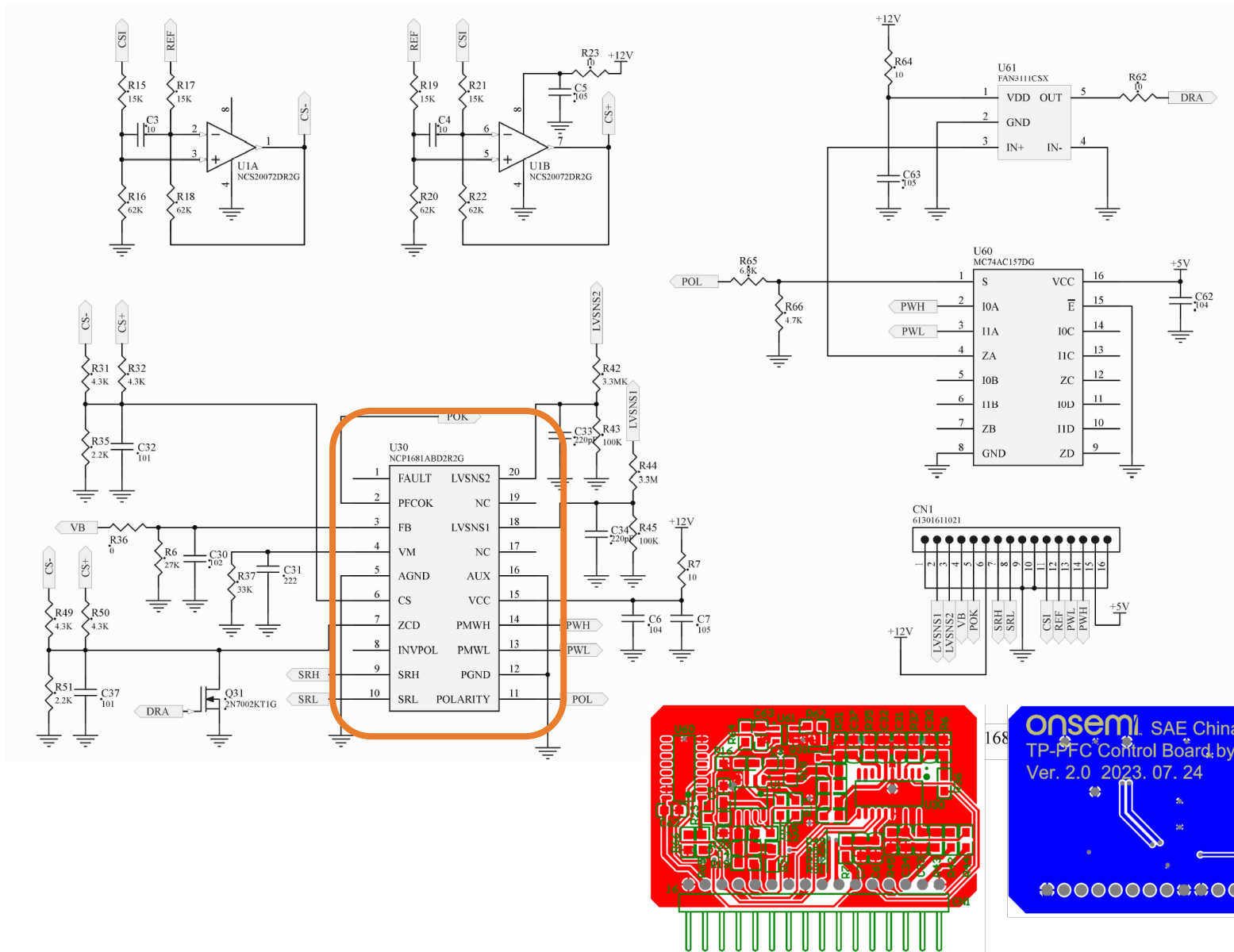


Ordering & Package information

- SOIC-WB16
- OPN : NCP51561xyDWR2G
- x: UVLO level
- y: Enable/Disable

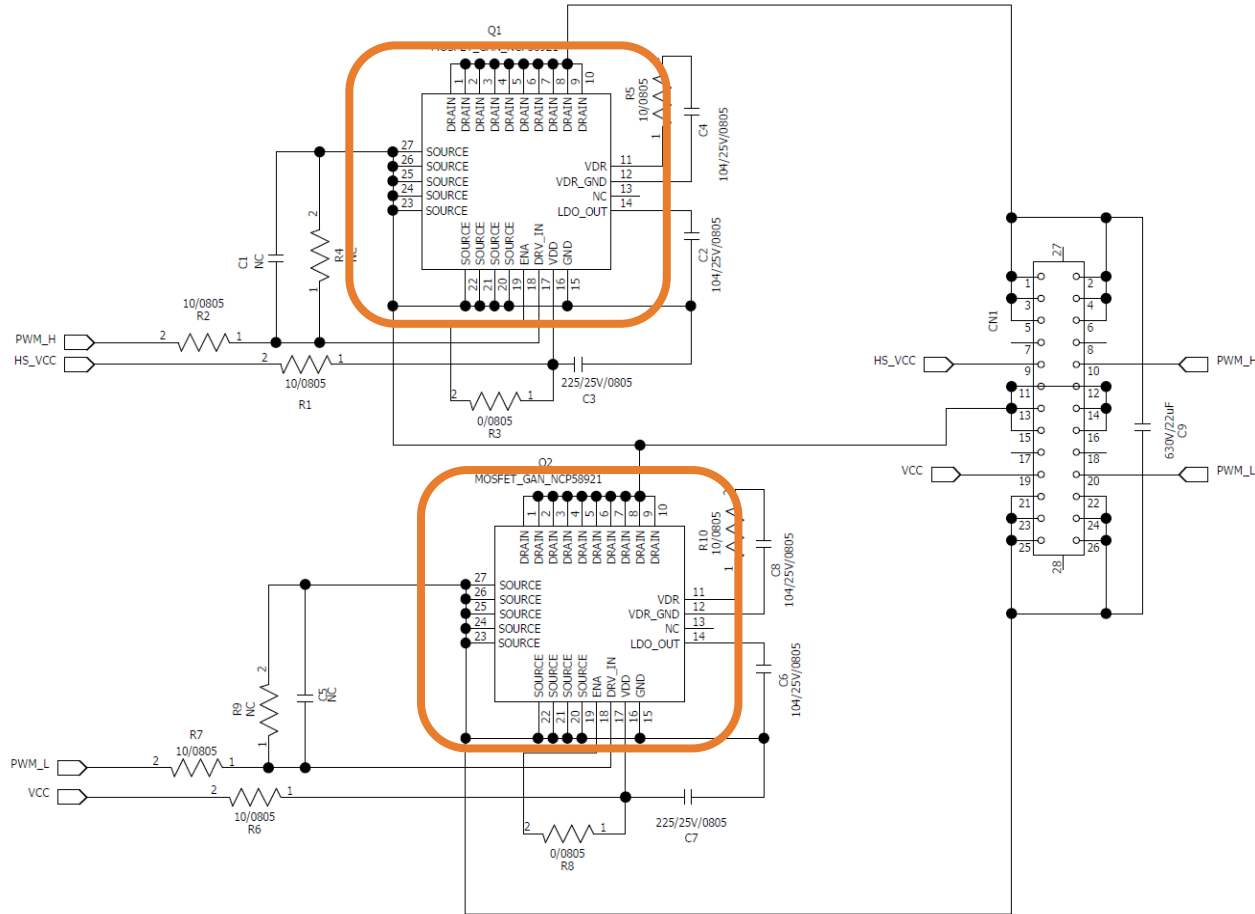
Board Stages

Schematic – PFC control board

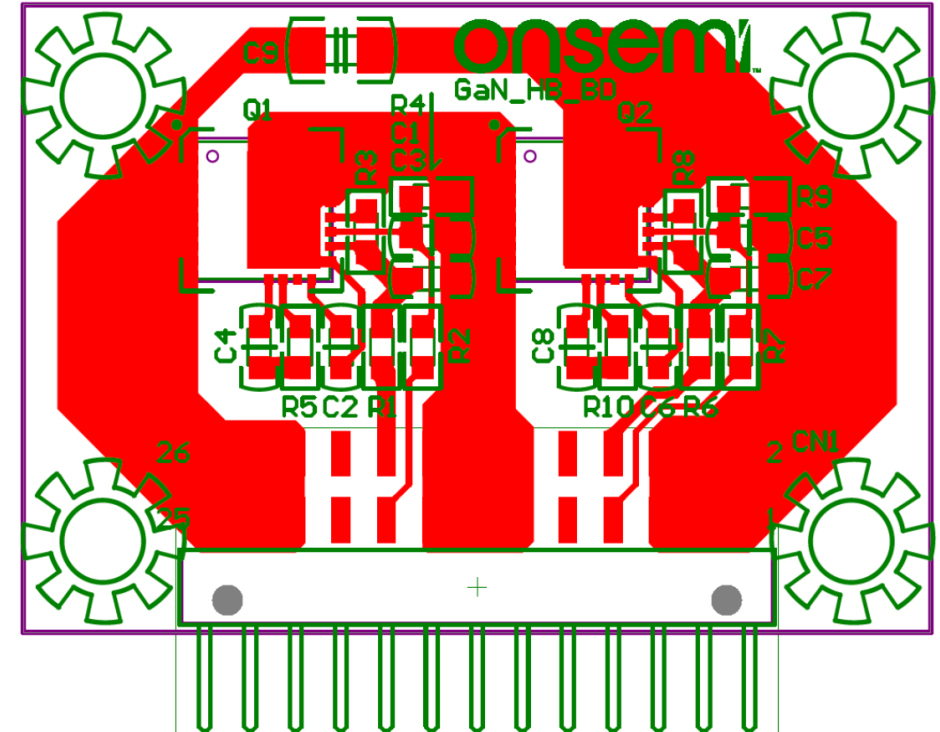


- NCP1681 - is a fixed frequency, Continuous Conduction Mode (CCM) Power Factor Correction (PFC) controller IC designed to drive the bridgeless Totem Pole PFC topology.
- NCP1681 Features:
 - AC line monitoring circuit & AC phase detection
 - Multi-mode operation
 - Brownout detection
 - Frequency foldback
 - Skip mode
 - PFCOK Indicator

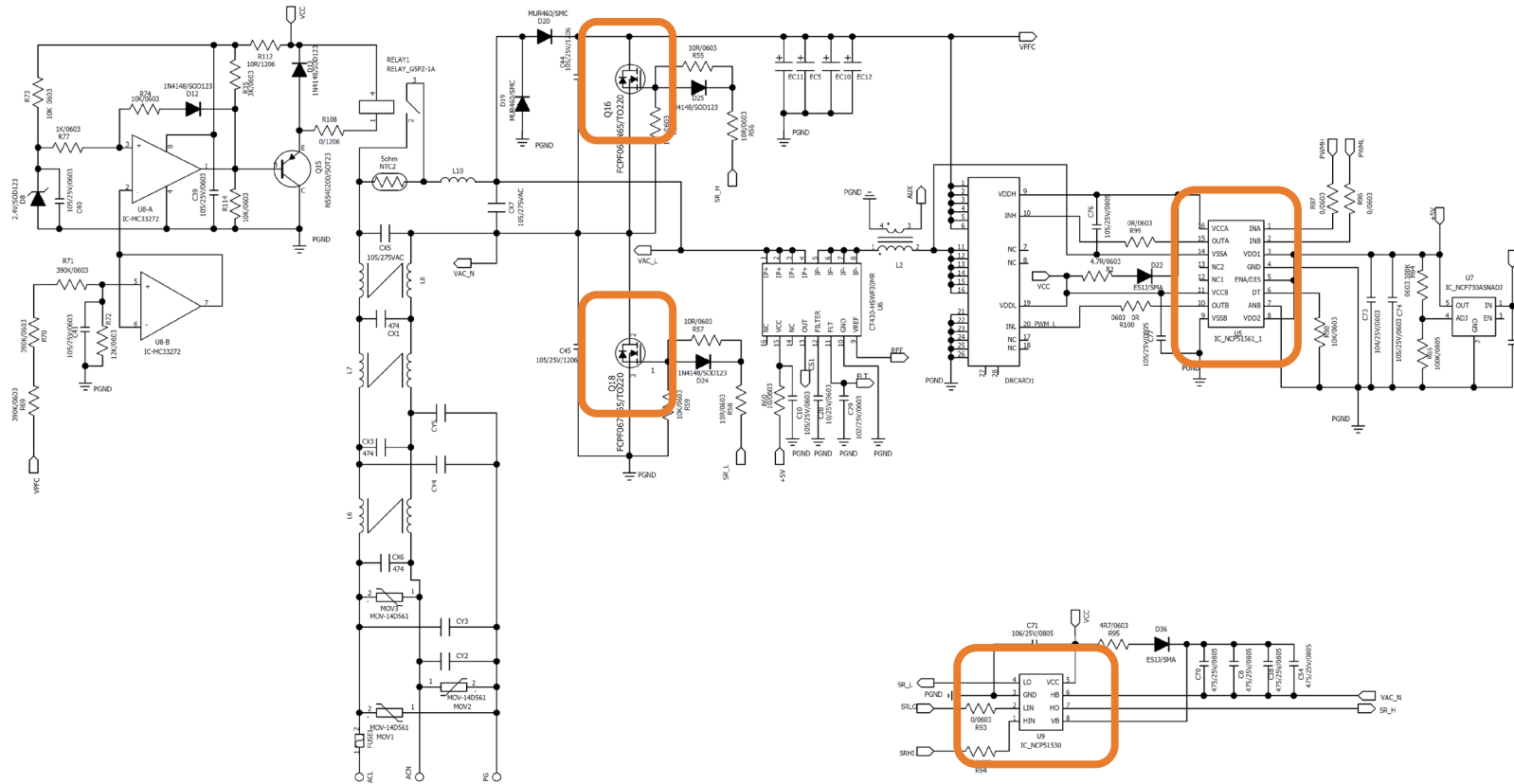
Schematic – PFC Fast Leg Switch Board



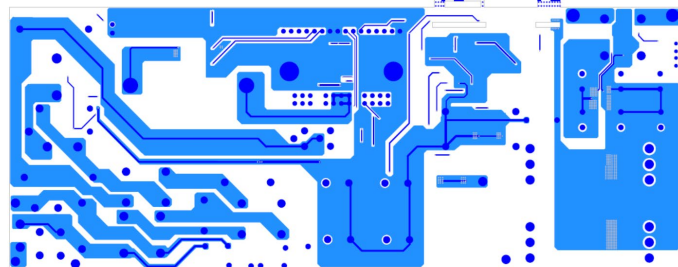
- NCP58921: HB Fast Leg Stage based on 650V 50 mΩ 30A GaN HEMT with Integrated Driver



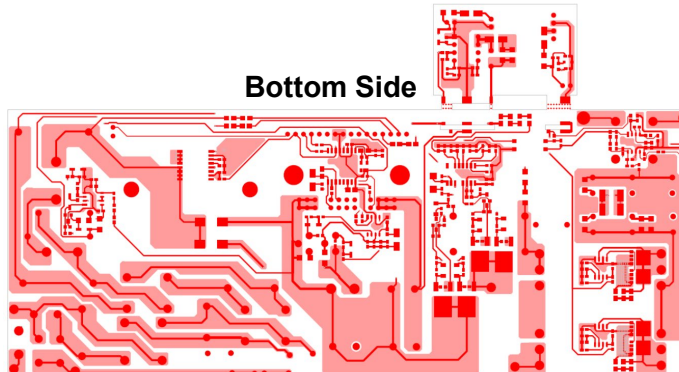
Schematic - Main board part



Top Side

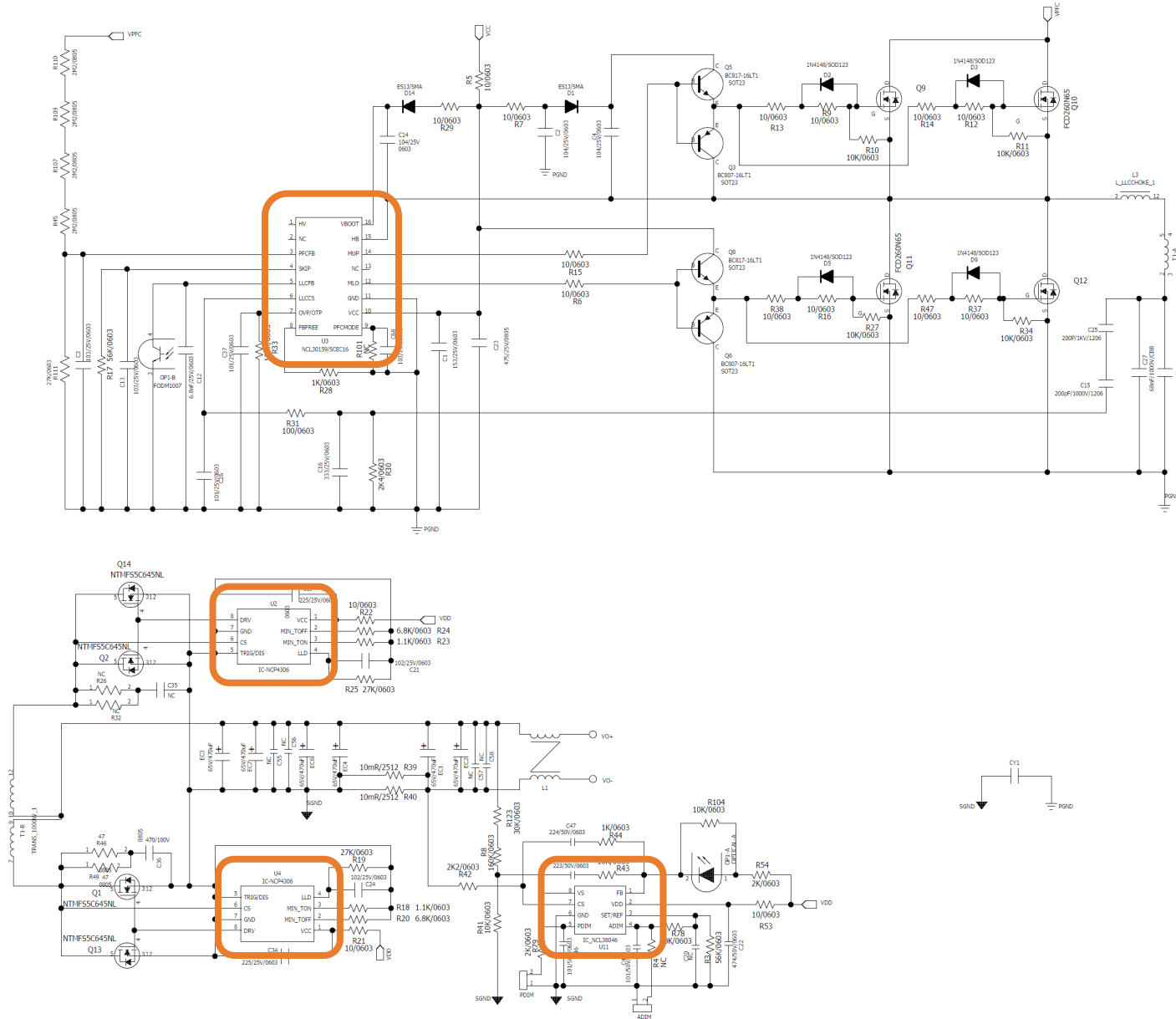


Bottom Side



- 2x FCPF067N65S3: HB Slow Leg Stage– Power MOSFET, N-Channel, SUPERFET® III, Easy Drive, 650 V, 44 A, 67 mΩ, TO-220F
- NCP51530: 700 V high frequency high-side and low-side drivers with very low and matched propagation delays
- NCP51561: isolated dual-channel gate drivers with 4.5–A/9–A source and sink peak current respectively

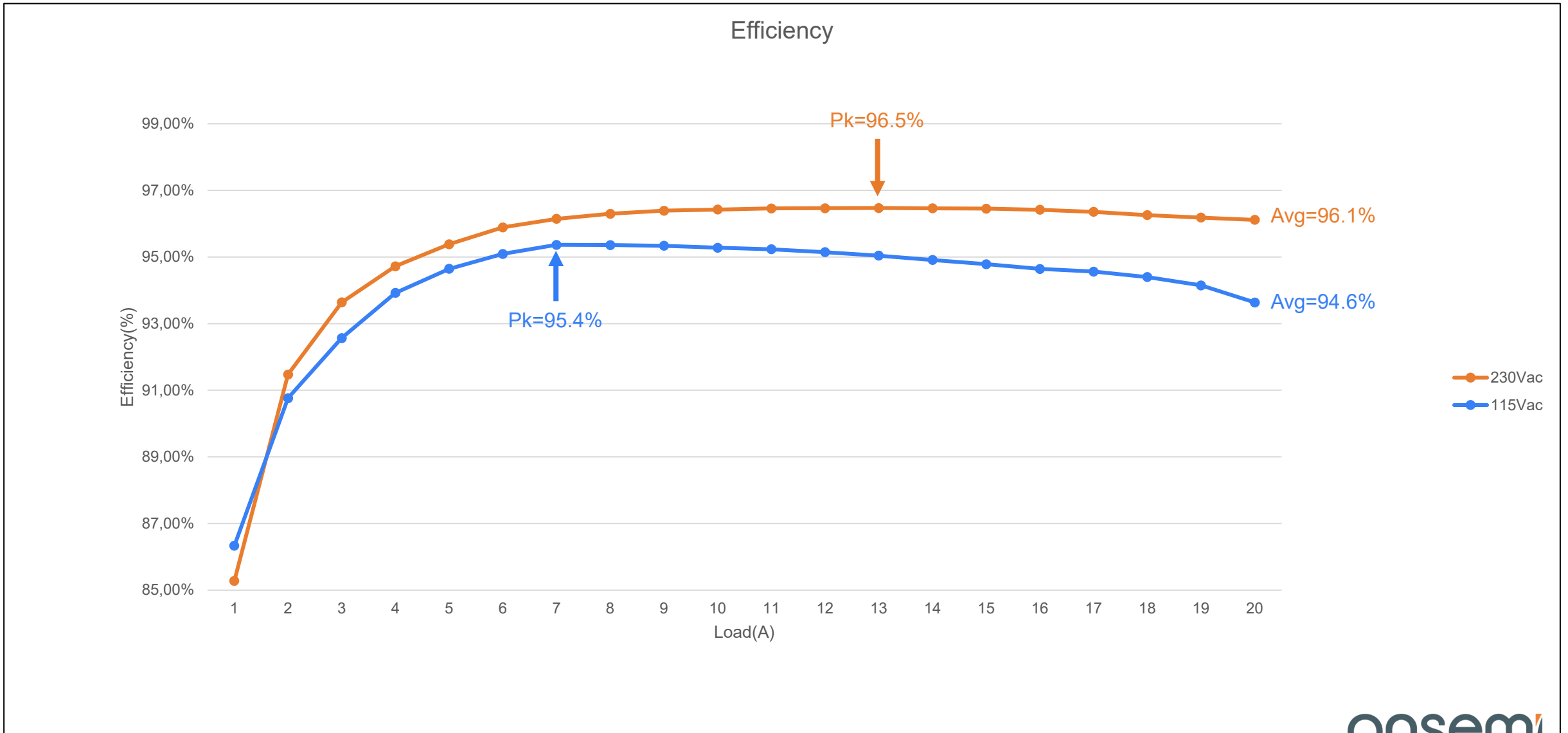
Schematic – LLC part



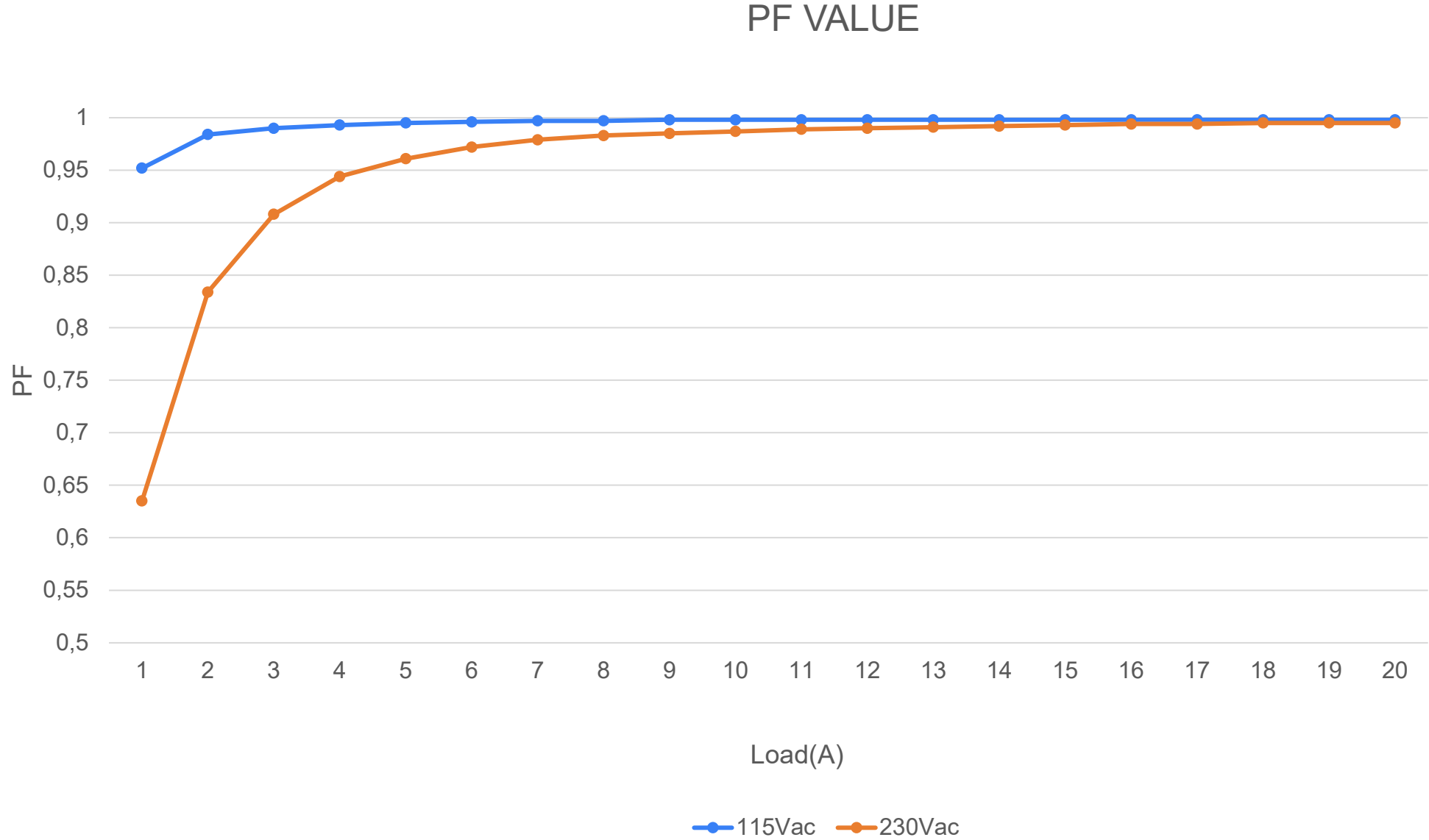
- NCL30159: primary side current mode LLC controller. The controller can provide wide dimming range operation in wide output condition
- 2x NCP4306: high performance driver tailored to control a synchronous rectification MOSFET in switch mode power supplies
- NCL30486: high PF Single stage Constant Current and Constant Voltage PSR PWM controller for Flyback/ Buck-Boost/ Sepic/ Boost.

Evaluation results

Efficiency vs. Output power

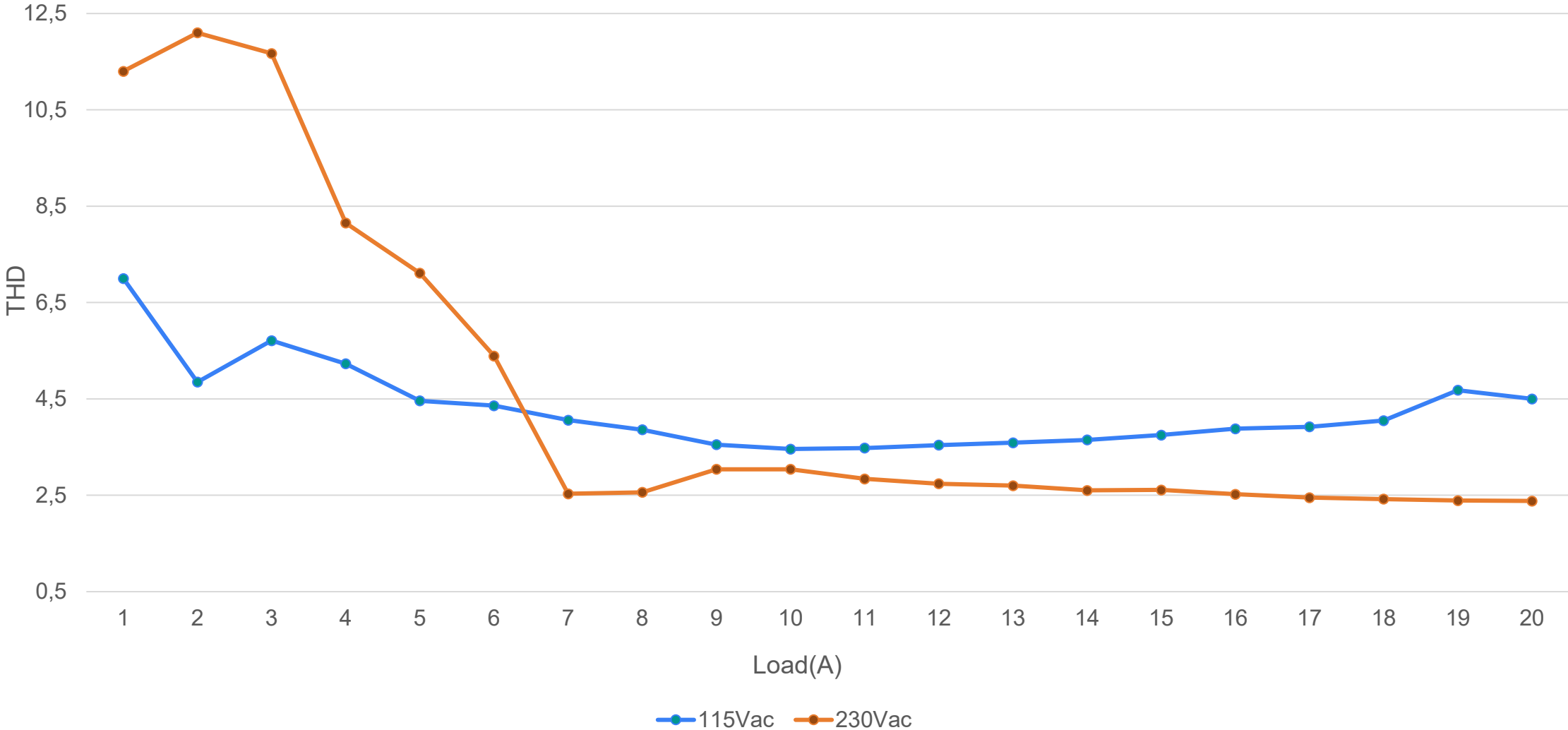


Power factor vs. Output power



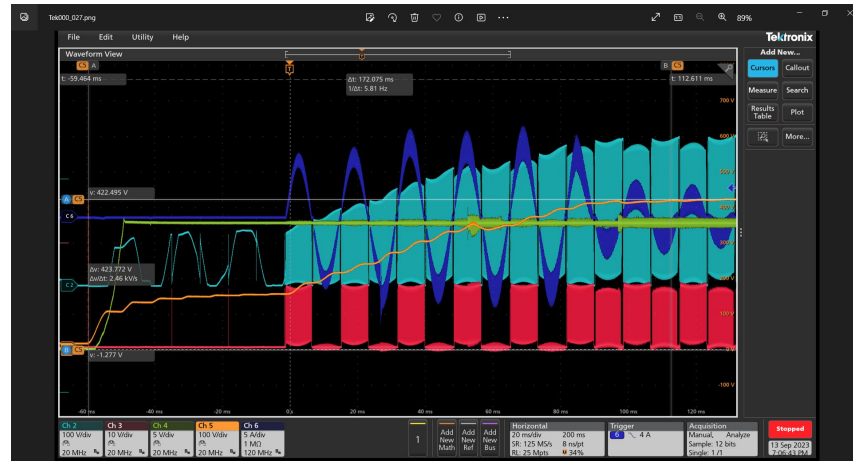
Total Harmonic Distortion vs. Output power

THD VS Load



PFC Part Wave Form – Start Up

CH1	
CH2	Fast Leg low side MOSFET D-S
CH3	Fast Leg low side MOSFET Driver
CH4	Vcc
CH5	PFC output Voltage
CH6	PFC choke current



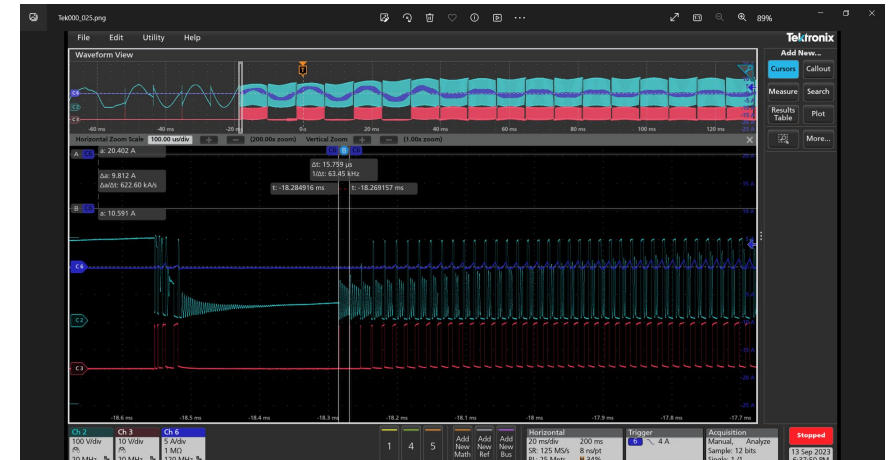
115Vac input



230Vac input



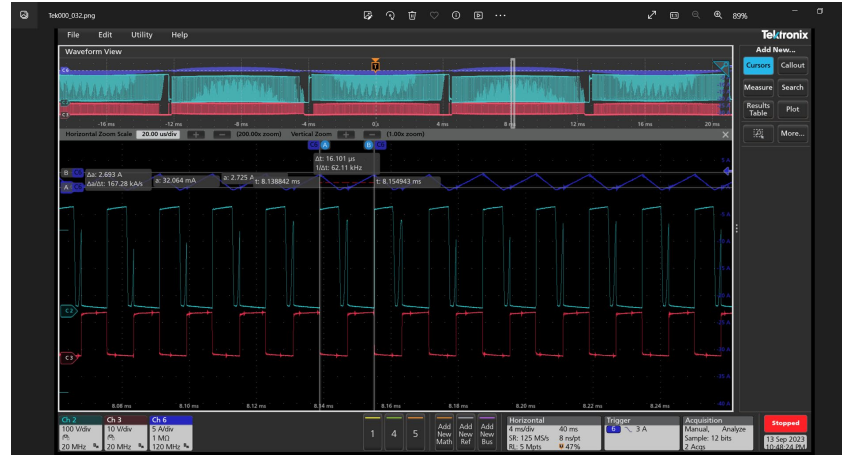
115Vac input



230Vac input

PFC Part Wave Form – DCM to CCM

CH1	
CH2	Fast Leg low side MOSFET D-S
CH3	Fast Leg low side MOSFET Driver
CH4	
CH5	
CH6	PFC choke current



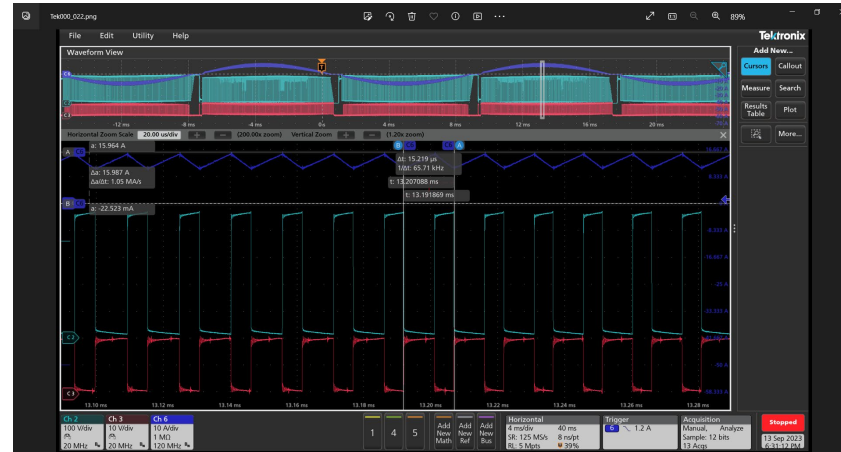
115Vac input & 1.7A



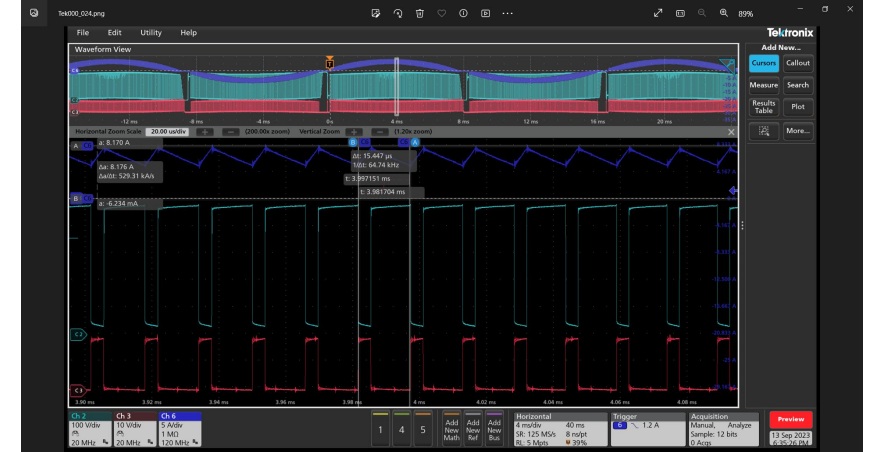
230Vac input & 4.3A

PFC Part Wave Form – Full Load

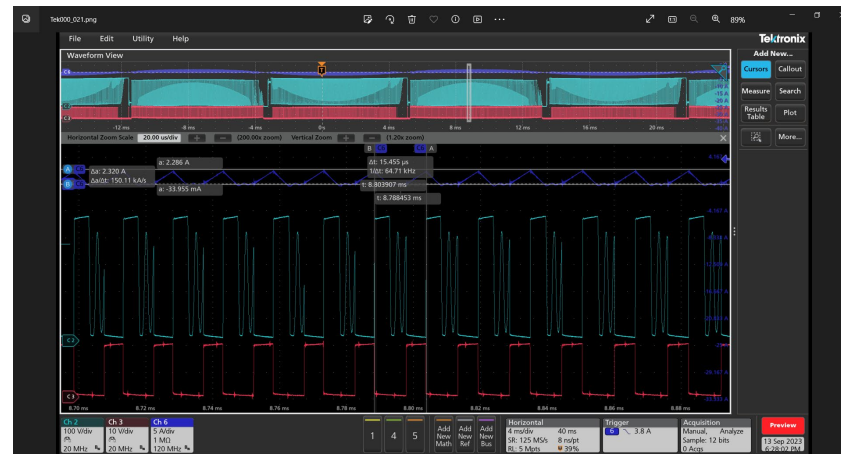
CH1	
CH2	Fast Leg low side MOSFET D-S
CH3	Fast Leg low side MOSFET Driver
CH4	
CH5	
CH6	PFC choke current



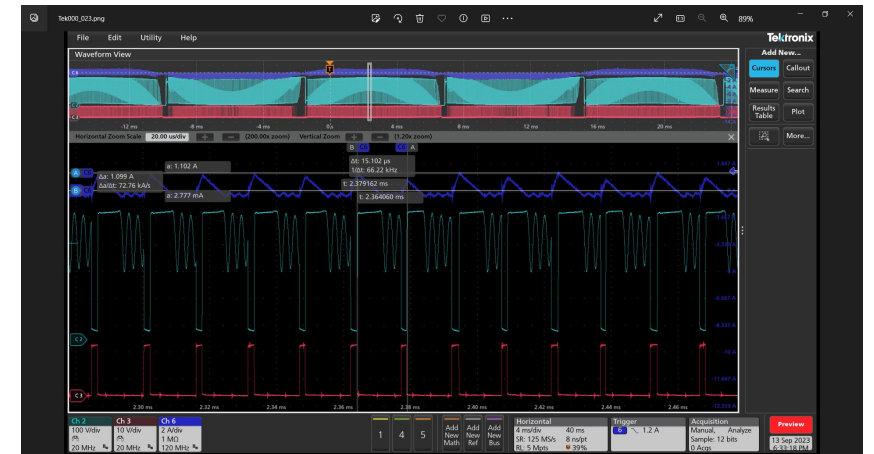
115Vac input & full load



230Vac input & full load



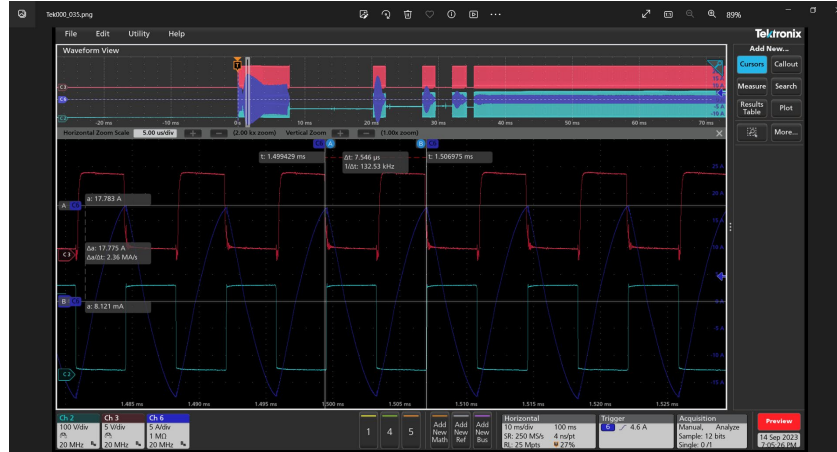
115Vac input & 1A load



230Vac input & 1A load

LLC Part Wave Form

CH1	
CH2	Low side MOSFET D-S
CH3	Low side MOSFET driver
CH4	
CH5	
CH6	Resonant current



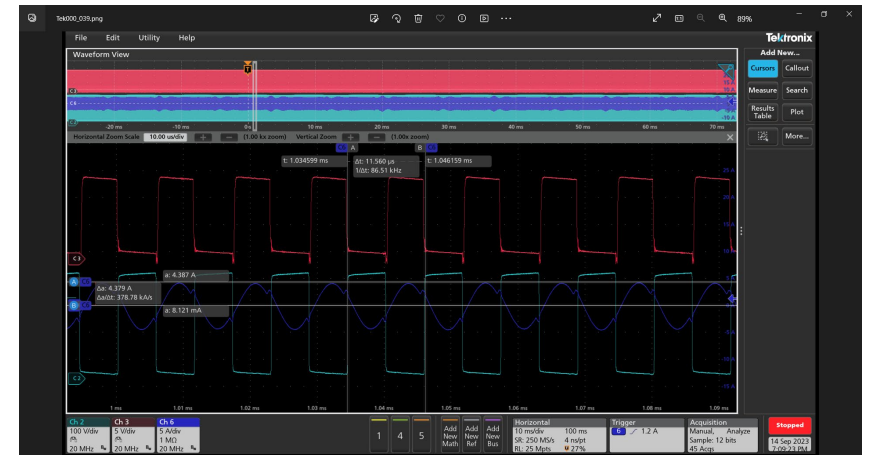
Start Up



Skip Mode 0.2A load



Light Load 1A load



Half load 10A

LLC Part Wave Form

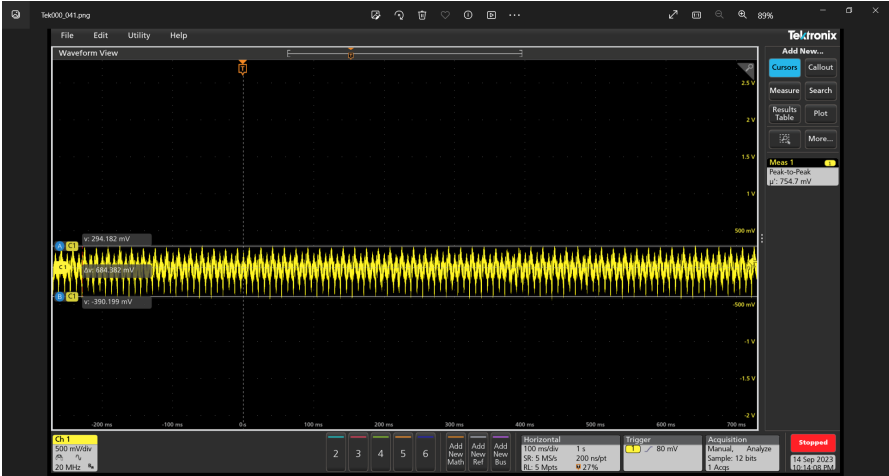
CH1	
CH2	Low side MOSFET D-S
CH3	Low side MOSFET driver
CH4	
CH5	
CH6	Resonant current



Full Load 20A

Output Voltage Ripple

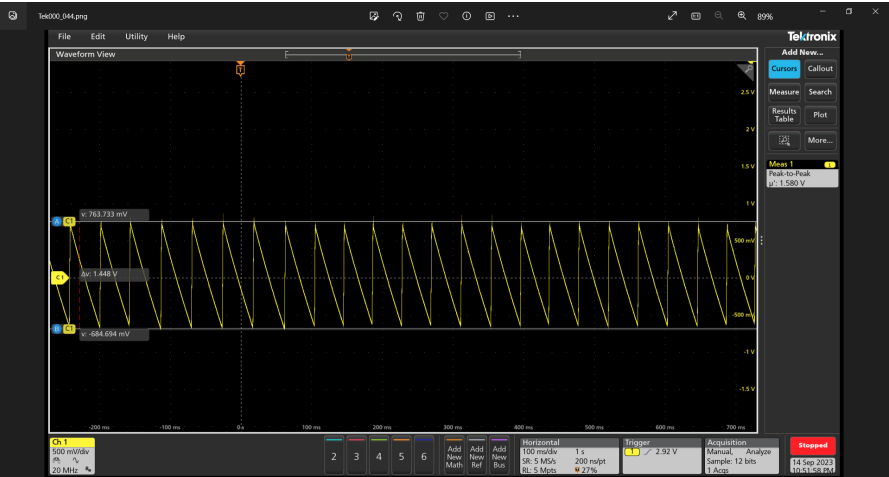
CH1	
CH2	Low side MOSFET D-S
CH3	Low side MOSFET driver
CH4	
CH5	
CH6	Resonant current



Full Load 20A



Half Load 10A



Light load 0.1A-skip mode

Highlights

- **High efficiency performance**
- OVP,SCP and OCP protection
- Open loop protection
- CC and CV mode load, with a very deep SKIP

Questions

& Answers



We are here for you now!
Ask us directly via our chat or via E-Mail.

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Alessandro.Maggioni@onsemi.com

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