DIGITAL WE DAYS 2023

HOW TO DESIGN A COMPACT AND EFFICIENT 1KW POWER SUPPLY

Partnered with onsemi

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Today's speakers

PRESENTATION
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MODERATION
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Marketing Department

Information about the Webinar

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However, you can ask us questions using the chat function.

Duration of the presentation	30 Min
Q&A:	10 – 15 Min

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AC/DC Power supply landscape

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

Industrial

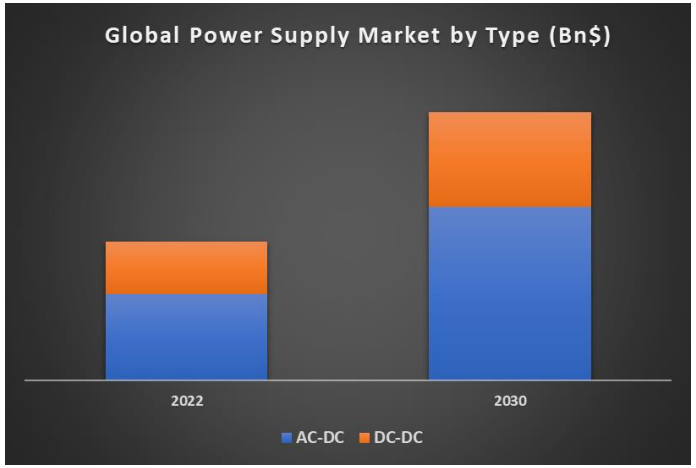
Automotive

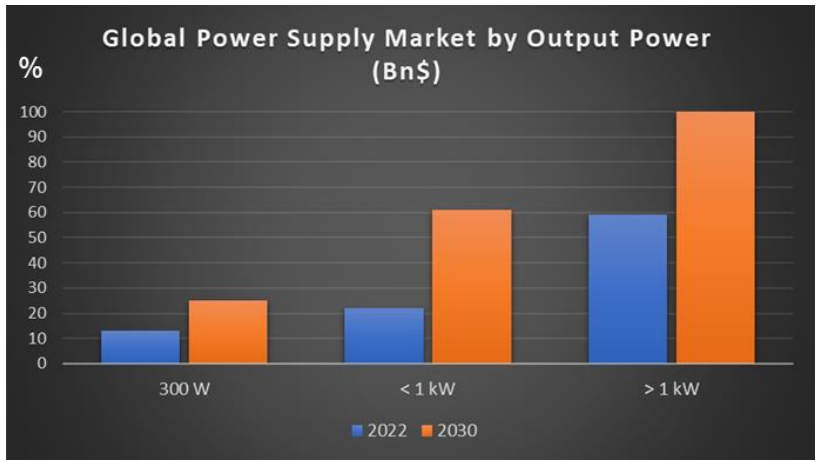
Medical

Smart cities

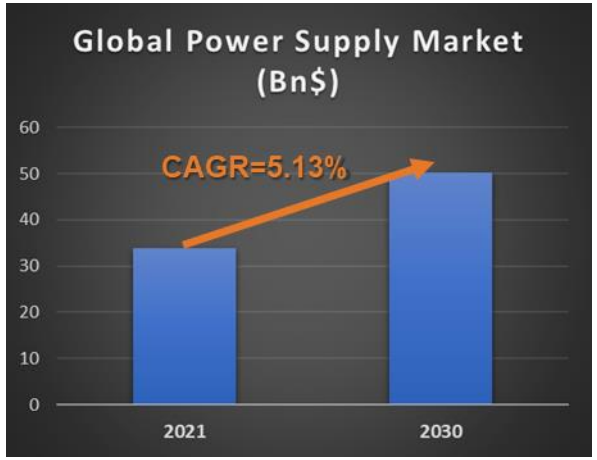
Computing & Clouds

AC-DC power supply are majority of the market





Increasing Demand with constant growth

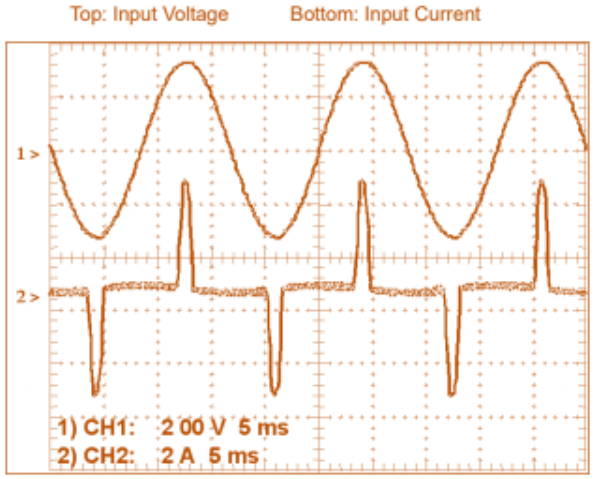


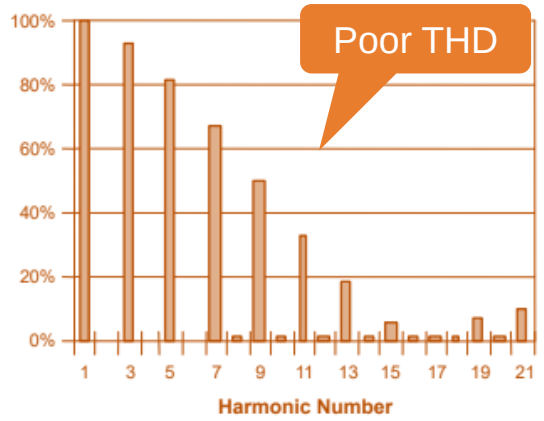
Source: Verified Market Research

PFC: Why?

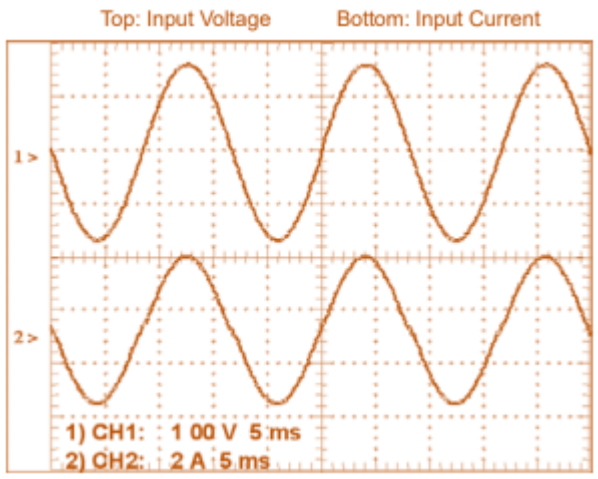
Problem…
When the power factor (load dependent) is not equal to 1, the current waveform does not follow the voltage waveform. This results not only in power losses but may also cause harmonics that travel down the neutral line and disrupt other devices connected to the line. The closer the power factor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

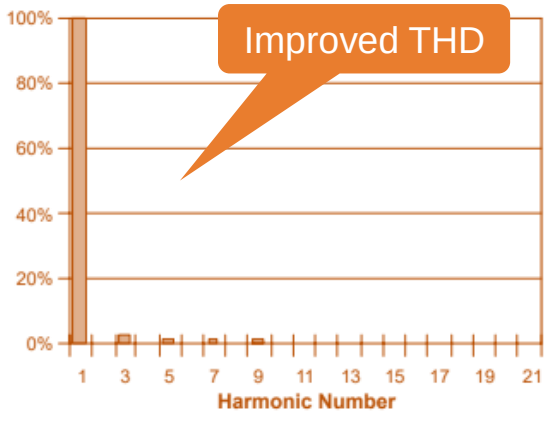
SMPS without PFC:





SMPS with PFC:





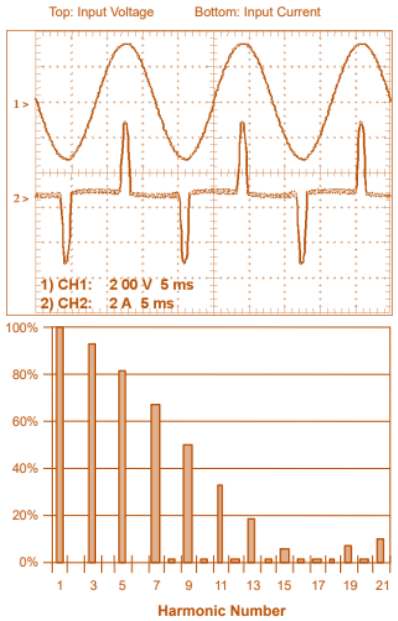
you need PFC > 75W

Source: PFC Handbook (HBD853/D)

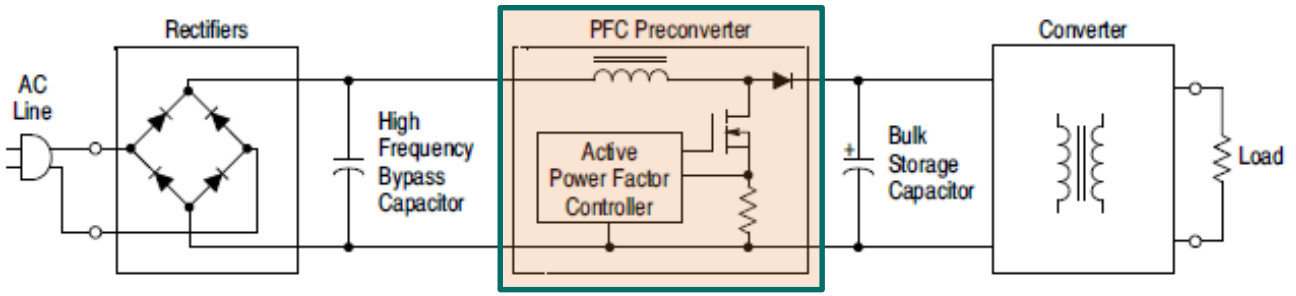
PFC Solution

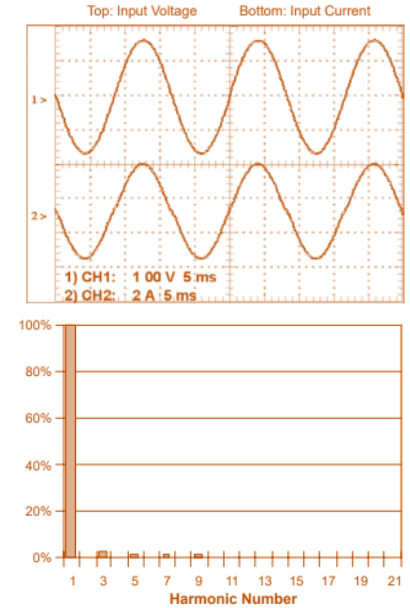
Solution:
Shape the input current to match the input voltage waveform.

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



Boost Converter:

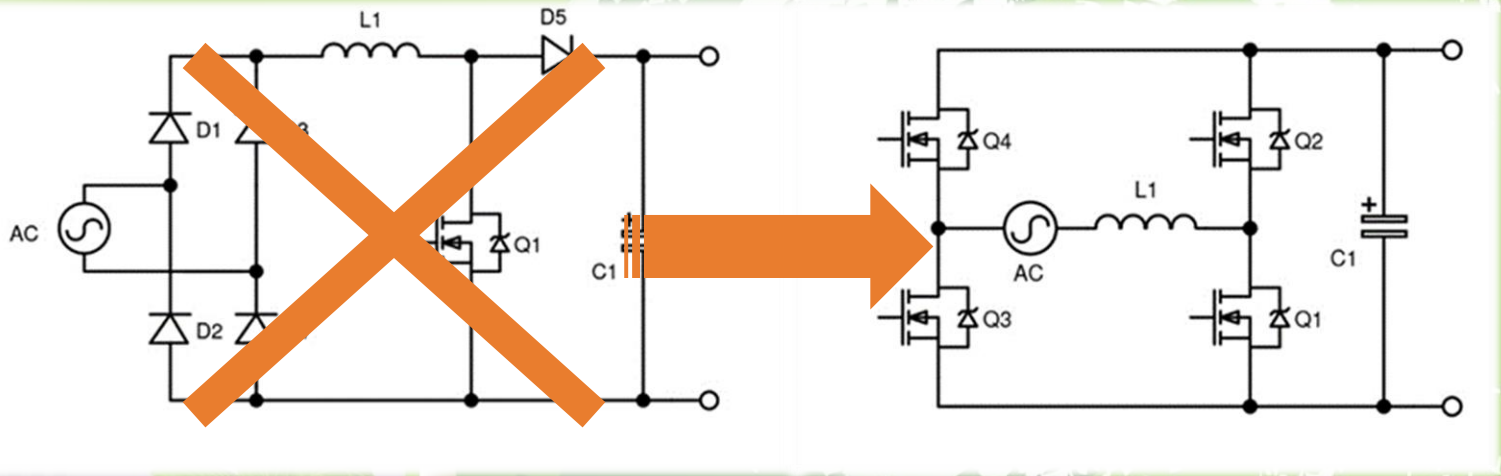


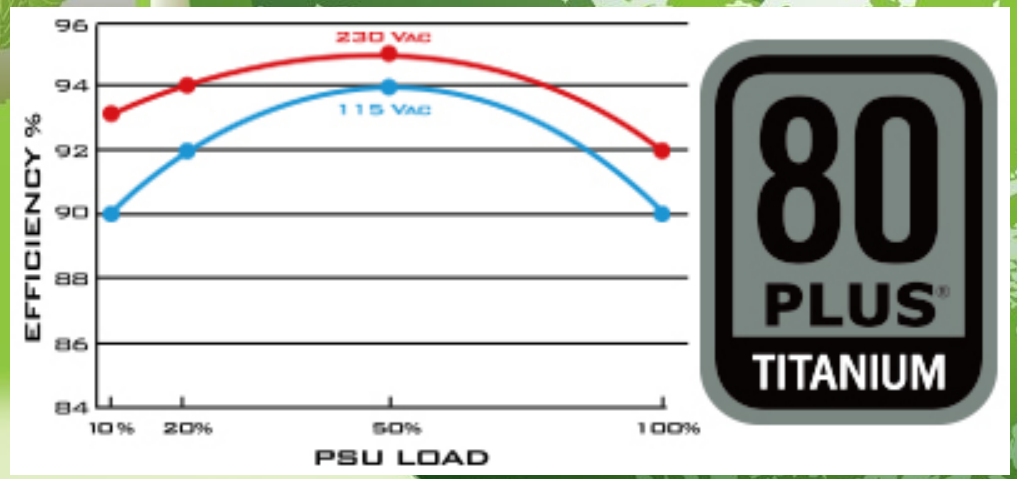


Source: PFC Handbook (HBD853/D)

High Demand for Energy-efficient Solutions

Typical PFC circuits: Conventional boost to bridgeless Totem Pole





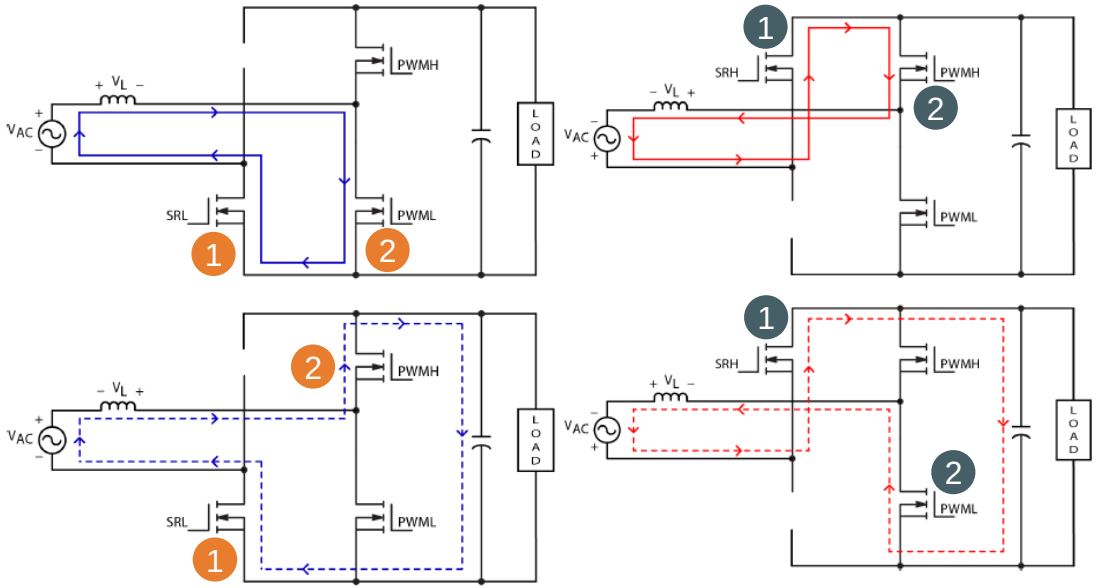
Efficiency: Bridgeless vs Bridge

Elegance = Simplicity
Simplicity = Elegance

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

PFC: Bridgeless Totem Pole

Conduction Path: 2 devices

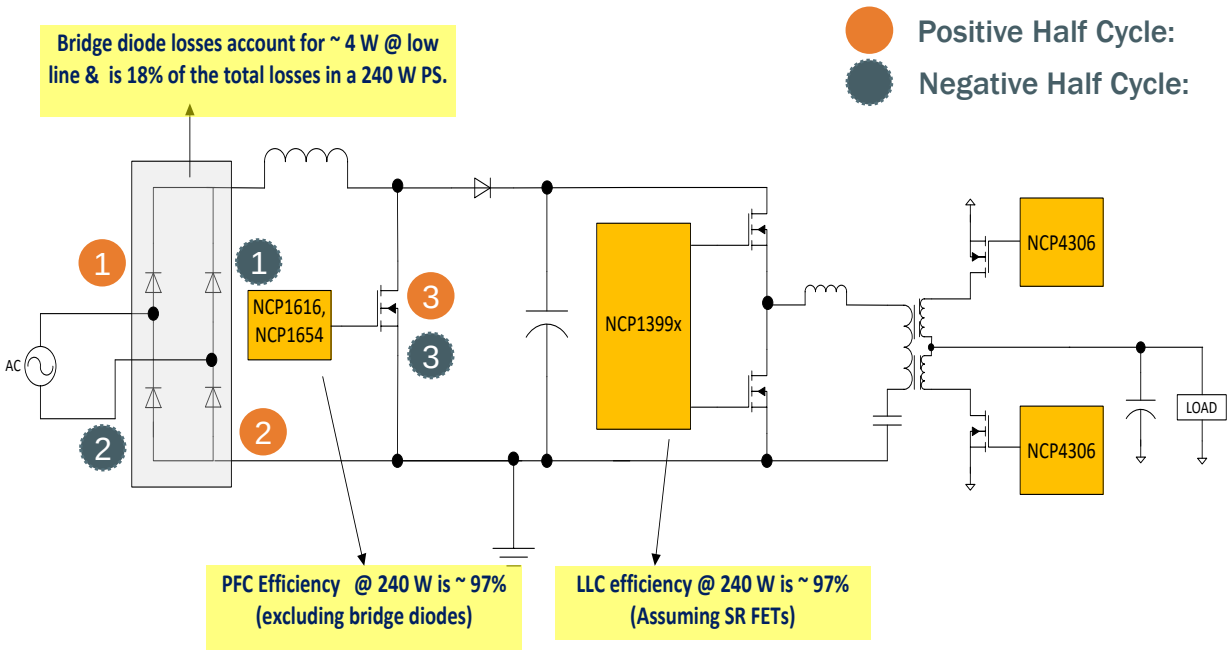


Positive Half Cycle:

Negative Half Cycle:

PFC: Bridge Diode

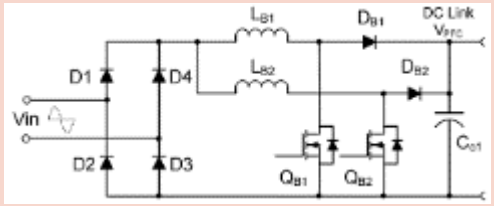
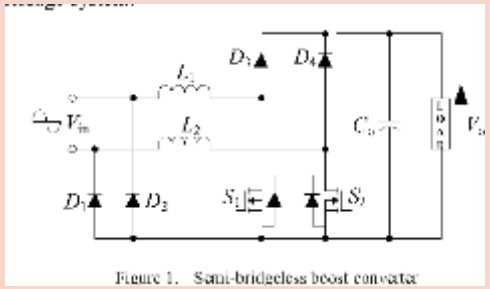
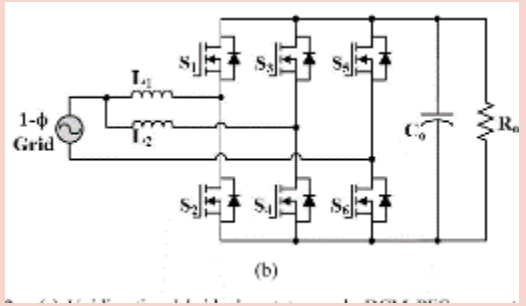
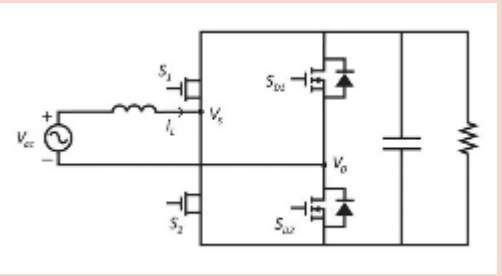
Conduction Path: 3 devices



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
		 Figure 1. Semi-bridgeless boost converter		
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	• Very straightforward • Well-known technology • Many control options	• Simple bridgeless PFC • Good efficiency above 98%	• ZCS mode with soft-switching • Higher efficiency than boost • Interleaved ripple cancellation	• Highest efficiency • Zero Qrr for GaN • Highest power density • Low component count
constrains	• Low efficiency • Lower power density	• High BOM cost • V/I sensing more complicated • High CM noise • Two large inductors	• High peak current crossing FETs • <1.5kW output power • Large EMI filter	• 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

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

Industrial: power supply, PSU, UPS…

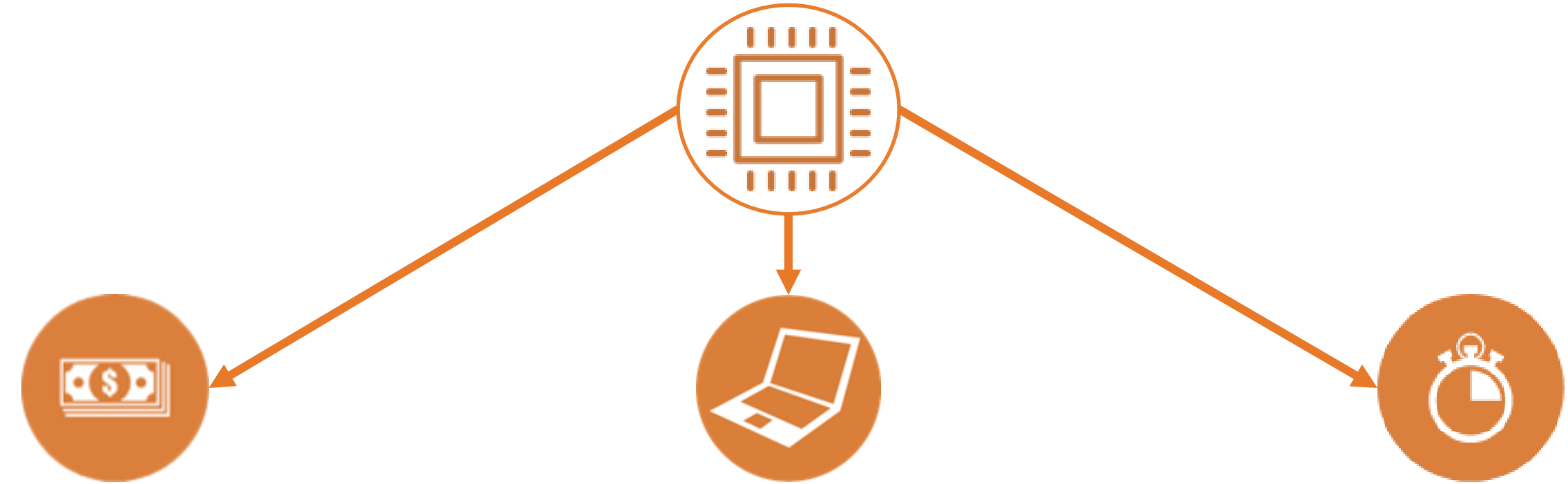
high power adapter

5G telecom power supply

external adapter power supply…

Totem Pole PFC Market Scenario – onsemi's advantages

Existing solutions on the market
MCU based



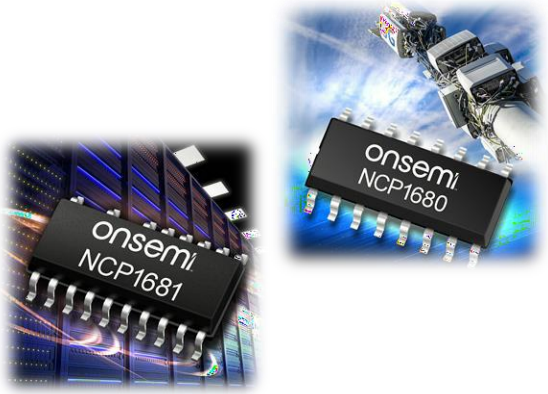
High BOM cost

Software code development

Complex design, time consuming

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

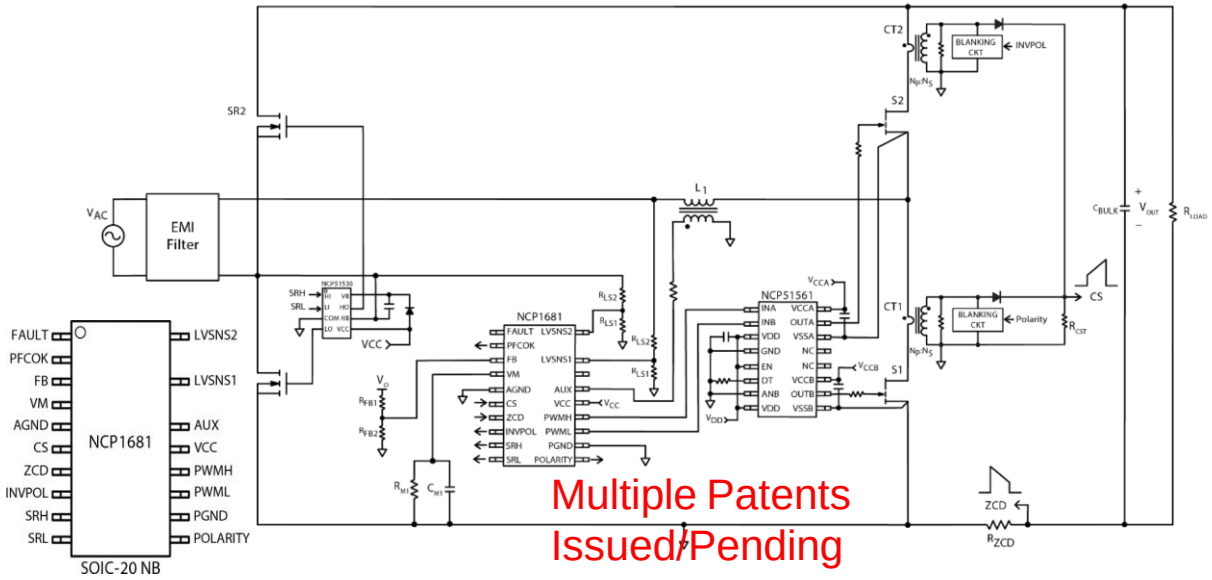
Other Features

- 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

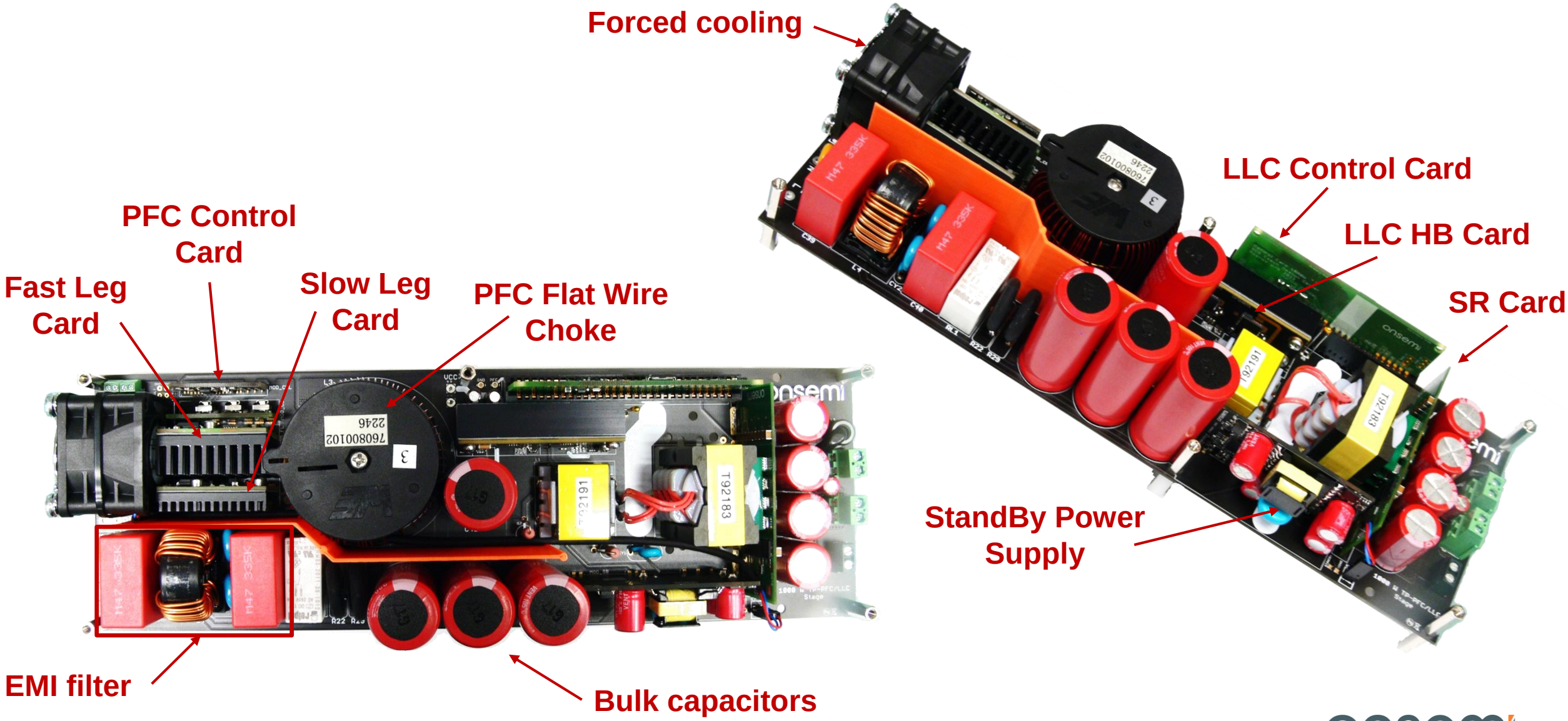
OPN	Operating Mode	F_{CCM} [kHz]	V_{ILIM} [V] LL / HL	$V_{ZCD(ARM)}$ [mV]
NCP1681AA	CCM	65	1 / 1	150
NCP1681AB	CCM	95	1 / 1	150
NCP1681BA	Multi-Mode	65	1.4 / 0.84	300

1kW Universal Input 48V Output Power Supply

Power Stage specification

- **Inputs:**
  - Input Voltage Range: 90 – 265 Vac
  - Line Frequency Range: 47−63 Hz
- **Output:**
  - Output voltage: 48 Vdc
  - Max output current: 21 A
- **Dimensions:**
  - 278 × 92.3 × 50 mm
- **Used controllers:**
  - PFC controller: NCP1681
  - LLC controller: NCP13994
  - SR controller: NCP4306, NCP4307
  - QR controller: NCP1343
  - Precision reference: NCP431
  - Gate Driver: NCP51561
  - LDO regulator: NCV8730, NCP718
- **Switching devices:**
  - GaN transistor with Integrated Driver
  - SR transistor: FDMS86202ET120
    NTMFS5C670N
  - Slow Leg transistor: NTMT064N65S3H
- **Highlights:**
  - Main Board PCB 2-layers only
  - Modular concept
  - PFC Flat Wire inductor
  - Bridgeless PFC, GaN technology
  - LLC 300+ kHz switching frequency
  - Synchronous rectifier

1kW TP PFC-LLC Power Stage photograph



Key Components

NCP13994 – High Performance Current Mode LLC Controller

Value Proposition

The NCP13994 is a high performance controller for half bridge LLC resonant converters supporting operation over a wide range of bulk or line voltages. Current mode controller and enhanced light load efficiency makes it ideal for high power designs. The controller also implements proprietary light load and quiet skip mode operation that improve light load efficiency, reduce no load power consumption as well as significantly reduce audible noise.

Unique Features

- 700 V HV Startup & Driver
- High Frequency 20 kHz to 750 kHz
- Light Load Mode
- X2 Discharge
- Quiet Skip Mode
- Option for Longer Dead-time Max
- 3-Level OCP

Benefits

- Enhanced Robustness
- Support UHD Design with GaN
- <150 mW No Load w/ PFC or <270 mW @ 120 mW Load w/ PFC
- Reduced Audible Noise
- Wide Dimming Range for LED
- LED Fault Protection

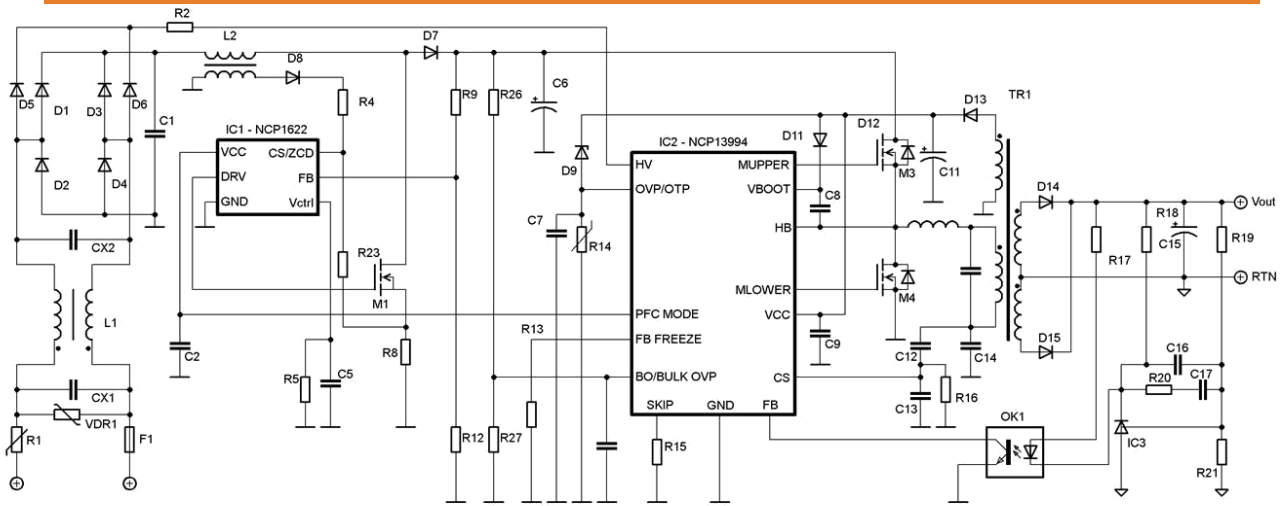
Other Features

- Line BO & OVP Protection
- Clamped Drive Output
- VCC rated to 30 V
- PFC Stage Operation Control According to Load Conditions
- Automatic Dead-time Max Clamp
- Safety Design for Pin-Pin Short and Open/Short

Market & Applications

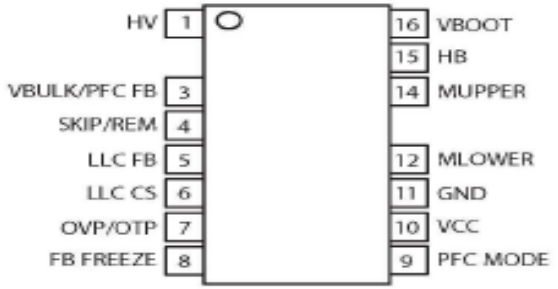
- High Power Gaming/Computing Adapter
- TV Power
- LED Lighting
- Industrial

Typical Application Schematic



Ordering & Package information

- NCP13994xy



NCP1342/3 High Frequency QR Controller

Value Proposition

The NCP1342/3 is a highly integrated quasi-resonant flyback controller capable of controlling rugged and high-performance off-line power supplies as required by adapter applications. Additionally, the NCP1343 integrates power excursion mode (PEM) to minimize transformer size in designs requiring high transient load capability

Unique Features

- Valley Switching Operation with Valley Lockout
- New Quiet-Skip Technology
- Min Peak Current Modulation for Rapid Frequency Foldback (RFF)
- Power Excursion Mode (PEM) (**NCP1343**)

Benefits

- Maximizes the efficiency over the entire power range
- Ensures Operation Outside Audible Range
- Fast reduction of switching frequency for improved light load efficiency
- Minimize transformer size for peak power applications

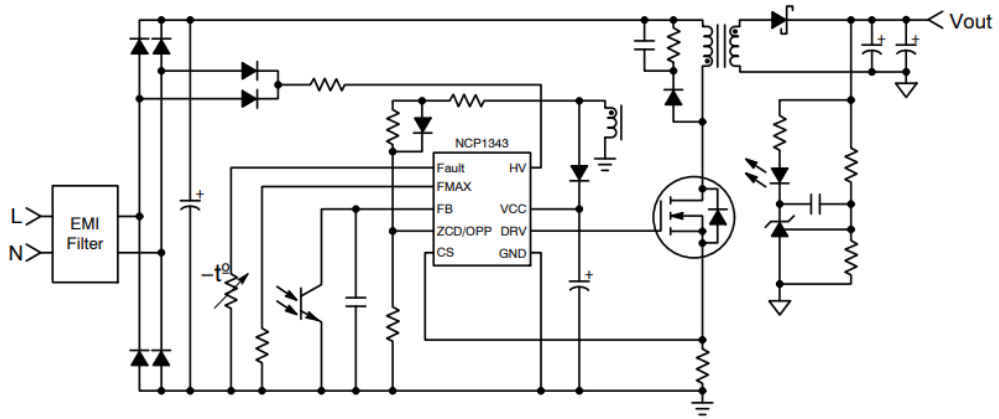
Other Features

- High voltage startup circuit with Integrated Brownout
- Valley Switching Operation with Valley Lockout
- Frequency Foldback with 25 kHz Minimum Frequency
- V_{CC} Overvoltage Detection
- NTC Compatible Fault Pin
- Soft-Start for Smooth Start-up Operation
- High Drive Capability: -500 mA / +800 mA

Market & Applications

- Low/Medium USB PD Adapters
- Notebook Computer Adapters

Typical Application Schematic



Package information

- SOIC-8 and SOIC-9
- Pin compatible with NCP1340

(Top Views)

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.

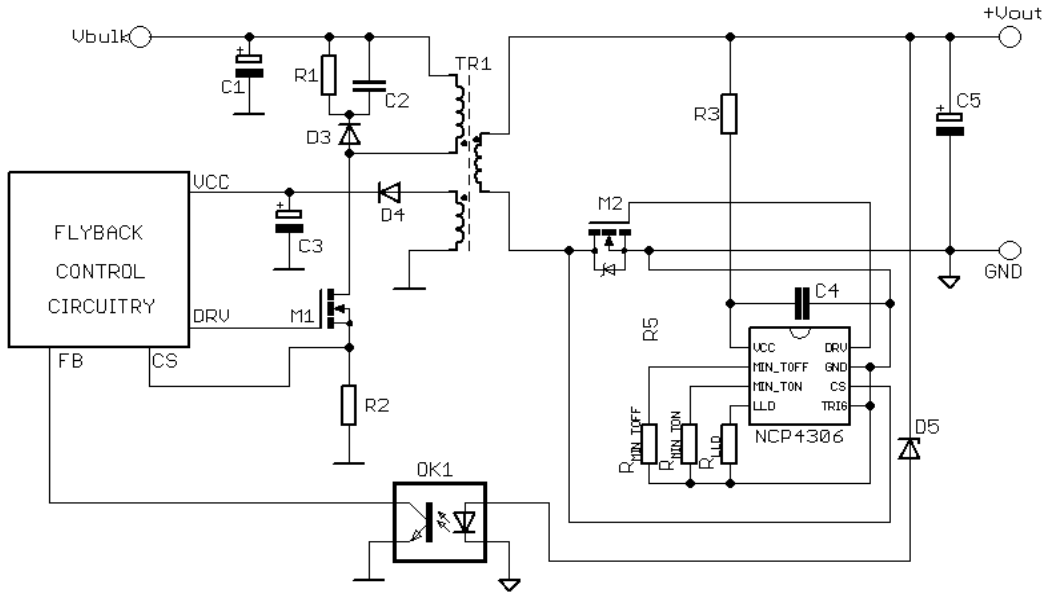
Unique Features

- 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

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



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

Package information

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

NCP4307 Synchronous Rectification Controller

Value Proposition

The NCP4307 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, active clamp flyback and forward. Self-supply capability and dual VCC pin option optimizes designs for wide VOUT range applications, such as USB PD, and can be configured for high side or low side operation.

Unique Features

- **Self-supply** capability
- **Dual V_{CC}** pins
- **Positive dV/dt detection**
- Precise True Secondary Zero Current Detection
- Internal Min. on/off-time blanking periods

Benefits

- Enable high side configuration and low V_{OUT} without aux supply
- Selects optimal V_{CC} source to minimize power loss
- For **ACF** Design, detects proper ACF to DCM conduction phase
- Allows proper timing of SR MOSFET turn on and off
- Reduce ringing affects by parastics

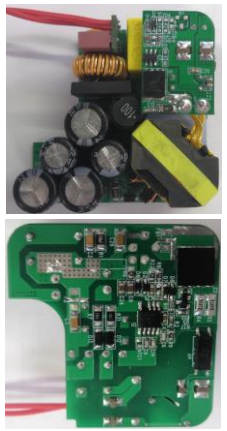
Other Featues

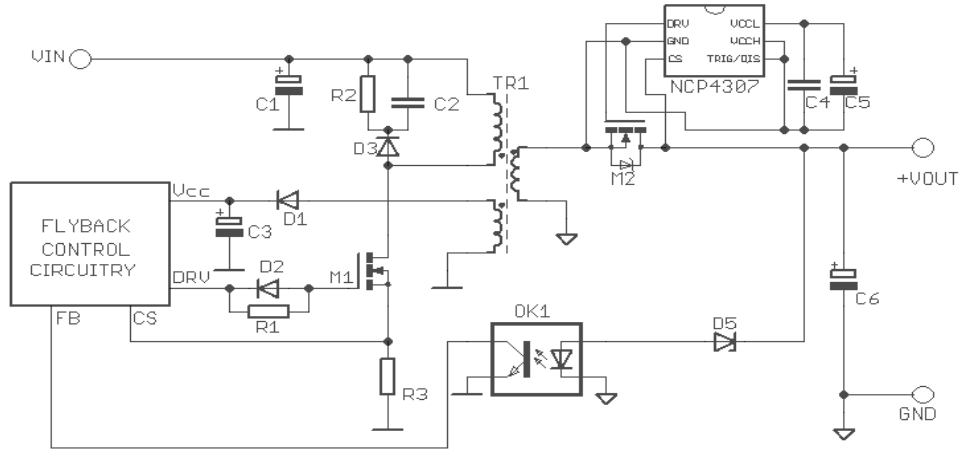
- Rugged 200 V max. current sense pin
- 35 V wide V_{CC} range
- High Drive Capability: -7 A / +2 A
- Light load detection to improve light load efficiency

Market & Applications

- USB PD Adapters
- High Power Density AC-DC Power Supplies
- DC-DC Modules & Telecom Power Supplies

Typical Application Schematic





65W – NCP1345PD65WGEVB

Ordering & Package information

OPN	Topology	Package
NCP4307FASNT1G	Flyback	TSOP6
NCP4307FBSNT1G	Flyback	TSOP6
NCP4307AASNT1G	Active Clamp Flyback	TSOP6
NCP4307WASNT1G	Forward	TSOP6

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.

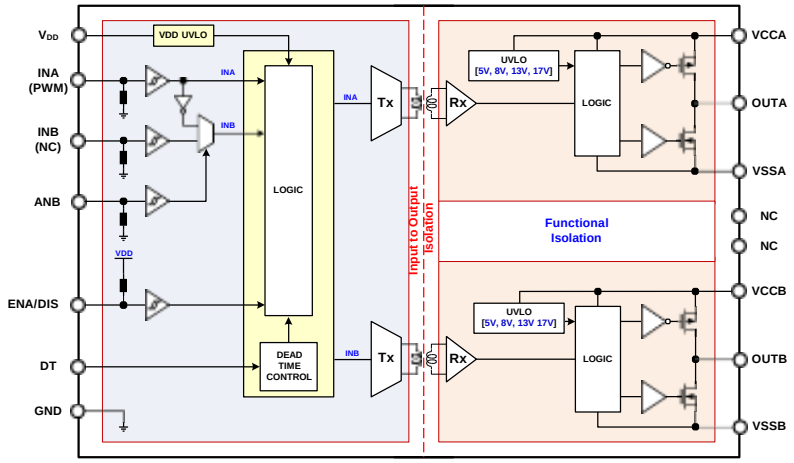
Unique Features

- Input side isolated from output drivers by 5-kVRMS isolation barrier
- **36 ns Prop Delay & 8 ns Delay Match**
- **>= 150 V/ns dV/dt Immunity**
- 4.5-A/9-A Typical Source/Sink Current Capability

Benefits

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

Device Pin-Out



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

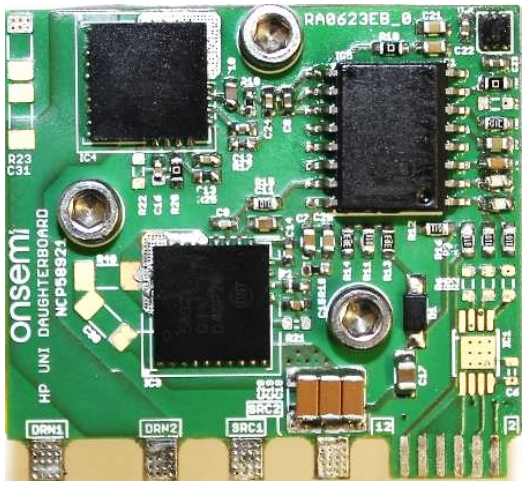
- Isolated Converters in Offline AC-to-DC Power Supplies
- Motor Drive and DC-to-AC Solar Inverters
- HEV and EV On-Board chargers

Ordering & Package information

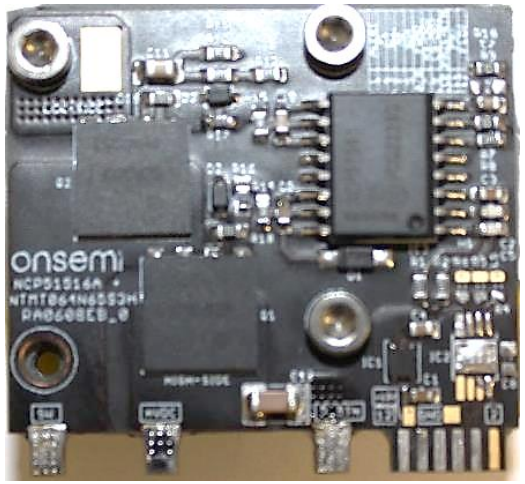
- SOIC-WB16
- OPN : NCP51561xyDWR2G
- x: UVLO level
- y: Enable/Disable

Totem Pole PFC Stage

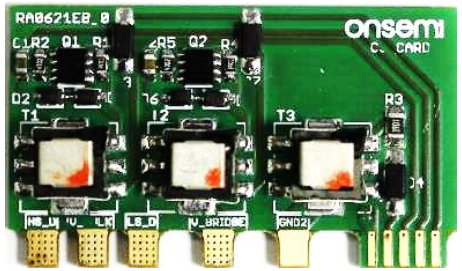
TP PFC Daughter Cards photographs



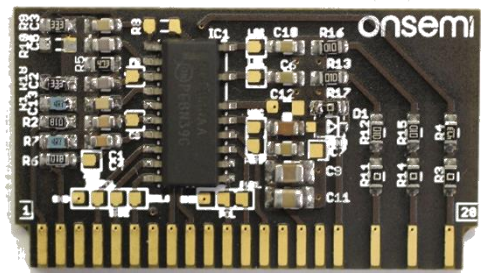
Fast Leg Card



Slow Leg Card

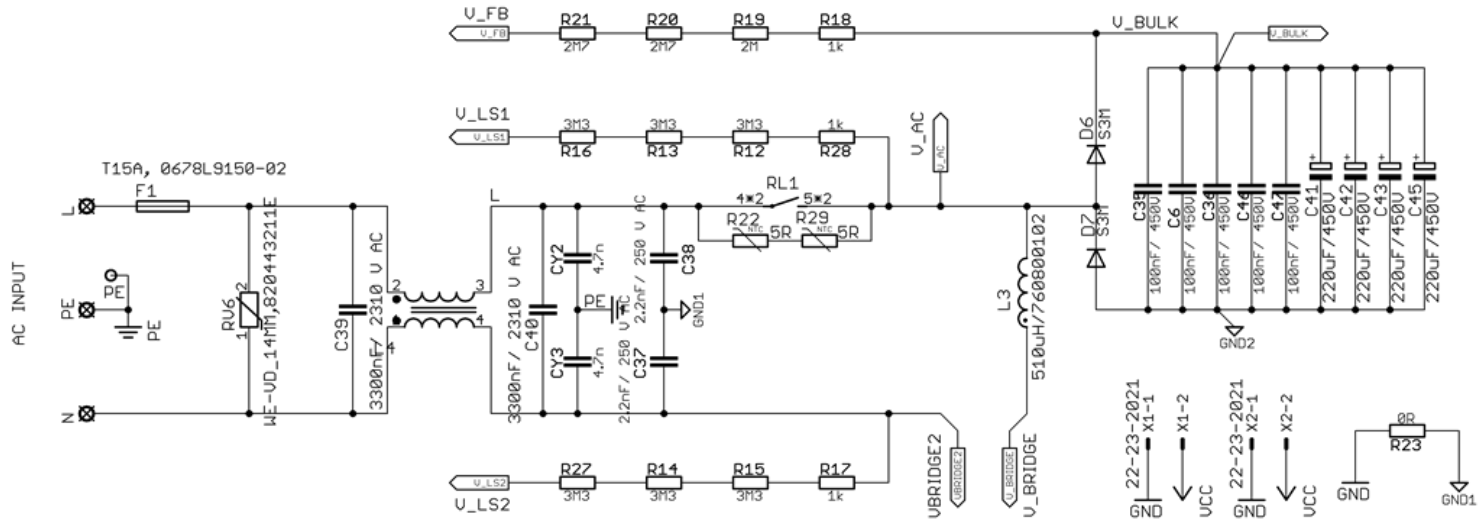


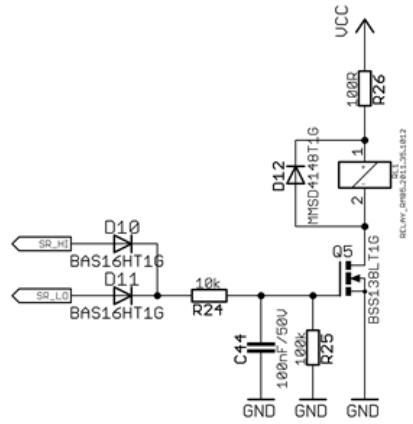
Control Card

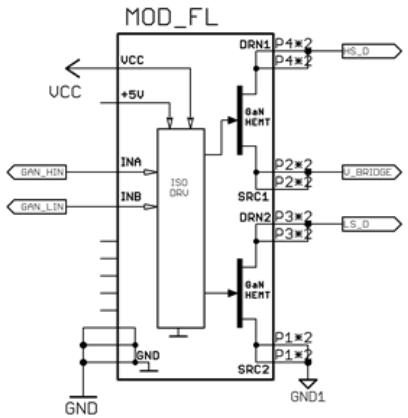


Current Sense Card

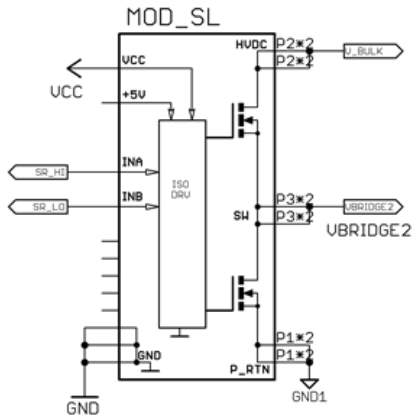
Schematic diagram of Totem Pole PFC Stage



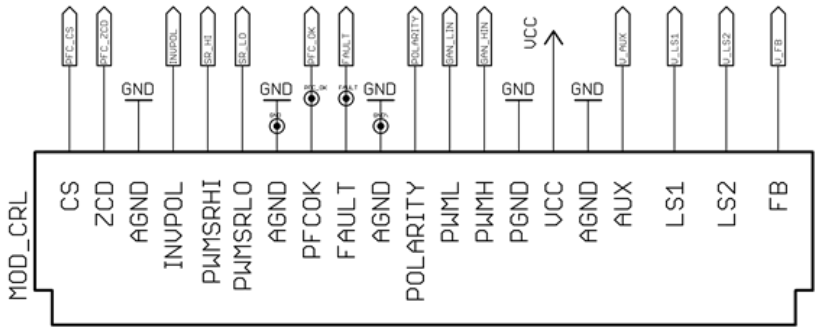




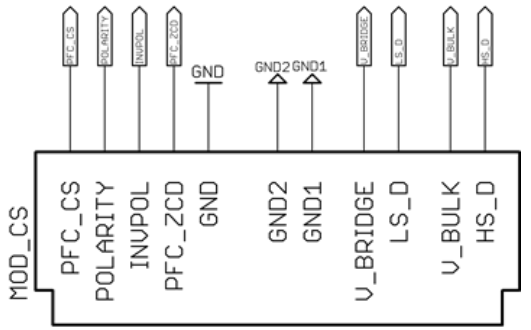
FAST LEG CARD



SLOW LEG CARD

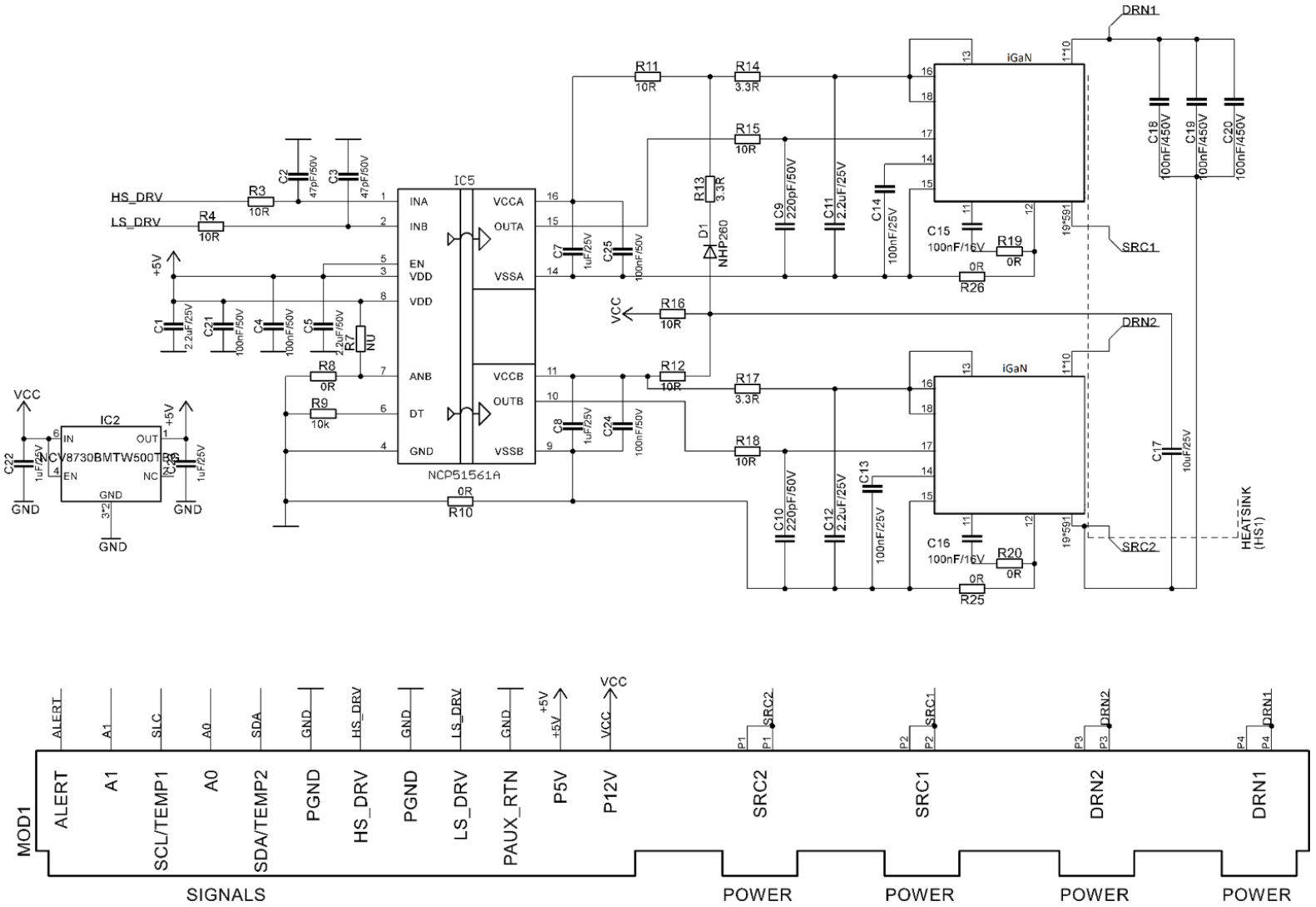


CONTROL CARD



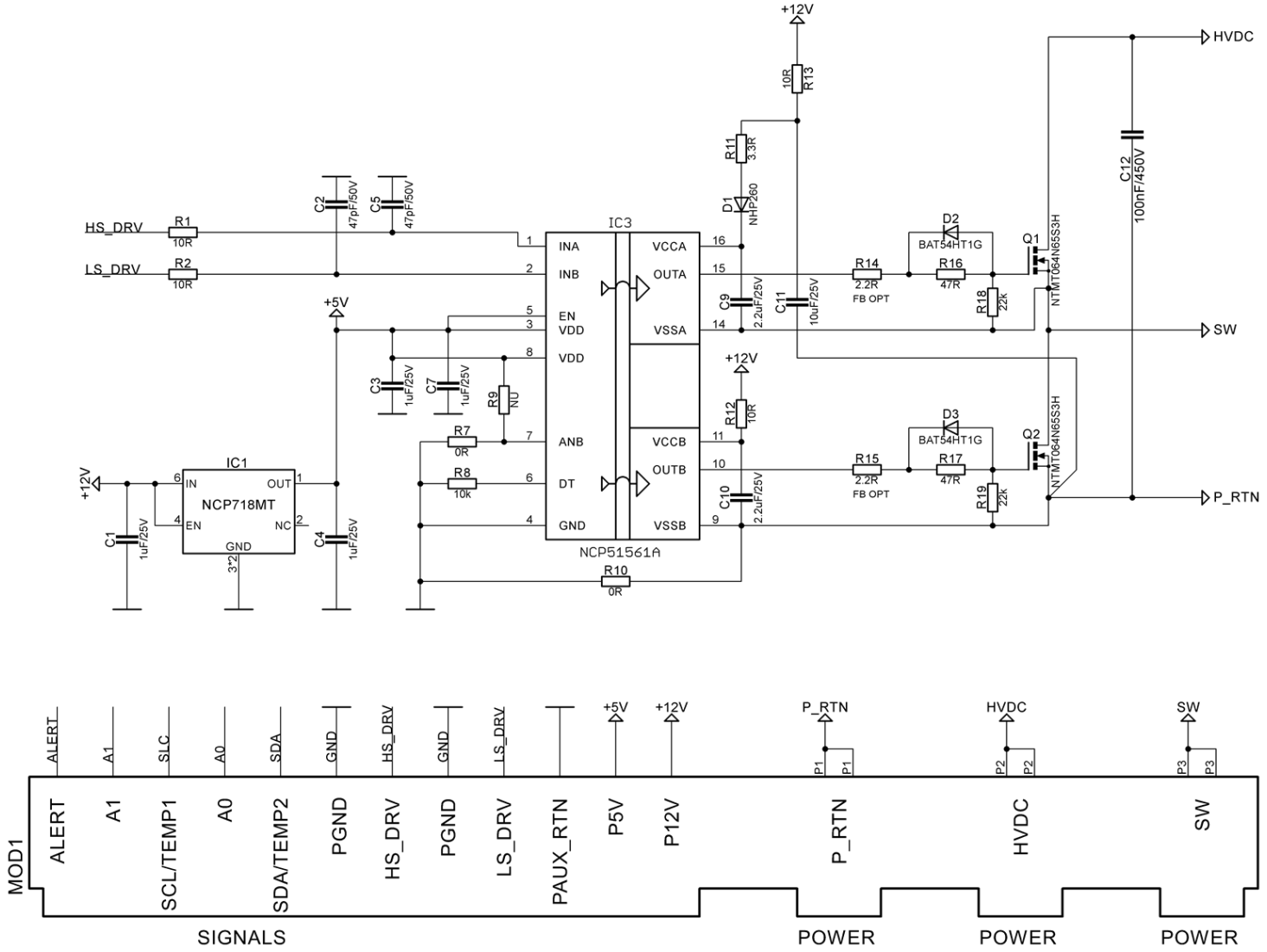
CS CARD

Schematic diagram of TP PFC Fast Leg Card



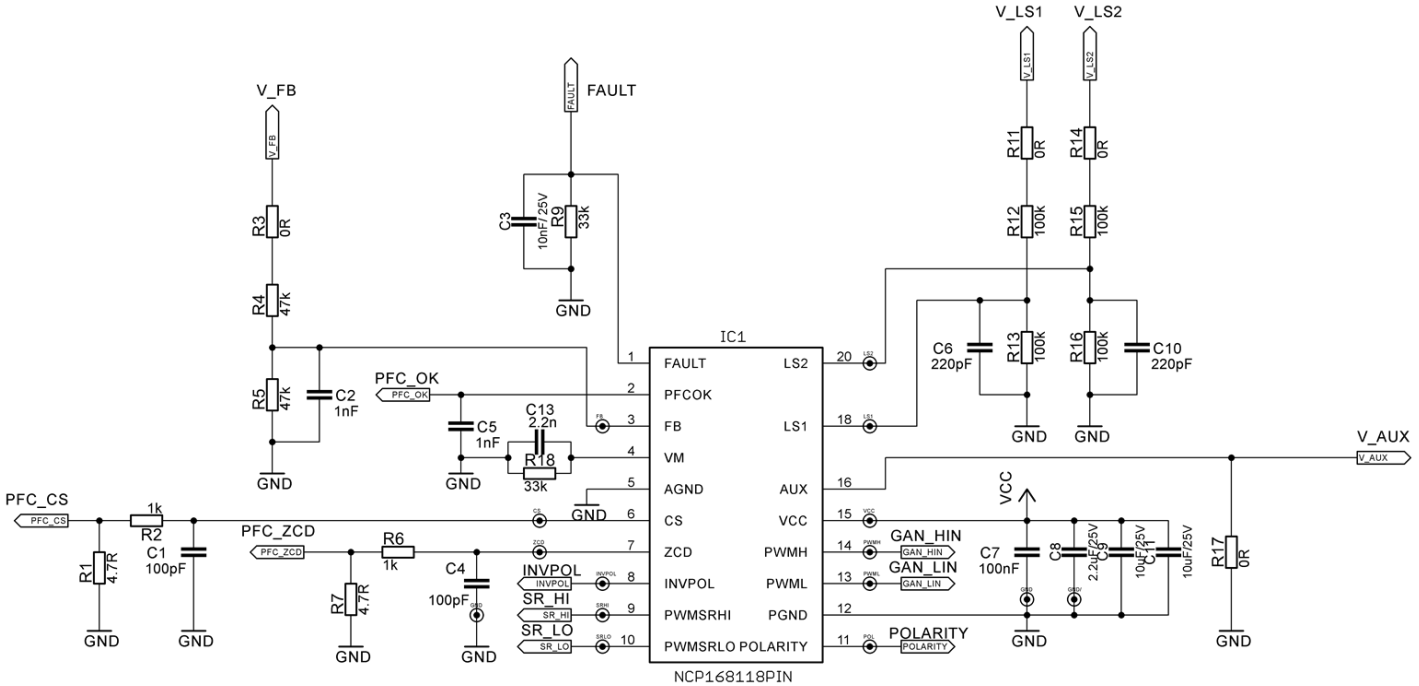
- HB Fast Leg Stage based on 650V 50 mΩ 30A GaN HEMT with Integrated Driver
- NCP51561 - isolated dual−channel gate drivers with 4.5−A/9−A source and sink peak current respectively

Schematic diagram of TP PFC Slow Leg Card



- HB Slow Leg Stage based on NTMT064N65S3H – Power MOSFET 650 V, 64 mΩ, 40 A, TDFN4 8X8 2P
- NCP51561 - isolated dual−channel gate drivers with 4.5−A/9−A source and sink peak current respectively

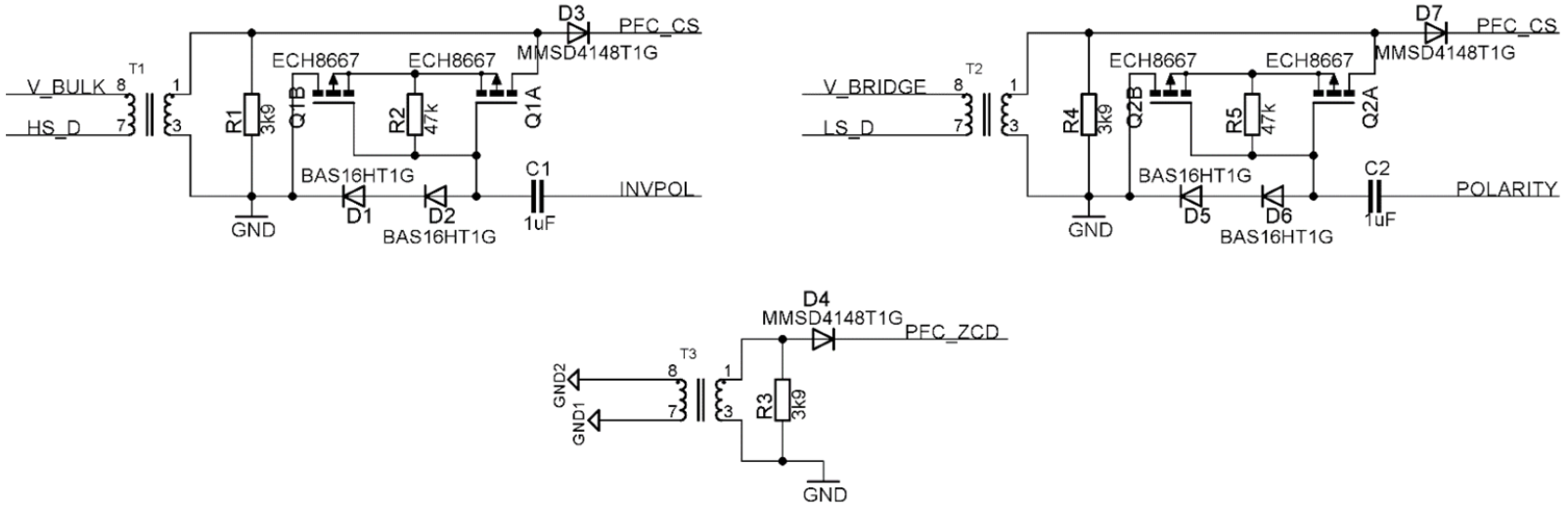
Schematic diagram of TP PFC Control Card

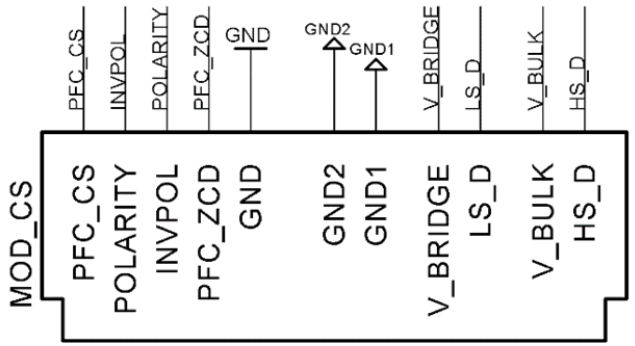


- NCP1681 - is a fixed frequency, Continuous Conduction Mode (CCM) Power Factor Correction (PFC) controller IC designed to drive the bridgeless Totem Pole PFC topology.

- NCP1681 Features:
  - AC line monitoring circuit & AC phase detection
  - Multi-mode operation
  - Brownout detection
  - Frequency foldback
  - Skip mode
  - PFCOK Indicator

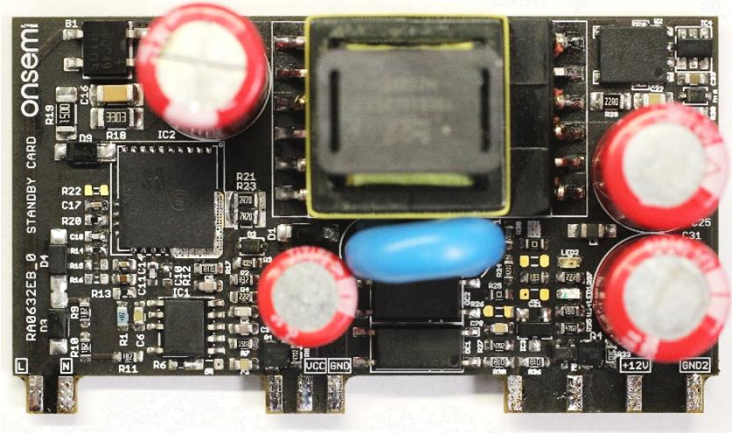
Schematic diagram of TP PFC Current Sense Card



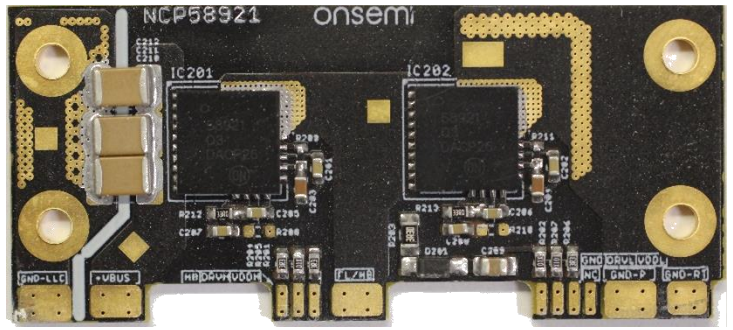


LLC Stage

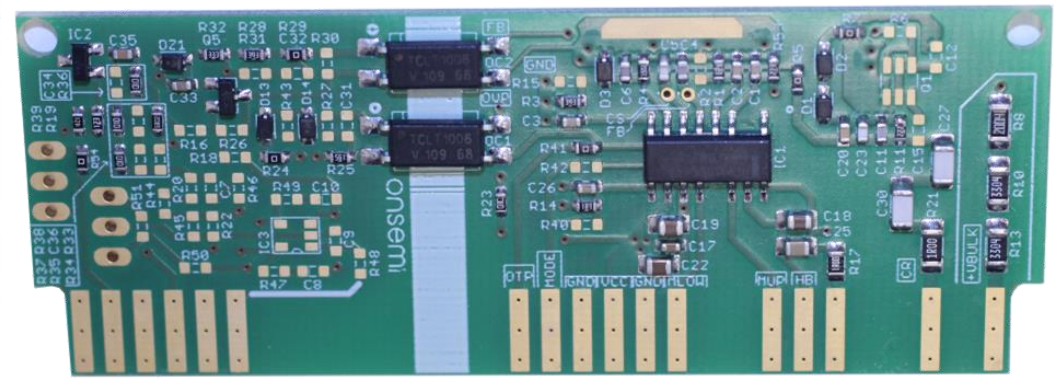
Daughter Cards photographs



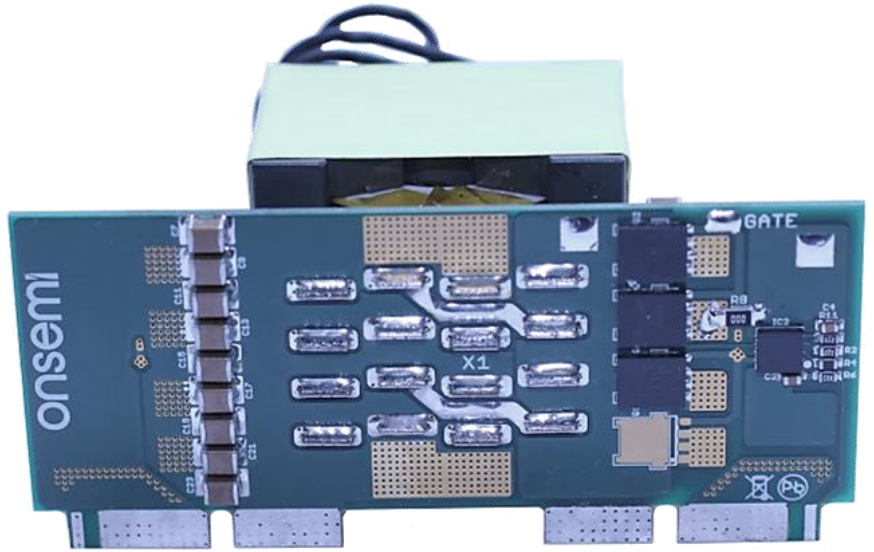
StandBy Card



LLC Half Bridge Card

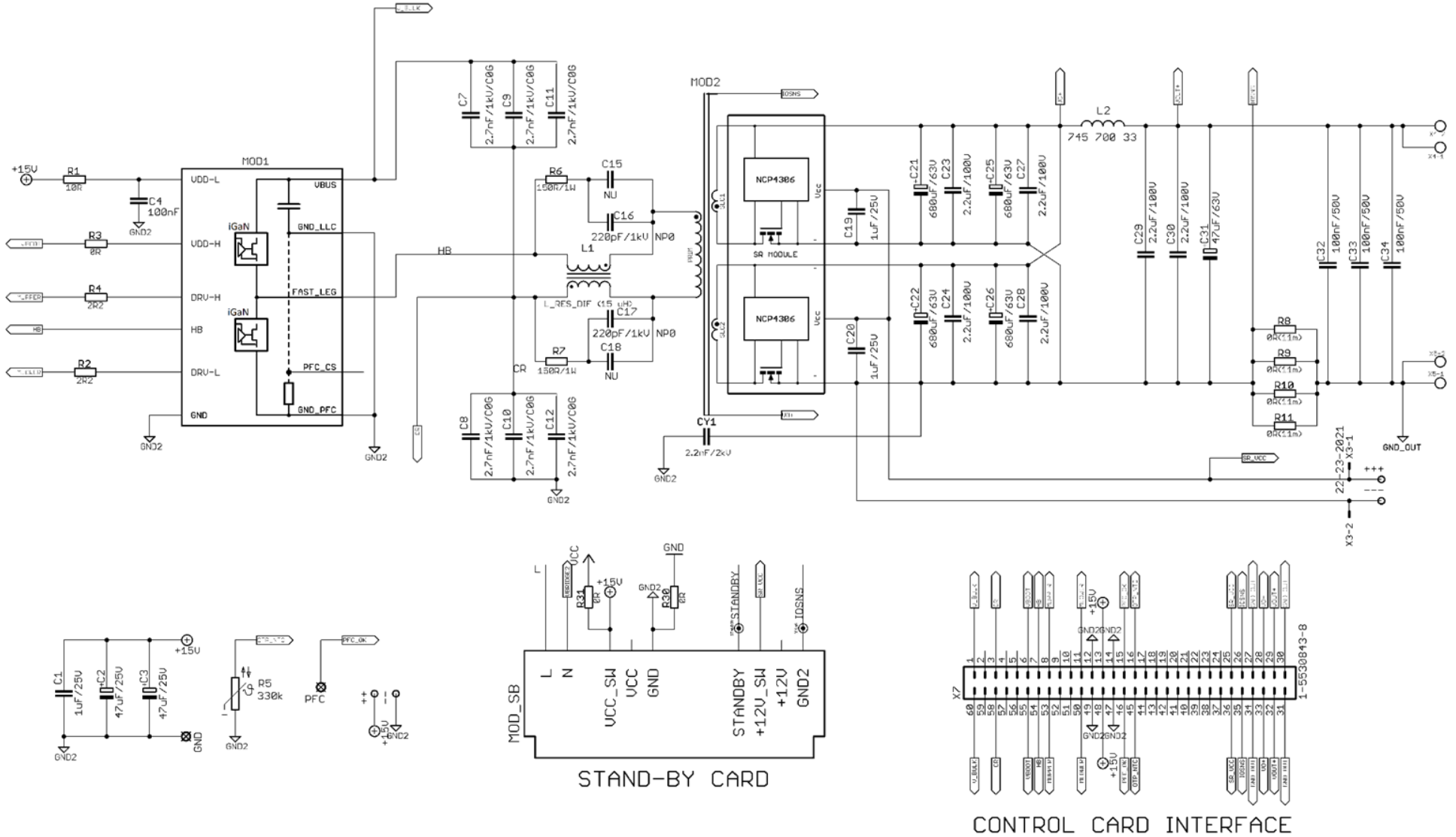


LLC Control Card

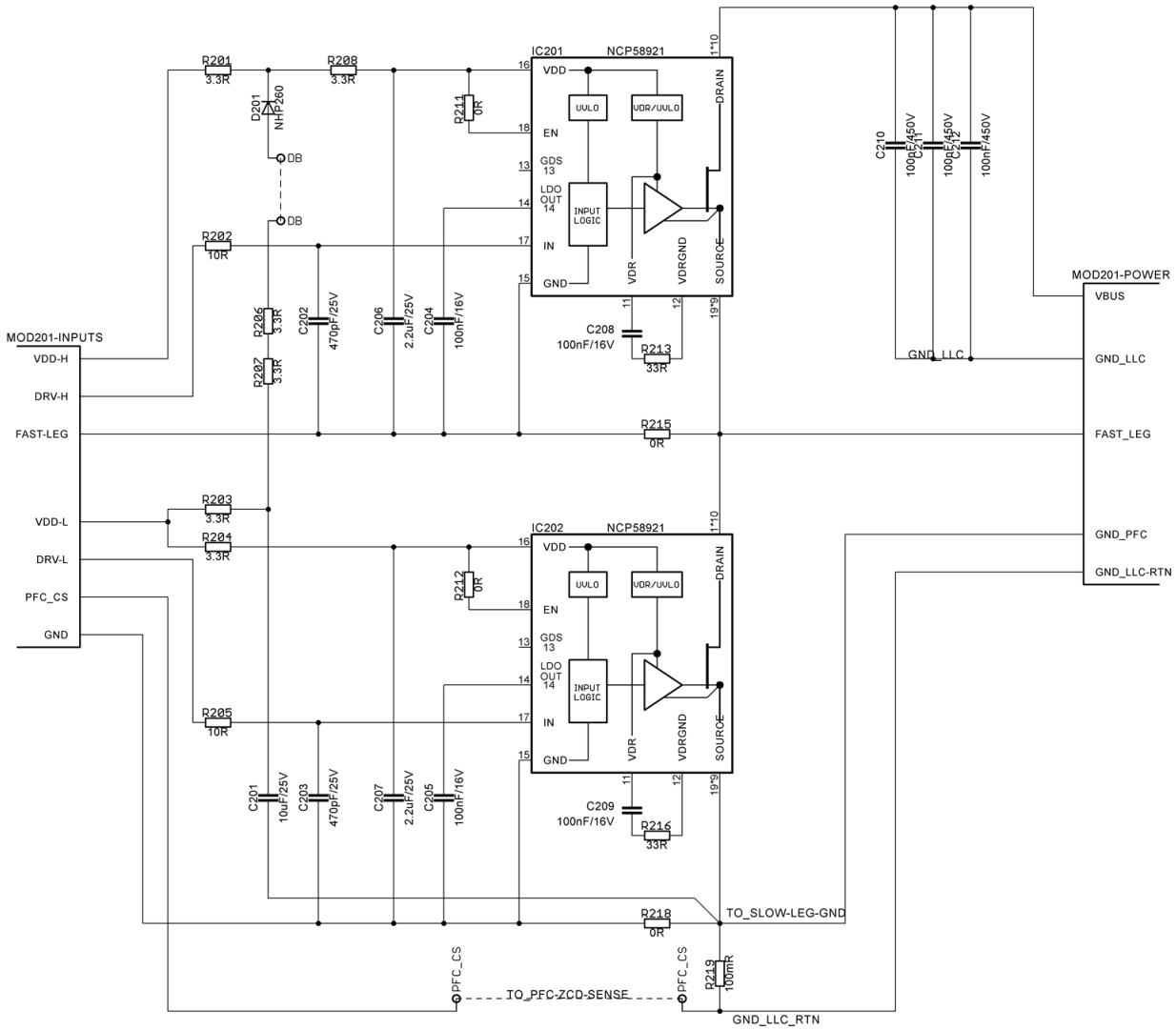


SR Card

Schematic diagram of LLC Stage

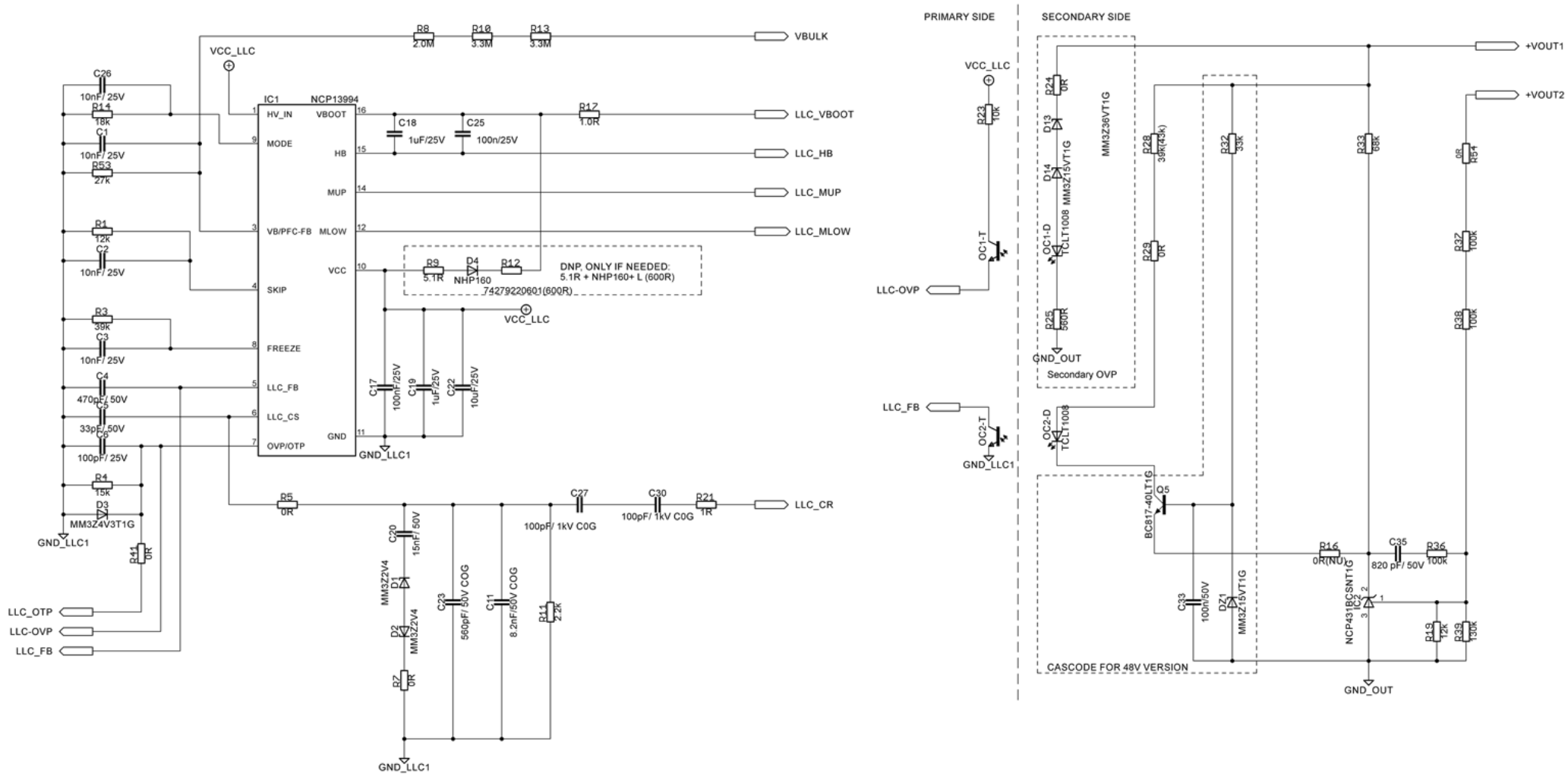


Schematic diagram of LLC Half Bridge Card



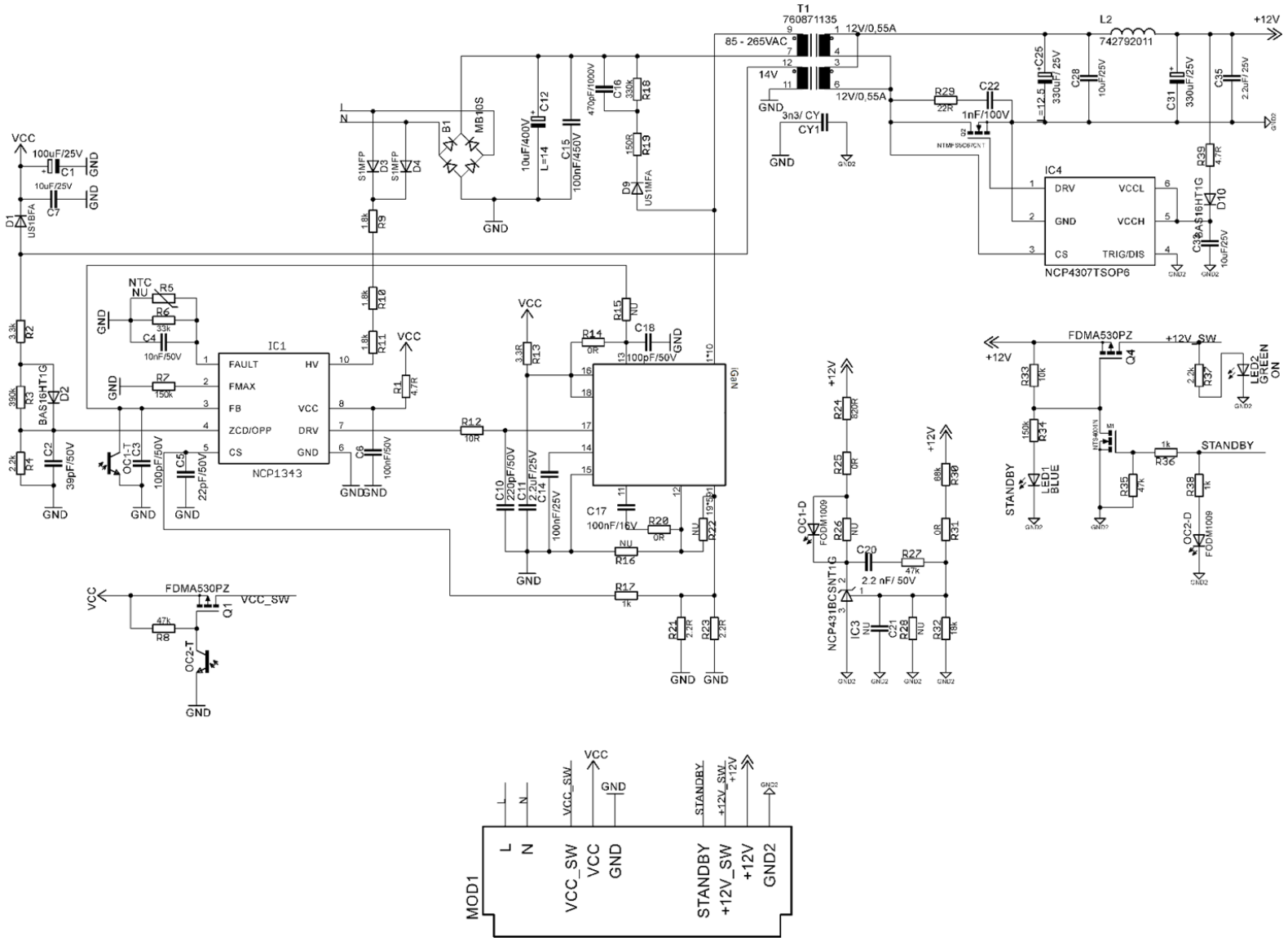
- HB Stage Based on 650V 50 mΩ 30A GaN HEMT with Integrated Driver
- High side supply using boot strap circuit
- Driving signal is ensured by insulated driver NCP51561

Schematic diagram of LLC Control Card



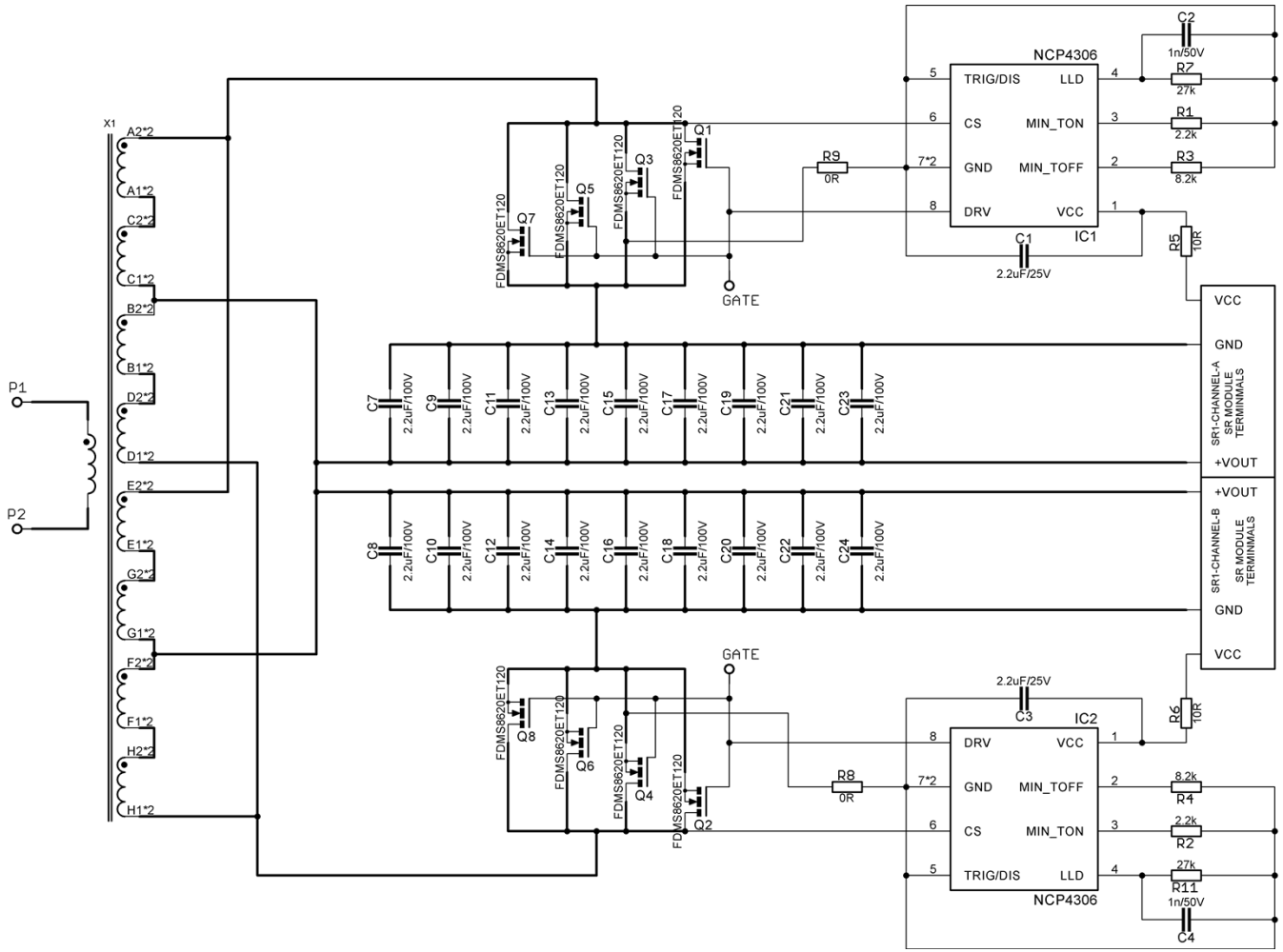
NCP13994 - current mode controller for half-bridge resonant converters

Schematic diagram of StandBy Card



- Main Power switch - 650V 150 mΩ 11A GaN HEMT with Integrated Driver
- SR MOSFET - NTMFS5C670N - 60 V, 7 mΩ, 71 A, DFN5 5x6
- NCP1343 - a quasi−resonant flyback controller
- NCP4307 - a synchronous rectification MOSFET controller

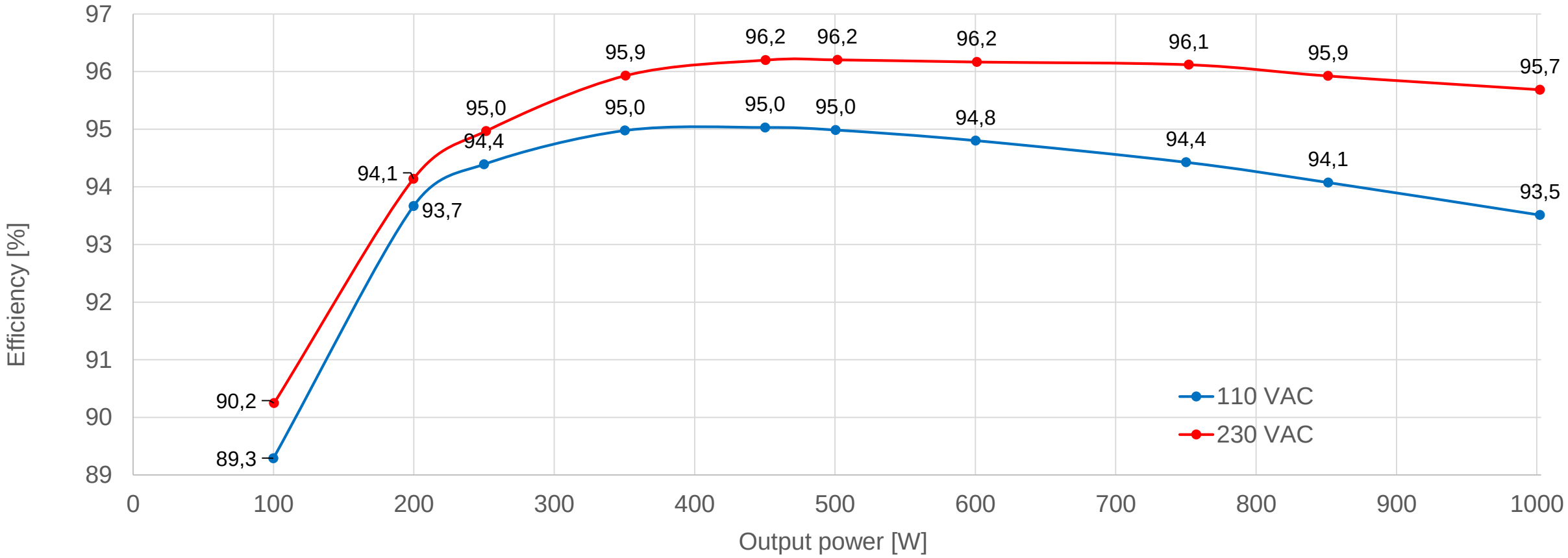
Schematic diagram of SR Card



- SR MOSFET - FDMS86202ET120 - 120 V, 7.2 mΩ, 102 A, Power 56
- NCP4306 - a synchronous rectification MOSFET controller
- NCP4306 Features:
  - Self−Contained Control of Synchronous Rectifier in CCM, DCM and QR for Flyback or LLC
  - Typically, 15 ns Turn off Delay from Current Sense Input to Driver
  - 7 A / 2 A Peak Current Sink / Source Drive Capability
  - Up to 35 V Supply
  - TSOP6, SOIC8, DFN8 4x4 and DFN8 2x2.2 Packages

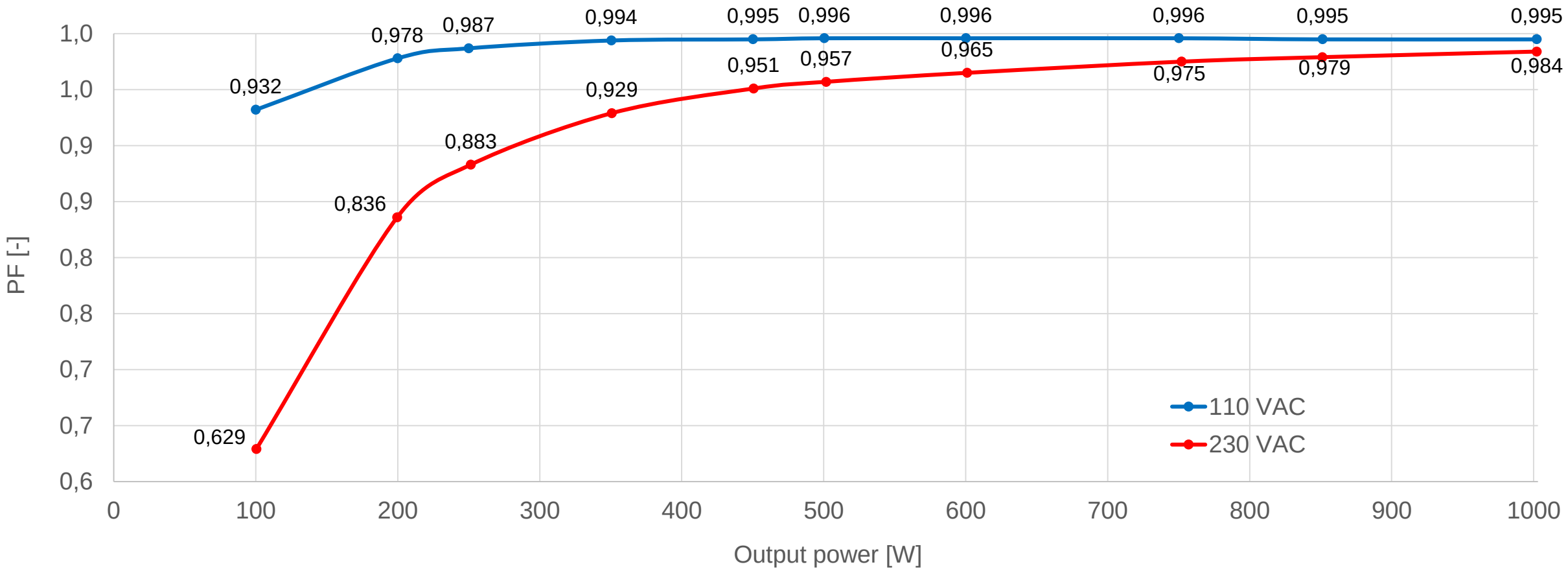
Evaluation results

Efficiency vs. Output power



Measured efficiency excluding self-consumption (Without StandBy Card)

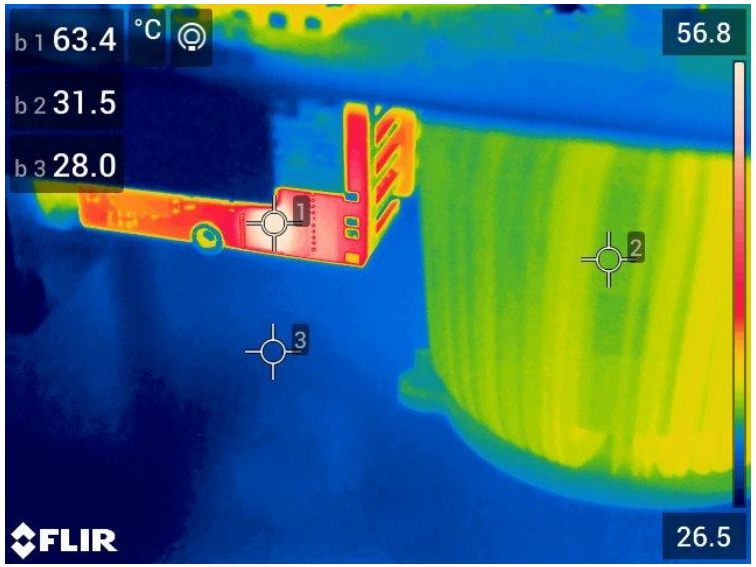
Power factor vs. Output power



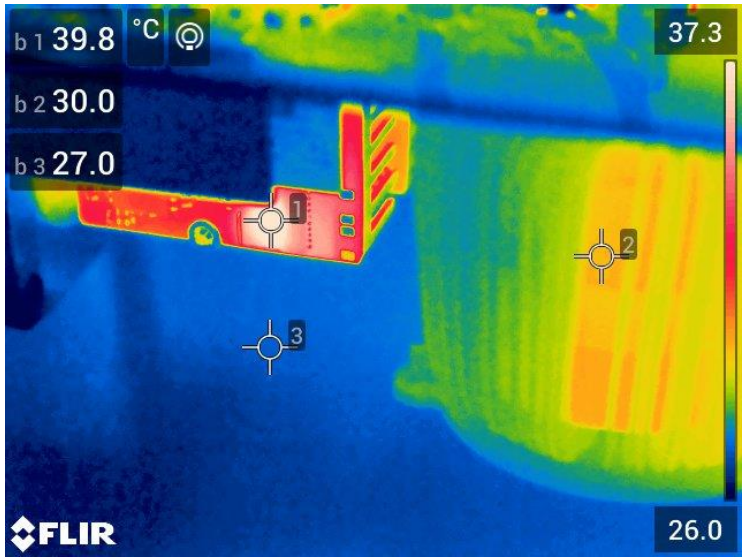
Thermal Images

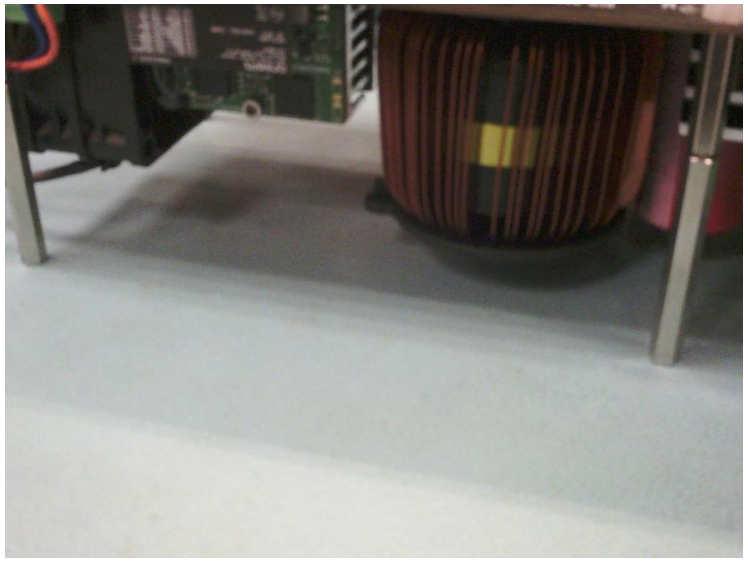
Thermal Images – PFC Fast Leg Card

@110V AC/ 1000W



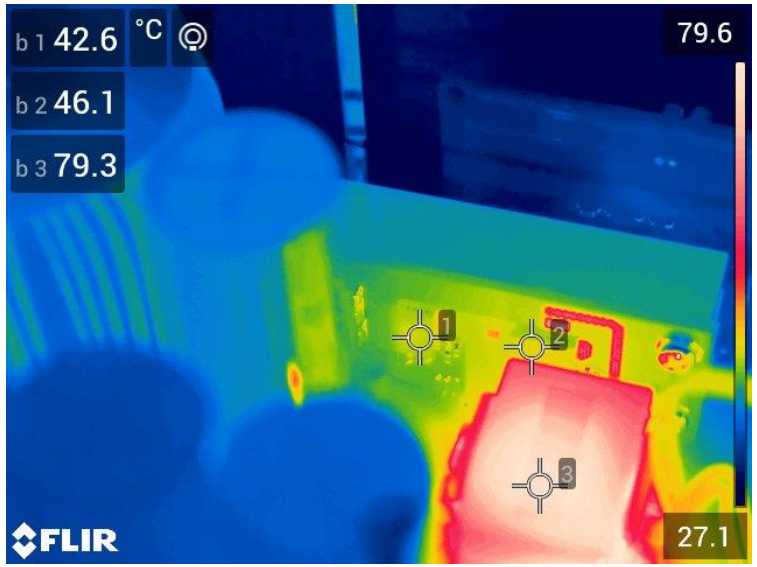
@230V AC/ 1000W

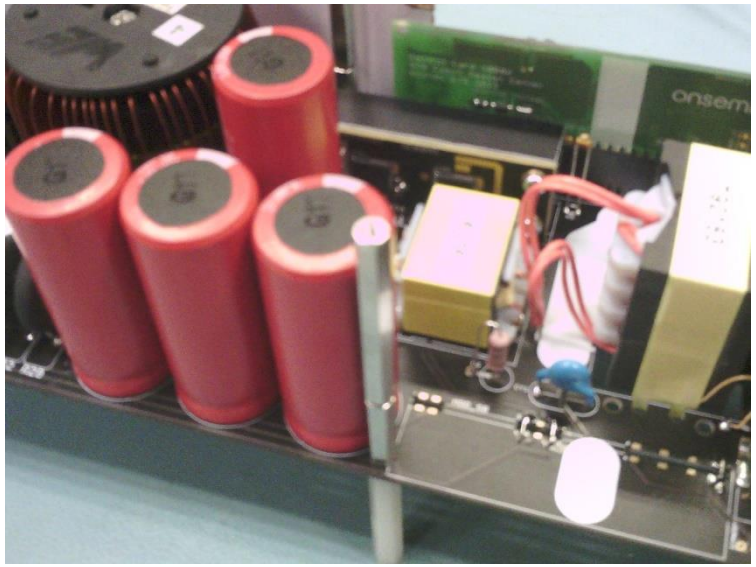




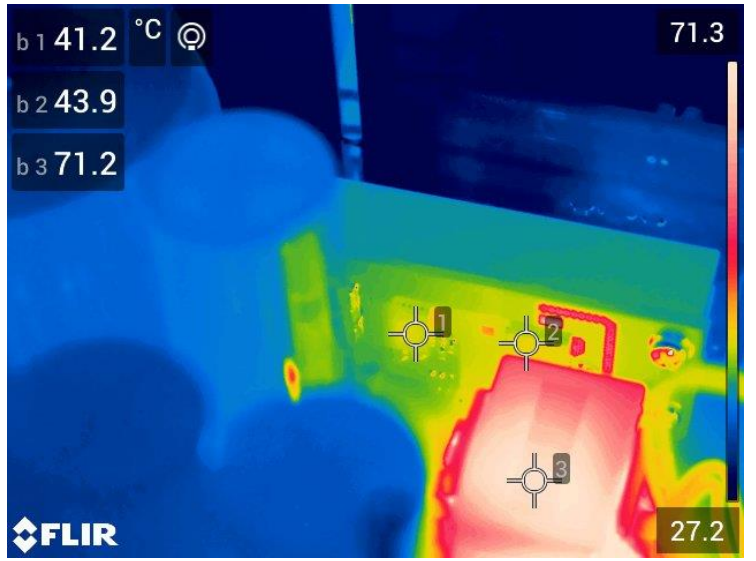
Thermal Images – LLC Half Bridge Card

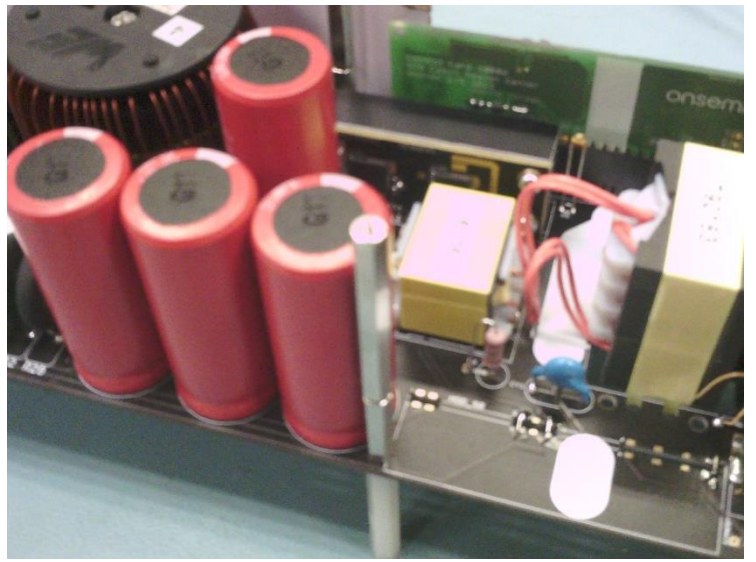
@110V AC/ 1000W





@230V AC/ 1000W





Highlights

Highlights

- Peak efficiency 96.2% @ 0.45 kW & 110 V AC (slide 19).
- Peak efficiency 95.03% @ 0.45 kW & 230 V AC (slide 19).
- Power factor 0.995 @ 1 kW & 110 V AC (slide 20).
- Power factor 0.984 @ 1 kW & 230 V AC (slide 20).

Questions

& Answers

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

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