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NCP1680 Totem Pole CrM PFC Controller

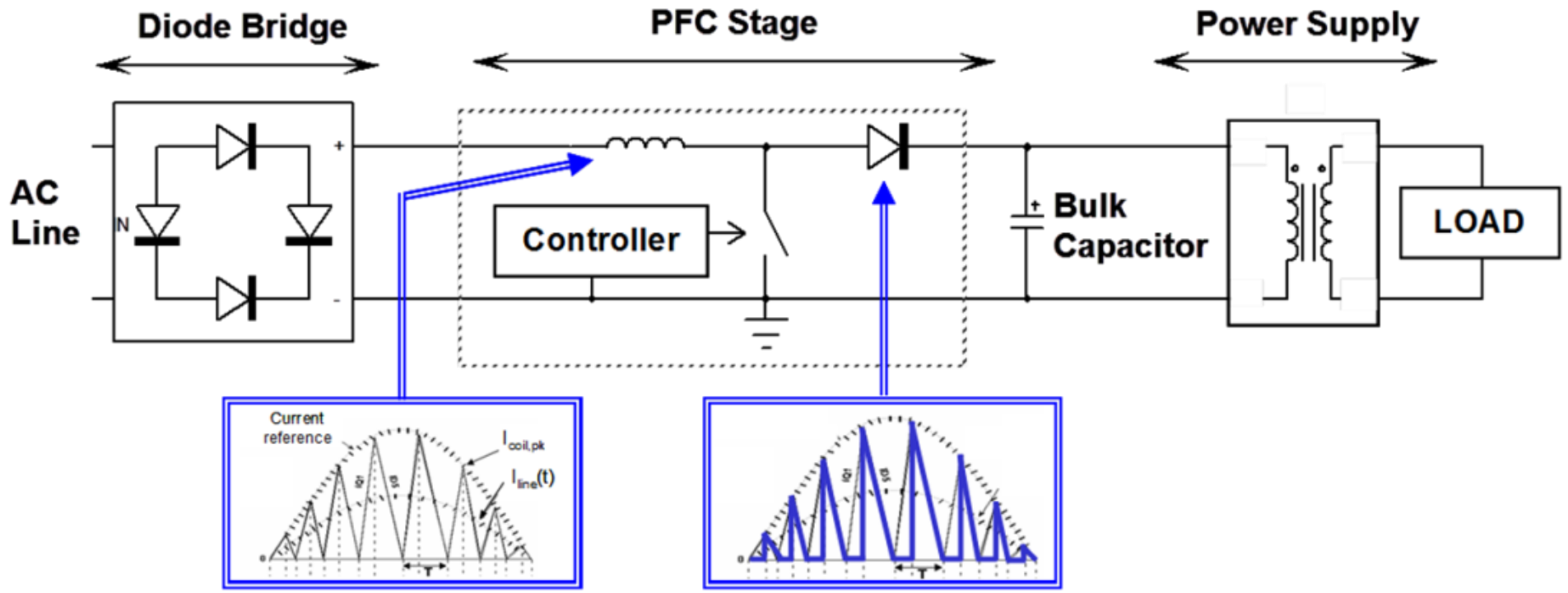
Product Introduction

Public Information

Agenda

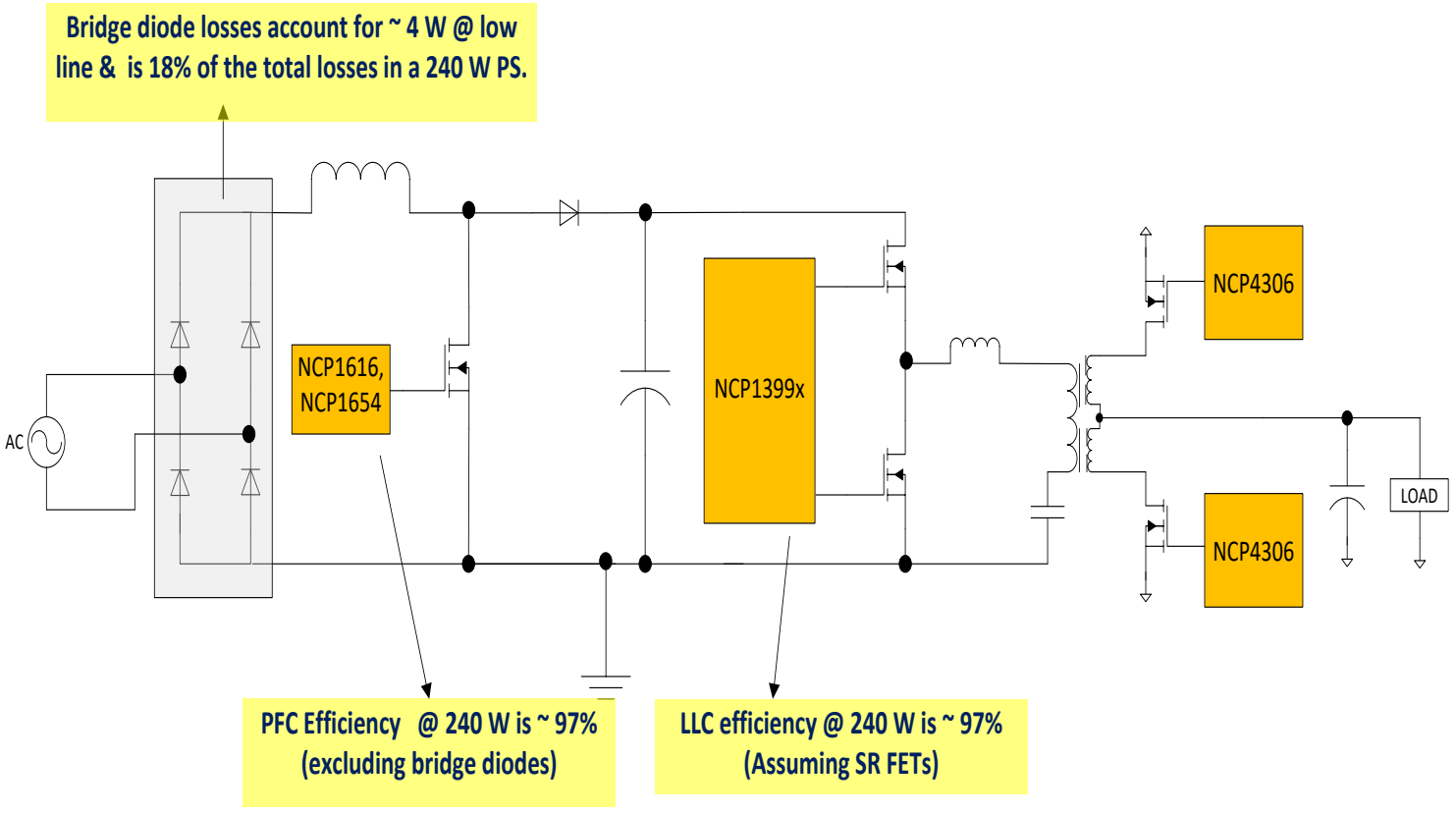
- Introduction to Totem Pole PFC operation
- Introduction to NCP1680 & key features
- Competitive landscape
- NCP1680 evaluation board data
- NCP1680 go to market collateral
- ON solution for ultra high density offline power supplies

Power Factor Correction (PFC)



- Inserted between the line and the main converter, a pre-converter draws a sinusoidal current from the mains and provides a dc voltage
- Traditionally, this is a boost converter
- The driver embeds a specific control law

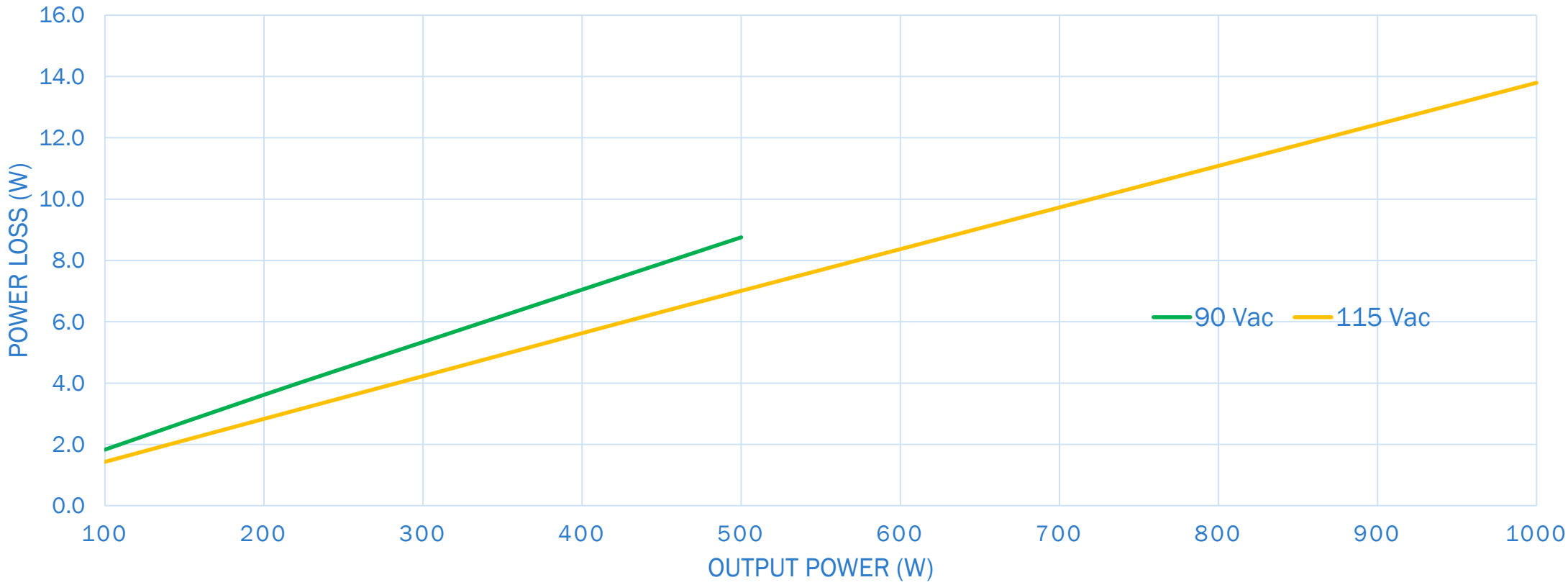
Why Totem Pole PFC?



Diode bridge with heat sink

Efficiency of the PFC boost stage & LLC stage have plateaued. Bridge diodes are the major source of power loss

Bridge diode power loss



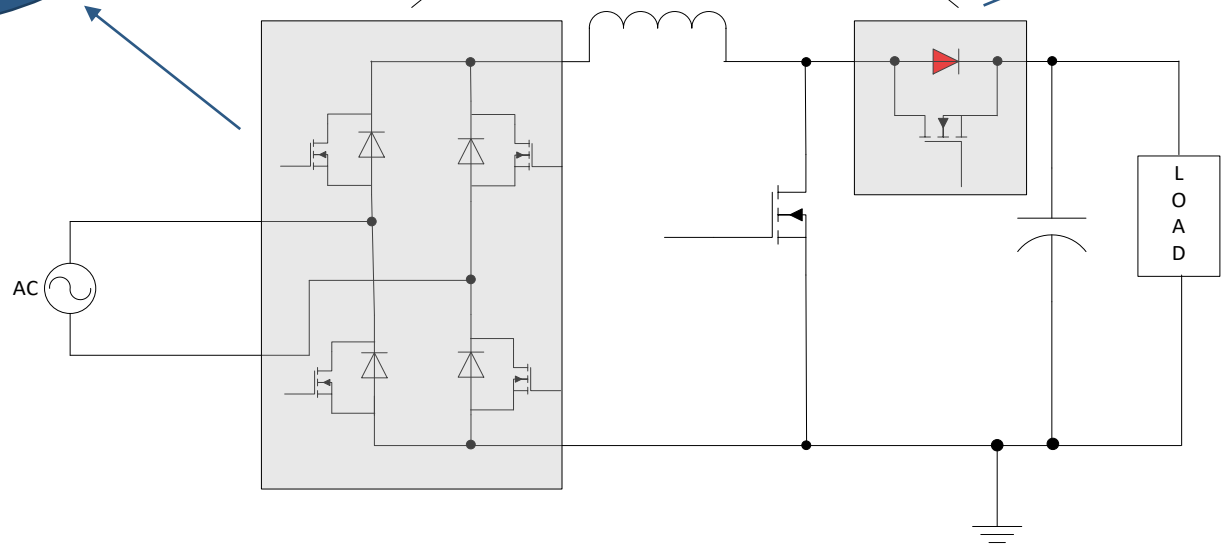
Efficiency of the PFC boost stage & LLC stage have plateaued. Bridge diodes are the major source of power loss

How to make boost PFC more efficient

Replace all the diodes with FETs

Active bridge solution is costly and clunky

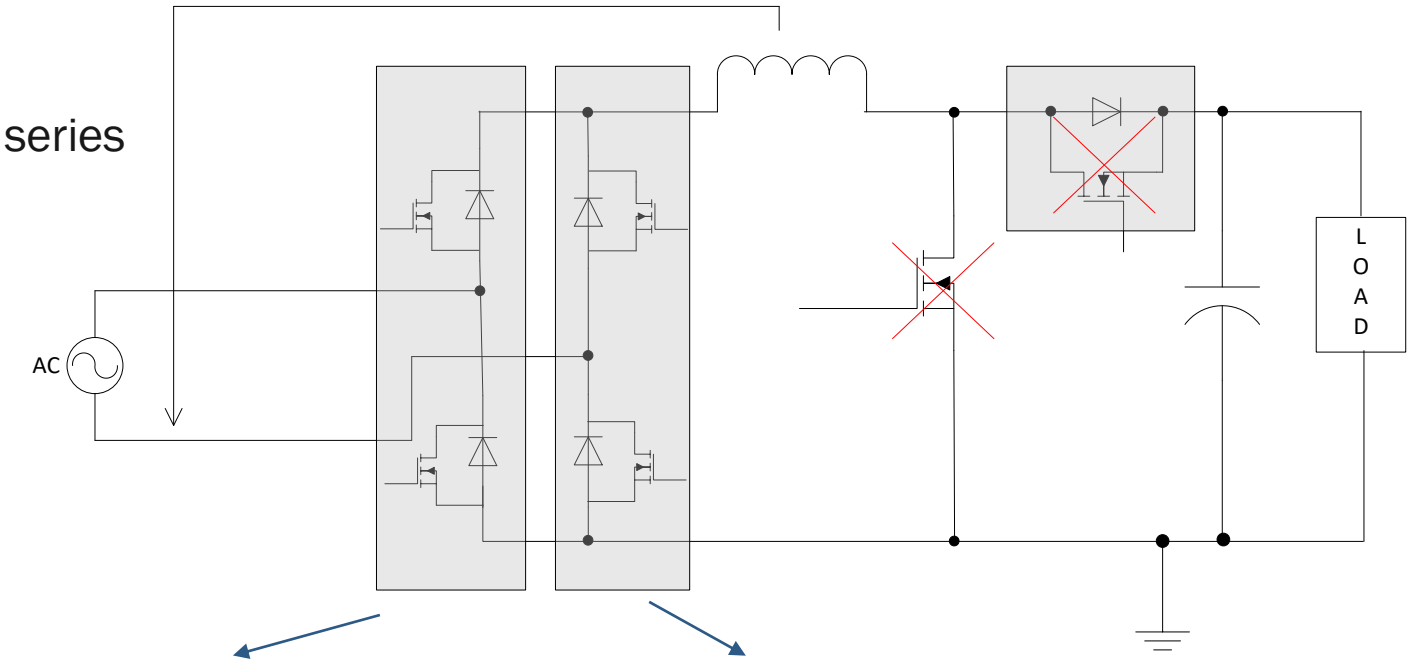
Body diode of Synchronous FET prevents CCM operation



- Replace input bridge diodes with FETs. All diodes have to be replaced with ~ 50 mΩ, 650 V FETs
- 2 FETs in the 'bridge' and 1 FET in the boost stage always conducting
- MOSFET marketer's dream come true!! 6 HV FETs!!!

Rearranging classical boost converter

Move the inductor in series with AC

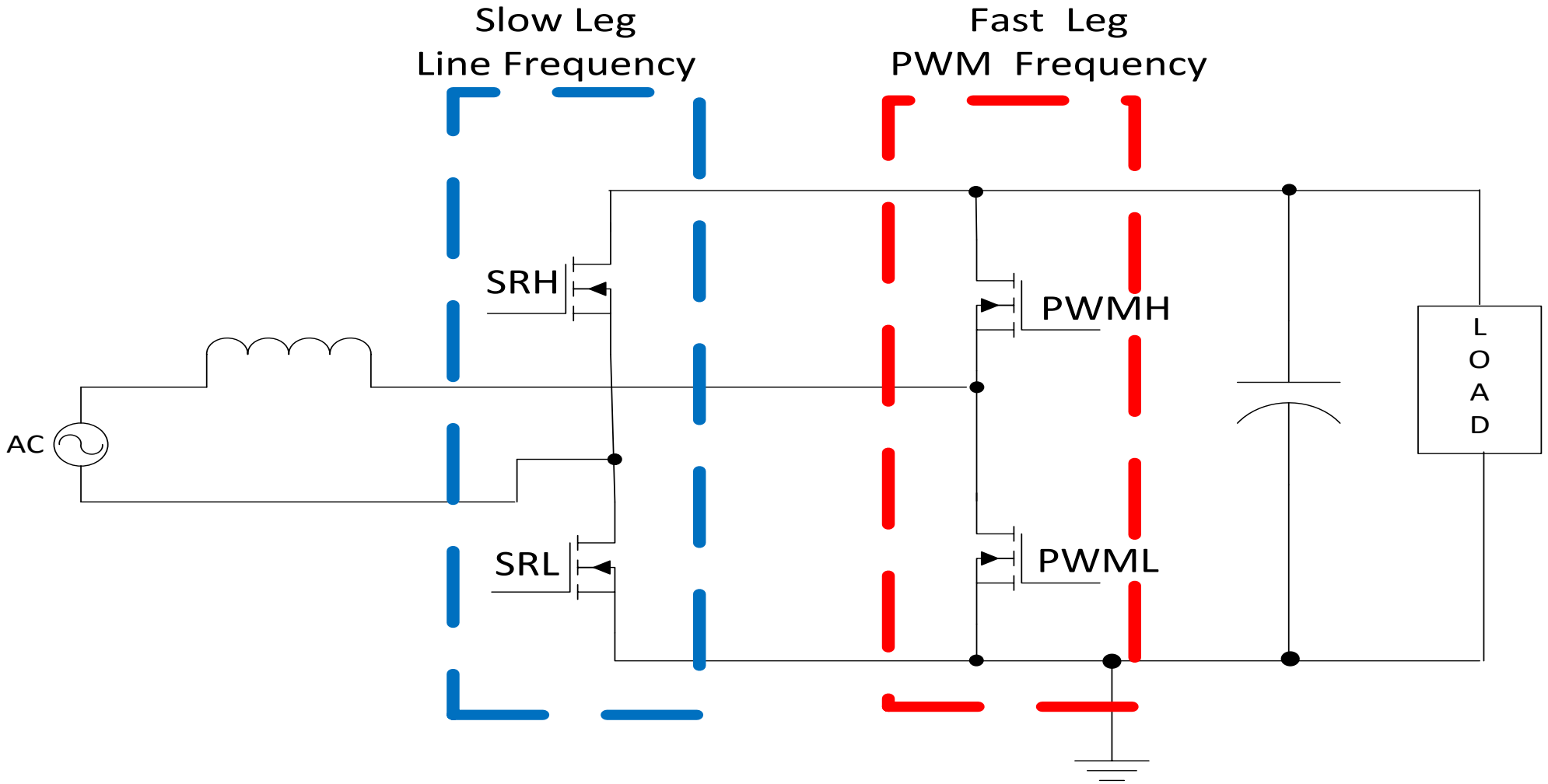


Low Frequency Leg

High Frequency Leg. WBG switches needed for CCM, SJ FETs w. low QRR viable for CrM

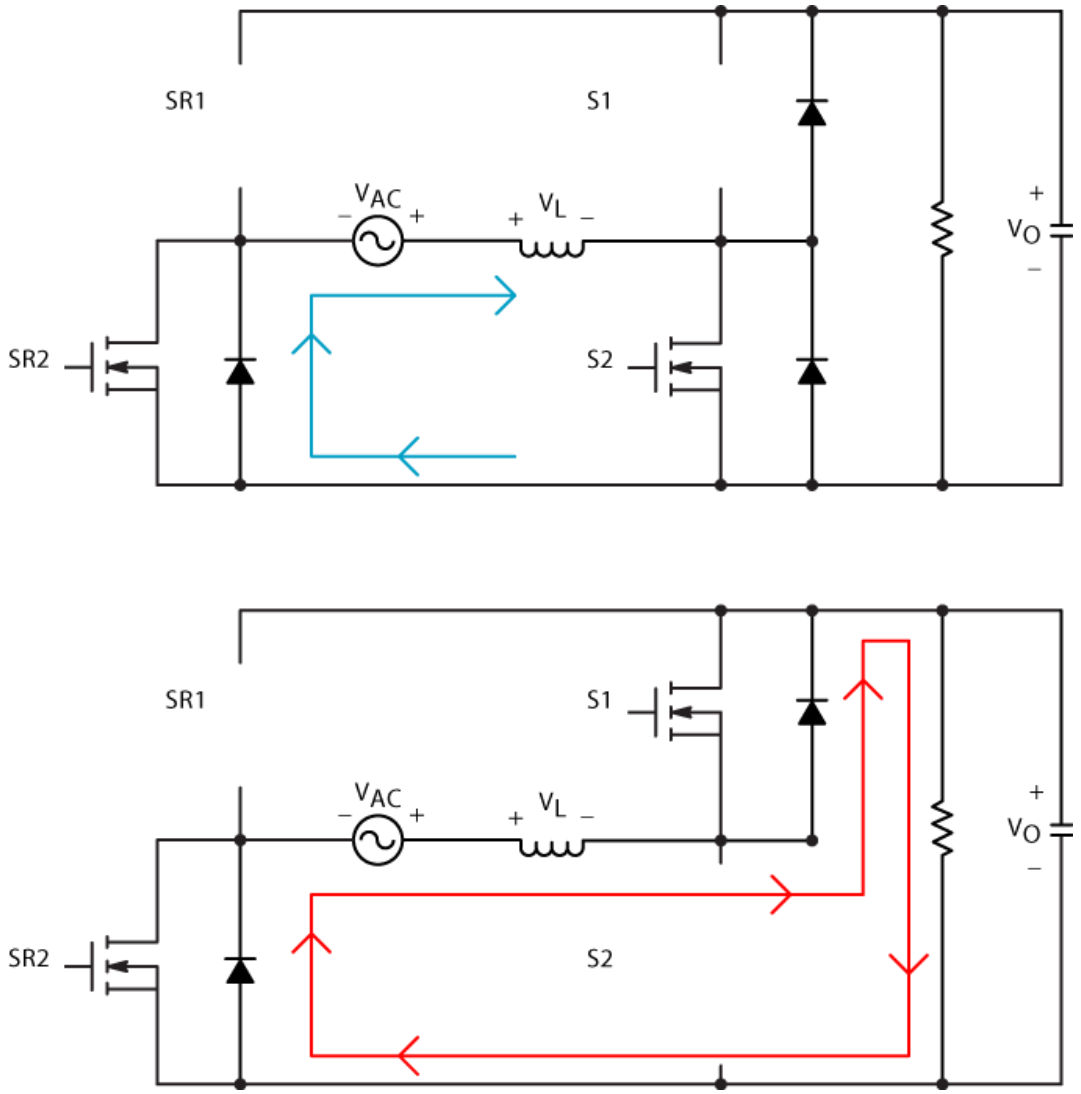
- Replace input bridge diodes with FETs and bring in the boost PFC stage

Bridgeless totem pole PFC



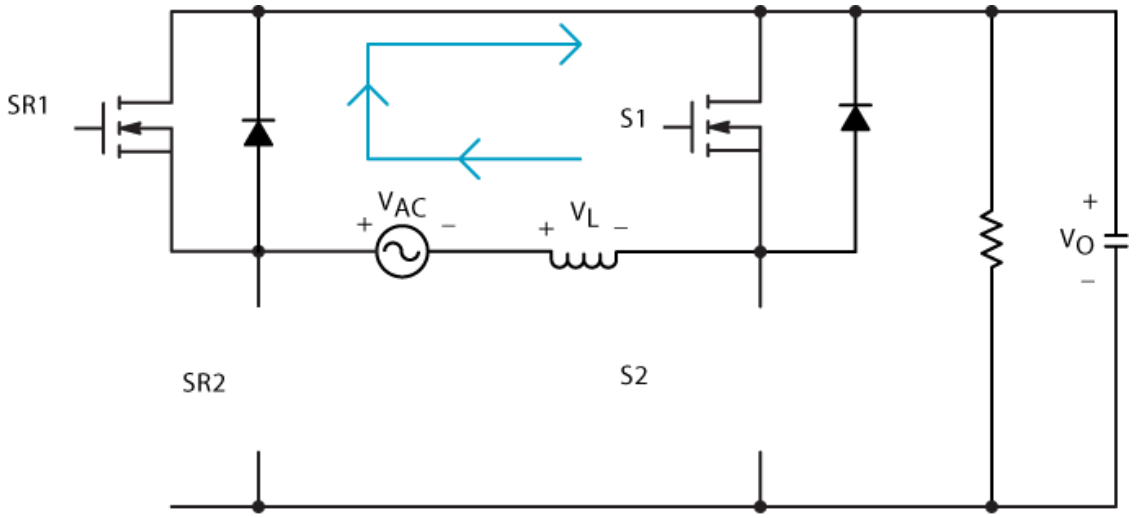
- Totem Pole is an elegant 4 switch boost solution that reduces number of components in the current path
- 1 FET in the “diode” section (Low Freq leg) and 1 FET in the boost section conducting

Positive Half Cycle Operation

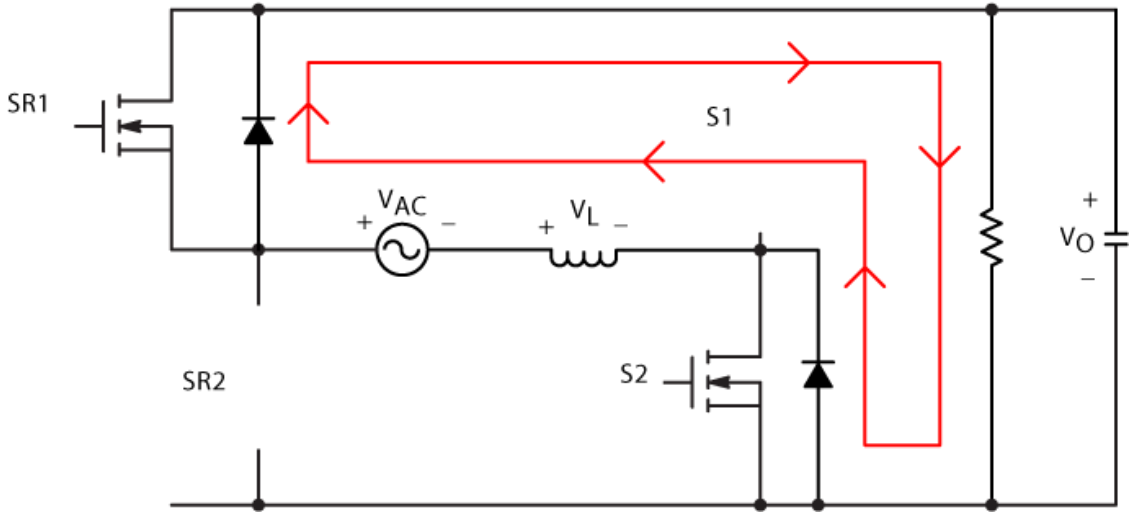


- S2 is the duty cycle (*d*) controlled device and S1 is the (*1-d*) device
- When S2 is on, $V_L = V_{AC}$ and current (blue path) circulates through S2 and SR2
- When S2 turns off, $V_L = V_{AC} - V_O$ and current free wheels through S1 and SR2 (red path). S1 can be turned on for increased efficiency
- SR2 is returning current to the source for the entire positive line cycle

Negative Half Cycle Operation



- S1 is the duty cycle (*d*) controlled device and S2 is the (*1-d*) device
- When S1 is on, $V_L = -V_{AC}$ and current (blue path) circulates through S1 and SR1



- When S1 turns off, $V_L = V_{AC} - V_O$ and current free wheels through S1 and SR2 (red path). S2 can be turned on for increased efficiency
- SR1 is returning current to the source for the entire negative line cycle

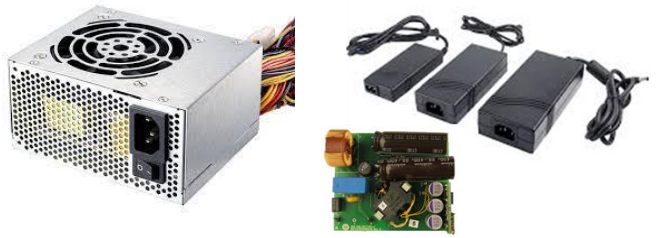
Bridgeless Totem Pole PFC Applications

Cloud-server power supply

5G telecom power supply

Industrial power supply

High power LED street light



Computing power supply

High end OLED TV and projector

NCP1680 Bridgeless Totem Pole CrM PFC Controller

Value Proposition

The NCP1680 is a CrM Totem Pole PFC Controller capable constant on time CrM and valley synchronized frequency foldback for optimized efficiency across the entire load range. With proprietary current sensing architectures and proven control algorithms the NCP1680 allows for a cost-effective solution without jeopardizing performance.

Unique Features

- Constant on-time CrM architecture w. valley switching during foldback
- **Novel Current Sense scheme**
- Line polarity detection
- **Novel valley sense scheme**
- Control loop Internally compensated

Benefits

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

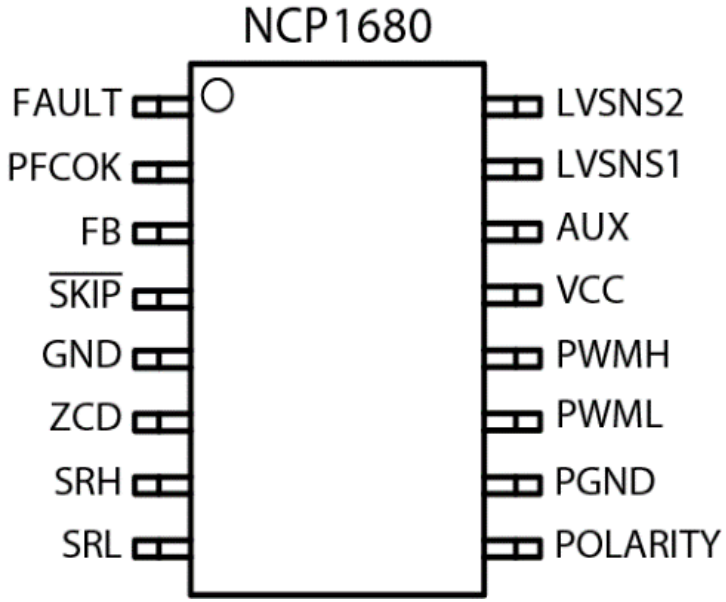
Other Features

- Two low voltage pins for sensing and recreating half-wave sinusoid.
- DCM with valley synchronized turn-on for improved light load efficiency
- Zero Current Detection for CrM Operation
- Integrated Digital voltage loop control

Market & Applications

- Telecom 5G / Networking Power Supplies
- Industrial Power Supplies
- Computing Power Supplies
- Gaming Console Power Supplies
- UHD TV Power Supplies

Device Pin-Out

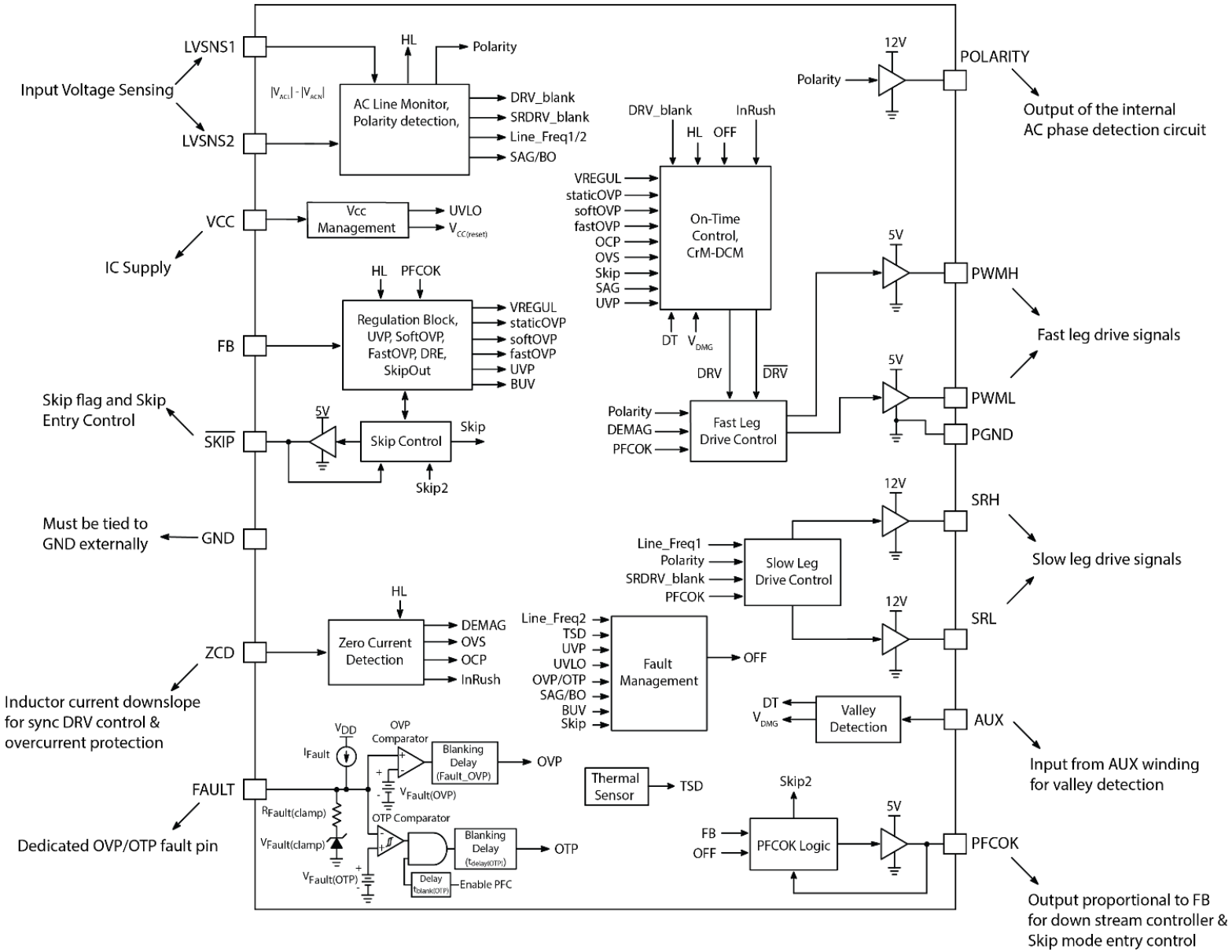


Ordering & Package information

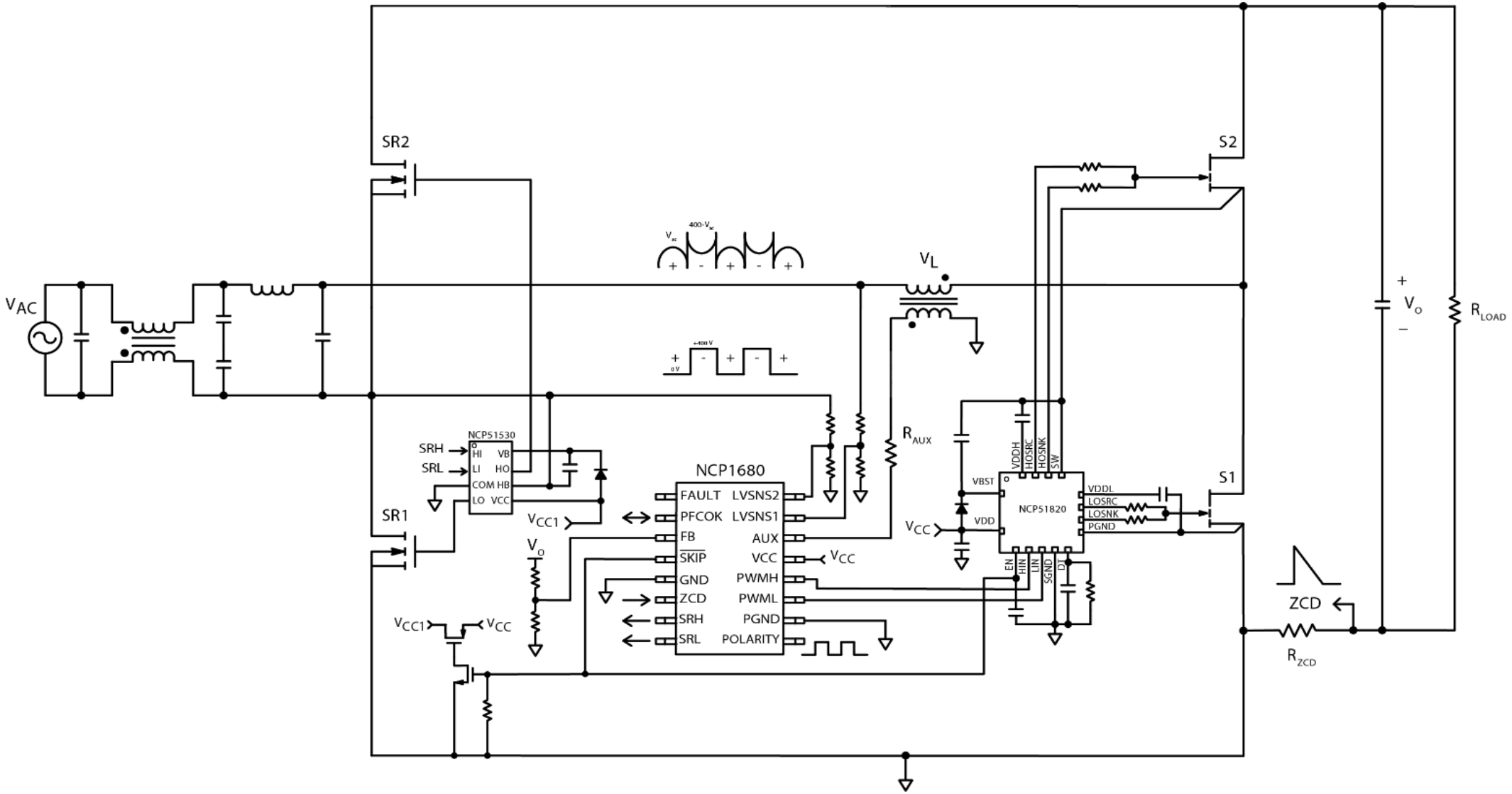
- SOIC-16

Multiple Patents Issued/Pending

NCP1680 Block Diagram



Typical Application Schematic NCP1680



Totem Pole PFC market scenario - ON advantages

Existing solution on the market

Complex MCU based solution, customers need to write software code and costly current sensing method to implement the topology

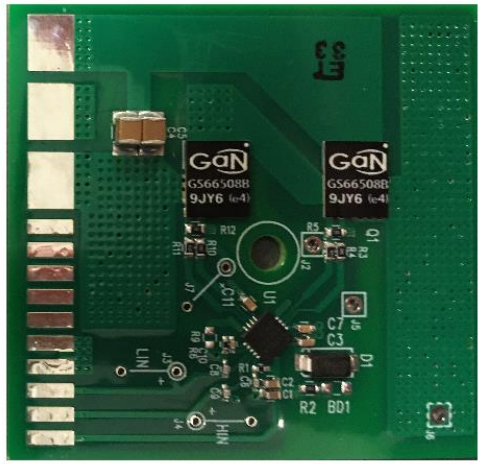
NCP1680 and NCP1681

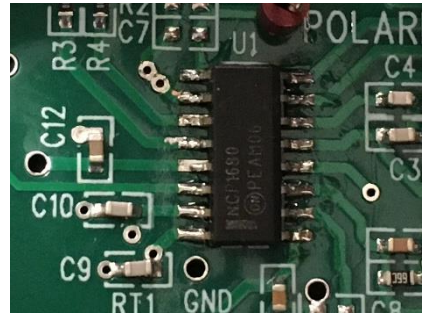
Industry's first mixed signal controller dedicated to totem pole PFC topology

Totem Pole PFC Mixed Signal vs. Digital Controller

Digital Controller (DSP/MCU)	Mixed Signal Controller (NCP1680 & 1)
Cloud/High end server	NCP1680 (CrM) -> Telecom 5G/industrial/computing up to 350 W NCP1681 (MM) -> Workstation/gaming console power up to 1 kW NCP1681 (CCM only) -> Network/cloud-server/industrial >2.5 kW
Supports multi-topologies: Boost PFC, Totem Pole PFC, voltage mode LLC etc.	Optimized for Totem Pole PFC: CrM and CCM
Flexibility - Customer can implement custom IP to distinguish from competition	Designed to pass standards for computing & gaming power supplies
Poor standby power. Icc of DSP/MCU is high	Excellent light load efficiency and standby power
THD <2% possible, look-up tables and custom IP	NCP1680 (CrM) -> THD better than standards set for computing NCP1681 (CCM only) -> THD <5%
Telemetry: Input voltage and current. Accuracy 5 %. PM Bus possible	No telemetry

NCP1680 300 W Evaluation Board Picture

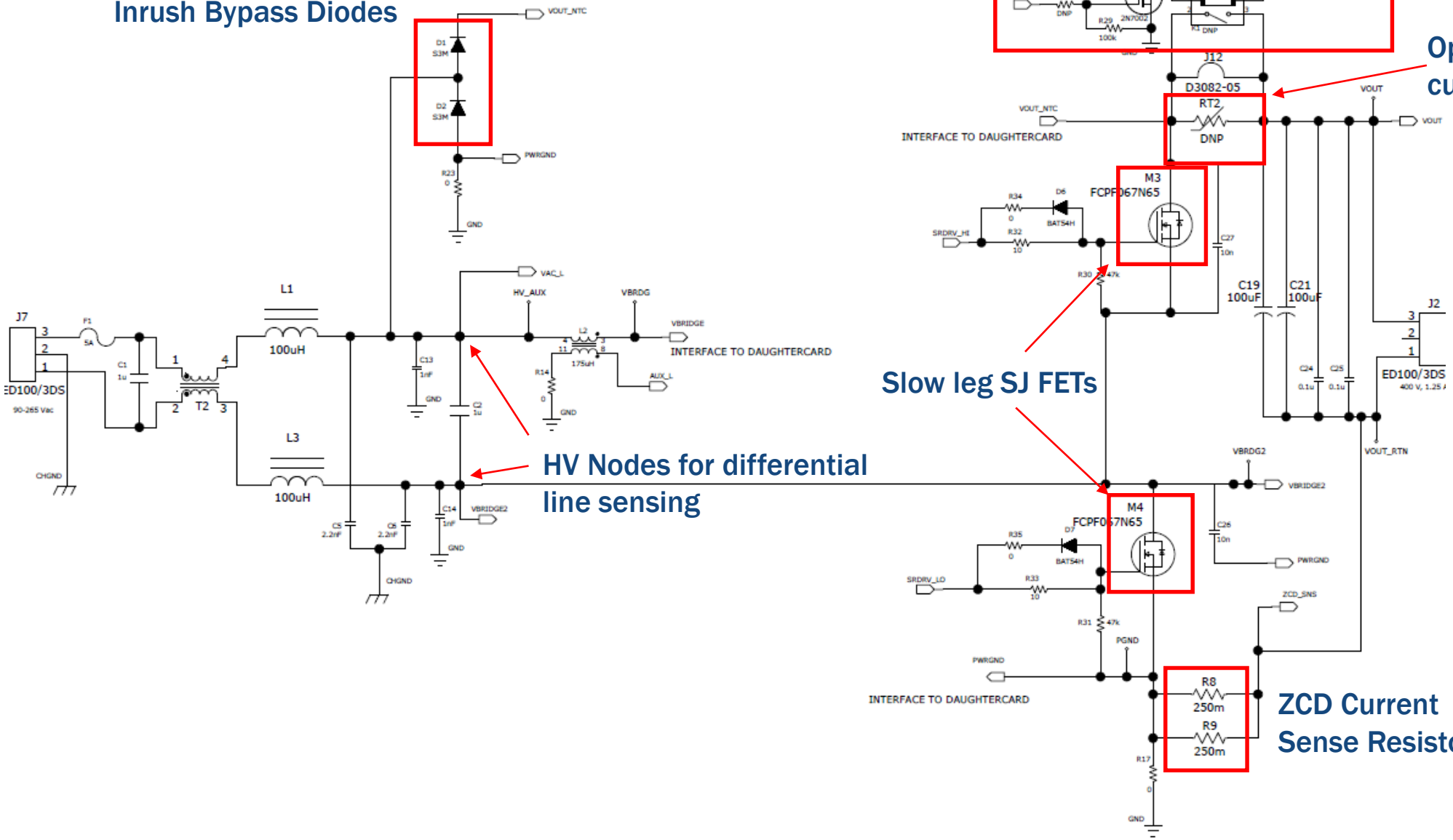




Evaluation Board Specs & Key Components

Description	Value	Units
Input Voltage Range	90 - 265	VAC
Line Frequency Range	47 - 63	Hz
Output Voltage	395	V
Output Power	300	W
Boost Inductor	175	µH
Bulk Capacitors	200	µF
Fast Leg Switch (1)	GS66508B	
Slow Leg Switch	FCPF067N65	
ZCD Resistor	125	mΩ

Power Train Schematic



Controller Schematic

AUX winding circuitry → Optimized for bidirectional operation

Optional V_{CC} bias ckt

Bulk voltage sensing

OVP & OTP Fault Monitoring

PFCOK indicator

Differential Line Voltage Sensing

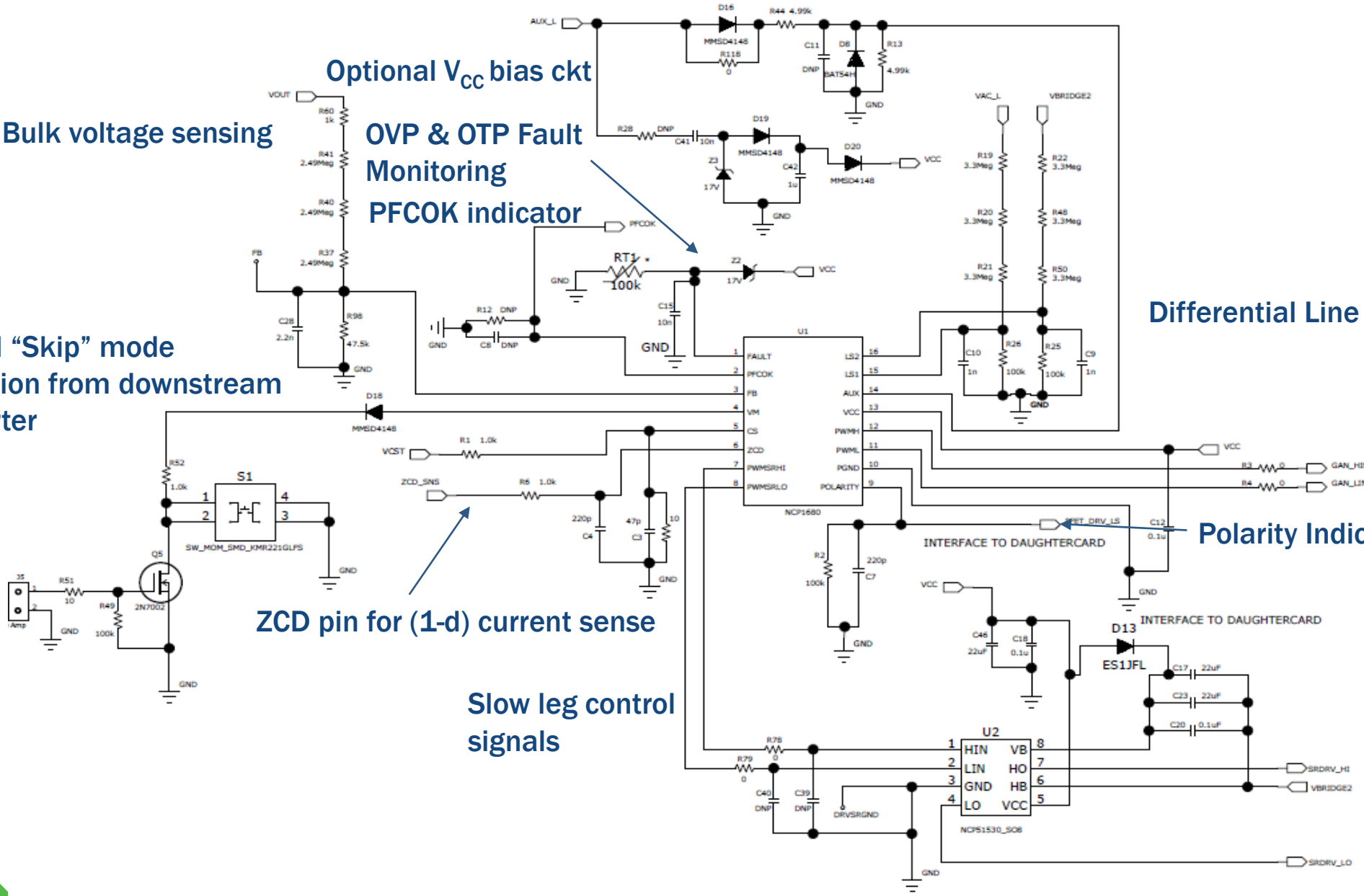
Forced “Skip” mode operation from downstream converter

Fast leg control signals

Polarity Indicator

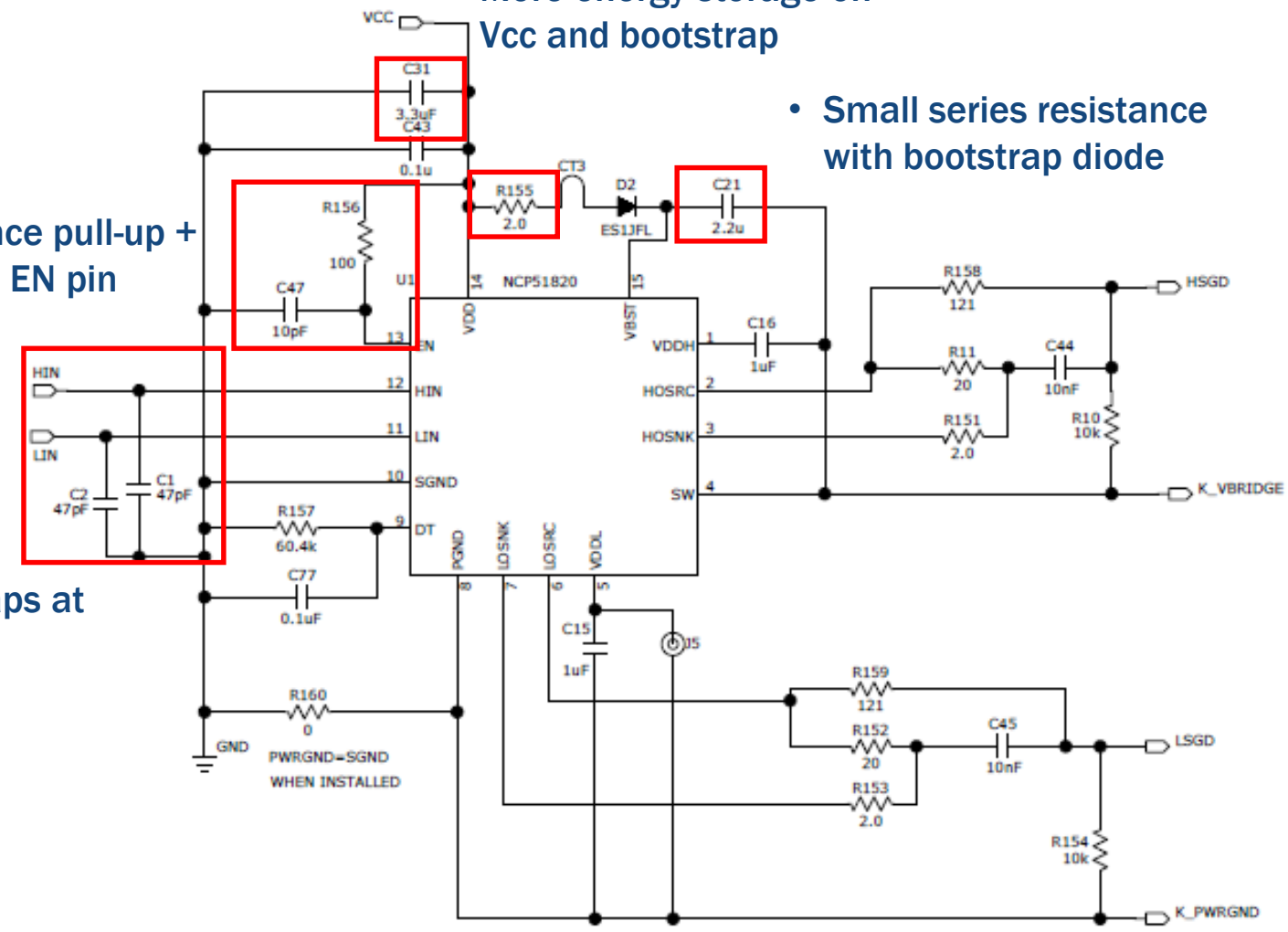
ZCD pin for (1-d) current sense

Slow leg control signals

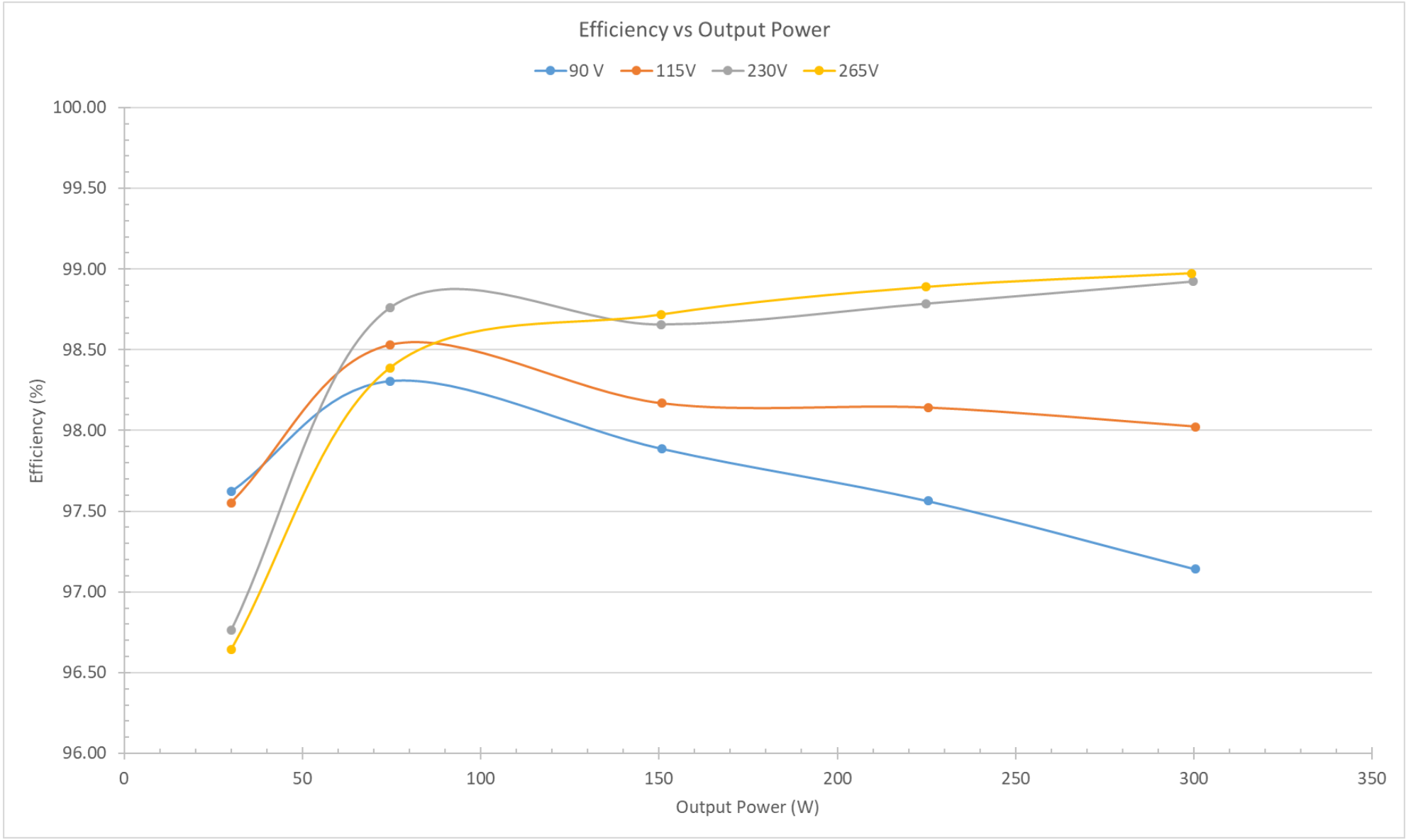


Daughter Card Schematic

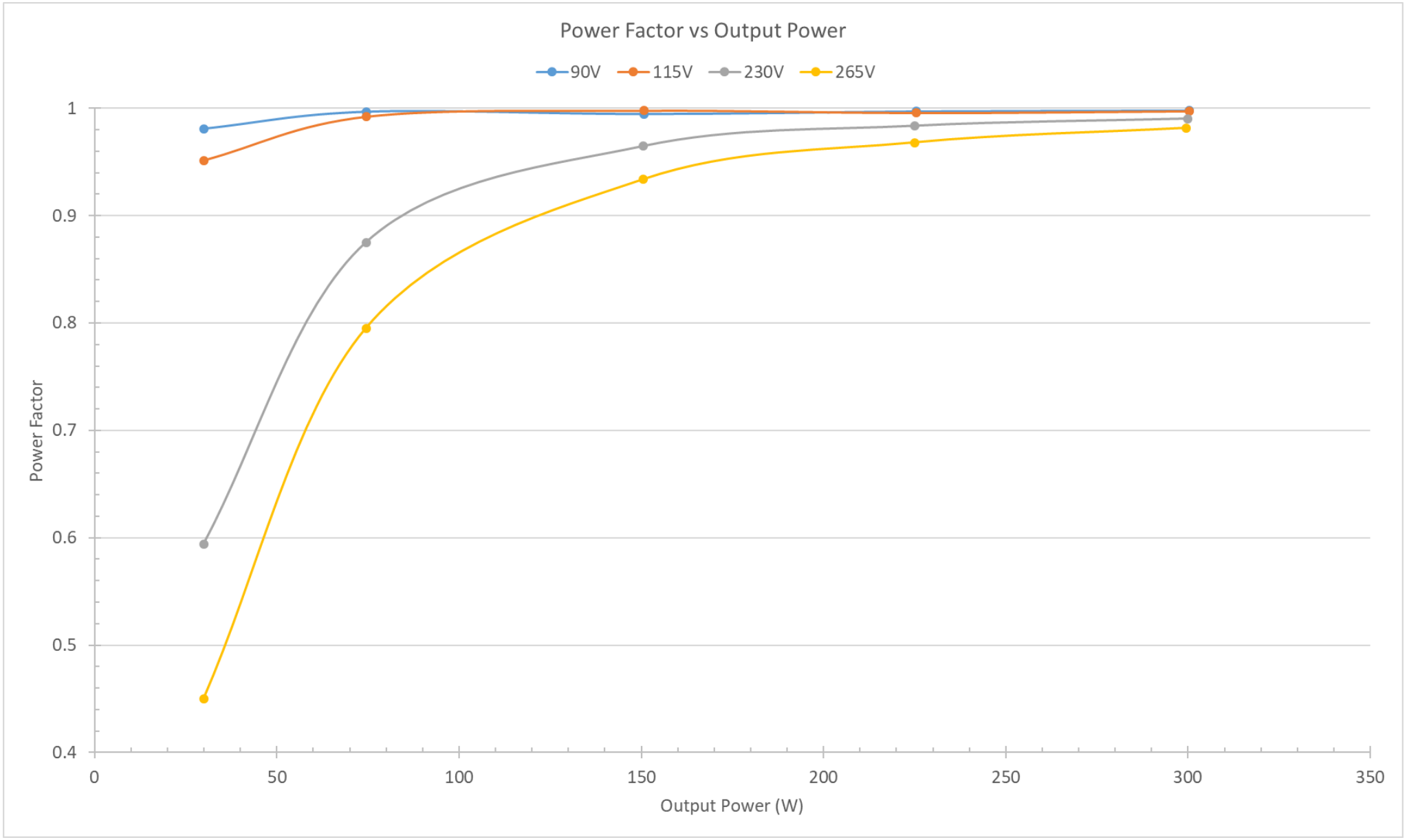
- More energy storage on Vcc and bootstrap
- Small series resistance with bootstrap diode
- Low impedance pull-up + small filter at EN pin
- Small de-coupling caps at logic inputs



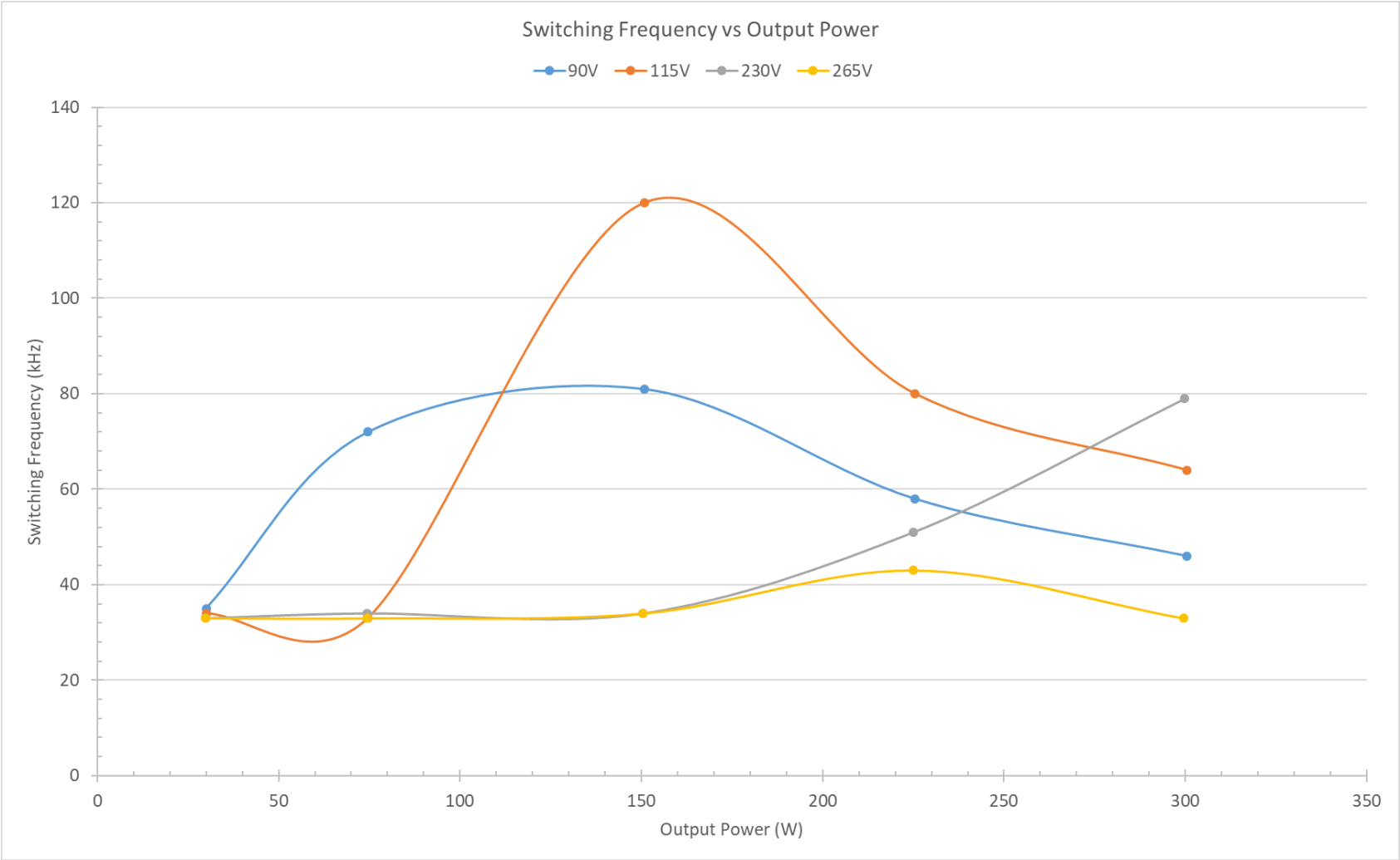
Efficiency



Power Factor

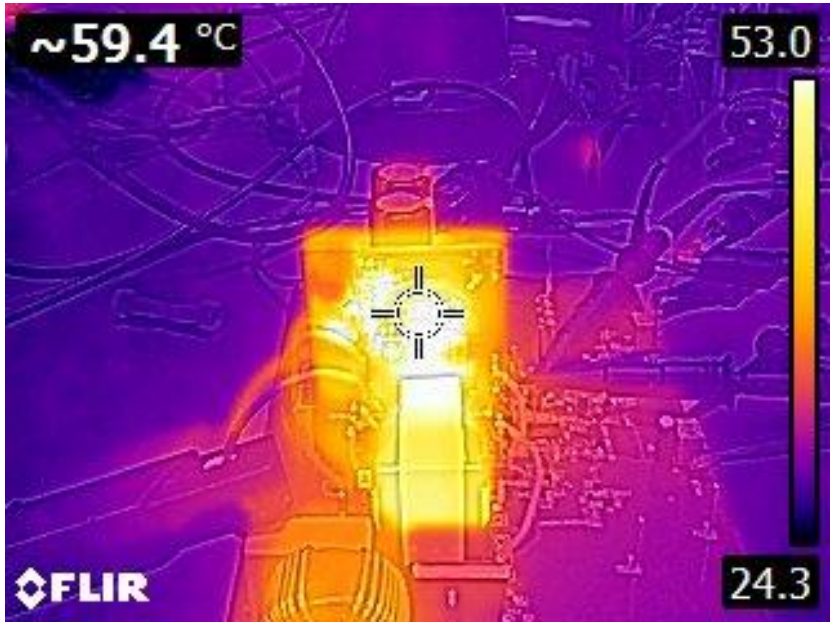


Switching frequency at the peak of AC line

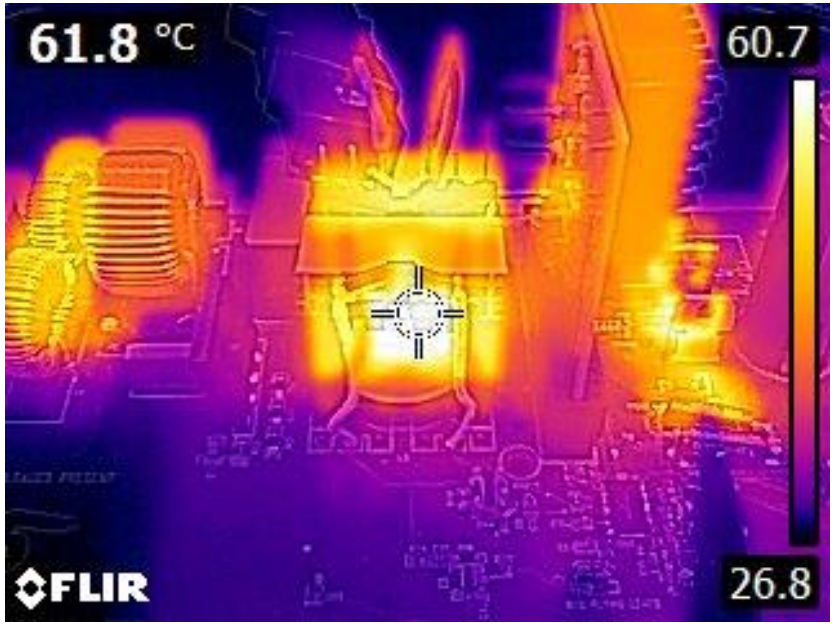


Thermal scan

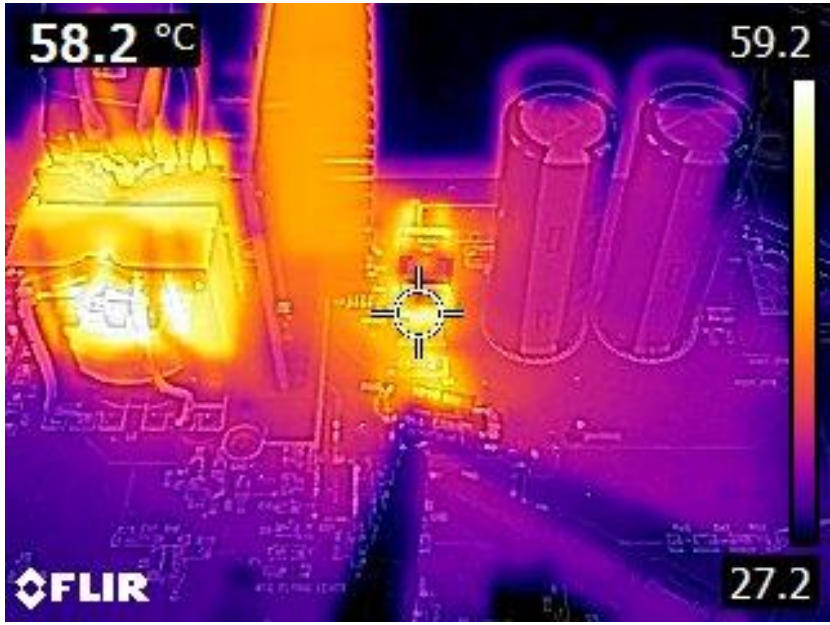
GaN HEMTs



Boost Inductor

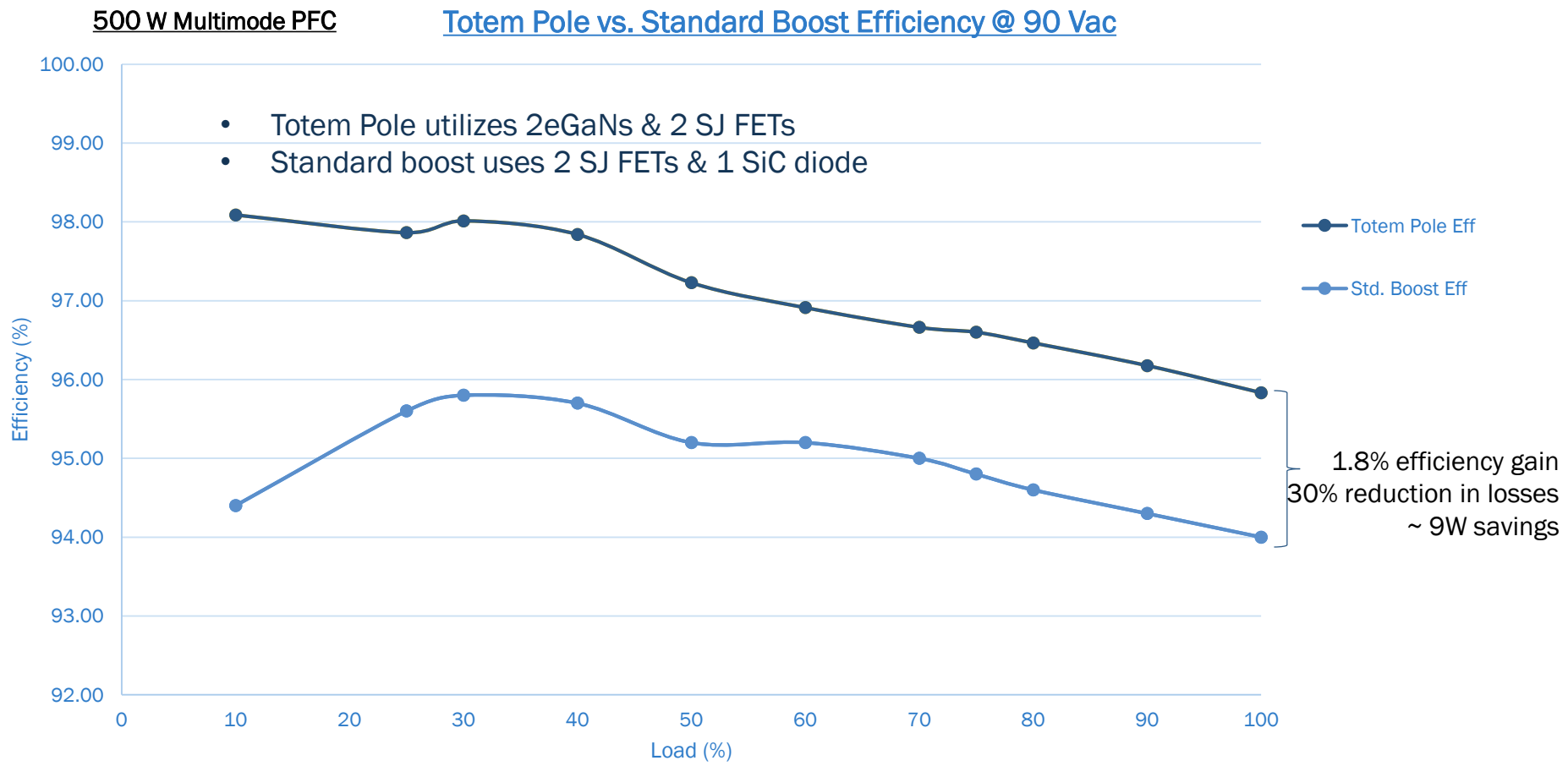


Slow leg Si FETs



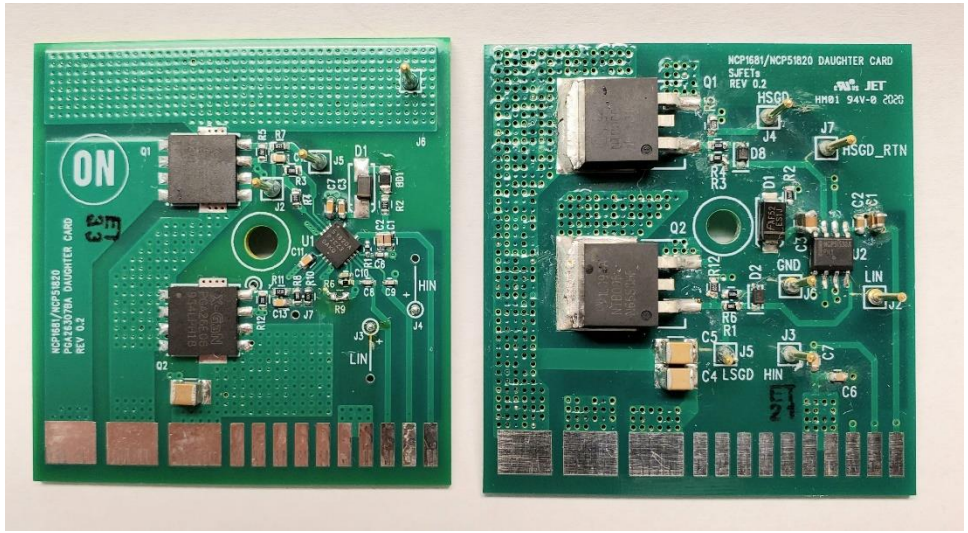
- Thermal scans showing the temperature of the 50 mΩ GaN HEMTs, boost inductor, and slow leg Si devices captured 90 Vac, 300 W, room temp ambient

Totem Pole vs. Standard Boost PFC Efficiency Comparison



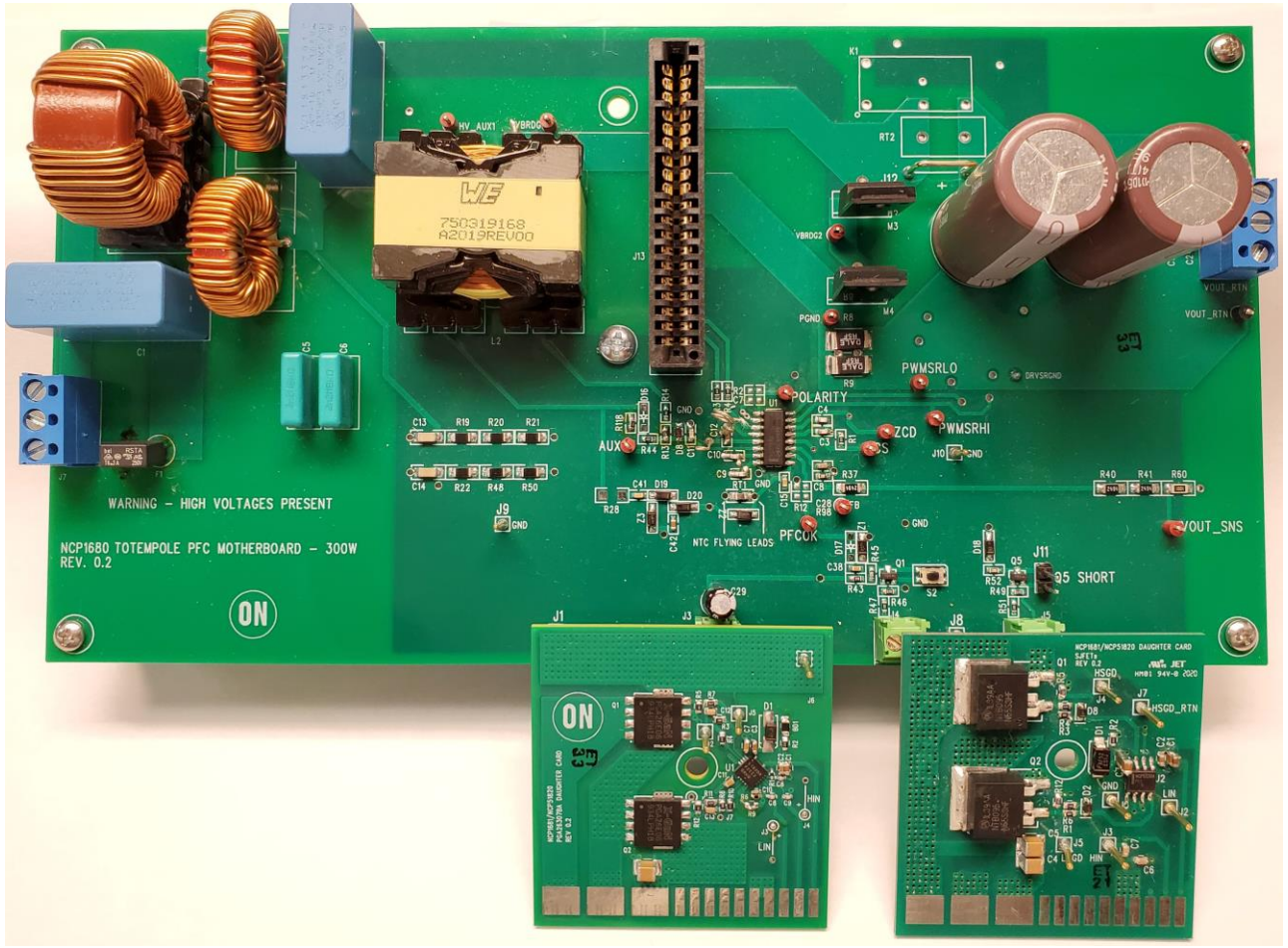
- Bridgeless Totem Pole PFC provides 1.8 % higher efficiency than standard boost PFC at full load, 90 Vac input condition equivalent to 9 W power loss reduction

Totem Pole PFC GaN vs. SJ MOSFET Efficiency Comparison



56 mOhm GaN fast leg daughter card

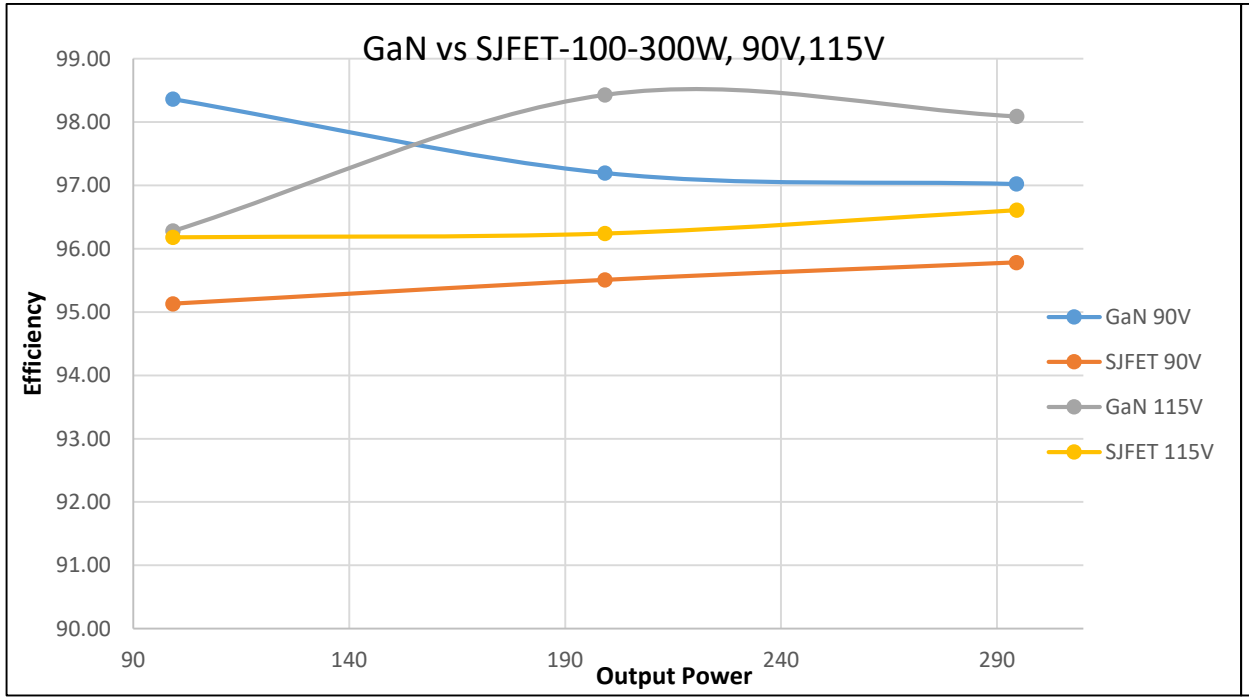
95 mOhm SJ FET NTB095N65S3HF fast leg daughter card

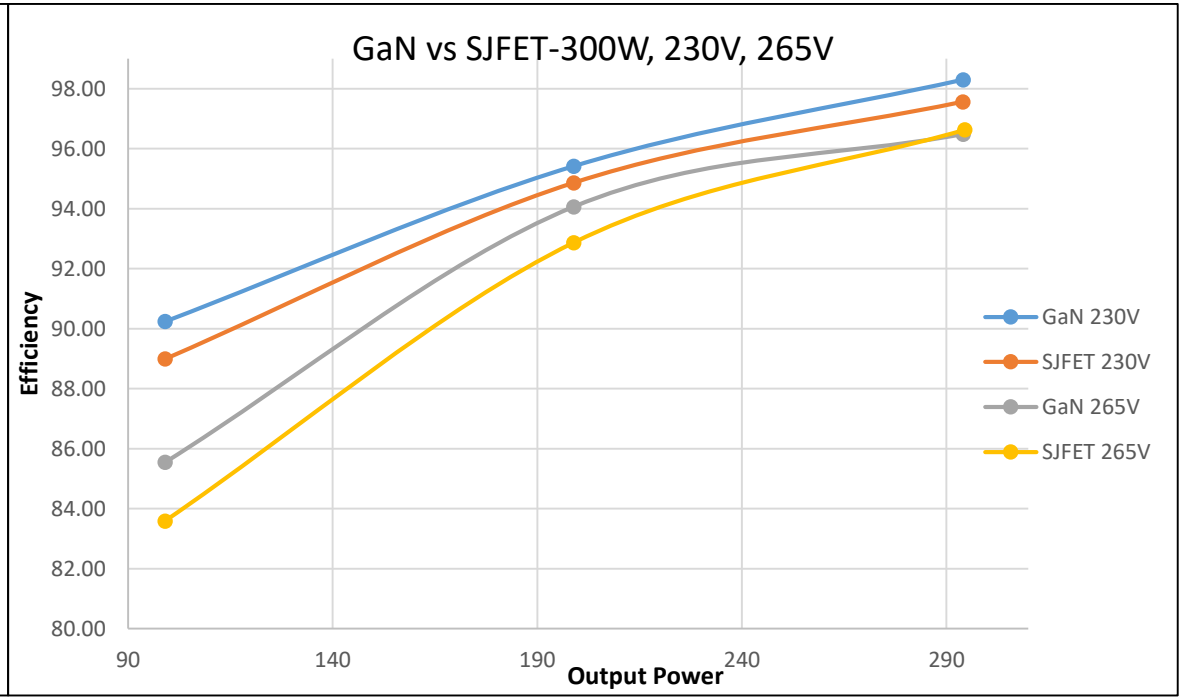


- Using NCP1680 300W CrM board to compare the performance of GaN versus SJ FET as the fast leg switches

Efficiency Comparison 90V, 115, 230V –300W

GaN vs SJ FET Efficiency Graphs

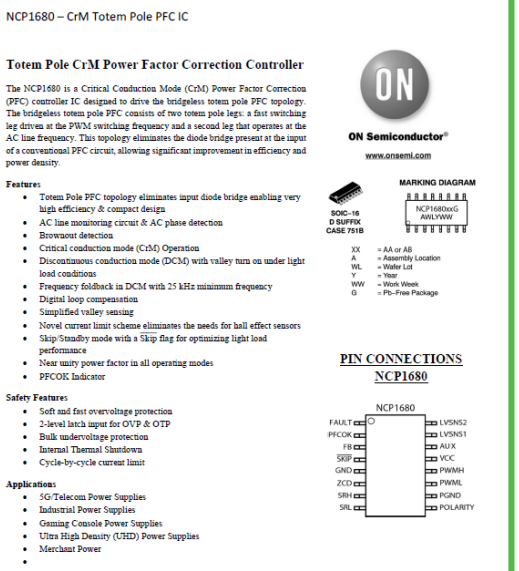




- Bridgeless Totem Pole PFC + GaN as the fast leg switches gains ~1 % higher efficiency versus SJ FET. Totem Pole + GaN also provides better THD performance

Support and Collateral

Data Sheet
Full DS for customers available upon request



NCP1680 – CrM Totem Pole PFC IC

Totem Pole CrM Power Factor Correction Controller

The NCP1680 is a Critical Conduction Mode (CrM) Power Factor Correction (PFC) controller IC designed to drive the bridgeless totem pole PFC topology. The bridgeless totem pole PFC consists of two totem pole legs: a fast switching leg driven at the PWM switching frequency and a second leg that operates at the AC line frequency. This topology eliminates the diode bridge present at the input of a conventional PFC circuit, allowing significant improvement in efficiency and power density.

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CASE 751B

MARKING DIAGRAM
NCP1680xG
AWLYWW

XX = AA or AB
A = Assembly Location
WL = Wafer Lot
Y = Year
WW = Work Week
G = Pb−Free Package

Features
- Totem Pole PFC topology eliminates input diode bridge enabling very high efficiency & compact design
- AC line monitoring circuit & AC phase detection
- Brownout detection
- Critical conduction mode (CrM) Operation
- Discontinuous conduction mode (DCM) with valley turn on under light load conditions
- Frequency foldback in DCM with 25 kHz minimum frequency
- Digital loop compensation
- Simplified valley sensing
- Novel current limit scheme eliminates the needs for hall effect sensors
- Skip/Standby mode with a Skip flag for optimizing light load performance
- Near unity power factor in all operating modes
- PFCOK Indicator

Safety Features
- Soft and fast overvoltage protection
- 2-level latch input for OVP & OTP
- Bulk undervoltage protection
- Internal Thermal Shutdown
- Cycle-by-cycle current limit

Applications
- 5G/Telecom Power Supplies
- Industrial Power Supplies
- Gaming Console Power Supplies
- Ultra High Density (UHD) Power Supplies
- Merchant Power

PIN CONNECTIONS
NCP1680

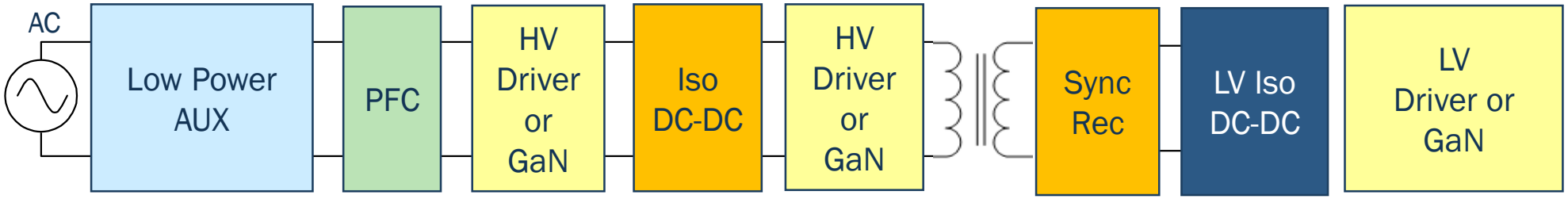
NCP1680
FAULT
PFCOK
FB
SKIP
GND
ZCD
SRH
SRL
LVSNS2
LVSNS1
AUX
VCC
PWMH
PWML
PGND
POLARITY

App Note
Coming Soon

Design Guide
Coming Soon

Evaluation Board
300 W CrM PFC

ONSEMI 1 kW Ultra High Density Power Solution



High Density Design

NCP1340
HF QR Ctrl
NCP1568
ACF Ctrl

NCP1618
Multi-mode PFC Ctrl

NCP13992 + NCP4318
LLC + SR Ctrl

NCP51820
650V HB GaN Driver

Not Serviceable

Ultra High Density Design

NCP1680 & 1
Totem Pole PFC Ctrl

NCP13994 + NCP4318EP
LLC + SR Ctrl

NCP58921 + NCP51561
650V Single Integrated Driver GaN + Isolated HB Driver

FD6000
LLC DCX Ctrl

NCP51810
150V HB GaN Driver

Discovery Questions

Discovery Questions	Relevance	Response
Are you looking to achieve the best possible PFC stage efficiency?	Design will benefit from bridgeless totem pole PFC	NCP1680 is designed to support bridgeless totem pole PFC, eliminate the loss of input diode bridge and achieve efficiency close to 99 %
Do you use digital MCU to implement totem pole PFC?	Digital MCU solution is more complex and expensive	NCP1680 is an analog mixed signal controller dedicated to totem pole PFC topology, simplifies design and reduces BOM count and cost
What are your efficiency requirements?	High light-and no-load efficiency targets benefit from NCP1680	NCP1680 features CrM operation and frequency fold back with valley turn on at light load ensuring high efficiency across power levels

END

Thank You