System Solution Guide

Offline SMPS

Updated: JUN-2024

Industry	Industrial Automation – Power Conversion
Application	Offline SMPS is a classic product to convert grid power into DC power according to the end loads. As there are usually two power conversion stages, higher efficiency is always a goal. Higher efficiency can be achieved by using power switches with better performance or by implementing different control strategies. In addition, choose the most appropriate topology in different conditions. In this system solution guide, basics about offline SMPS will be delivered, together with the featured products and solutions provided by **onsemi**.

System Purpose

Offline SMPS is widely used in every corner of human life which has been discussed and studied since last century. Offline SMPS generally refers to a switching power supply with an isolation transformer which is powered by the grid. It ranges from 65W in your laptop battery charger to thousands of watt in server power supply units in datacenters.

With the mass producing of wide-band gap semiconductor products, new topologies are utilized to reach optimized efficiency, size and integrated level according to real cases. New designed controllers can also contribute to the system safety, power consumption and performance.

“Zero carbon” has set more strict efficiency standards of energy saving and emission reduction on SMPS globally. For example, the European Union Executive Committee's latest CoC V5 and the U.S. Department of Energy DoE VI have clear requirements on the power loss and efficiency during not only full load, but light load/no load to achieve energy saving and emission reduction.

System Implementations

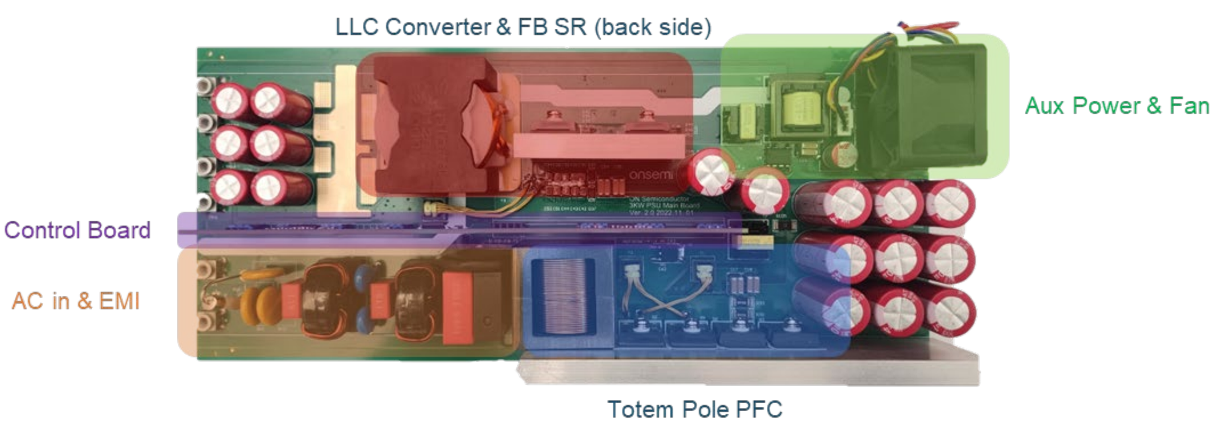


Fig 1: 3kw Totem Pole PFC + LLC PSU Reference Design

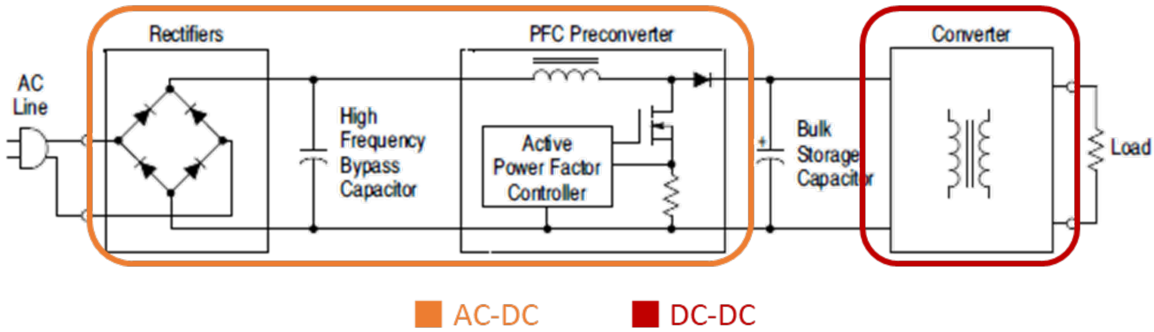


Fig 2: A Typical Offline SMPS

System Description

Standards

There are mainly 3 types of standards. Safety standards like the 2nd edition of IEC 62368-1 is the latest revision clarifying the definitions of insulation, isolation, clearances, creepage distance, etc. IEC 61000-3-2 is an international emissions standard that limits mains voltage distortion by prescribing the maximum value for harmonic currents from the second harmonic up to and including the 40th harmonic current. It applies to equipment with a rated current up to 16A while for equipment above 16A, IEC 61000-3-12 should be followed.

There is a wide variety of regulations covering energy efficiency around the world, from the California Energy Commission to Energy Star and Energy-related Products (ErP). Specific to external power supplies (wall mount or desktop), the US Department of Energy (DoE) publishes a standard described in levels (Level VI is the most recent and most stringent), while in Europe, the European Union (EU) Code of Conduct (CoC) on External Power Supplies (EPS) is prepared by the Joint Research Centre, the European Commission’s science, and knowledge service. The 80 PLUS® program promotes 80% efficiency or greater, between 20% and 100% loading and a power factor of 0.9 or higher at 100% loading. The highest level in this program (known as the 80+ Titanium standard) specifies a minimum efficiency of 92% at 20% loading and 94 % efficiency at 100 % loading.

Power Factor Correction

PFC (Power Factor Correction) is a crucial stage for offline power supply. The key mission of PFC is to shape the input current to maximize the real power available from the mains, reduce the high-frequency harmonic current to minimizes losses and costs associated not only with the distribution of the power, but also with the generation of the power and the capital equipment involved in the process. THD (Total Harmonic Distortion) is an important method in determining the quality of line current in any system and is often mentioned in place of the power factor. Another important value is that PFC stage can provide regulated DC output voltage, optimizing the design of the following isolated DC-DC converter with a narrow DC input.

DC-DC Stage

The purpose of a DC-DC stage is to convert a range of input voltages through an isolated transformer and PWM or resonant converter to a desired DC output voltage(s) and current(s). The key challenge of this stage is the magnetic component design. For example, the skin effect and proximity effect lead to eddy currents of a high-frequency transformer, selection of magnetic core materials, losses from core and copper, etc.

Current Control Mode

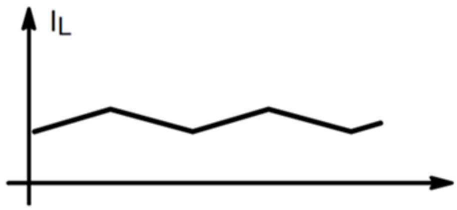
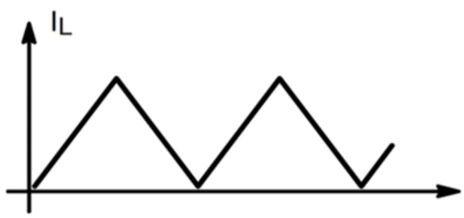
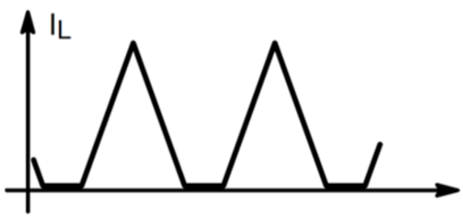
It's necessary to repeat the classical operating modes as they can completely affect not only the choice of topology, but the entire system design. CCM (Continuous Conduction Mode) is more popular at higher power levels as it has minimal peak and rms currents. In CCM, the inductor current ripple is reduced, but the MOSFET turns on while the boost diode is conducting. Low t_{rr} diodes are now necessary to avoid excessive losses and stress at MOSFET turn on. CrM (Critical Conduction Mode) is very popular for low power applications. In this mode the inductor current reaches zero before the start of the next cycle and the frequency varies with line and load conditions. One benefit of CrM is that the current loop is intrinsically stable and there is no need for ramp compensation. In addition, the inductor current reaching zero every cycle causes the diode to turn off without reverse recovery losses and enables the use of a less expensive boost diode without performance penalties. Similarly, the MOSFET turn-on can be at a low voltage, which reduces switching losses.

DCM (Discontinuous Conduction Mode) is usually active at light loads of a CrM/CCM system to ensure power factor and limit the EMI generation because of the significant rising frequency near the zero crossing.

FCCrM (Frequency-Clamped Critical conduction Mode) is an approach introduced by **onsemi** to limit the switching frequency spread of CrM circuits. A maximum frequency clamp forces DCM when the converter operates in light-load and/or near the line zero crossing. Without this circuitry, the CrM switching frequency would exceed the upper clamp threshold, naturally increasing switching losses. A circuitry is added to compensate the DCM-engendered dead-times so that the line current keeps being properly shaped.

System Description

Table 1: Operation modes of switched mode power supplies

Waveform	Symbol	Features
	Continuous Conduction Mode (CCM)	• Always hard switching • Large inductance • Minimized rms current
	Critical Conduction Mode (CrM)	• Highest rms current • Unfixed switching frequency
	Discontinuous Conduction Mode (DCM)	• Higher rms current • Reduced inductance • Best stability

Market Information & Trend

Wide Band-gap Semiconductors

With the mass production of WBG devices, we are experiencing or will soon see SiC/GaN based SMPS. Utilizing the characteristics of these materials (better reverse recovery, excellent thermal performance, high operating voltage, high temperature), the new systems can operate at higher frequency, smaller PCB sizes and even without heatsink or forced colling. However, high frequency will also bring potential issues like emissions, overshoot, etc., which means a completely new design.

Integration

Integration is an effective way to save PCB space and external passive components, which finally increase the power density and flexibility of mounting. For example, GaN HEMT is a popular choice in low/med power supplies (Pout<1500W) for the minimized size of end-product. Under such circumstance that dv/dt might be over 100V/ns, reduction of parasitic inductance is necessary. Integrating the GaN HEMT and driver in a same package can reduce the inductance caused by lead and PCB, result in a better switching performance.

New Topologies for Better Efficiency

Totem pole PFC saves the losses caused by rectifier bridges, makes it a preferred PFC topology than single boost in high power density products. Now LLC is becoming the no.1 popular DC-DC topology in medium and high-power range for its wider range of soft switching, narrow frequency range with entire load change and smaller circulating current. WBG semiconductor plays a key role in these new topologies while a smart and low-power controller is another important factor for high efficiency.

Offline SMPS

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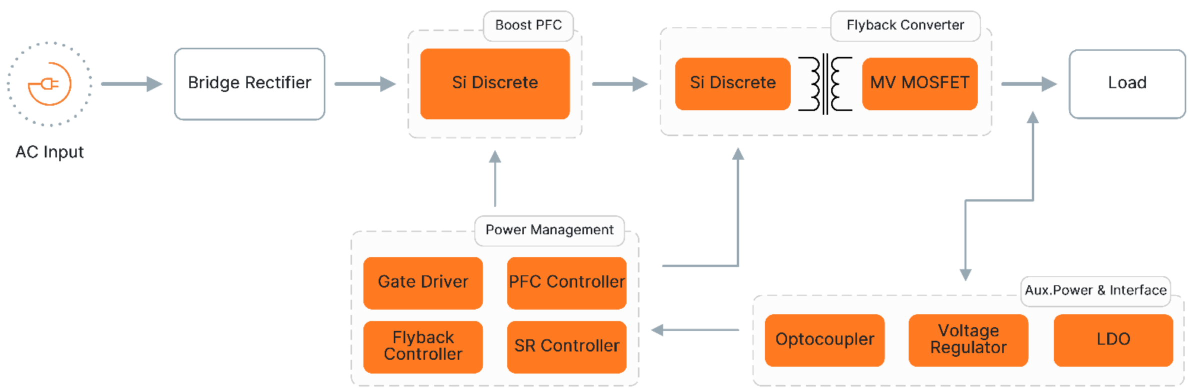
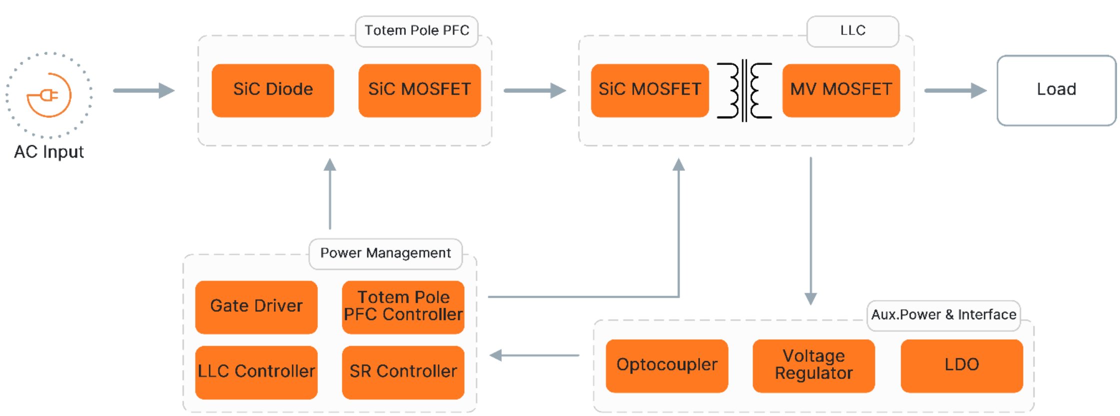
Solution Overview

Offline Power Supply (Bridge PFC + Flyback Converter)

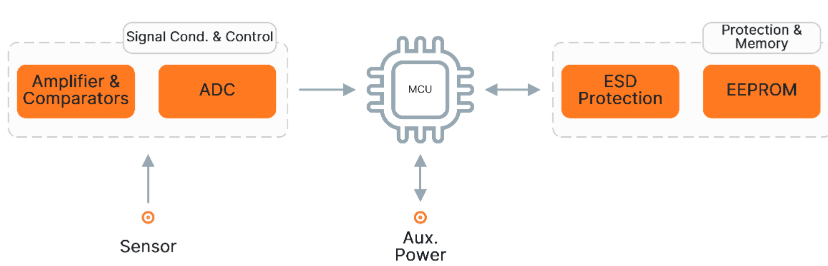


[Find Interractive Block Diagram on the Web]

Offline Power Supply (Totem Pole PFC + LLC Resonant Converter)



*Optional



[Find Interractive Block Diagram on the Web] onsemi

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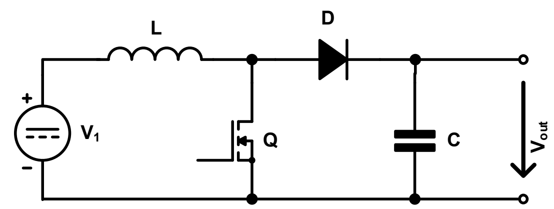
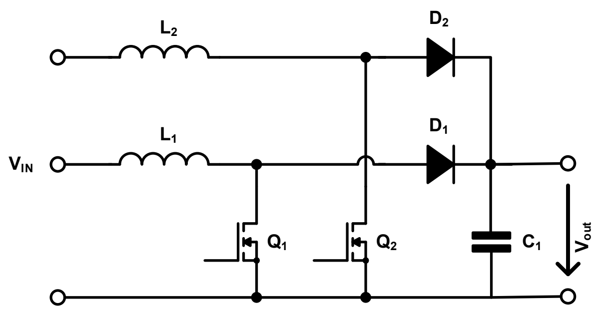
Solution Overview

PFC



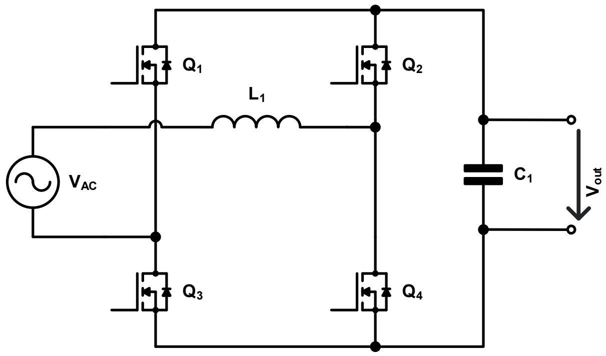
Single Boost PFC

- Simplest circuit and easiest control
- Low BOM cost, low failure rate
- Unavoidable losses caused by rectifers
- Moderate size and EMI performance



Interleaved Boost PFC

- 2x/more power and passive components
- Switches are controlled with 180/120 degrees out of phase
- Unavoidable losses caused by rectifers
- Improved efficiency and ripple current
- Improved total inductor size vs. a big single inductor
- An easy approach to improve output power



Totem Pole PFC

- Reduced power switch quantity
- More complex control than boost PFC
- Best efficiency and higher power with bridgeless structure
- WBG required in fast leg
- Emission and surge current issues
- Preferred in high-end PSU with power density/efficiency requirement

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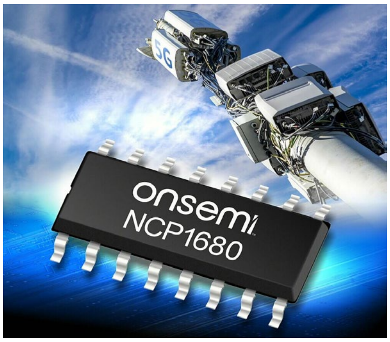
Solution Overview

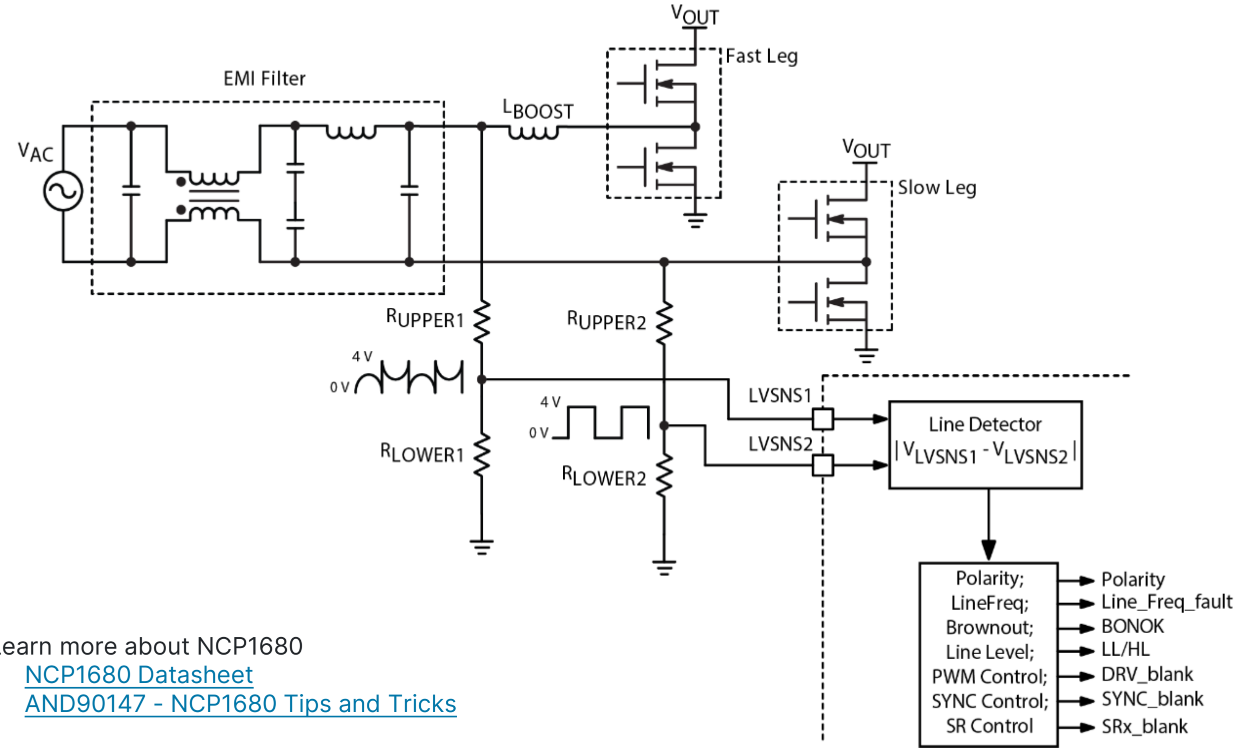


NCP1680
CrM Totem Pole PFC Controller

- Constant on-time CrM and valley switching frequency foldback
- AC line monitoring & phase detection
- Novel current sensing scheme
- UVLO, thermal shutdown
- Cycle by cycle current limit without hall sensor
- Target application – High power-density PSU

Line Voltage Sensing of NCP1680

In the Totem Pole topology, the AC line voltage floats with respect to the controller ground. This necessitates a differential measurement technique to determine the AC line voltage magnitude. The NCP1680 employs differential voltage detection and rectification to reconstruct a waveform equal to $|V_{LVSNS1} - V_{LVSNS2}|$. The line voltage sensing will additionally be responsible for determining the polarity (i.e. positive or negative half–line cycle) of the AC voltage and the other important functions:
a. AC Line Frequency Monitoring
c. Brownout protection feature
d. Line level detection
e. AC zero crossing drive management

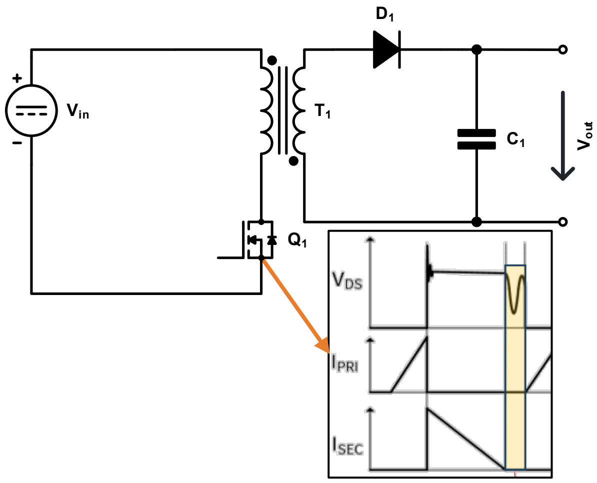


Learn more about NCP1680
- NCP1680 Datasheet
- AND90147 - NCP1680 Tips and Tricks

Fig 3: Line Sensing Configuration

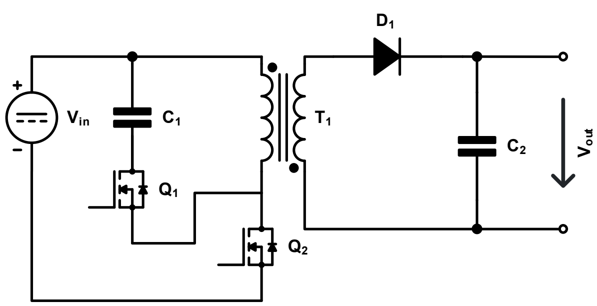
Solution Overview

DC-DC Stage



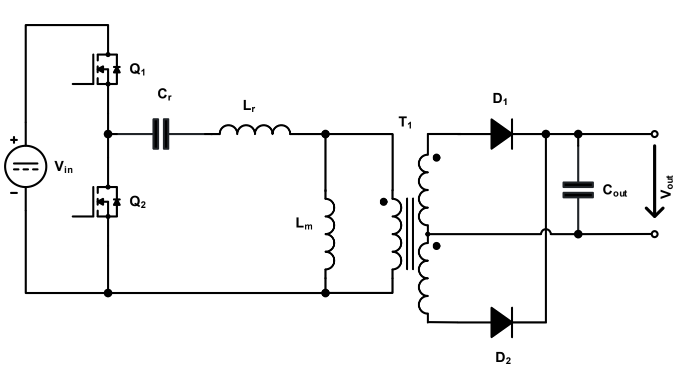
Quasi-Resonant (QR) Flyback

- Same circuit design as a classic flyback, low cost and simple design
- Valley switching to reduce losses after Isec=0A
- Dangerous primary voltage spike caused by leakage inductance (converter to heat with RCD snubber)
- Targeting low output level (<200W)
- Need demagnetization detection



Active Clamp Flyback (ACF)

- Additional clamp switch is used to improve efficiency and protect main switch
- Recycle leakage inductance current instead of consuming it with a snubber
- Clamp capacitor and leakage inductance realize ZVS
- Medium output level is targeted (120W-240W)
- Need accurate resonant circuit parameter calculation



LLC

- Resonant converter achieve wide range of soft switching to improve efficiency
- ZVS at primary side, ZCS at secondary side
- Integrated inductor to save space
- Simple BOM, complicated resonant tank design and control alogrithm
- Good EMI and output ripple
- Limited output range
- High ouput level is targeted (>240W)

Solution Overview

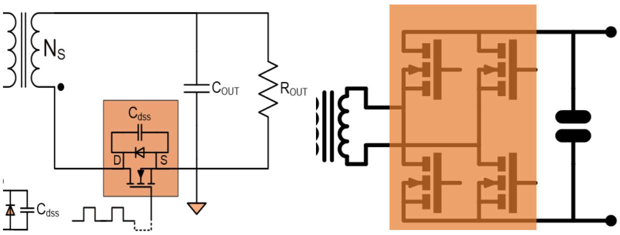
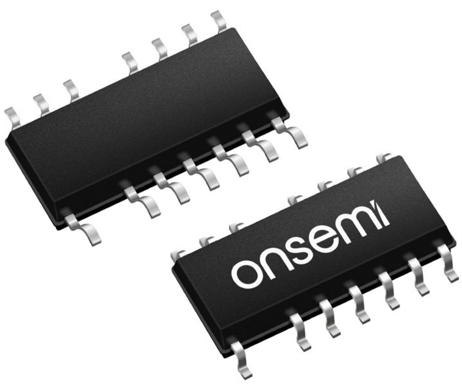


Fig 4: Synchronous rectification

Synchronous Rectification for Flyback/LLC

- Relacing diodes with MOSFET switches to reduce conduction losses and improve efficiency
- Accurate switching timing detection



NCP4390

Dual Channel LLC Controller

- Constant on-time CrM and valley switching frequency foldback
- AC line monitoring & phase detection
- Novel current sensing scheme
- UVLO, thermal shutdown
- Cycle by cycle current limit without hall sensor
- Target application – High power-density PSU

Dual Edge Tracking of NCP4390

NCP4390 uses a dual–edge–tracking method that anticipates the SR current zero–crossing instant with respect to two different time references. This technique not only minimizes the dead time during the normal operation but also provides stable SR control during any transient and mode change.

Learn more about NCP4390

- NCP4390 Datasheet
- AND90061 - Half-Bridge LLC Resonant Converter Design Using NCP4390/NCV4390

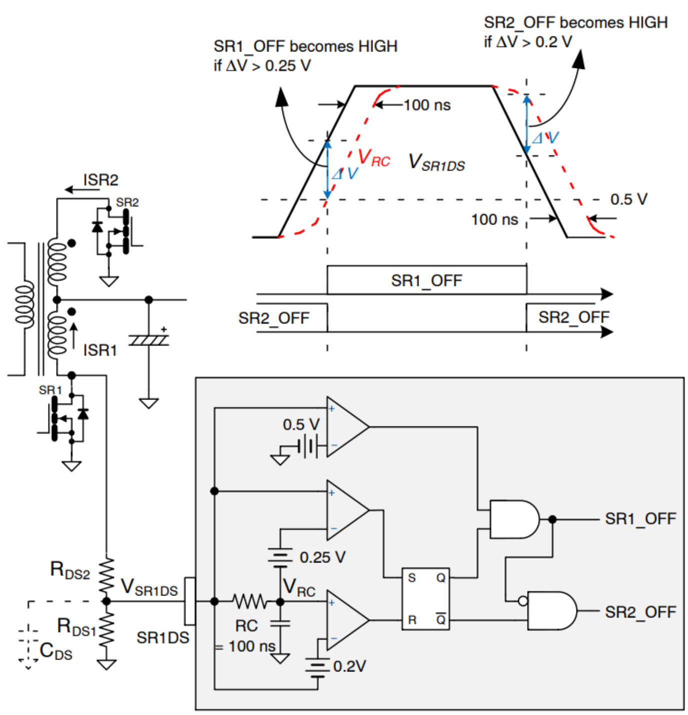


Fig 5: SR Conduction Detection with Single Pin

Recommended Products

Suggested Block	Part Number	Description
	Offline Power Supply (Bridge PFC + Flyback Converter)	
Boost PFC & Flyback Converter (Primary Stage)	NTD280N60S5Z	Power MOSFET, N-Channel, 600V, 280mΩ, 13A, DPAK
	NTP125N60S5H	Power MOSFET, N-Channel, 600V, 125mΩ, 22A, TO-220
	NTMT280N60S5Z	Power MOSFET, N-Channel, 600V, 280mΩ, 13A, Power88
	NTBL150N60S5H	Power MOSFET, N-Channel, 600V, 150mΩ, 19A, TOLL
	NTBL125N60S5H	Power MOSFET, N-Channel, 600V, 125mΩ, 22A, TOLL
	Application Recommended Si MOSFET	
Flyback Converter (Inc. Sync. Rectifier)	MUR810G	Power Rectifier, 100V, 8A, to-220
	MBR60H100CTG	Schottky Rectifier, 100V, 60A, TO-220
	NRTS30100MFS	Trench Schottky Rectifier, 100V, 30A, SO8-FL
	MBR41H100CTG	Schottky Barrier Rectifier, 100V, 40A, TO-220
	Application Recommended Secondary Stage Diode	
	MURA160T3G	Power Rectifier, 600V, 1A, SMA-2
	NRVUHS160V	Ultrafast Rectifier, 600V, 1A, SMB-2
	MURHS160T3	Ultrafast Rectifier, 600V, 1A, SMB2
	Application Recommended Snubber Diode	
	NTMFS0D4N04XM	Power MOSFET, N-Channel, 40V, 0.7mΩ, 323A, SO8-FL 5x6
	NTMFWS1D5N08X	Power MOSFET, N-Channel, STD Gate. SO8FL-HEFET, 80V, 1.5mΩ, 247 A
	NTBGS004N10G	Power MOSFET, N-Channel, 203 A, 100V, D2PAK 7L
	NTMFS3D2N10MD	N-Channel Shielded Gate PowerTrench® MOSFET 100V, 142A, 3.2mΩ
	NTMFS7D5N15MC	N-Channel Shielded Gate PowerTrench® MOSFET 150V, 95.6A, 7.9mΩ
	Application Recommended SR MOSFET	
Power Management	NCP4305	Sync. Rectification Driver for QR, Forward & LLC
	NCP4306	Sync. Rectification Driver for QR, Forward & LLC
	NCP4307	SR Driver with Dual Vcc and Self-supply for ACF, QR, Forward & LLC
	NCP4318	Dual Channel Sync. Rectification Driver for LLC
	Application Recommended SR Controller	
	NCP1623	Critical Conduction Mode (CrM) PFC Controller, Follower Boost
	NCP1632	Critical Conduction Mode (CrM) PFC Controller, 2 Channel Interleaved
	NCP1618	Multimode (CrM-CCM) PFC Controller, Active X2
	NCP1654	Continuous Conduction Mode (CCM) PFC Controller
	NCP1616	Critical Conduction Mode (CrM) PFC Controller, CCFF, Active X2
	Application Recommended PFC Controller	

Recommended Products

Suggested Block	Part Number	Description
Power Management	NCP1251	PWM Controller, Current Mode for Offline Power Suppliers
	NCP1342	Quasi-Resonant Flyback Controller with Valley Lock-out Switching
	NCP1343	Quasi-Resonant Flyback Controller with Power Excursion Mode
	NCP1345	Quasi-Resonant flyback controller for offline USB-PD and USB Type-C
	NCP1568	AC-DC Active Clamp Flyback PWM Controller
	Application Recommended Flyback Controller	
	NCP51530	High Performance, 700 V- 3.5/3.0 A High and Low Side MOSFET Driver
	NCP5183	High Voltage 4.3 A High and Low Side Driver
	NCP51810	High Performance, 150 V Half Bridge Gate Driver for GaN Power Switches
	NCP51561	4.5/9A Isolated Dual Channel Gate Driver with 8V UVLO and DISABLE
	Application Recommended Gate Driver	
Aux. Power & Interface	FOD817 series	4-Pin DIP Phototransistor Optocouplers
	FOD217 series	4-Pin Phototransistor Optocoupler In Half-Pitch Mini-Flat
	FODM100 series	Single Channel, Phototransistor Optocoupler In Stretched Body SOP 4-Pin
	Application Recommended Optocoupler	
	NCP718	LDO Regulator, 300 mA, Wide Vin, Ultra-Low Iq
	NCP730	LDO Regulator, 150 mA, 38 V, 1 uA IQ, with PG
	NCP731	LDO Regulator, 150 mA, 38 V, 8 μVrms with Enable and external Soft Start.
	NCP164	LDO Regulator, 150 mA, Ultra-Low Noise, High PSRR with Power Good
	Application Recommended LDO	
	NCV6324	Synchronous Buck Converter, 3 MHz, 2.0 A
	LM257 series	Buck Regulator, Switching Adjustable Output Voltage
	Application Recommended Voltage Regulator	
Offline Power Supply (Totem Pole PFC + LLC Resonant Converter)		
Totem Pole PFC	NTH4L023N065M3S	SiC MOSFET - EliteSiC, 23 mΩ, 650 V, M3S, TO-247-4L
	NTHL023N065M3S	SiC MOSFET - EliteSiC, 23 mΩ, 650 V, M3S, TO-247-3L
	NTBG023N065M3S	SiC MOSFET - EliteSiC, 23 mΩ, 650 V, M3S, D2PAK-7L
	NTBG015N065SC1	SiC MOSFET - EliteSiC, 12 mohm, 650 V, M2, D2PAK-7L
	NTBL045N065SC1	SiC MOSFET - EliteSiC, 33 mohm, 650 V, M2, TOLL
	NTH4L015N065SC1	SiC MOSFET - EliteSiC, 12 mohm, 650 V, M2, TO-247-4L
	NTMT045N065SC1	SiC MOSFET - EliteSiC, 33 mohm, 650 V, M2, Power88
	NTHL075N065SC1	SiC MOSFET - EliteSiC, 57 mohm, 650 V, M2, TO-247-3L
	Application Recommended SiC MOSFET	

Recommended Products

Suggested Block	Part Number	Description
Totem Pole PFC	FFSD0665B	SiC Schottky Diode – EliteSiC, 6 A, 650 V, D2, DPAK
	FFSP0665B	SiC Schottky Diode – EliteSiC, 6 A, 650 V, D2, TO-220-2L
	FFSM0865B	SiC Schottky Diode – EliteSiC, 8 A, 650 V, D2, Power88
	FFSB1065B	SiC Schottky Diode – EliteSiC, 10 A, 650 V, D2, D2PAK-2L
	Application Recommended SiC Diode	
LLC	NTBG015N065SC1	SiC MOSFET - EliteSiC, 12 mohm, 650 V, M2, D2PAK-7L
	NTBL045N065SC1	SiC MOSFET - EliteSiC, 33 mohm, 650 V, M2, TOLL
	NTH4L015N065SC1	SiC MOSFET - EliteSiC, 12 mohm, 650 V, M2, TO-247-4L
	NTMT045N065SC1	SiC MOSFET - EliteSiC, 33 mohm, 650 V, M2, Power88
	NTHL075N065SC1	SiC MOSFET - EliteSiC, 57 mohm, 650 V, M2, TO-247-3L
	Application Recommended SiC MOSFET	
	NTMFS0D4N04XM	Power MOSFET, N-Channel, 40V, 0.7mΩ, 323A, SO8-FL 5x6
	NTMFWS1D5N08X	Power MOSFET, N-Channel, STD Gate. SO8FL-HEFET, 80V, 1.5mΩ, 247 A
	NTBGS004N10G	Power MOSFET, N-Channel, 203 A, 100V, D2PAK 7L
	NTMFS3D2N10MD	N-Channel Shielded Gate PowerTrench® MOSFET 100V, 142A, 3.2mΩ
	NTMFS7D5N15MC	N-Channel Shielded Gate PowerTrench® MOSFET 150V, 95.6A, 7.9mΩ
	Application Recommended MV MOSFET	
Power Management Gate Driver	NCP51530	High Performance, 700 V- 3.5/3.0 A High and Low Side MOSFET Driver
	NCP5183	High Voltage 4.3 A High and Low Side Driver
	NCP51810	High Performance, 150 V Half Bridge Gate Driver for GaN Power Switches
	NCP51561	4.5/9A Isolated Dual Channel Gate Driver with 8V UVLO and DISABLE
	Application Recommended Gate Driver	
	NCP1680	Totem Pole CrM Power Factor Correction Controller
	NCP1681	Totem Pole CCM/ Multi-mode (CrM-CCM) PFC Controller
	Application Recommended Totem Pole PFC Controller	
	NCP4390	Resonant Controller with Sync. Rectifier Control, Enhanced Light Load
	NCP13992	Current Mode Resonant Controller with Integrated High Voltage Drivers, Enhanced Light Load
	NCP13994	Current Mode Resonant Controller with Integrated High Voltage Drivers, Enhanced Protections, Active X2
	Application Recommended LLC Converter Controller	

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	FOD217 series	4-Pin Phototransistor Optocoupler In Half-Pitch Mini-Flat
	FODM100 series	Single Channel, Phototransistor Optocoupler In Stretched Body SOP 4-Pin
	Application Recommended Optocoupler	
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	NCP730	LDO Regulator, 150 mA, 38 V, 1 uA IQ, with PG
	NCP731	LDO Regulator, 150 mA, 38 V, 8 μVrms with Enable and external Soft Start.
	NCP164	LDO Regulator, 150 mA, Ultra-Low Noise, High PSRR with Power Good
	Application Recommended LDO	
	NCV6324	Synchronous Buck Converter, 3 MHz, 2.0 A
	LM257 series	Buck Regulator, Switching Adjustable Output Voltage
	Application Recommended Voltage Regulator	
Optional Parts - Offline Power Supply (Totem Pole PFC + LLC Resonant Converter)		
Signal Cond. & Control	NCS21 series	Current Sense Amplifier, 26V, Low-/High-Side Voltage Out
	NCS2007 series	Operational Amplifier, Wide Supply Range, 3MHz CMOS
	LM393	Comparator, Dual, Low Offset Voltage
	Application Recommended Amplifier & Comparator	
Protection & Memory	CAT24M01	EEPROM Serial 1 MB I2C
	CAT24C64	EEPROM Serial 64 kb I2C
	Application Recommended EEPROM	
	NCID9 series	High Speed Dual/3ch/Quad Digital Isolator
	NIS3071	Electronic fuse (eFuse) 4-channel, 8V to 60V, 10A in 5x6mm package
	MM5Z series	500 mW Tight Tolerance Zener Diode Voltage Regulator

Development Tools & Resources

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Perform simulations for our EliteSiC MOSFETs, modules, FieldStop7 IGBTs and PowerTrench® T10 MOSFETs using appropriate engineering tools and software.

Simulate Now

Self-Service PLECS Model Generator

Increase Accuracy with Customization and Improve Circuit Performance

Generate PLECS Model

Technical Documents

Type	Description & Link
Power Discrete	
Whitepaper	Silicon Carbide (SiC) – From Challenging Material to Robust Reliability
Whitepaper	Physically Based, Scalable SPICE Modeling Methodologies for Modern Power Electronic Devices
Application Note	Mounting Considerations for Power Semiconductors
Gate Driver	
Application Note	NCD(V)57000/57001 Gate Driver Design Note
Whitepaper	SiC MOSFETs: Gate Drive Optimization
Application Note	Practical Design Guidelines on the Usage of an Isolated Gate Driver
Application Note	Design and Application Guide of Bootstrap Circuit for High-Voltage Gate-Drive IC
Application Note	Analysis of Power Dissipation and Thermal Considerations for High Voltage Gate Drivers
Power Factor Correction	
Whitepaper	Meeting Challenging Efficiency Standards with Bridgeless Totem Pole Power Factor Correction
Application Note	Power Factor Correction Basics
Whitepaper	Power Factor Correction – Optimization Options
Application Note	Design Guideline for 3-Ch Interleaved CCM PFC Using the FAN9673 5kW CCM PFC Controller
Whitepaper	Totem Pole PFC Layout Considerations
Application Note	Key Steps to Design A Compact, High-Efficiency PFC Stage Using NCP1623A
Application Note	CrM Totem Pole PFC IC Tips and Tricks
Application Note	Key Steps to Design a Multimode PFC Stage Using the NCP1618A
Application Note	FAN9672/3 Tips and Tricks
Flyback	
Whitepaper	High-Density AC-DC Power Supplies using Active-Clamp Flyback Topology
Application Note	Design of a 100W ACF DC-DC Converter for Telecom System Using NCP1262
LLC	
Application Note	Half-Bridge LLC Resonant Converter Design Using NCP4390/NCV4390
Application Note	Understanding the LLC Structure in Resonant Applications

Technical Documents

Type	Description & Link
Miscellaneous	
Application Note	Current Sense Amplifiers, FAQ
Application Overview	
Collateral	Power Supply Solutions
Whitepaper	Popular Topologies in Offline Power Supplies
White Paper	Meeting Ultra−High−Density Design Challenges with GaN−based 300W Totem Pole PFC and LLC Power Supply
Evaluation Board	High Performance 800 V Off-line Switcher with HV Startup and SenseFET Evaluation Board
Evaluation Board	NCP1345 USB-PD 65W Evaluation Board
Evaluation Board	NCP1343 100 W USB PD Evaluation Board
White Paper	3kW Totem-Pole PFC and Secondary-Side Regulated LLC Power Supply Using SiC MOSFETs
Design Tool	NCP1680 Design Calculator
Design Tool	NCP1681 Totem Pole Multi-Mode Controller Design Excel Calculator
Design Tool	NCP1681 Totem Pole CCM Controller Design Excel Calculator
Design Tool	NCP1681 Design Worksheet
Design Tool	NCP134x Design Tool
Design Tool	NCP1399x Design Tool

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