System Solution Guide

Uninterruptible Power Supply (UPS)

Updated: MAR-2024

Industry	Energy Infrastructure – UPS (Uninterruptible Power Supply)
Application	In the 20th century, when the UPS was first invented, its sole purpose was to provide emergency power during power failures, and its expensive cost limited its application. Today, with the continuous development of power electronics, the UPS can efficiently optimize power quality, filter line noise, suppress surges, and provide longer backup power in any location on demand. Low energy consumption, high reliability and small footprint have become the new development directions for the UPS in a low-carbon society.

System Purpose

AC power is stable and clean upon generation. However, during transmission and distribution, it is subject to voltage sags, spikes and outages that can disrupt computer operations, cause data loss and damage equipment.

The uninterruptible power supplies protect the connected equipment from power problems and provide battery backup during power outages. Additionally, they protect against damage to the expensive equipment, data loss and downtime. Depending on the type they can also protect against abnormal voltages. An important attribute of any UPS is its output capacity. The output capacity is the maximum power that the connected load can draw from the UPS system. It is expressed in VA (volt amperes).

Currently, there are three types of the UPS systems: online, offline and line-interactive. Each of them has advantages and is more suitable for some applications than others.

The online UPS excels in providing high reliability and power protection. It is designed to provide continuous power to the connected load. Its distinctive feature is a double power conversion stage, which ensures maximum reliability and at the same time places extremely high demands on the efficiency of the power conversion. The load is always connected to the inverter of the UPS, eliminating switching delays. Thanks to the power factor correction stage the output power is in phase with the input power, improving the overall efficiency. Its battery storage system combined with a bidirectional charger can provide continuous, seamless power when the AC input is interrupted. The online UPS is the most expensive, but it can effectively deal with a wide range of power issues and provide the highest quality output. This makes it the best choice for highly sensitive devices, data centers, and other critical equipment.

System Purpose

Since it is the most complex and sought after solution, the research and innovation in the UPS systems has tended to focus more on the online UPS, involving not only hardware but also software. Despite being an application that emphasizes reliability it has been relatively slow to develop compared to applications such as electric vehicles. But with the increasing demand for green energy and the continuous development of AI, big data and cloud computing, we can expect more evolution and incorporation of new technologies and materials, such as SiC, GaN and others.

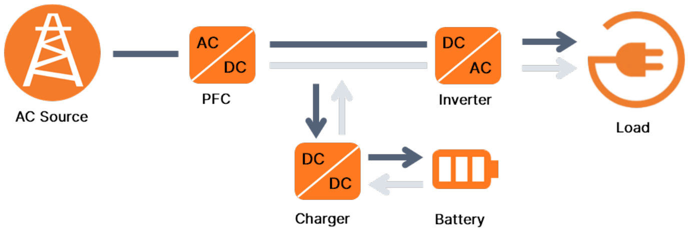


Fig.1: Online UPS

The offline UPS (also called standby UPS) has the load directly connected and powered by the input power, and the backup power is only activated when the source fails. It always experiences short interruption (tens of milliseconds) when switching to the battery. It has the lowest cost and provides no additional safety features. This makes it less suitable for safeguarding industrial facilities due to potential safety concerns associated with the switching delay. It is most commonly used in homes and small office environments where the required backup power is relatively small, and the requirements are less stringent.

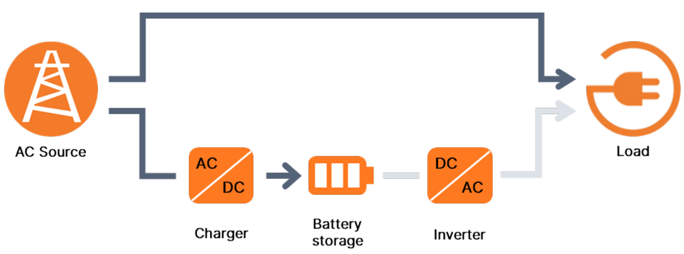


Fig.2: Offline UPS

The line-interactive UPS is similar to the offline UPS, but additionally uses an active voltage conditioner. It regulates and compensates the AC output by either increasing or decreasing the voltage to provide a more stable output voltage to the load. The line-interactive UPS can act as a voltage optimizer and help to extend battery life, since it is activated less frequently. When using the line-interactive UPS, the input power issues are addressed to some extent, whereas the offline UPS has to resort to the battery mode whenever the abnormal input conditions occur. The line-interactive UPS can be used for small and medium businesses and wherever the mains voltage and quality is unreliable.

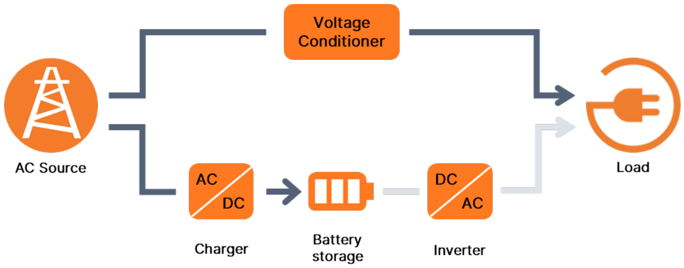


Fig.3: Line-interactive UPS

Market Information & Trends

Blooming Global Market

Considering a number of factors, the outlook for the UPS market appears promising. The UPS market is expected to reach USD 14.3 billion in 2029, growing at a CAGR (compound annual growth rate) of 4.05%. The ongoing digital transformation has led to continuous growth and increasing demand for reliable and stable power supply. The market is driven by the rising demand for IOT and smart buildings, the ever-increasing number of data centres and the growing cloud computing sector. High-stakes applications such as cloud computing and big data, impose strict requirements for efficient and stable electrical power. Industries like manufacturing and healthcare, dependent on 24×7 operations, require a reliable backup power supply. Moreover, the evolving demands of environmental protection contribute to the development of energy management, with energy efficiency and emission reduction becoming paramount societal goals.

Major restraint against higher adoption is the high cost of the online UPS systems. Additionally, maintenance costs may be increased by the need for battery replacements. The capacity of the UPS units is limited, and therefore may not be sufficient for high power applications.

Power Grid Anomalies

When choosing the appropriate UPS solution for a particular application, it is important to consider its purpose, power output requirements and overall budget. It is important to know what the quality of the power grid is and what power irregularities can be expected. Some of the features are essential while in some cases, advanced features might not be required. The performance of the UPS types is shown in the Table 1.

Table 1: UPS protection against different anomalies

Power Issue	Offline	Line-interactive	Online
Power Failure	Yes	Yes	Yes
Power Surges	Yes	Yes	Yes
Spikes/Transients	Yes	Yes	Yes
Under/Overvoltage	No	Yes	Yes
Brownouts	No	Yes	Yes
Frequency Variation/ Harmonic Distortion	No	No	Yes

Market Information & Trends

Modular UPS

The demand for the modular UPS is growing. Modularity brings scalability, redundancy, adaptability, lower repair costs, space savings and enhanced fault isolation. These features make the modular UPS a preferred choice in various applications especially those requiring reliable and flexible power solutions.

Higher Power Density & Efficiency

The adoption of the modular design has, to some extent, accelerated the development of high-power density products. Faced with challenges such as limited space, increasing output capacity, and harder to cool environments, the next generation of the UPS products needs to transition towards the higher power density designs. This entails achieving more compact physical dimensions while increasing output capability. The concept of high switching frequency remains a key consideration.

It is undeniable that the efficiency improvement is the leading development direction for all power converters, particularly for products such as the online UPS which continuously undergo power conversion. The improved efficiency translates into cost-effectiveness and addresses the imperative of sustainability. By incorporating more advanced power electronic devices and topologies, the energy losses can be minimized, especially with a focus on improving efficiency under light load conditions.

Battery System

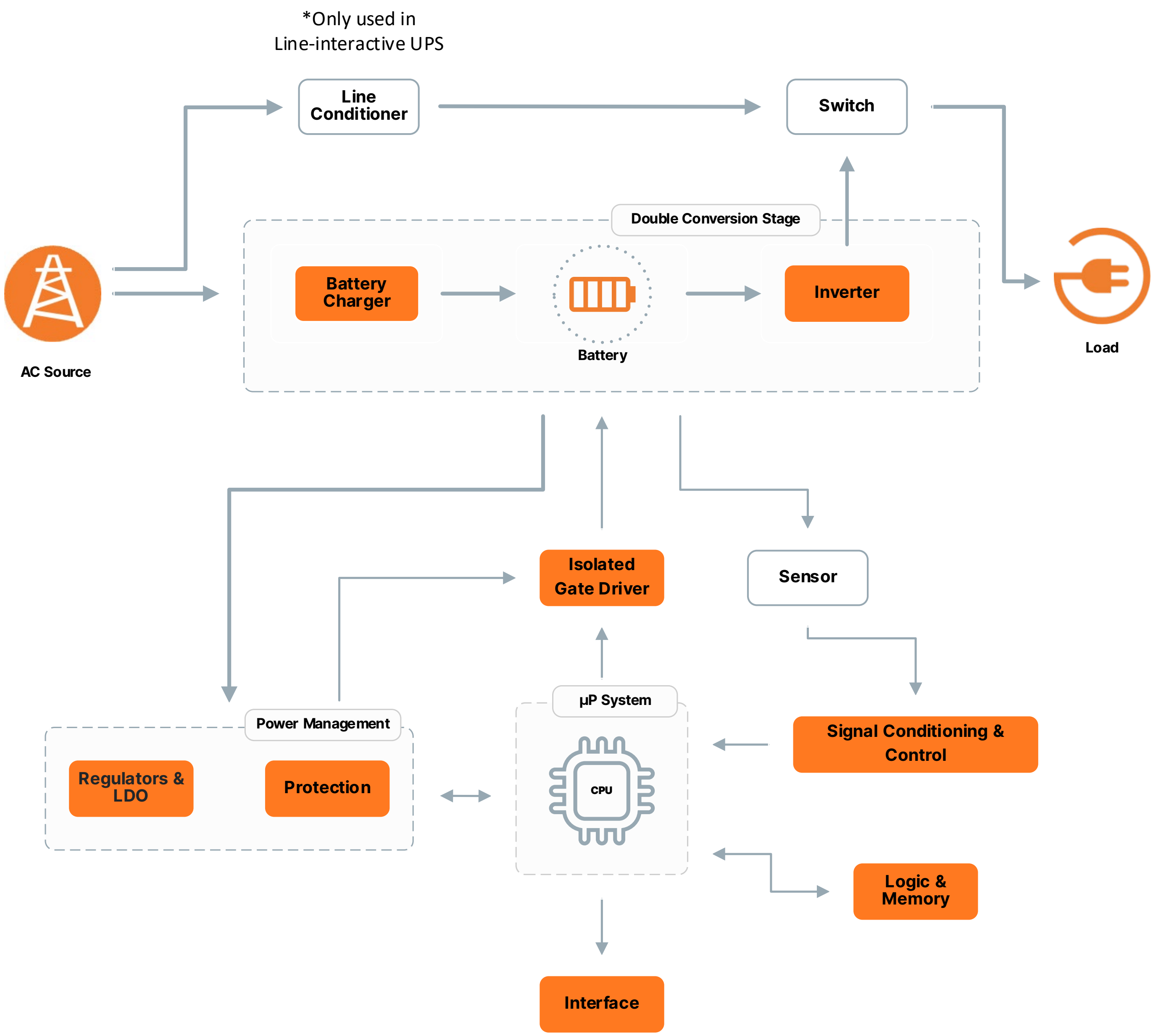
The batteries and battery management systems, constitute critical components of the UPS. The UPS uses mainly lead-acid and lithium-ion (Li-ion) batteries. Lead-acid batteries are reliable, cost-effective and have low internal resistance. On the other hand, they are robust, therefore suitable where weight and space are not an issue. The Li-ion batteries have significantly higher power density (can be smaller and lighter), high reliability (thanks to the integrated battery monitoring system) but are still the more expensive option. The adoption of more advanced and compact battery technologies aims to provide longer backup power and higher energy density.

Table 2: Pros and Cons of UPS systems

UPS type	Pros	Cons	Power Range
Offline	• Low price • High-efficiency – the inverter is used only in cases of main power failure	• Limited protection against power irregularities • The load is exposed to transients and spikes, risk of load damage • Time delay when switching to battery operation	<2kVA
Line-interactive	• Reliable and efficient • Adequate voltage conditioning – helps with unstable power line	• Does not provide PFC or frequency regulation • Time delay when switching to battery operation	<5kVA
Online	• No fluctuation in voltage • No downtime in cases of main failure • Highest available protection against all power irregularities	• Complex and expensive • Lower efficiency – double conversion is always active • The AC/DC stage requires– higher wattage	>10kVA

Solution Overview

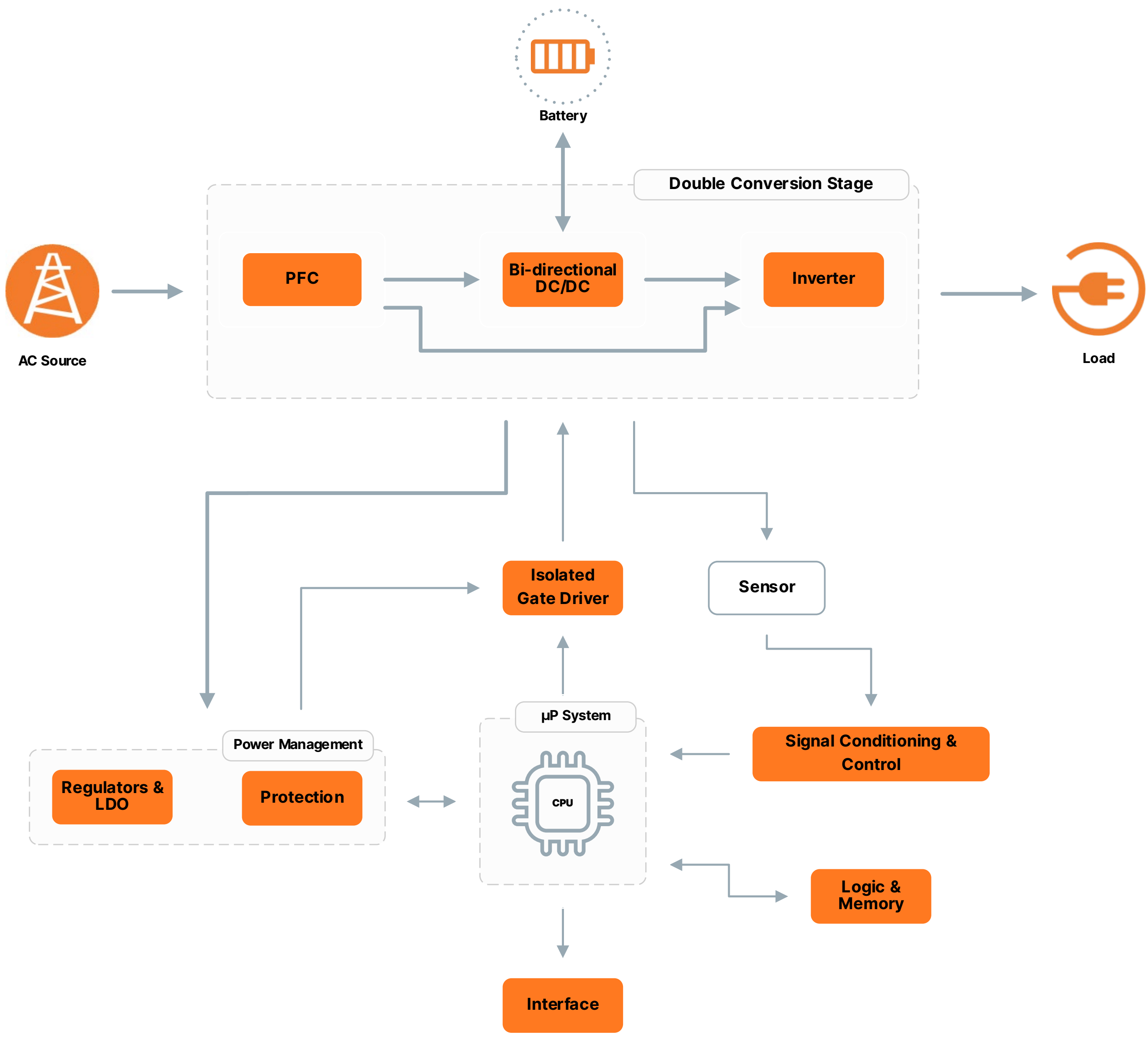
System Block Diagram – Offline & Line-interactive UPS



Find Interactive Block Diagram on the Web

Solution Overview

System Block Diagram – Online UPS



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Solution Overview

Topology

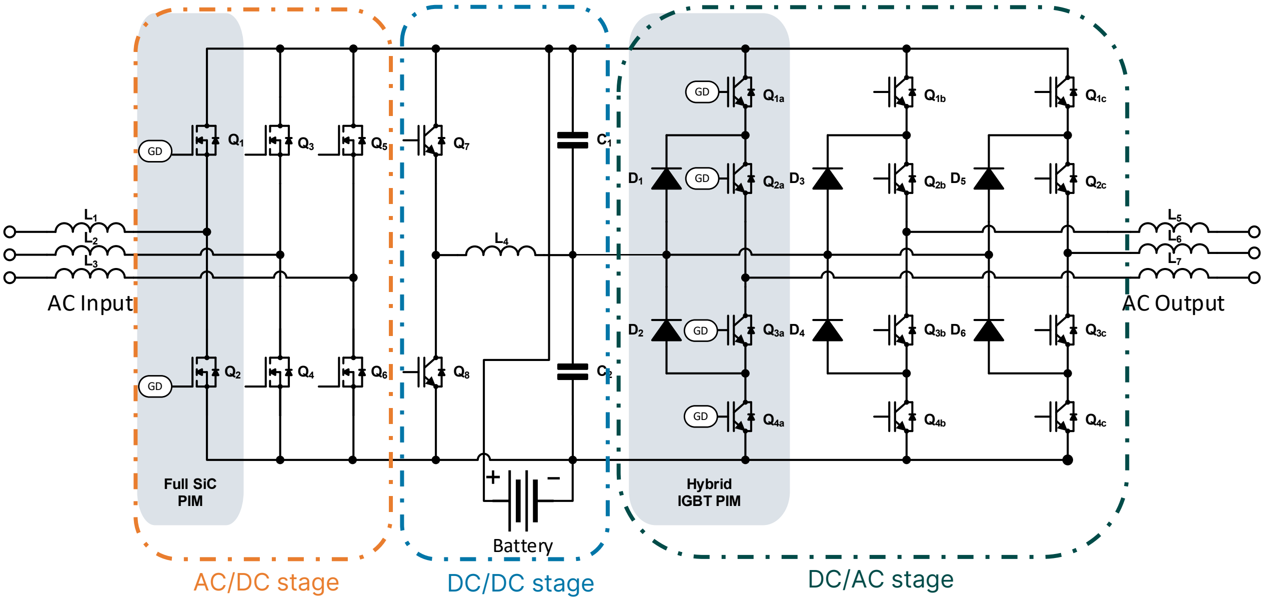


Fig.4: Double Conversion stage of Online UPS

The Online UPS is a complex system with multi-stage power conversion. A schematic of a three-phase system is shown in the Figure 4. In the online UPS system, a huge importance is placed on the efficiency, since in the hybrid mode (also known as normal mode), the system's battery is being charged, and simultaneously a stable AC output is required. This also means that the system must be able to withstand this additional charging current.

The most common topologies for all the stages of the UPS system can be found at pages 21-24. Advantages, challenges and suitable applications of the topologies shown are also presented.

AC/DC stage

The input AC voltage is converted into DC voltage using a PFC stage. Currently, the solution can be chosen from various topologies. Selected approach depends on the power level and on the number of phases. For single phase systems – low power, traditional boost PFC can be used. Please refer to Demystifying Three-Phase Active Front End or Power Factor Correction (PFC) Topologies and DC–DC Power Conversion Topologies for Battery Energy Storage Systems (BESS) for more information on AC/DC topologies.

Totem Pole is a widely used PFC topology for high power applications, due to improved efficiency by replacing diodes with active switches. It can be used for both single and three phase applications. The Totem Pole PFC stage consists of a fast-leg (switched at high frequency 100 kHz or more) and a slow-leg (switched at mains frequency).

For the fast leg, it is recommended to take use of the emerging SiC (Silicon Carbide) technology. SiC increases power density, allowing the system to switch faster, use smaller passives, therefore reducing the overall power dissipation. It also allows the system to operate at higher voltages, reducing conduction losses. **onsemi** offers both discrete SiC (MOSFETs and diodes) and power integrated modules (PIM).

IGBTs or SUPER FETs from **onsemi** portfolio can be used as slow-leg switches.

Last but not least, the Vienna rectifier is a popular three-phase topology. Due to its highest power level, it requires SiC technology – SiC diodes and either SiC MOSFETs or SiC Power Integrated Modules.

Solution Overview

DC-DC battery charger

A bidirectional battery charger is placed between the PFC stage and the inverter stage. Bidirectional operation means, that current can flow in both directions, to the battery when charging, and to the load whenever required. In some cases where galvanic isolation is not required, non-isolated topologies can be used. Isolated types are, however, more suitable for high voltage applications. The most common isolated DC-DC converter topology are the CLLC resonant converter and the dual active bridge (DAB). The dual active bridge has high efficiency and can operate as a rectifier or a converter, depending on its mode. Different switches can be used depending on the voltage and power level. For single phase, any 650V technology can be used – Si, SiC, IGBT. For three phase systems 1200V SiC MOSFETs are ideal.

DC-AC Inverter stage

The inverter defines the output performance of any UPS system. A sine wave output is always the goal to avoid damage to sensitive equipment. The inverter stage uses a three-level or multi-level topology to produce a high-quality AC output. IGBT (Insulated-Gate Bipolar Transistor) is currently preferred to be used as a main switch in inverter, due to its price and maturity of the technology. The UPS is not a product like solar inverter, which is undergoing a rapid development. The FGHL40T120RWD, a 1200 V rated IGBT featuring the latest FS7 technology complemented with the EliteSiC SiC diodes, will accomplish high-performance in I-NPC inverter.

Half-bridge configuration is common. Gate drivers are used to drive the switches safely and efficiently. The NCD57200 is a high voltage dual gate driver with one non-isolated low-side gate driver and one galvanically isolated high or low-side gate driver. The high-side driver can be bootstrapped.

PFC Controller

onsemi provides mixed signal controllers without need for MCU software development.

Power Factor Controllers FAN9672/3

- 2/3-channel interleaved CCM PFC Controller
- Boost Power Factor Correction
- Recommended for high power applications
- Programmable frequency and output voltage
- Advanced safety features – Soft-Start, UVLO, Sag Protection
- Tri Fault Detect protects against feedback loop failure

Power Factor Controllers NCP1681

Bridgeless Totem-Pole Multi-Mode PFC Controller

- Fixed frequency CCM (Constant Conduction Mode) with Constant on-time CrM and valley switching frequency foldback
- Proprietary Current Sense Scheme
- Proprietary valley sense scheme
- Ideal for high power: Multi-Mode applications up to 1kW, CCM >2.5kW

Critical Conduction Mode (CrM):

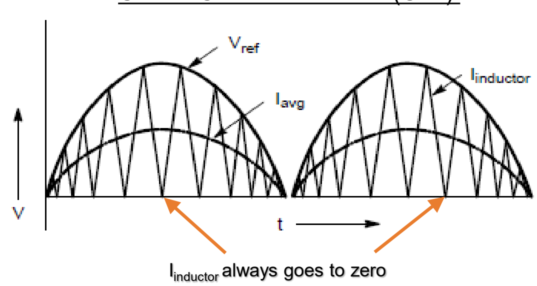
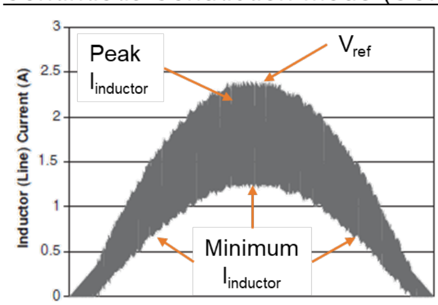


Fig.5: Critical Conduction Mode

Continuous Conduction Mode (CCM):



$I_{inductor}$ never goes to zero

Fig.6: Continuous Conduction Mode

Solution Overview

Silicon Carbide MOSFET

onsemi offers discrete SiC diodes and MOSFETS with different voltage ratings. The SiC MOSFETs offer the best performance when used at higher power and higher switching frequencies. The SiC MOSFETs are offered from 650V to 1700V breakdown voltage. 650V MOSFETs can be used in boost PFC stages and in bi-directional DC-DC converter. The 1200V and 1700V portfolios are suitable for totem pole PFC and three-phase systems. All families of onsemi SiC MOSFETs have no drift in $R_{DS(ON)}$, V_{TH} , or diode–forward voltage over a lifetime due to a special planar design.

SiC MOSFET NTH4L022N120M3S

- Planar SiC MOSFET from new 1200V M3S Family
- Optimized for high temperature operation
- Improved parasitic cap for high-frequency operation
- $R_{DS(ON)}$=22 mΩ @V_{GS}=18 V
- Ultra low gate charge ($Q_{G(TOT)}$)=137 nC
- High speed switching with low cap. (C_{OSS}=146 pF)

Learn more about M3 family - AND90204 - onsemi EliteSiC Gen 2 1200 V SiC MOSFET M3S Series

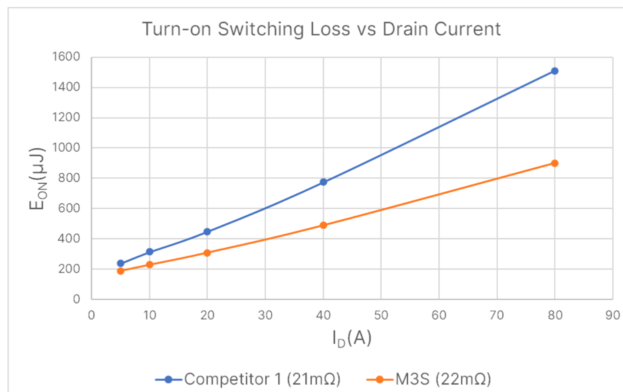


Fig.7: Turn-on switching performance of NTH4L022N120M3S @800V, 150°C

Silicon Carbide Diodes

The SiC diodes can be used as rectifiers to increase efficiency as they have lower reverse recovery losses and improved power dissipation compared to the traditional Si diodes. The **onsemi** portfolio includes diodes with voltage ratings 650V, 1200V and 1700V. For PFC boost applications, 650V diodes are sufficient. For three-phase DC/AC conversion, the higher voltage variants are ideal.

SiC Diodes FFSD0665B-F085

- SiC Diode from 650V D2 Family
- **Useful as a rectifier in Boost PFC stage**
- Optimized for high temperature operation
- 6A Continuous current
- Avalanche Rated 24.5mJ
- No Reverse Recovery
- DPAK package

Solution Overview

Power Integrated Modules (PIM) in UPS Systems

onsemi has shown outstanding performance in the industrial power integrated module (PIM) design area, using SiC MOSFET and IGBT technologies to enable UPS design improvements, including a PFC, DC/DC and Inverter modules using 1200 V SiC devices. SiC power devices are getting adopted fast in the Energy–infrastructure segment to improve efficiency or increase power density. Lower switching losses enable higher efficiency with less cooling efforts or higher switching frequency with reduced size and value of passive components. These benefits can justify the higher costs of SiC power devices.

Employing a SiC MOSFET module has proven to provide benefits in terms of electrical and thermal performance as well as power density. **onsemi** released its 2^{nd} generation of 1200V SiC modules, with M3S MOSFET technology which is focused on improving switching performance and reduction of $R_{DS(ON)}$*Area.

Table 3: SiC PIM Modules for UPS

Half-Bridge (2-Pack) Modules	Full-Bridge (4-Pack) Modules	T-Type & Vienna Modules	Boost Stage Modules
Half-Bridge SiC PIM List	Full-Bridge SiC PIM List	Recommended SiC PIM List	Recommended SiC PIM List

NXH011F120M3F2PTHG is an example of **SiC 1200V Full-Bridge module** containing also a thermistor with HPS DBC in an F2 package.

- M3S MOSFET technology provides typical $R_{DS(ON)}$ = 11.3 mΩ at V_{GS}=18V , I_D = 100A.
- Use Elite Power Simulator and PLECS Model Generator to simulate wide range of power topologies with SiC modules.

NXH008T120M3F2PTHG is a **T-type neutral point clamped converter (TNPC) SiC module** based on 1200V M3S technology.

- M3S MOSFET technology provides typical $R_{DS(ON)}$ = 8.5 mΩ at V_{GS}=18V , I_D = 100A.

NXH800H120L7QDSG is a **1200V, 800A rated IGBT Half-Bridge** power module. PIM11 (QD3) Package.

- New Field Stop Trench 7 IGBT technology and Gen. 7 diodes provide lower conduction losses and switching losses, enabling designers to achieve high efficiency and superior reliability.
- NTC Thermistor, Low Inductive Layout.

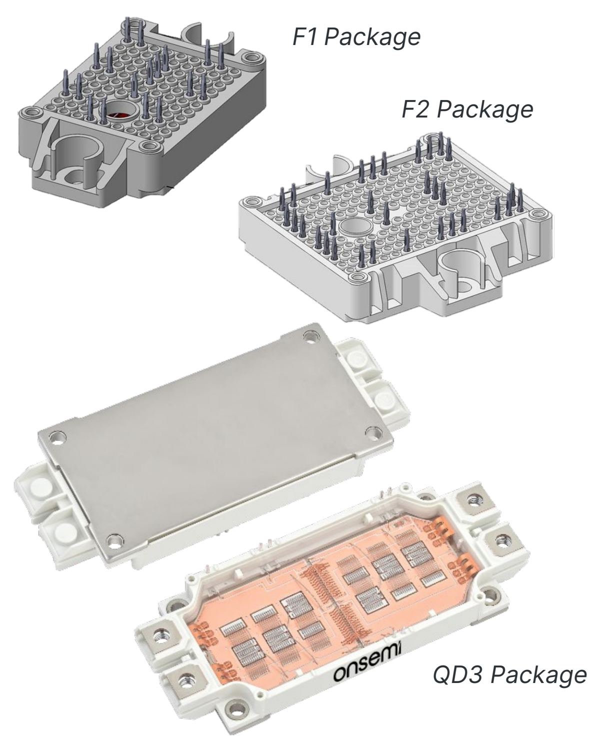


Fig.8: Various **onsemi** module packages

Table 4: IGBT and Hybrid PIM Modules for UPS

IGBT Based PIM Modules	Hybrid PIM Modules (IGBT + SiC)
Available PIM Modules (Various Topologies)	Available PIM Modules (Various Topologies)

Solution Overview

IGBT

IGBTs are ideal for high voltage applications, since compared to the Si MOSFETs, they provides higher blocking voltage for the equivalent material thickness. IGBT switches are ideal to be used in DC/AC inverters and in the slow leg of the totem pole PFC.

Field Stop VII, IGBT, 1200V

- New Family of 1200 V Trench Field Stop VII IGBT
- Fast switching type suitable for high switching applications
- Improved parasitic cap for high-frequency operation
- Optimized diode for low V_F and softness

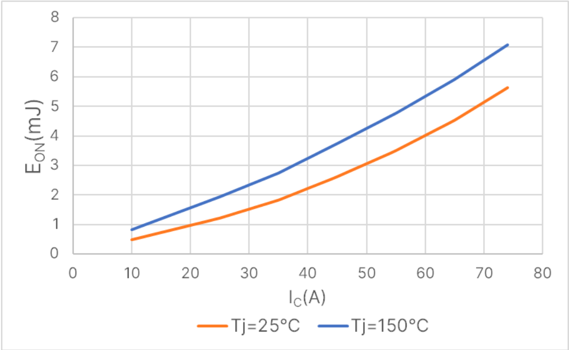


Fig.9: Switching-on losses of Field Stop VII @V_{CE}=600V

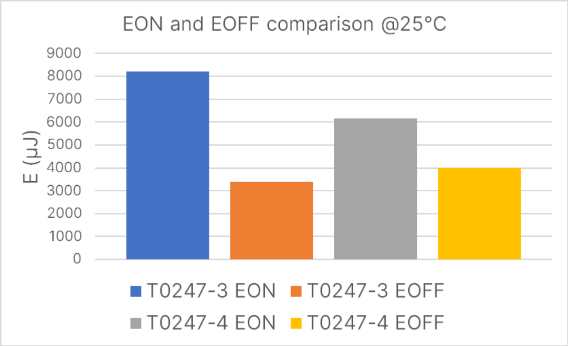


Fig.10: Comparison of switching losses of Field Stop VII in TO247-3 and TO247-4 packages

IGBT FGY4L140T120SWD

- 1200V, 140A IGBT from FS7 family
- TO247-4 package has lower E_{on}, which enables higher switching frequency and power

High Voltage Super Junction (SJ) Mosfet

- Silicon high voltage technology
- Cheaper alternative for SiC, in less power demanding applications
- Can be used as a switch in various high voltage applications – boost PFC, DC-DC conversion and DC-AC stage, at higher powers losses are significant
- **onsemi** FAST versions from SUPERFET V (600V) and SUPERFET III (650V) families are ideal for fast-switching applications
- Many available packages

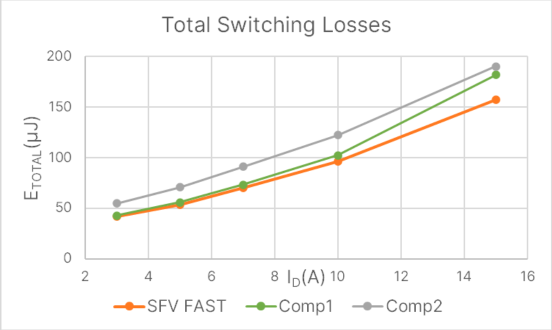


Fig.11: Comparison of Total switching losses of NTHL041N605SH and competition

MOSFET NTHL041N60S5H

- Single N-channel, SUPERFET V, 600V, 57A, 41mΩ
- TO-247 package
- P_D up to 329W
- R_g @1MHz 0.6Ω
- MOSFET dV/d_t 120 V/ns

Solution Overview

Pairing a Gate Driver to the Power Switch

The power MOSFET is a voltage–controlled device that is used as a switching element. To operate a MOSFET, typically a voltage must be applied to the gate that is relative to the source or emitter of the device. Dedicated drivers are used to apply voltage and provide drive current to the gate of the power device.

The gate drivers need to be used because the control circuitry operates at low voltage and thus cannot provide sufficient power to charge gate of the MOSFET quickly and safely. The voltage level required to control various types of switches is illustrated in the Figure 12. The gate driver serves to turn the power device on and off, respectively.

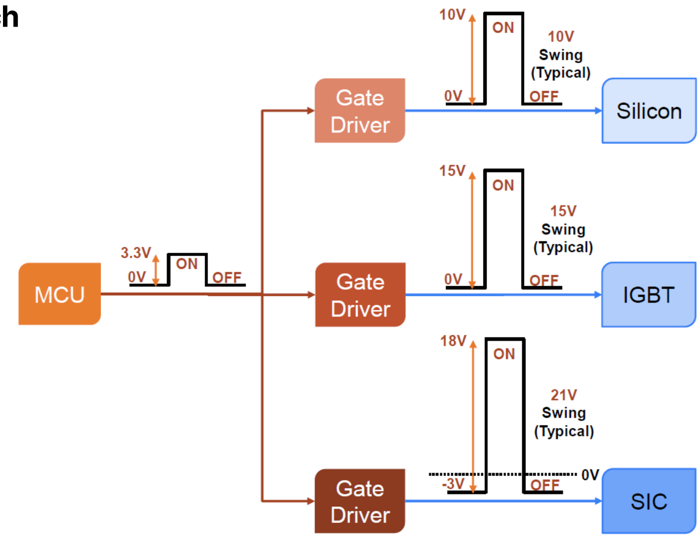


Fig.12: Driving of MOSFETs and IGBTs

In the Figure 12, an interesting characteristic of the driving of the SiC MOSFETs can be seen – negative gate bias supply. Providing the negative voltage to the gate has two important reasons.

When the MOSFET is turning off, at the end of the turn-off sequence, V_{GS}(Gate to Source Voltage) is typically at 0V, excessive ringing can occur. This is caused by very high dV/dt and is augmented by parasitic capacitances, creating an inductive kick. This inductive kick may cause unintended turn on, when the MOSFET should already have been off, which can cause a short circuit within a half-bridge and damage the MOSFET. If instead the V_{GS} is reduced to negative voltage, additional headroom is created, and possibility of the inductive kick is reduced.

What's more, by lowering the turn off voltage to below 0V, switching losses can be reduced. As illustrated in Figure 13 when driving **onsemi's** Gen 2 "M3S" series of SiC MOSFETS, switching losses can be reduced by as much as 100uJ, which yields 25% reduction in E_{OFF} losses. More information can be found in [onsemi EliteSiC Gen 2 1200V SiC MOSFET M3S Series] application note.

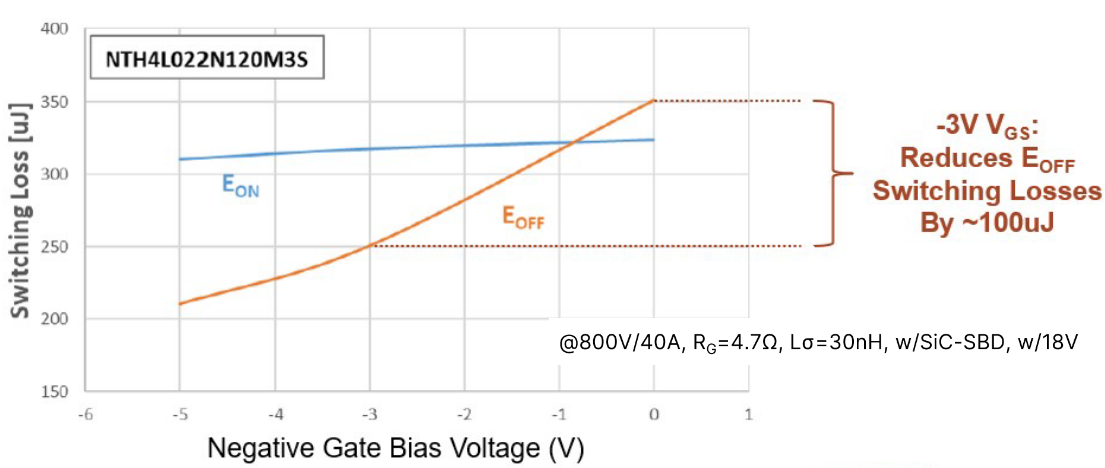


Fig.13: Switching loss by negative gate bias voltage

Solution Overview

The SiC gate driver portfolio can be seen in the Table 5. It shows their maximum operating voltage, source/sink current and number of channels. The portfolio of isolated IGBT gate drivers with their features, voltage rating and source/sink current is shown in Table 6.

*Table 5: **onsemi** SiC gate driver portfolio*

<table>
<tr><th>V(BR)DSS</th><th>1-channel (4.5/9A)</th><th>1-channel (6.5/6.5A)</th><th>1-channel (7A/7A)</th><th>2-channel (6.5/6.5A)</th><th>2-channel (4.5/9A)</th></tr>
<tr><td>650V</td><td rowspan="4">NCP51752</td><td rowspan="2">NCD57090</td><td rowspan="4">NCD57100</td><td rowspan="4">NCD57540</td><td rowspan="4">NCP51560</td></tr>
<tr><td>750V</td></tr>
<tr><td>900V</td><td>-</td></tr>
<tr><td>1200V</td><td>-</td></tr>
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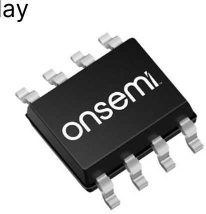
*Table 6: **onsemi** IGBT gate driver portfolio*

	Working Voltage (V)	Source/Sink Current(A)	Features
NCD57090	870	6.5/6.5	Single channel, Active Miller Clamp, Negative Bias, 5kV galvanic isolation
NCD57530	1200	6.5/6.5	Two channel, Enable, 5kV galvanic isolation, 1.5kV channel to channel isolation
NCD57100	1424	7/7	Single channel, Active Miller Clamp, Negative Bias, 5kV galvanic isolation, Separate low and high output

Gate Driver NCD57080

Isolated High Current Gate Driver

- High current peak output (6.5 A/6.5 A)
- UVLO, Active Miller Clamp
- 3.75 kV galvanic isolation, CMTI≥100 V/ns
- Typical 60 ns propagation delay
- Single channel
- SOIC-8 package



Gate Driver NCP51752

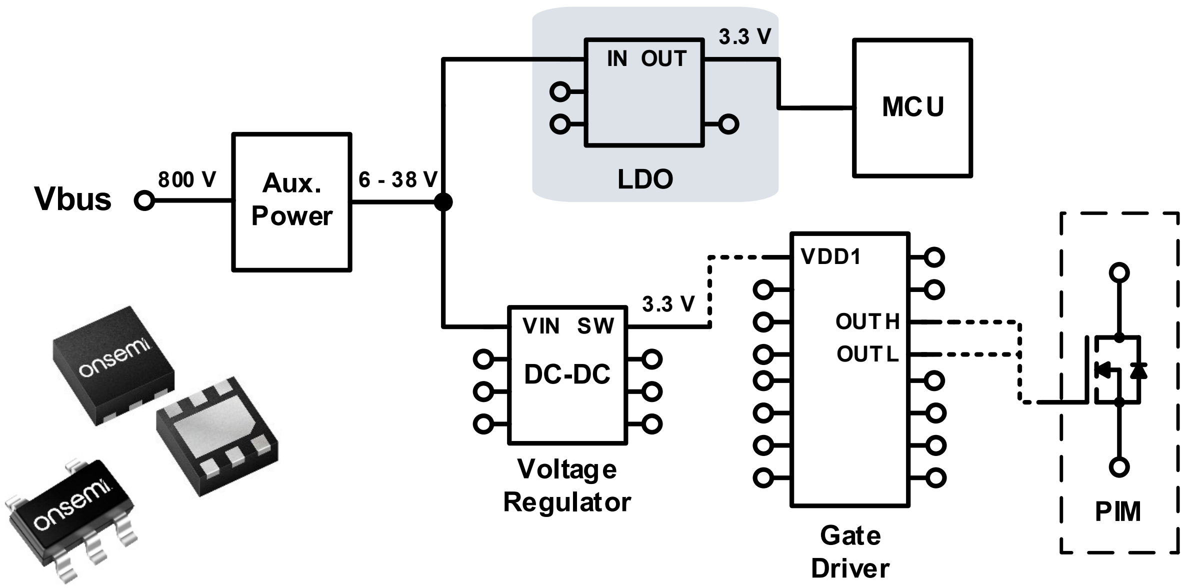
Gate Driver for SiC devices

- 4.5 A/9 A source/sink peak current
- 30V Output Swing
- 36 ns propagation delay with 5 ns max delay matching
- 3.75 kV galvanic isolation, CMTI≥200 V/ns
- Single channel
- **Integrated negative bias generation – simplified driving and system cost saves**
- SOIC-8 package

Solution Overview

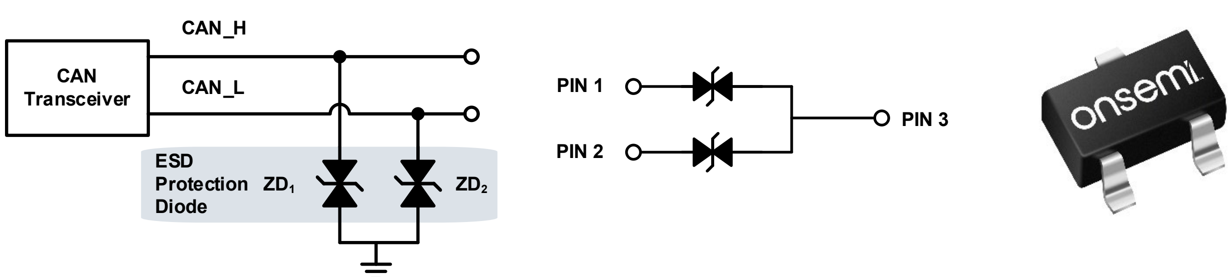
Usually, voltage regulator and LDO are used to provide stable low voltage. The LDOs are preferred in designs which require simple circuit, low cost and low operating current. Although switched mode voltage regulator is able to provide better efficiency and thus less power dissipation, in most cases their design is more complex, and they are more expensive.

NCP730 is a CMOS LDO regulator with very low quiescent current (1 μA typ.), fast transient response and wide input range(2.7 V – 38 V). Available in both fixed and adjustable versions.



Ensuring the safe operation of the low-voltage system is important in UPS and any other power application. ESD can occur in systems with exposed connectors, including CAN bus interfaces which is critical in industrial UPS. During installation and maintenance, these interfaces may be exposed. Excessive charges can accumulate on these modules, and when connecting cables to control modules with CAN transceivers, the excess charge may flow from the cable into the module, then into the CAN transceiver, with a maximum discharge of up to 30 kV, potentially damaging the system. Robust system-level protection is one of the outstanding features provided by **onsemi** products.

The NUP2105L has been designed to protect the CAN transceiver in high–speed and fault tolerant networks from ESD and other harmful transient voltage events. Giving the system designer a low-cost option for improving system reliability and meeting stringent EMI requirements including IEC 61000-4-2, level 4, 30 kV.



Recommended Products

Suggested Block	Part Number	Description
AC-DC & DC-AC conversion		
SiC MOSFET	NTH4L014N120M3P	SiC MOSFET - EliteSiC, 14 mΩ, 1200 V, M3P, TO-247-4L
	NTH4L013N120M3S	SiC MOSFET - EliteSiC, 13 mΩ, 1200 V, M3S, TO-247-4L
	NTBG020N090SC1	SiC MOSFET - EliteSiC, 20 mΩ, 900 V, M2, D2PAK-7L
	NTBG015N065SC1	SiC MOSFET - EliteSiC, 12 mΩ, 650 V, M2, D2PAK-7L
	NTBL045N065SC1	SiC MOSFET - EliteSiC, 33 mΩ, 650 V, M2, TOLL
	Application Recommended SiC MOSFET	
SiC Diode	FFSH10120A	SiC Diode – EliteSiC, 10 A, 1200 V, D1, TO-247-2L
	FFSB20120A	SiC Diode – EliteSiC, 20 A, 1200 V, D1, D2PAK-2
	FFSH30120ADN	SiC Diode – EliteSiC, 30 A, 1200V, D1, TO-247-3L
	FFSD0665B	SiC Diode – EliteSiC, 6 A, 650 V, D2, DPAK
	FFSB1065B	SiC Diode – EliteSiC, 10 A, 650 V, D2, D2PAK-2L
	Application Recommended SiC Diode	
IGBT	FGHL40T120RWD	1200 V 40 A FS7 IGBT, Low Vce(sat), TO-247-3L
	FGY75T120SWD	1200 V 75 A FS7 IGBT, Fast Switching, TO-247-3L
	FGY140T120SWD	1200 V 140 A FS7 IGBT, Fast Switching, TO-247-3L
	FGH4L50T65SQD	650 V 50 A FS4 high speed IGBT with copack diode, TO-247-4L
	FGH4L50T65MQDC50	650 V 50 A FS4 high speed IGBT with SiC diode, TO-247-4L
	Application Recommended IGBT Discrete	
Power Integrated Module	NXH006P120MNF2	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 6 mΩ, M1
	NXH003P120M3F2	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 3 mΩ, M3S
	NXH011T120M3F2PTHG	Full SiC PIM, EliteSiC, T-NPC, 1200 V, 11 mΩ, M3S
	NXH40T120L3Q1	IGBT PIM, 3-Ch T-NPC, 1200 V, 40 A IGBT, 650 V, 25 A Diode
	NXH80T120L3Q0	IGBT PIM, T-NPC, 1200 V, 80 A IGBT, 600 V, 50 A Diode
	NXH400N100L4Q2F2	IGBT PIM, I-NPC, 1000 V, 200 A IGBT, 1000 V, 75 A Diode
	NXH200T120H3Q2F2STNG	Hybrid IGBT PIM, Split T-NPC, 1200 V, 200 A IGBT, 650 V SiC Diode
	Application Recommended PIM for Power Conversion	

Recommended Products

Suggested Block	Part Number	Description
SUPERFET	NTHL017N60S5H	SUPERFET V, N-Channel, 600 V, 75 A, 17.9 mΩ, TO-247
	NVH4L027N65S3F	SUPERFET III, N-Channel, 650 V, 75 A, 27 mΩ, TO-247
	NTHL019N60S5F	SUPERFET V, N-Channel, 600 V, 75 A, 19 mΩ, TO-247
	Application Recommended SUPERFET	
DC-DC stage		
MOSFET for Bidirectional DC-DC stage	NTBLS0D8N08X	Power MOSFET, N-Channel, 80 V, 457 A, 0.79 mΩ, TOLL
	NTBLS1D5N10MC	Power MOSFET, N-Channel, 100 V, 312 A, 1.53 mΩ, TOLL
	NTBGS004N10G	Power MOSFET, N-Channel, 203 A, 100 V, D2PAK-7L
	NTMFS7D5N15MC	N-Channel Shielded Gate PowerTrench® MOSFET 150 V, 95.6 A, 7.9 mΩ
	Application Recommended MOSFET for Secondary side Bidirectional DC-DC Stage	
	NTHL017N60S5H	SUPERFET V, N-Channel, 600 V, 75 A, 17.9 mΩ, TO-247
	NVH4L027N65S3F	SUPERFET III, N-Channel, 650 V, 75 A, 27 mΩ, TO-247
	NTHL019N60S5F	SUPERFET V, N-Channel, 600 V, 75 A, 19 mΩ, TO-247
	Application Recommended SUPERFET for Primary side Bidirectional DC-DC Stage	
Gate Driver		
IGBT Gate Driver	NCD57080	Gate Driver, Isolated Single Channel IGBT/MOSFET Driver ±6.5 A
	NCP51752	Gate Driver, Isolated Single Channel Driver, 4.5 A/9 A, Neg. Bias Control
	NCD57252	Gate Driver, Isolated Dual Channel IGBT Gate Driver
	NCD57200	Gate Driver, Isolated Dual Channel IGBT Gare Driver 1.9 A/2.3 A
	Application Recommended Gate Driver	
SiC Gate Driver	NCP51561	Gate Driver, Isolated Dual Channel Gate Driver for SiC, 4.5 A/9 A
	NCD57090	Gate Driver, Isolated single channel, 6.5A/6.5A
	NCD57100	Gate Driver, Isolated single channel, 7A/7A
	NCD57540	Gate Driver, Isolated dual channel, 6.5A/6.5A
Power Management		
PFC Controller	NCP1618	Multimode PFC Controller, Active X2
	FAN9673	Three-channel Interleaved PFC Controller, CCM
	NCP1680	Totem-Pole PFC Controller, CrM
	NCP1681	Totem-Pole PFC Controller, CCM/Multi-mode
	Application Recommended Offline Controller	

Uninterruptible Power Supply (UPS)

Updated: MAR-2024

Recommended Products

Suggested Block	Part Number	Description
LDO	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, 300 mA, Ultra-Low Noise, High PSRR with Power Good
	Application Recommended LDO	
Offline Regulator	FSL336LR	650 V Integrated Power Switch with Error Amp and no bias winding
	NCP11184	800 V Switcher, Enhanced Standby Mode 2.25 Ω
	NCP1076	700 V Integrated Power Switch, 4.7 Ω
	Application Recommended Offline Regulator	
Miscellaneous		
ESD Protection	NUP2105	27 V ESD Protection Diode - Dual Line CAN Bus Protector
	NUP3105L	32V Dual Line CAN Bus Protector in SOT-23
	ESDM2032	3.3 V Bidirectional ESD and Surge Protection Diode
	NSPM8151	15 V Unidirectional ESD and Surge Protection Device
	Application Recommended ESD Protection Diode	
Smart Protection	NCID9 series	High Speed Dual/3ch/Quad Digital Isolator
	NIS3071	Electronic fuse (eFuse) 4-channel, 8 V to 60 V, 10 A in 5x6mm package
	MM5Z series	500 mW Tight Tolerance Zener Diode Voltage Regulator
	Application Recommended Zener Diode and others	
CSA	NCS21 series	Current Sense Amplifier, 26 V, Low-/High-Side Voltage Out
	NCS20071	Operational Amplifier, Wide Supply Range, 3MHz CMOS
	LM393	Comparator, Dual, Low Offset Voltage
ADC	NCD98010	12-Bit Low Power SAR ADC Unsigned Output
	NCD98011	12-Bit Low Power SAR ADC Signed Output
EEPROM	CAT24M01	EEPROM Serial 1 MB I2C
	CAT24C64	EEPROM Serial 64 kb I2C
	Application Recommended EEPROM	
Logic Gate	MC74AC00	Quad 2-Input NAND Gate
	74LCX08	Low Voltage Quad 2-Input AND Gate with 5V Tolerant Inputs
	Application Recommended Logic Gate	
Interface	NCN26010	Ethernet Controller,10 Mb/s,Single-Pair, MAC+PHY, 802.3cg, 10BASE−T1S
	NCV7340	CAN Transceiver, High Speed, Low Power
	NCV7343	CAN FD Transceiver, Low Power, Wake and Error Detection

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Technical Documents

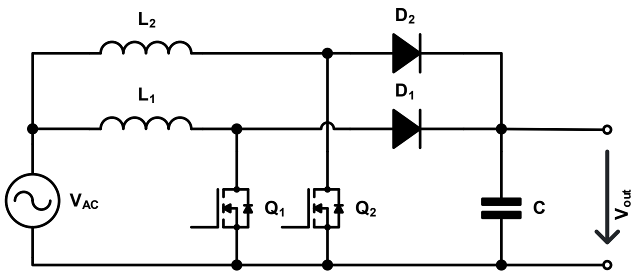
Type	Description & Link
Whitepaper	Uninterruptible Power Supply (UPS) Design Challenges and Considerations
Whitepaper	Designing High Frequency Uninterruptible Power Supplies for Reliability and Efficiency
Webinar	Video – UPS Webinar
Whitepaper	Popular Topologies in Offline Power Supplies
Whitepaper	DC−DC Power Conversion Topologies for Battery Energy Storage Systems (BESS)
Application Note	Demystifying Three-Phase Active Front End orPower Factor Correction (PFC) Topologies
Application Note	FAN9672/3 Tips and Tricks
Webinar	Video – Buck-Boost Topology Overview
Whitepaper	Silicon Carbide – From Challenging Material to Robust Reliability
Whitepaper	Physically Based, Scalable SPICE Modeling Methodologies for Modern Power Electronic Devices
Whitepaper	onsemi EliteSiC M3S Technology for High−Speed Switching Applications
Application Note	onsemi EliteSiC Gen2 1200V SiC MOSFET M3S Series
Application Note	onsemi M1 1200V SiC MOSFETs & Modules: Characteristics and Driving Recommendations
Webinar	Video – Understanding Single Pulse Avalanche Rating in Silicon Carbide MOSFETs
Webinar	Video – Introducing New Next-Generation 1200 V EliteSiC Half Bridge Power Integrated Modules (PIMs) M3S Technology
Application Note	MOSFET Basic
Application Note	IGBT Basic II
Application Note	Active Miller Clamp Technology

Technical Documents

Type	Description & Link
Whitepaper	IGBT Technologies and Applications Overview: How and When to Use an IGBT
Whitepaper	Common IGBT Topologies Used in Energy Infrastructure Applications
Whitepaper	SiC MOSFETs: Gate Drive Optimization
Application Note	NCD(V)57000/1 Gate Driver Design Note
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
Application Note	A Guideline on the Usage of an Isolated Gate Driver to Efficiently Drive SiC MOSFETs
Evaluation Board	6-18 Vdc Input Isolated IGBT Gate Driver Supply +15V/-7.5V/7.5V with Automotive Qualified NCV3064 Controller
Application Note	Current Sense Amplifiers, FAQ

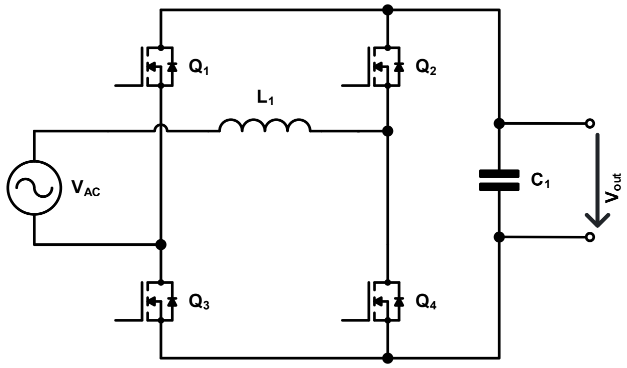
Topologies Overview

Common AC-DC Topologies



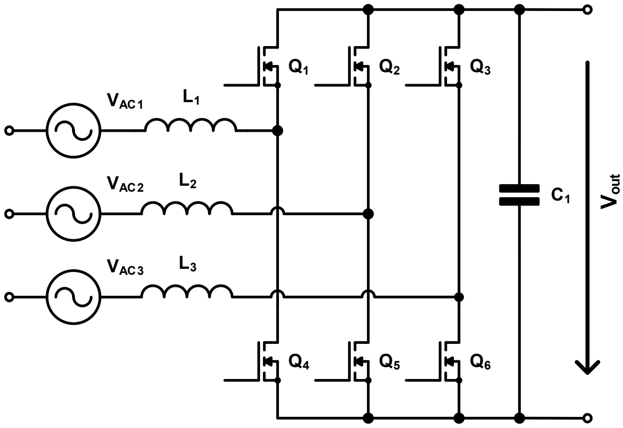
Single-Phase, Interleaved Boost Converter

- Simple circuit, easy control, few components
- Switches need to endure full bus voltage and spikes
- Easy to expand output power
- Bridge rectifers causes losses
- Requires high-capacity transformer, increase cost and end-system size
- WBG is perferred to reduce THD, inductor size



Totem Pole PFC, Single-Phase

- Improved efficiency, EMI, THD, and reduced quantity of switches which are conducted per cycle
- High power density due to low quantity of switches
- Wide bandgap components are required to reduce recovery losses
- Zero crossing point noise, common mode noise
- Allowed for bidirectional conversion



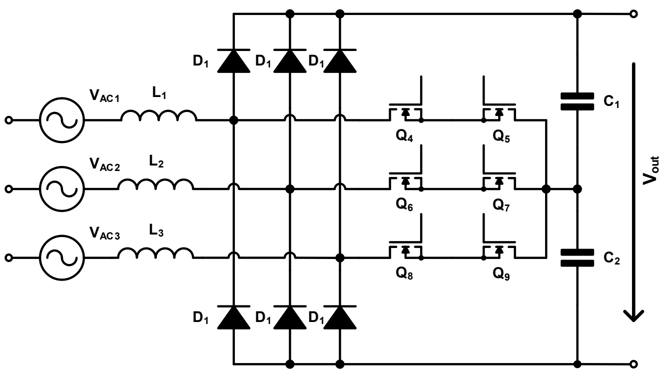
Three-Phase, Active Front End

- Removing diode bridge reduces conduction losses
- Simple circuit, easy control, few components
- Switches need to endure full bus voltage and spikes
- WBG is preferred to reduce THD, inductor size

Uninterruptible Power Supply (UPS)

Updated: MAR-2024

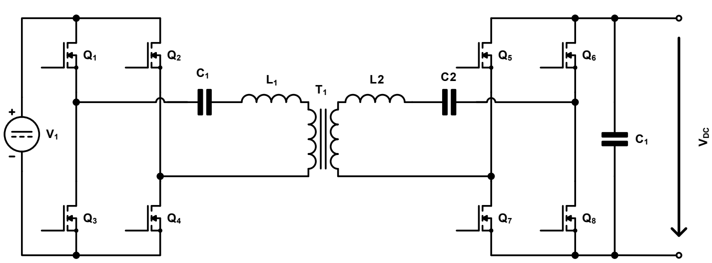
Topologies Overview



Three Phase Vienna Rectifier

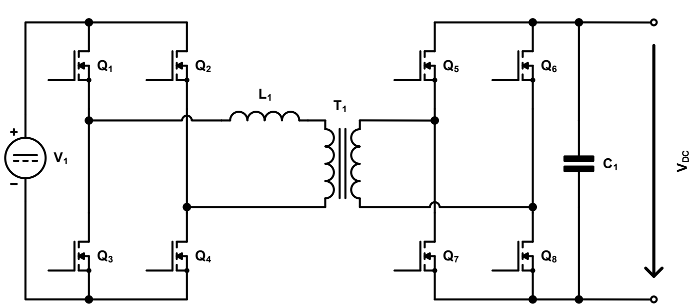
- Reduced THD and voltage stress on (some) switches as a three-level configuration
- More gate drivers and more complicated control
- Better efficiency, higher cost
- Requires 1 driving signal (T-NPC)

Common Biderctional DC-DC Topologies



CLLC DC-DC Converter

- CLLC to realize bidirectional conversion with high efficiency
- One more buck-boost stage to expand charging/discharging voltage range to improve battery usage
- Realize bidirectional power conversion when charging/discharging
- Isolation if required
- Increased cost and design complexity with double stage structure

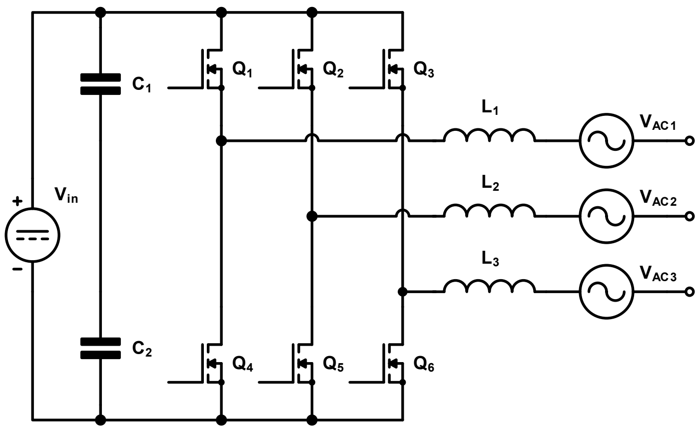


Dual Active Bridge Converter

- Run phase-shift modulation To realize ZVS at high loads
- Unexpected loss caused by mismatch of current in both stages
- Complicated design regarding phase shift, transformer, frequency, etc. to reach expected efficiency
- WBG is preferred in high-frequency/high voltage operation
- Reduced output current ripple to reduce size of output capacitor, preferred in high-power cases

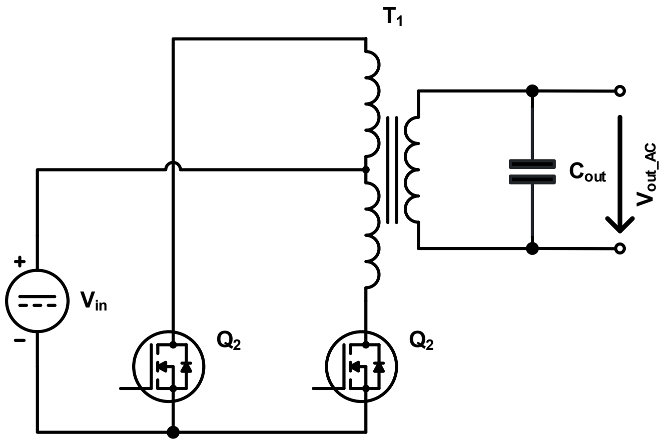
Topologies Overview

Common DC-AC Topologies



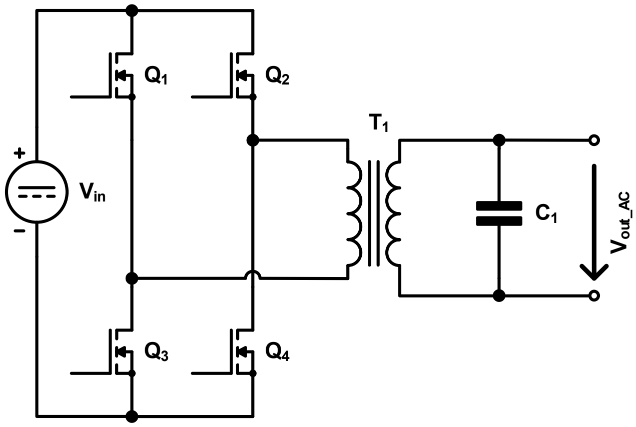
Three-Phase, Two-Level Converter

- Simple circuit, easy control, few components
- Low conduction loss, easy thermal management
- Low switching loss, high THD
- Low power density, medium/high efficiency
- Full bus voltage applied to each switch
- Better to use wide band-gap components to improve overall performance



Push-Pull

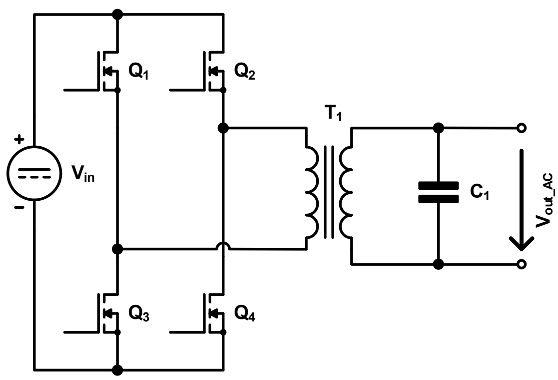
- Simple circuit, easy control, few components
- Low conduction loss, easy thermal management
- Double battery voltage applied to each switch



Full Bridge

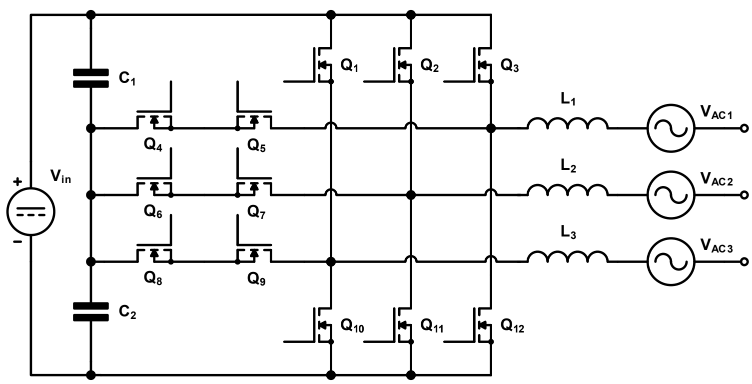
- Four switches
- Full voltage on each switch
- No center tap required
- Needs two high side gate drivers

Topologies Overview



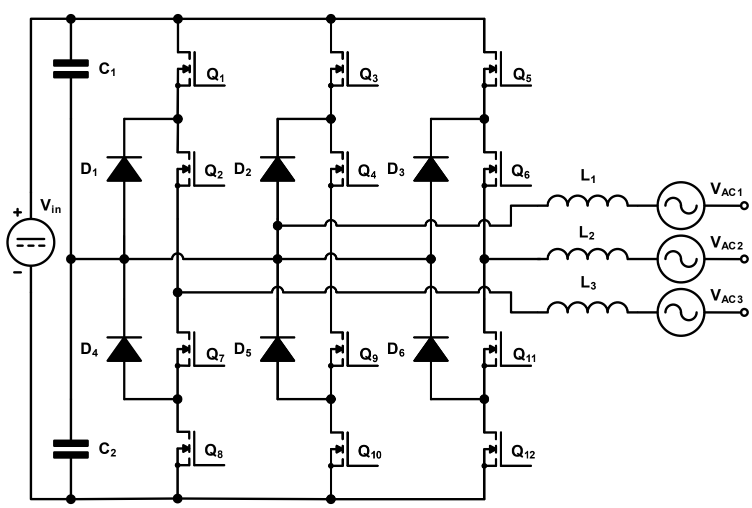
Full Bridge

- Four switches
- Full voltage on each switch
- No center tap required
- Needs two high side gate drivers



T-NPC

- Widely used, complex control
- Full voltage on only vertical switches
- Better efficiency with 3 level topology, low switching loss
- Better harmonic quality and lower dv/dt



I-NPC

- Widely used, complex control
- Halved voltage on switches
- Better efficiency with 3 level topology
- Better harmonic quality and lower dv/dt
- Loss imbalance
- High conduction loss, low switching loss

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