System Solution Guide

Battery Energy Storage System

Updated: JAN-2024

Industry	Energy Infrastructure – Battery Energy Storage System
Application	ESS (Energy storage system) plays a crucial role in building a low-carbon world and is currently one of the most flourishing industrial applications. The reasons behind include the positive policies led by decarbonization goals in various countries, the needs for storage and control of renewable energy like solar power during the rapid development of new energy applications, and the continuous reduction in the cost of Li-ion batteries. Energy storage system has so close relationship with solar system and EV charging stations in terms of application that they are also sharing similarities in hardware design and component selection. This guide provides a comprehensive introduction to the energy storage system and its market, as well as the industry-leading products and solutions offered by **onsemi**.

System Purpose

ESS is an application that has been studied extensively. It stores the energy (electricity) from different power generation elements (coal, nuclear, wind, solar, etc.) in a variety of forms like electrochemical storage (battery), mechanical storage (compressed air), thermal storage (molten salt), etc. In this guide, battery energy storage system connected with the solar inverter system will be targeted.

BESS (Battery Energy Storage System) is widely employed in both residential and commercial cases. In residential applications, a BESS serves as a backup power supply, preventing unexpected power outages and contributing to cost saving by shifting electrical energy from low-value to high-value periods. In commercial applications, which involve larger systems, BESS can efficiently store and manage the free and clean energy produced by solar inverter, achieving low-carbon emissions. Another key attribute of BESS today is its ability to reduce the grid pressure caused by growing demands of EV charging.

Lithium-ion battery, which is known as the major part of electrochemical storage system, has high power/energy density, high roundtrip efficiency, compact footprint, and flexibility for expansion. The Li-ion battery is a relatively mature technology that has benefited from more than three decades of commercial development, which makes it a reliable and low-cost solution. It can be regarded that the continuous cost-down of Li-ion battery has strongly accelerated the development of energy storage.

Market Information & Trends

Growing Demands of BESS

According to World Energy Outlook 2023, in the Stated Policies Scenario, the total capacity of battery storage will grow from 45 TWh in 2022 to 552 TWh in 2030, at a CAGR of 37%. On the other hand, the price of lithium-ion battery cell has dropped to a record low of 107 USD/kWh, decreased by about 80% compared to 2013 (535 USD/kWh) based on the data source from Bloomberg NEF, which largely drives the BESS market. And don't ignore the positive influence by renewable energy, over 800 GW of new solar infrastructures are going to be deployed in 2030, forecasted by IEA.

Market Information & Trends

Higher Power and Voltage

High-power charger is typically used in commercial cases, BESS is usually paired with solar inverter system. Currently, 1500 V-rated solar inverters have entered mass production and are in use. Therefore, the DC voltage of PCS (Power Conversion System) also needs to be increased to the same level. High voltage is a clear trend in high-power conversion applications like solar inverter and DC EV charger, as high voltage brings lower current (at the same output power), reduces system losses and cable diameter. However, high-voltage system also challenges the components. In a 1500 V system, generally 1200 V rated power devices in a multi-level circuit configuration, or 2000 V rated SiC MOSFETs in a two-level topology are preferred. Additionally, safety and EMI issues lead by higher voltage and higher power need to be carefully considered.

Distributed System and Intelligent System

The new generation of distributed BESS can address the shortcomings of centralized systems. When multiple battery packs are connected in parallel, it's relatively easy to cause imbalance among them, leading to the overuse of certain batteries over time and ultimately affecting the overall performance of the battery systems. In contrast, distributed system enables decentralized management of subsystems, making maintenance easier and enhancing system lifespan, thereby improving the battery charging cycles. Similarly, solar inverter system also shares these characteristics and trends.

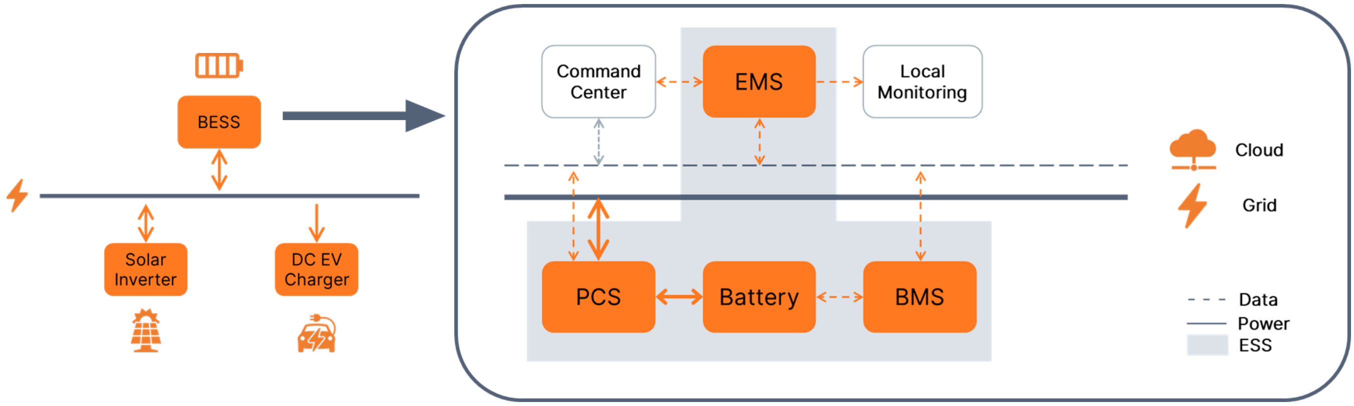
EMS, which stands for Energy Management System, is the command center responsible for controlling and decision-making, and concurrently monitors system faults during operation, making it a crucial component in BESS. The content involved in the EMS of commercial BESS is complex, requiring real-time data collection and control. It involves controlling each node based on different strategies and commands from the grid dispatch center, such as peak shaving and valley filling, solar system engagement, etc. Soon, big data analysis will be integrated to predict operational conditions, reduce manual management, and maximize efficiency.

Figure 1: Centralized and Distributed BESS Solution

Ecosystem Integrating BESS and Solar Inverter System

The expansion of DC charging stations poses challenges to the local power grid. Potential issues include the impact on the grid when a large number of charging devices operate simultaneously, harmonic pollution to the grid caused by low power factor equipment or equipment in a no-load state, and limitations imposed by the capacity of local electrical transformers. Connecting solar inverter systems and BESS becomes essential in commercial cases. Solar inverters can share a portion of the electrical load with the grid, while BESS, which is more crucial, can reduce the impact on the grid, realize energy arbitrage, and decrease user costs. Residential BESS can also contribute to the peak demand reduction, leading to cost saving for the family. As another feature, residential BESS can act as a backup power supply, providing emergency power in case of grid failure.

System Implementation



System Description

Four Elements to Build BESS

A BESS is made up of 4 parts, not only for commercial type, but for residential type. Battery packs consist of battery cells to establish a commercial level system, and high-voltage modules are integrated into racks or banks for higher capacity. Usually charging and discharging voltage ranging from 50 V to 1100 V is dependent on the battery voltage and circuit topology. BMS (Battery Management System) is an electronic system managing rechargeable batteries by ensuring batteries are operating in SOA (Safe Operating Area), monitoring operating states, calculating and reporting real-time data, etc. to realize a longer operational life. PCS is another important sub-system for bidirectional conversion of electrical energy connected between the battery pack and the grid and/or load. It determines largely the system cost, size and performance. EMS, as explained just now, is a software-based system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation or transmission system.

AC-coupled System and DC-coupled System

BESS is currently segmented into 2 types, AC-coupled and DC-coupled systems. AC-coupled BESS is a separated system that can be added to existing solar/energy generation system/grid, making it an easy upgrade. However, it requires additional power conversion stages to accomplish full charging/discharging, leading to higher losses. On the other hand, DC-coupled system, commonly employed in residential hybrid solar inverters, offer extra energy storage capacity by connecting to the DC bus. It involves single DC-DC conversion step but requires a decision during product design, as DC bus voltage is often high and may pose safety or retrofitting challenges.

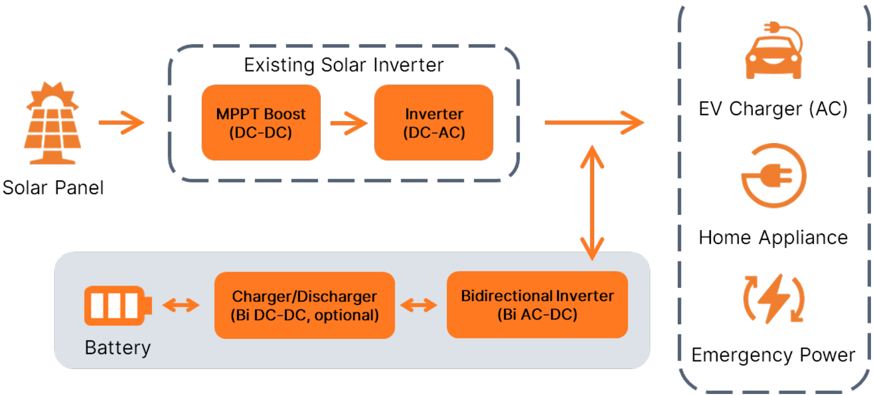


Figure 2: AC-coupled System

System Description

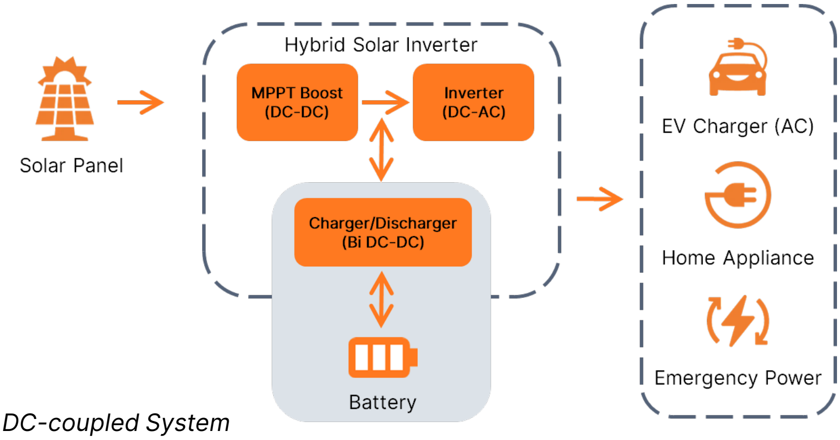


Figure 3: DC-coupled System

Bidirectional Operation

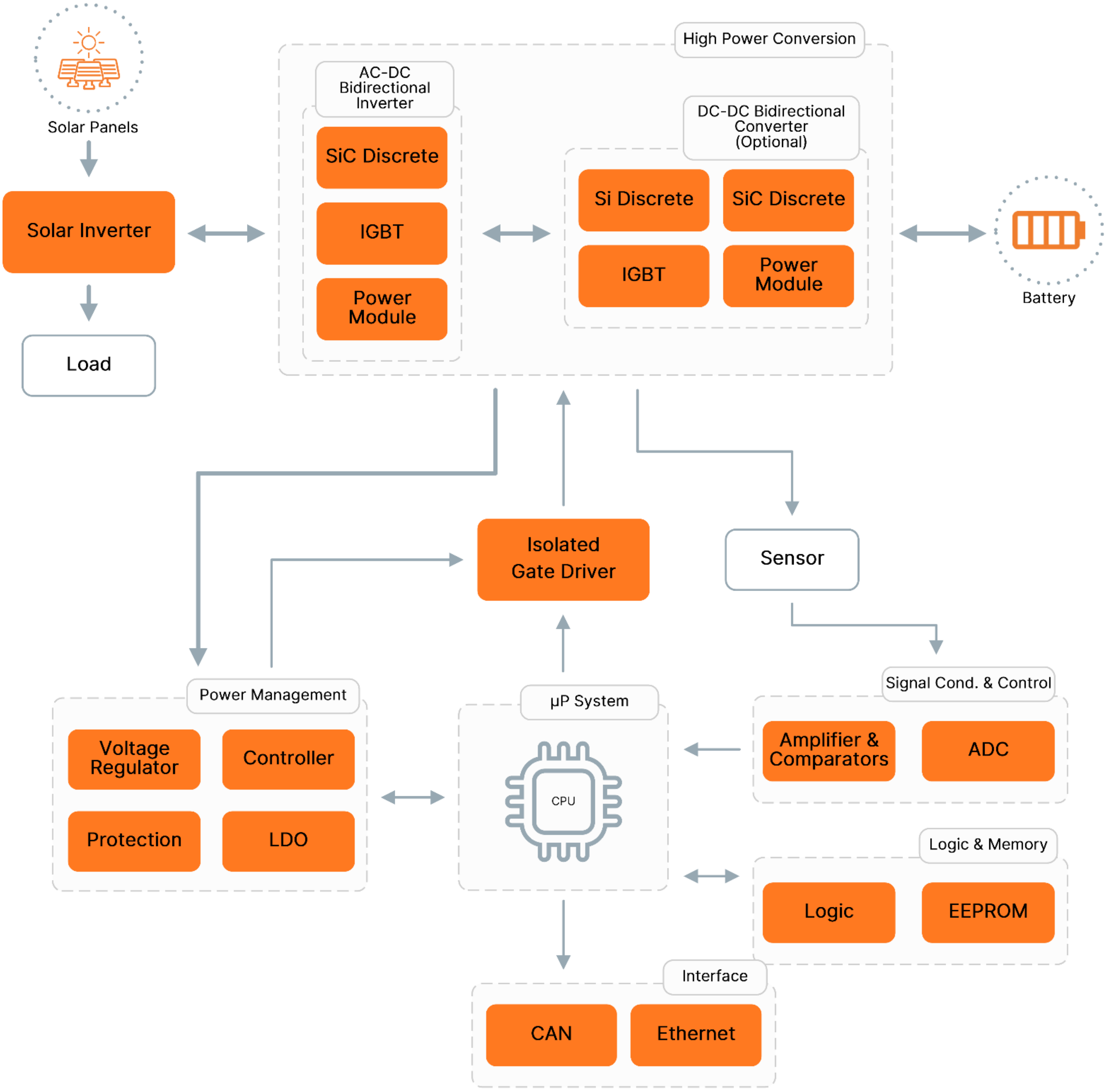
The power conversion stage of BESS requires a bidirectional operation. *Commonly, three-phase inverters can be bidirectional and behave as an AC-DC converter when operating in reverse mode, or reactive mode for UPS or braking mode for motor drive. There is a significant point to highlight here, though. In general power converters, and in particular topologies, are optimized for one use case and one direction of the power flow through the selection and relative sizing of the switches and diodes. Three–phase inverters used as AC-DC converters in PFC mode will not be as efficient as an optimized AC-DC PFC converter. Even DC-AC topologies designed to be bidirectional will show better performance in one direction than the other. So, it is important to bear in mind what will be the most common use case. Also, bidirectionality will not be achievable with all topologies as we will see, so selecting the right one upfront is an important factor*. Read AND90142 - Demystifying Three-Phase Power Factor Correction Topologies to understand three-level technology and featured three-level PFC circuits.

Use Silicon Carbide Products in PCS

Compared to IGBT, SiC device has more advantages in high-voltage and high-current applications, such as enabling high-frequency switching. Although IGBT remains the preferred choice in BESS design, considering different switching strategies, incorporating SiC devices in certain sections can yield superior performance. For instance, in the bidirectional inverter using A-NPC, SiC devices may be selected in the inner legs to reduce switching losses because of the dedicated switching strategy requiring high switching frequency of inner switches, while the rest switches can still utilize low $V_{CE(SAT)}$ IGBTs to maintain controllable cost.

Solution Overview

System Block Diagram – AC Coupled Battery Energy Storage System



Find Interactive Block Diagram on the Web

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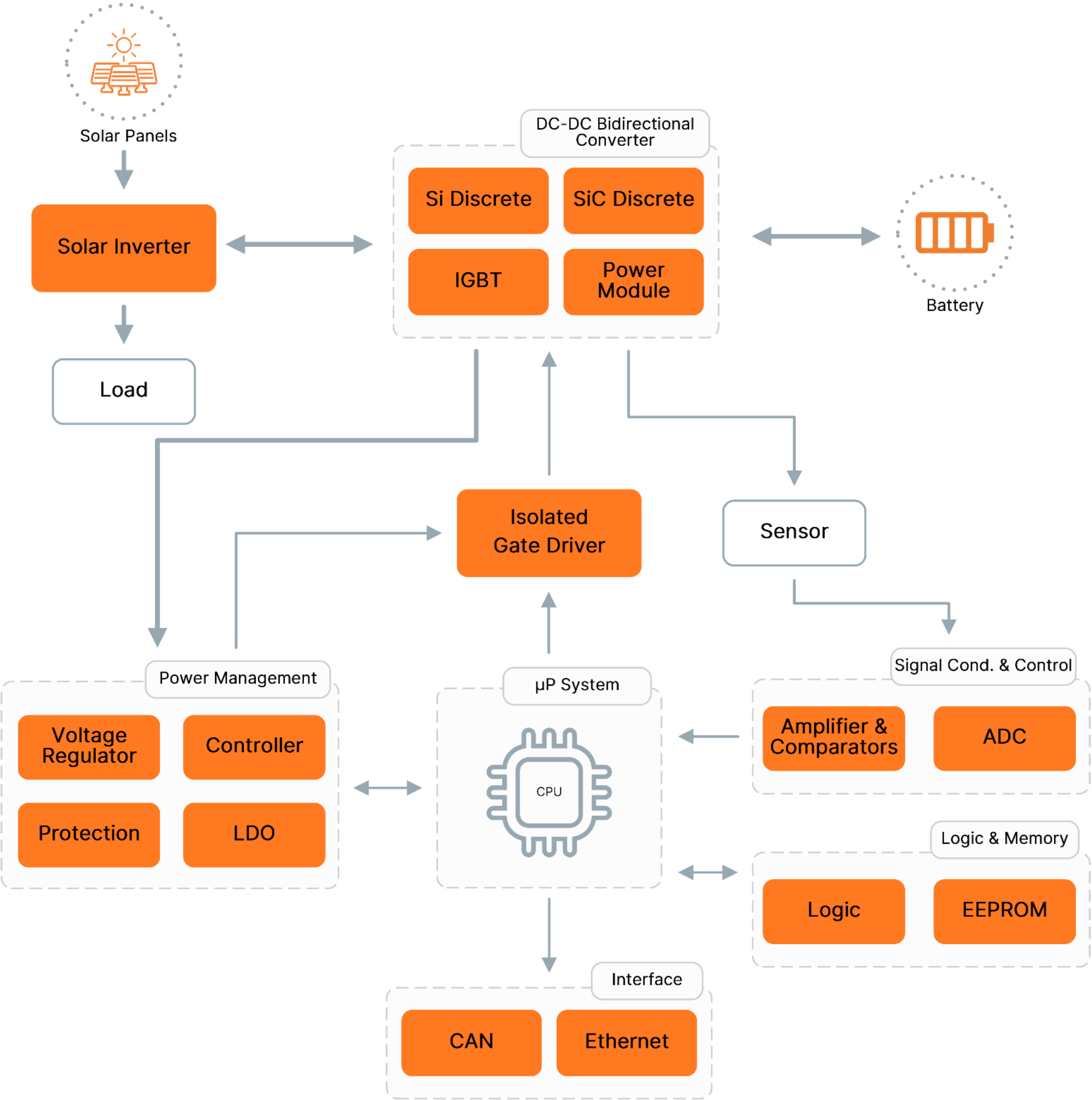
Solution Overview

System Block Diagram – DC Coupled Battery Energy Storage System



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Solution Overview

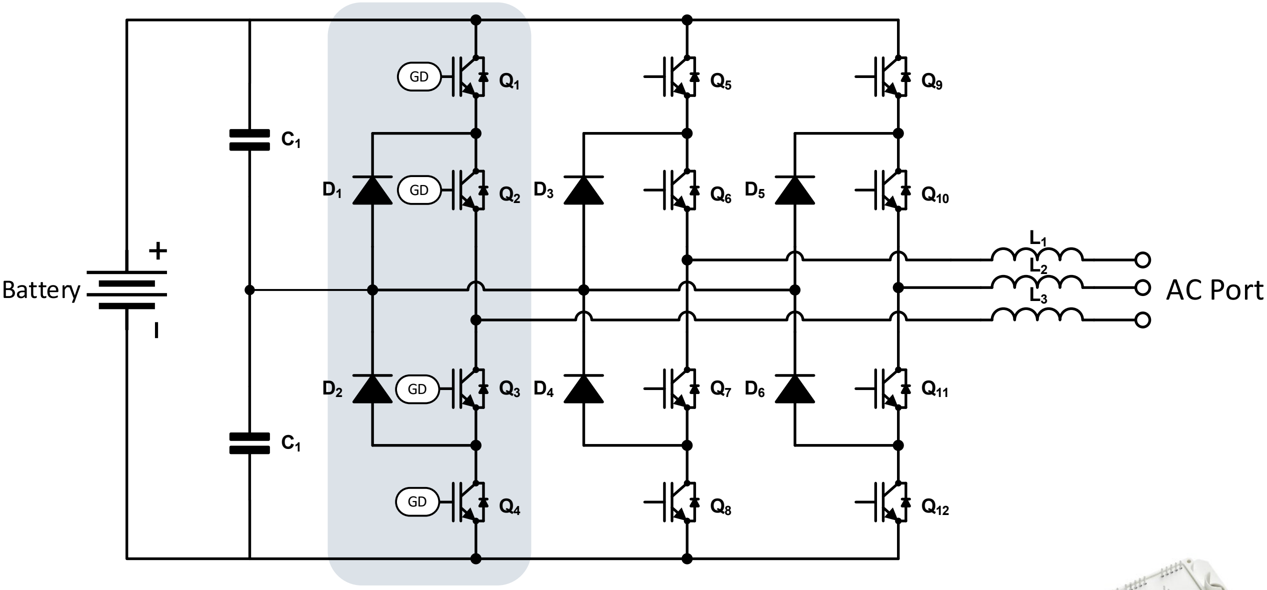
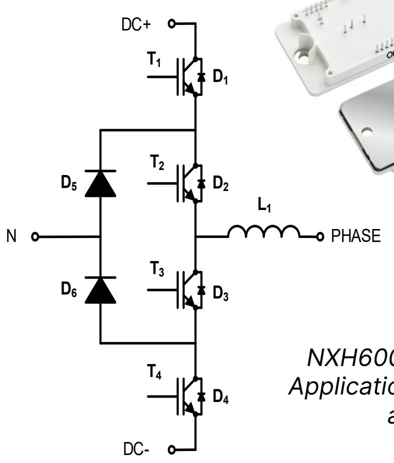


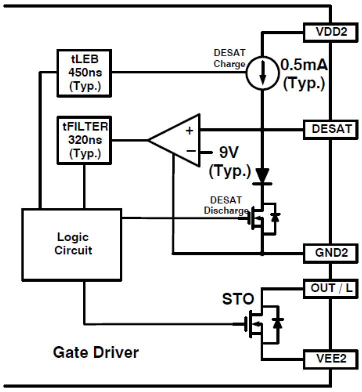
Figure 4: Three-phase I-NPC , Bidirectional Topology

Three-phase I-NPC is a common bidirectional topology in PCS to match the increasing bus voltage. Comparing to two-level topologies like three-phase half bridge, I-NPC requires more components and driving signals, complicated switching scheme also challenge the designers. But the advantages are distinct that it reduces the switching losses, lower the current ripple, reduce EMI, etc.

NXH600N65L4Q2F2 is a high-performance 650 V IGBT PIM containing an I-NPC inverter. It's designed to endure high currents from both directions, making it the best fit for commercial PCS over 100 kW.



NXH600N65L4Q2F2 Application Schematic and Package



DESAT (Desaturation) is one of the important protections preferred in high-power conversion. It can prevent the IGBTs/MOSFETs from the damage occurred by short circuit through shutting down the switches as fast as possible.

NCD57000 integrates a desaturation detecting function, when V_{CESAT} reaches the target, an internal STO(Soft Turn Off) MOSFET is activated to discharge the gate capacitor in order to reduce the over voltage stress and losses caused by high dV/dt.

What's more, this single channel gate driver has a high source/sink current (4 A/6 A), 5 kVrms galvanic isolation, and other protection functions like UVLO, active miller clamp, etc.

Primary Side PWM QR Controller

NCP1362, SOIC-8

Usually, the auxiliary power supplies are designed based on a flyback topology using a primary-side-regulated, QR (quasi-resonant) flyback controller.

NCP1362 is a primary side PWM controller for low power offline SMPS. The biggest advantages of using NCP1362 is that it requires no optocoupled feedback, improving the reliability of power supply. Additionally, it turns off the switch at low V_{DS} to improve efficiency and save heat generation.

- Primary side QR flyback controller
- No secondary feedback circuitry is required
- Valley lockout QR peak current mode control
- Optimized light load efficiency and stand-by performance

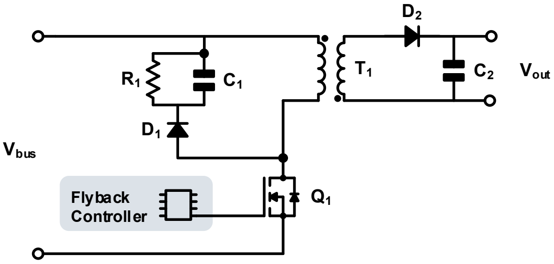


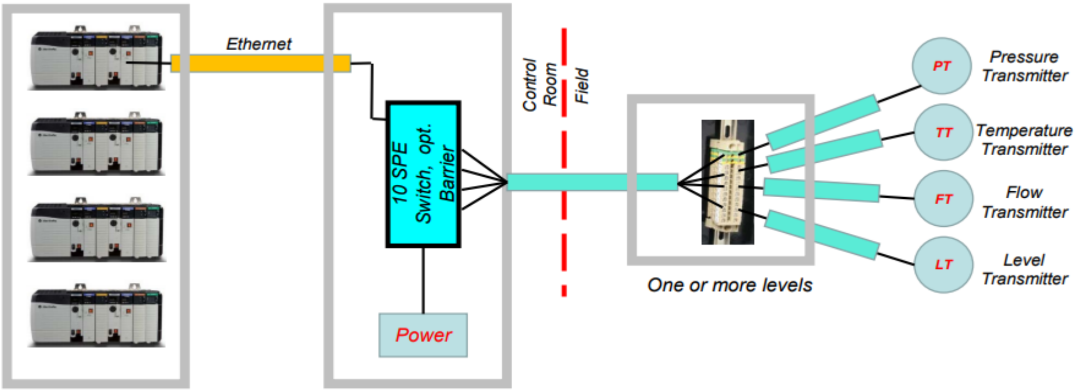
Figure 5: Example Schematic based on NCP1362 flyback controller (above) Evaluation Board with NCP1362 (below)

Learn more about NCP1362 with 40W auxiliary PSU reference design - SECO-HVDCDC1362-40W-GEVB

Ethernet interface in BESS

Distributed energy storage system is likely comprised of hundreds of PCS and control units. Modern command center must adapt more sophisticated connectivity solutions to meet the increasing demands of nodes and computing. the NCN26010 from **onsemi** is one of the first 802.3cg compliant controllers available on the market. It offers benefits like

- Good noise immunity which exceeds the noise immunity levels in IEEE 802.3cg to enable 50+ meters of range.
- Up to 70% fewer cables and up to 80% lower installation costs
- Lower software maintenance costs



Solution Overview

EliteSiC, 1200 V MOSFET, M3S

- New Family of 1200 V M3S Planar SiC MOSFET
- 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)*
- 4-pin package with Kelvin Source*

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

*Key characteristics of NTH4L022N120M3S.

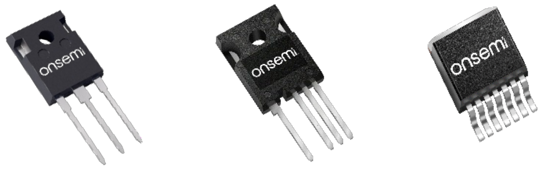
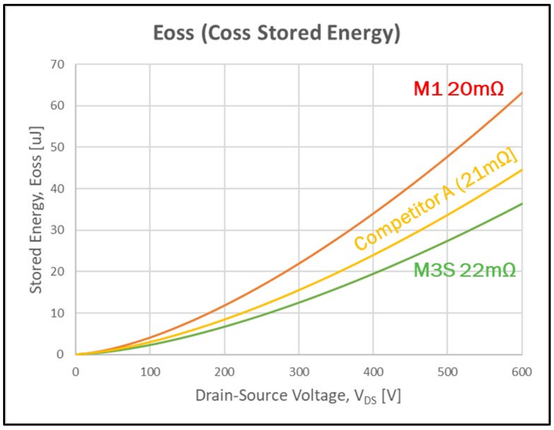


Figure 6: Package variants of M3S MOSFET family TO-247-3LD (left) , TO-247-4LD (middle), D2PAK-7L (right)

Table 1: Comparison of E_{OSS} parameter between M3S, M1 MOSFET families and Competitor A

	E_{OSS} [uJ] at 0-600V	FOM [Ω*uJ] $R_{DS(on)}$*E_{OSS}
onsemi M1 20mΩ	63	1.38
onsemi M3S 22mΩ	36	0.77
Competitor A 21mΩ	45	0.86

Figure 7: Chart Comparison of E_{OSS} parameter

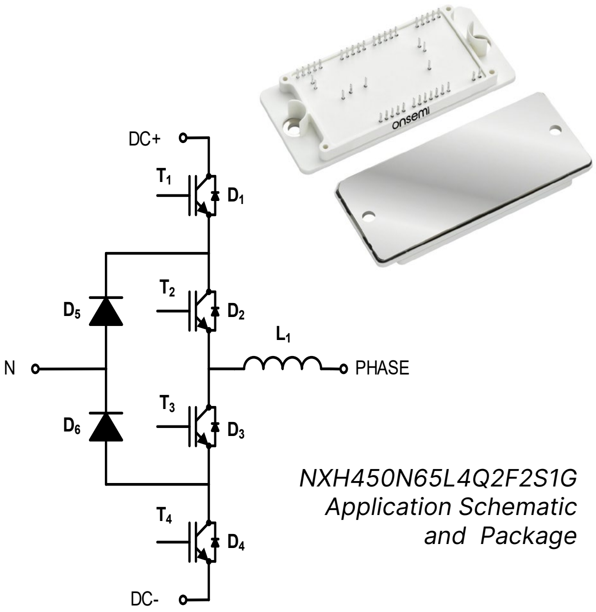


Field Stop VII, IGBT, 1200 V

- New Family of 1200 V Trench Field Stop VII IGBT
- Trench narrow mesa & Proton implant multiple buffer
- Fast switching type and low $V_{CE(SAT)}$ type available
- Improved parasitic cap for high-frequency operation
- Common packages
- Target applications - Energy infrastructure, Factory Automation

IGBT Power Integrated Modules (PIM), I-NPC

- Application recommended IGBT PIM , I-NPC
- 650 V / 1000 V IGBT, Diode inside
- High Operating Current
- Internal NTC thermistor
- Low Inductive Layout
- Improved efficiency or higher power density
- Extreme Efficient Trench with Field Stop Tech



NXH450N65L4Q2F2S1G Application Schematic and Package

Solution Overview

How to Choose a Gate Driver

Current driving capability. The fact of turn-on and turn-off of a switch is the discharging and charging process of the input and output capacitors. Higher sink and source current capability means quicker turn-on and turn-off, and eventually, smaller switching losses.

Fault detection. A gate driver is not only used to drive switches but protect switches and even the entire system. For example, UVLO (under voltage lock out) ensures the power supply of gate driver is in a good condition, DESAT (Desaturation) is used to detect the short circuit and active miller clamp is to prevent false turn on especially in a quick switching system. Read AND9949 – NCD(V)57000/57001 Gate Driver Design Note to learn the protecting functions.

Immunity. CMTI (Common Mode Transient Immunity) determines if this product can be used in a quick-switching system, it is defined as the maximum tolerable rate of the rise or fall of the common-mode voltage applied between the input and output circuit in a gate driver. High power system is operating at very quick changing rate which generates very large voltage transient, for example, >100 V/ns. The isolated gate driver needs to be able to withstand CMTI above the rated level to prevent noise on the low-voltage circuitry side, and to prevent failure of the isolation barrier.

Propagation delay. Propagation delay is defined as the time delay from 10% of the input to 90% of the output (might be different among suppliers), this delay affects the timing of the switching between devices, which is critical in high-frequency applications. Dead time is set to avoid shoot-through and further damage, the less dead time is set, the less switching loss you will have.

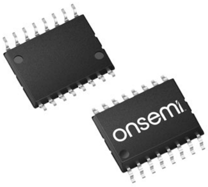
Compatibility. A pin-to-pin replacement is always preferred in a new project if there's no significant design change. Choosing a gate driver with similar specifications and package is benefit for a quick design.

Of course, not every point needs to be followed. For example, unlike IGBT, the output characteristic of SiC MOSFET behaves more like a variable resistance and there's no saturation region, which means the normal desaturation detecting principle doesn't work. As one of the solution, a current sensor is usually used to detect overcurrent, or a temperature sensor for abnormal temperature.

NCP51561

Dual Channel Isolated Gate Driver

- 4.5A / 9A Source/Sink Peak Current
- Typical 36 ns propagation delay with 5ns max delay matching
- Single or Dual Input Modes via ANB
- 5 kV galvanic isolation, CMTI ≥ 200 kV/μs
- SOIC-16WB with 8mm creepage distance



NCD57080 / NCD57090

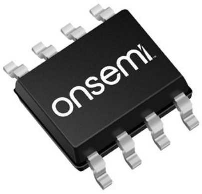
Single Channel Isolated Gate Driver

- 6.5 A Source/Sink Peak Current
- Available with Split Output Active Miller Clamp or Negative Bias versions
- 3.3 V, 5 V and 15 V Logic Input
- 3.5 kV galvanic isolation, CMTI ≥ 100 kV/μs
- SOIC-8 with 4mm creepage distance (NCD57080)
- SOIC-8WB with 8mm creepage distance (NCD57090)

NCD57100

Single Channel Isolated Gate Driver

- 7 A Source/Sink Peak Current
- UVLO and DESAT Protection
- Wide Bias Voltage Range including Negative VEE
- 3.3 V, 5V and 15 V Logic Input
- 3.5 kV galvanic isolation, CMTI ≥ 100 kV/μs
- SOIC-16WB with 8mm creepage distance

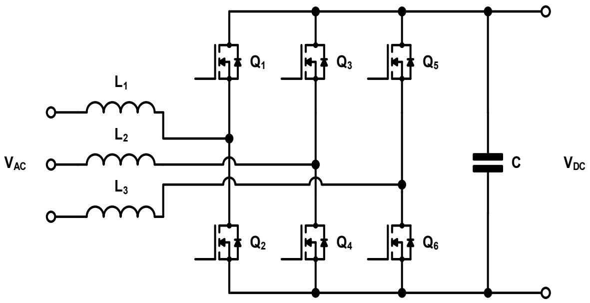


Solution Overview

Common Topologies in Bidirectional AC-DC

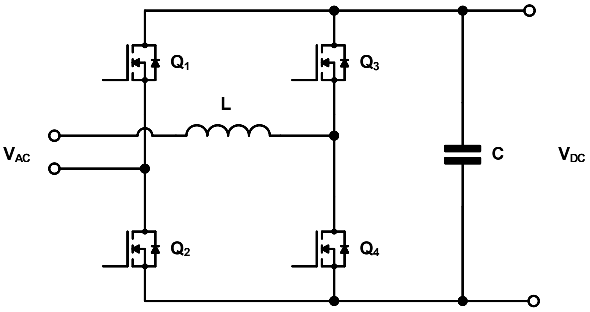
Three-Phase, Full Bridge Converter

- Simple circuit, easy control, few components
- Switches need to endure full bus voltage and spikes
- Requires high-capacity transformer, increase cost and end-system size
- Wide bandgap components is preferred to reduce THD, inductor size



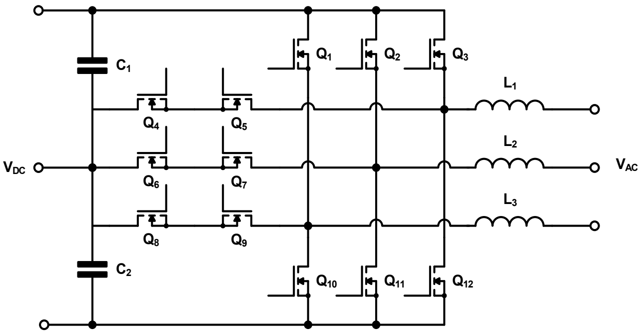
Single/Three-Phase, Totem Pole Converter

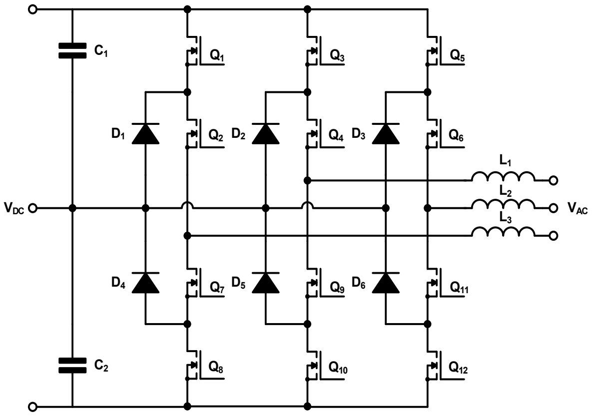
- Improved efficiency, EMI, THD, and reduced quantity of switches which are conducted per cycle
- High power density due to low quantity of switches
- Wide bandgap components are required to reduce recovery losses
- Zero crossing point noise, common mode noise



Three-Phase, Three-level Converters

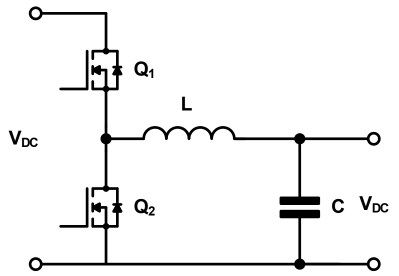
- Reduced THD and voltage stress on (some) switches as a three-level configuration
- More gate drivers and more complicated control
- Better efficiency, higher cost
- Proven configuration in solar inverter designs





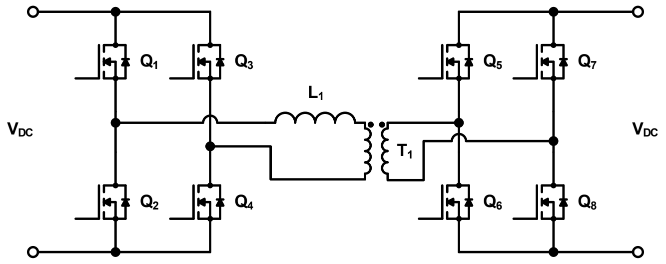
Solution Overview

Common Topologies in Bidirectional DC-DC



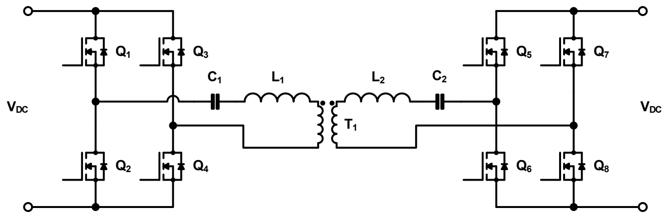
Buck-Boost Converter

- Expand charging/discharging voltage range to improve battery usage
- Realize bidirectional power conversion when charging/discharging
- Few components and easy control
- Optional according to battery voltage



Dual Active Bridge Converter

- Run phase-shift modulation To realize ZVS at high loads
- Unexpected loss caused by mismatch of current in both stage
- Complicated design regarding phase shift, transformer, frequency, etc. to reach expected efficiency
- Wide bandgap components are preferred in such high-frequency/high voltage operation
- Reduced output current ripple to reduce size of output capacitor, preferred in high-power cases
- Isolated conversion to ensure safety



CLLC Resonant Converter

- One additional capacitor added to realize bidirectional conversion based on LLC
- Complicated frequency modulation and passive selection to reach high efficiency in both directions
- Need extra DC-DC conversion to reach wide output range to ensure good efficiency
- Better efficiency than DAB during entire load range
- Isolated conversion to ensure safety

Recommended Products

Suggested Block	Part Number	Description
AC-Coupled & DC-Coupled BESS - Power Conversion Stage		
Bidirectional AC-DC & Bidirectional DC-DC	NTH4L028N170M1	Silicon Carbide (SiC) MOSFET - EliteSiC, 28 mΩ, 1700 V, M1, TO-247-4L
	NTH4L014N120M3P	Silicon Carbide (SiC) MOSFET - EliteSiC, 14 mΩ, 1200 V, M3P, TO-247-4L
	NTHL022N120M3S	Silicon Carbide (SiC) MOSFET - EliteSiC, 22 mΩ, 1200 V, M3S, TO-247-3L
	NTH4L040N120M3S	Silicon Carbide (SiC) MOSFET - EliteSiC, 40 mΩ, 1200 V, M3S, TO-247-4L
	NTBG070N120M3S	Silicon Carbide (SiC) MOSFET - EliteSiC, 65 mΩ, 1200 V, M3S, D2PAK-7L
	NTBG020N090SC1	Silicon Carbide (SiC) MOSFET - EliteSiC, 20 mΩ, 900 V, M2, D2PAK-7L
	NTBG015N065SC1	Silicon Carbide (SiC) MOSFET - EliteSiC, 12 mΩ, 650 V, M2, D2PAK-7L
	NTBL045N065SC1	Silicon Carbide (SiC) MOSFET - EliteSiC, 33 mΩ, 650 V, M2, TOLL
	NTH4L015N065SC1	Silicon Carbide (SiC) MOSFET - EliteSiC, 12 mΩ, 650 V, M2, TO-247-4L
	NTHL075N065SC1	Silicon Carbide (SiC) MOSFET - EliteSiC, 57 mΩ, 650 V, M2, TO-247-3L
	Application Recommended SiC MOSFET	
	NDSH25170A	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 25 A,1700 V,D1,TO-247-2L
	FFSH10120A	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 10 A, 1200 V,D1,TO-247-2L
	FFSB20120A	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 20 A, 1200 V,D1,D2PAK-2L
	FFSH30120ADN	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 30 A,1200 V,D1,TO-247-3L
	FFSH40120ADN	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 40 A,1200 V,D1,TO-247-3L
	NDSH50120C	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 50 A,1200 V,D3,TO-247-2L
	FFSD0665B	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 6 A, 650 V, D2, DPAK
	FFSP0665B	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 6 A, 650 V, D2, TO-220-2L
	FFSB0665B	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 6 A, 650 V, D2, D2PAK-2L
	FFSB1065B	Silicon Carbide (SiC) Schottky Diode – EliteSiC, 10 A, 650 V, D2, D2PAK-2L
	Application Recommended SiC Diode	
	FGHL40T120RWD	1200 V 40 A FS7 IGBT, Low Vce(sat), TO-247-3L
	FGHL60T120RWD	1200 V 60 A FS7 IGBT, Low Vce(sat), TO-247-3L
	FGHL40T120SWD	1200 V 60 A FS7 IGBT, Fast Switching, TO-247-3L
	FGY140T120SWD	1200 V 140 A FS7 IGBT, Fast Switching, TO-247-3L
	FGY75T120SWD	1200 V 75 A FS7 IGBT, Fast Switching, TO-247-3L
	FGHL50T65LQDT	650 V 50 A FS4 low Vce(sat) IGBT with full rated copack diode, TO-247-3
	FGHL50T65LQDTL4	650 V 50 A FS4 low Vce(sat) IGBT with full rated copack diode, TO-247-4
	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	

Recommended Products

Suggested Block	Part Number	Description
Bidirectional AC-DC & Bidirectional DC-DC	NXH006P120MNF2	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 6 mΩ, M1
	NXH010P120MNF1	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 10 mΩ, M1
	NXH004P120M3F2	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 4 mΩ, M3S
	NXH003P120M3F2	Full SiC PIM, EliteSiC, Half Bridge, 1200 V, 3 mΩ, M3S
	NXH400N100L4Q2F2	IGBT PIM, I-Type NPC, 1000 V, 200 A IGBT, 1000 V, 75 A Diode
	NXH600N65L4Q2F2	IGBT PIM, I-Type NPC, 650 V, 600 A IGBT, 650 V, 300 A Diode
	Application Recommended PIM for Bidirectional AC-DC & DC-DC Stages	
	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
	NTBLS1D7N10MC	Power MOSFET, N-Channel, 100 V, 272 A, 1.8 mΩ, TOLL
	NTMFWS1D5N08X	Power MOSFET, N-Channel, STD Gate, SO8FL-HEFET,80V,1.43 mΩ,253 A
	NTBGS004N10G	Power MOSFET, N-Channel, 203 A, 100V, D2PAK-7L
	NTMFS3D2N10MD	N-Channel Shielded Gate PowerTrench® MOSFET 100 V, 142 A, 3.2 mΩ
	NTMFS7D5N15MC	N-Channel Shielded Gate PowerTrench® MOSFET 150 V, 95.6 A, 7.9 mΩ
	Application Recommended MOSFET for Optional Bidirectional DC-DC Stage	
Rest Common Parts		
Isolated Gate Driver	NCD57080 NCD57090	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
	NCD57100	Gate Driver, Isolated Single Channel IGBT Gare Driver ±7A
	NCP51561	Gate Driver, Isolated Dual Channel Gate Driver for SiC, 4.5 A/9 A
	Application Recommended Gate Driver	
Power Management	FSL336LR	650V Integrated Power Switch with Error Amp and no bias winding
	NCP11184	800V Switcher, Enhanced Standby Mode 2.25 Ω
	NCP1076	700V Integrated Power Switch, 4.8 Ω
	Application Recommended Offline Regulator	
	NCP189	LDO, 500 mA, Low noise, High PSRR, Low V_{DO}
	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, 300 mA, Ultra-Low Noise, High PSRR with Power Good
	Application Recommended LDO	

Recommended Products

Suggested Block	Part Number	Description
Power Management	NCP1251	PWM Controller, Current Mode for Offline Power Suppliers
	NCP1362	Quasi-Resonant Flyback Controller with Valley Lock-out Switching
	NCP1680	Totem-Pole PFC Controller, CrM
	NCP1568	AC-DC Active Clamp Flyback PWM Controller
	NCP13992	Current Mode Resonant Controller
	Application Recommended Offline Controller	
	NUP2105	27 V ESD Protection Diode - Dual Line CAN Bus Protector
	NUP3105L	32 V Dual Line CAN Bus Protector in SOT-23
	ESDM2032MX	3.3 V Bidirectional ESD and Surge Protection Diode
	ESDM3032MX	3.3 V Bidirectional Micro−Packaged ESD Protection Diode
	Application Recommended ESD Protection Diode	
	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
	NTBG1000N170M1	Silicon Carbide (SiC) MOSFET - EliteSiC, 960 mΩ, 1700 V, M1, D2PAK-7L
	NTHL1000N170M1	Silicon Carbide (SiC) MOSFET - EliteSiC, 960 mΩ, 1700 V, M1, TO-247-3L
	Application Recommended Zener Diode and others	
Signal Cond. & Control	NCS21 series	Current Sense Amplifier, 26 V, Low-/High-Side Voltage Out
	NCS2007 series	Operational Amplifier, Wide Supply Range, 3 MHz CMOS
	LM393	Comparator, Dual, Low Offset Voltage
	Application Recommended Amplifier & Comparator	
	NCD98010	12-Bit Low Power SAR ADC Unsigned Output
	NCD98011	12-Bit Low Power SAR ADC Signed Output
	Application Recommended ADC	
Logic & Memory	CAT24M01	EEPROM Serial 1 MB I2C
	CAT24C64	EEPROM Serial 64 kb I2C
	Application Recommended EEPROM	
	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
	Application Recommended Interface Components	

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Technical Documents

Type	Description & Link
Application Note	AND90204 – onsemi EliteSiC Gen2 1200V SiC MOSFET M3S Series
Whitepaper	TND6396 – Silicon Carbide – From Challenging Material to Robust Reliability
Whitepaper	TND6260 - Physically Based, Scalable SPICE Modeling Methodologies for Modern Power Electronic Devices
Application Note	AN1040 – Mounting Considerations for Power Semiconductors
Whitepaper	TND6330 - Using Physical and Scalable Simulation Models to Evaluate Parameters and Application Results
Application Note	AND90103 – onsemi M1 1200V SiC MOSFETs & Modules: Characteristics and Driving Recommendations
Application Note	AND9949 – NCD(V)57000/1 Gate Driver Design Note
Whitepaper	TND6237 – SiC MOSFETs: Gate Drive Optimization
Application Note	AND90190 – Practical Design Guidelines on the Usage of an Isolated Gate Driver
Application Note	AND9674 – Design and Application Guide of Bootstrap Circuit for High-Voltage Gate-Drive IC
Application Note	AND90004 – Analysis of Power Dissipation and Thermal Considerations for High Voltage Gate Drivers
Application Note	AND90061 – Half-Bridge LLC Resonant Converter Design Using NCP4390/NCV4390
Application Note	AND9925 – FAN9672/3 Tips and Tricks
Application Note	AND8273 – Design of a 100W ACF DC-DC Converter for Telecom System Using NCP1262
Application Note	AND9750 – Current Sense Amplifiers, FAQ
Brochure	BRD8092 – Energy Storage System Solutions
Video	Video – Buck-Boost Topology Overview
Video	Video – Understanding Single Pulse Avalanche Rating in Silicon Carbide MOSFETs

Technical Documents

Type	Description & Link
Video	Video – Introducing New Next-Generation 1200 V EliteSiC Half Bridge Power Integrated Modules (PIMs) M3S Technology
Ref Design (Evaluation Board)	25kW DC EV Charger (For reference only)
Ref Design (Evaluation Board)	15 W SiC High-Voltage Auxiliary Power Supply for HEV & BEV Applications
Ref Design (Evaluation Board)	40 W SiC high-voltage auxiliary power supply for HEV & BEV applications
Ref Design (Evaluation Board)	6-18 Vdc Input Isolated SiC Gate Driver Supply +20V/-5V/5V with Automotive Qualified NCV3064 Controller Evaluation Board
Ref Design (Evaluation Board)	6-18 Vdc Input Isolated IGBT Gate Driver Supply +15V/-7.5V/7.5V with Automotive Qualified NCV3064 Controller

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