SiC Solutions for Industrial Applications

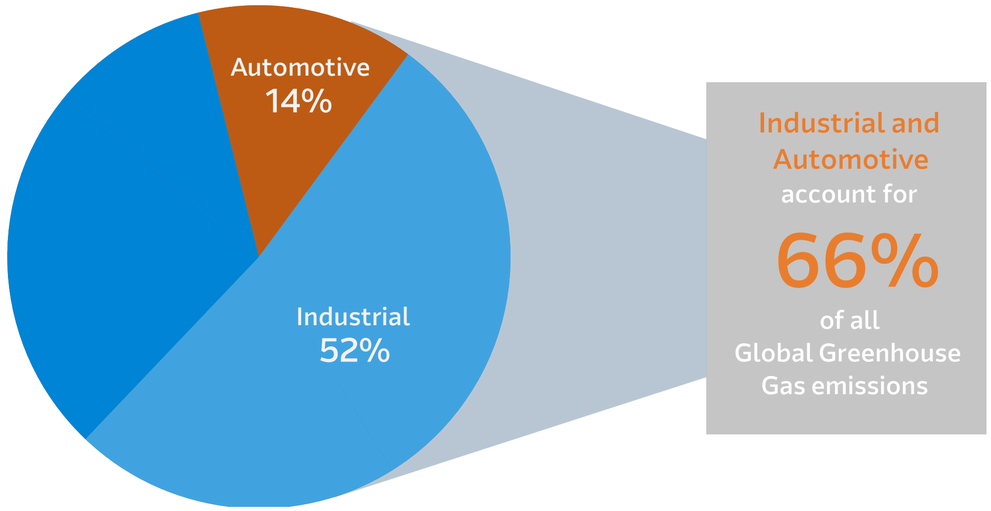
ARROW onsemi

Driving Towards Energy-Efficient Infrastructure

Energy generation, distribution, and storage are expanding markets. Increasing consumer demand and the need to meet targets set by government policy are driving stakeholder interest in new technological innovations. Superior efficiency, reduced CO_2 emissions, and a focus on renewable and clean energy are key factors in the evolution of the energy market.

High-power industrial and automotive applications consume a significant portion of the world's power and now present many opportunities for energy-efficient electronics. These applications are undergoing a transition to Silicon Carbide (SiC) power semiconductors from traditional silicon (Si) power semiconductors due to the advantages they offer — lower power consumption, higher efficiency, better reliability, and lower heat dissipation.

Global Greenhouse Gas Emissions



Source: **onsemi**, 2021

onsemi addresses the needs of demanding applications such as solar inverters, electric vehicle chargers, and uninterruptible power supplies with a comprehensive portfolio of energy efficient Silicon Carbide (SiC) Diodes, MOSFETs, Modules, and Gate Drivers.

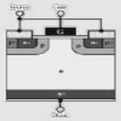
Watch video: Utilizing Wide Bandgap in Server and Industrial Power Applications

onsemi EliteSiC Portfolio Leadership

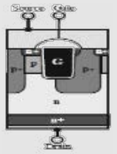
Substrates/Epi

- 150/200 mm SiC wafering & epi fully internal in **onsemi** today
- **onsemi** acquisition of GT Advanced Technologies complete

Fab



SiC Planar available today

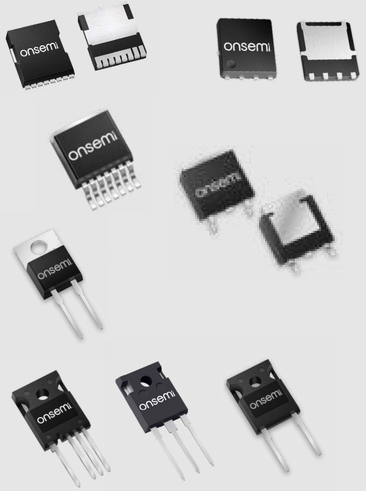


Working on trench for the future

200mm migration ready

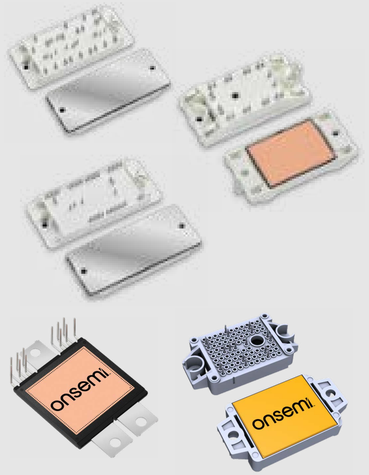
- Fabs ready today for 150 mm ⟶ 200 mm migration

Devices/Die



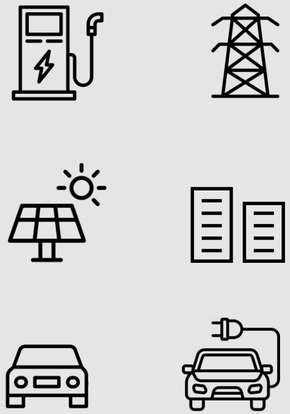
- Full portfolio of diodes & MOSFETs
- Broad base of packages
- Die only & metal options
- Auto & industrial devices

Modules



- Case & transfer molded options
- Full portfolio of hybrid & full SiC modules
- Single & dual cooling, direct & indirect

Systems



- Deep application & system know-how for automotive & industrial
- EMEA, US, Asia-based apps support

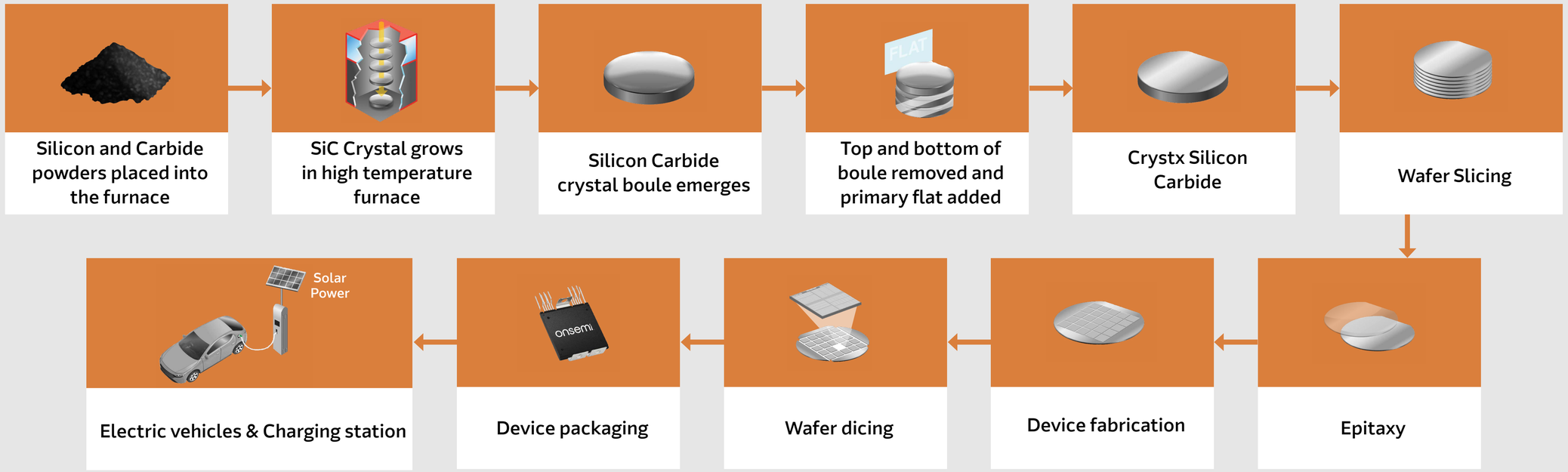
onsemi EliteSiC technology has multiple competitive advantages, such as its internal supply chain, fully integrated manufacturing expertise, a diverse offering of devices and packages, compelling performance to price ratio, best-in-class design tools, and in-house Gate Driver solutions. The third generation of Diodes and MOSFETs are currently released with improved performances, dedicated for high frequency operation & increased performance over temperature.

Formidable Manufacturing & Supply Chain

In-house Capability to Produce Automotive Solutions from Foundry to Final Test

EliteSiC

Fully Vertically Integrated Silicon Carbide (SiC) Supply Chain



onsemi EliteSiC Portfolio for Industrial and Energy Markets

EliteSiC Diodes

650 V/1200 V/1700 V

High efficiency, faster operating frequency, increased power density, reduced EMI, and reduced system size and cost

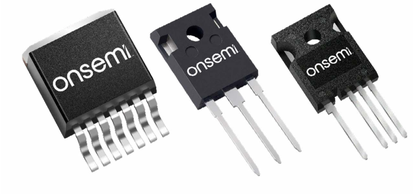
- No reverse QRR recovery, No forward recovery
- Low VF (lower conduction losses)
- Leakage stability over temperature range
- Switching characteristics independent of temperature
- Higher surge and avalanche capacity
- Positive temperature coefficient
- Higher operating temperature (TJMAX=175°C)
- Multiple packages available
  - DPAK-3/TO-252-3LD
  - D2PAK-2/TO-263-2LD
  - D2PAK-3/TO-263-2LD
  - PQFN-4
  - TO-220-2LD
  - TO-220-3LD
  - TO-220FP/TO-220F-2FS
  - TO-247-2LD
  - TO-247−3LD

EliteSiC MOSFETs

650 V/900 V/1200 V/1700 V

High efficiency, faster operating frequency, increased power density, reduced EMI, and reduced system size and cost

- High power density
- Ultra-low gate charge
- Low effective output capacitance
- Low VF (lower conduction losses)
- Leakage stability over temperature range
- 100% UIL tested
- Higher operating temperature (TJMAX=175°C)
- Multiple packages available
  - D2PAK7 (TO-263-7L HV)
  - TO-247-3LD
  - TO-247-4



EliteSiC Hybrid Modules

650 V/1000 V/1200 V/1700 V

Improved efficiency with SiC diodes & fast switching low VCE (SAT) IGBT

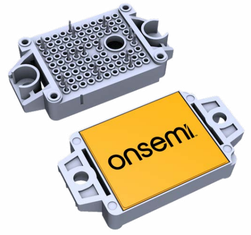
- Range of pin compatible SiC hybrid and full SiC options
- Integrated bypass diodes
- Low thermal impedance baseplate
- Split T-type NPC inverter
- I-Type NPC 1000 V, 350 A/450 A IGBT, 1200 V, 100 A SiC diode
- 3 Channel Symmetric Boost 1000 V, 150 A IGBT, 1200 V, 30 A SiC diode
- 3 Channel 1200 V IGBT + SiC Boost, 80 A IGBT and 20 A SiC diode
- F1 and F2 modules available

EliteSiC Full Modules

900 V/1200 V

Lower conduction and switching losses, while enabling designers to achieve high efficiency and superior reliability

- Low thermal resistance from larger die than with trench MOSFETs
- Easy to drive with negative gate voltages
- Industry standard pinout with same pinout for different $R_{DS(on)}$ levels and voltages
- Industry standard pinout option
- Reduced voltage ringing from using capacitors integrated into the module (F2 module)
- Q0 and Q1 Boost modules available



EliteSiC MOSFET and Diode Families

MOSFETs

Family	Series	Optimization	650 V	900 V	1200 V	1700 V	Primary Applications
M1	M1	Low $R_{DS(on)}$ High SCWT			..120SC1	170M1	
M2	M2	Low $R_{DS(on)}$ High SCWT	..065SC1	..090SC1			
M3	M3S	High speed			..120M3S		
	M3T	Low $R_{DS(on)}$ High SCWT			..120M3x SCWT dependent		

Diodes

Family	Optimization	650 V		1200 V	1700 V	Primary Applications
D1	High IFSM	..065A		..120A	..170A	
D2	Low QC	..065B				
D3	Low QC x VF			..120C		

EV Charging Station

UPS/Energy Storage

Solar

High Power Industrial

Traction

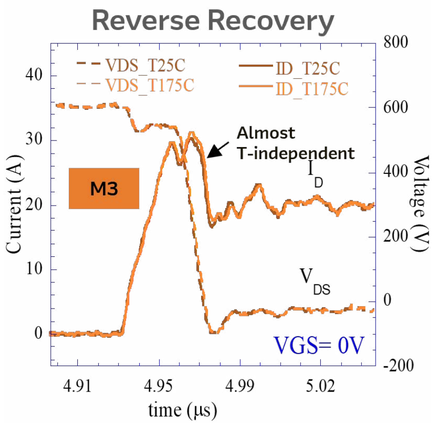
On-board Charger

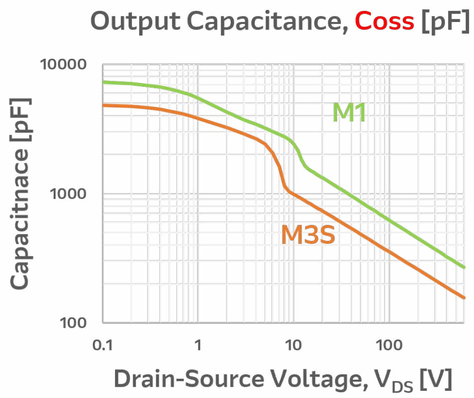
onsemi EliteSiC - Benefits of 3rd Generation SiC MOSFETs

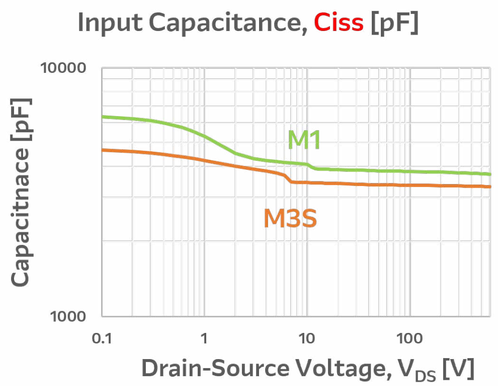
Key Parameters @ conditions, RT		M1 20mΩ, NTH4L020N120SC1	M3 22mΩ, NTH4L022N120M3S	
$V_{gs(op)}$ [V]		20V/-5V	18V/-3V	
$R_{ds(on)}$ [mΩ]	@ Vgs=18V, 40A	21.9	21.6	
Q_g [nC]	@ 800V, 40A, Vgs=18/-3V	191	135	
E_{oss} [uJ]	@ 600V	63	36	
FOM 1 [Ω*nC]	Rds(on) * Qg	4.2	2.9	**31%↓**
FOM2 [Ω*uJ]	Rdson * Eoss	1.38	0.77	**44%↓**
E_{on} [uJ] w/SiC-SBD	Inductive load switching @ 800V, 40A @ Rg=4.7Ω, Vgs=18V/-3V	280	219	
E_{on} [uJ] w/Body-D		769	415	
E_{off} [uJ]		420	251	
V_{SD} [V]	@ 30A, Vgs=-3V	3.63	4.28	
t_{rr} [ns]	@ 40A, 2kA/us, Vgs=-3V	28	18	
Q_{rr} [ns]		347	188	

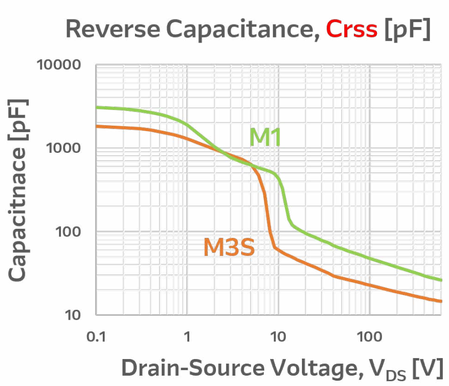
3rd Generation SiC offering

- Optimized for high temperature operation
- Stable reverse recovery over temperature
- Improved parasitic capacitances for high frequency high efficiency application
- Large die with low $R_{DS(on)}$ available



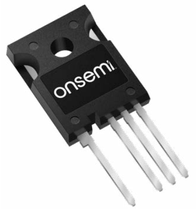






1200V SiC MOSFETs – M3 Family

Automotive grade uses “NV”
Industrial grade uses “NT”

$R_{DS(ON)}$ (mΩ) Typical @Vgs: 18V	TO-247-3L	TO-247-4L	D2PAK-7L
			
14		NTH4L014N120M3P	NTBG014N120M3P
22	NTHL022N120M3S	NTH4L022N120M3S NVH4L022N120M3S	NTBG022N120M3S NVBG022N120M3S
29	NTHL030N120M3S	NTH4L030N120M3S NVH4L030N120M3S	NTBG030N120M3S NVBG030N120M3S
40	NTHL040N120M3S	NTH4L040N120M3S NVH4L040N120M3S	NTBG040N120M3S NVBG040N120M3S
65	NTHL070N120M3S	NTH4L070N120M3S NVH4L070N120M3S	NTBG070N120M3S NVBG070N120M3S

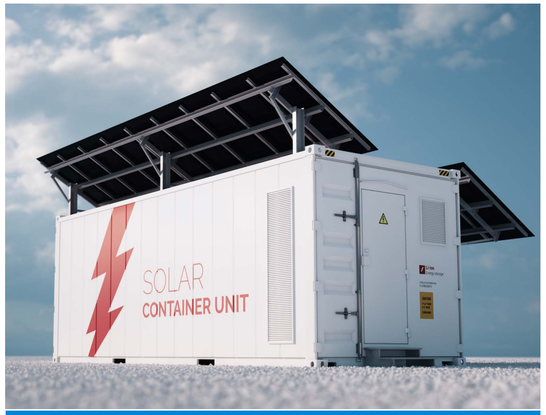
Ideal Energy and Industrial Applications for SiC

Silicon Carbide (SiC) is ideal for use cases such as solar energy equipment, energy storage, alternative energy modes, and high voltage applications. SiC semiconductor's higher mechanical, chemical and thermal stability increases its efficiency and reduces cooling requirements for these and other industrial applications. Additionally, using SiC also simplifies design without sacrificing performance by reducing passive components.

EV Charging Stations

Uninterruptible Power Supplies (UPS)

Solar Inverters



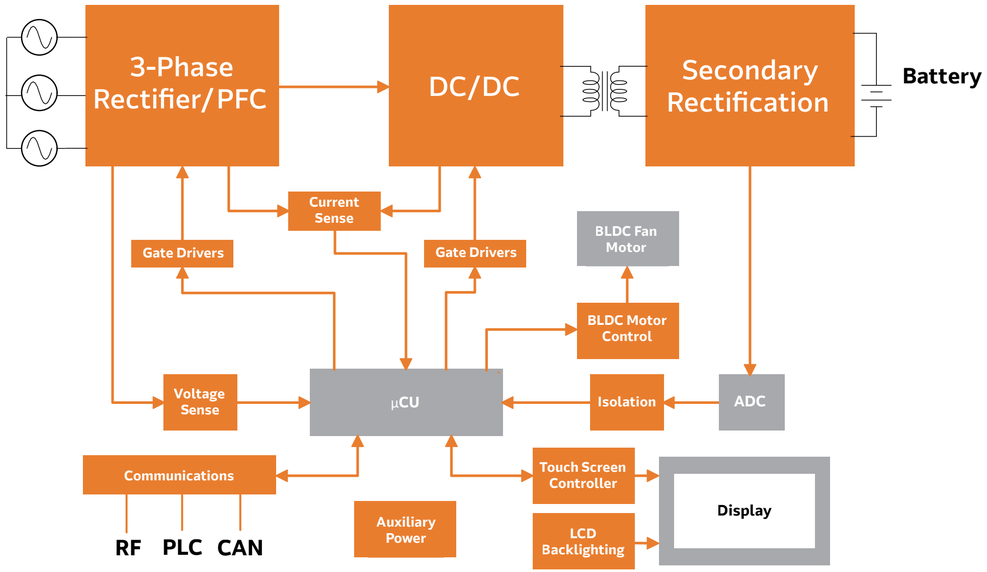
Energy Storage

EV Charging Stations

High-voltage SiC power devices enable the rapid-charging infrastructure that is the last major barrier to the widespread adoption of EV-based transportation. SiC is very efficient at high voltages, enabling fast battery charging times comparable to filling the tank of conventional vehicles.

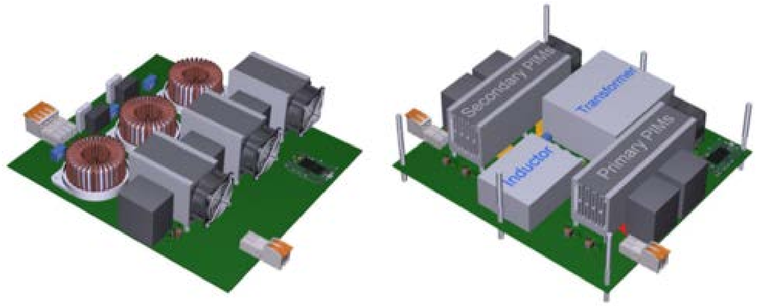
onsemi's leading EliteSiC technology and innovative packaging solutions help simplify the design process for EV chargers. With a comprehensive portfolio of discrete power, analog solutions, protections, sensing, and connectivity, **onsemi** offers the industry's most comprehensive portfolio of high-quality components that can be tailored to specific needs.

DC Fast Charger



Reference Design

25 kW PFC Stage and DC-DC Stage for EV Charging Station Solution



300 kW EV Charging Station can be Built Using 12 x 25 kW Building Blocks

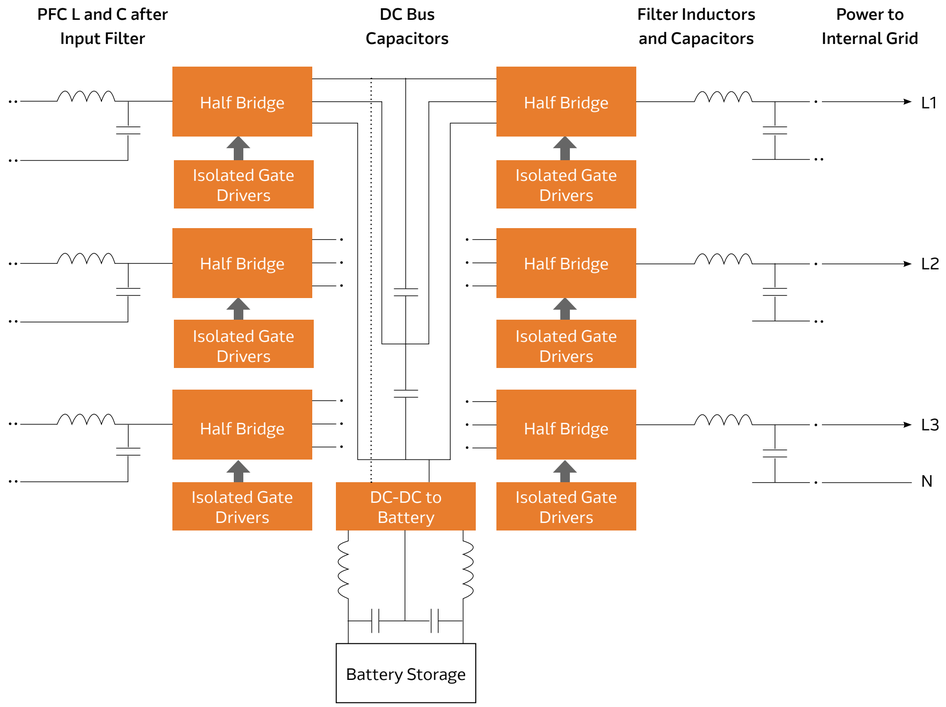
25 kW building block	25 kW building block
25 kW building block	25 kW building block
25 kW building block	25 kW building block
25 kW building block	25 kW building block
25 kW building block	25 kW building block
25 kW building block	25 kW building block

- Read Article Series: Developing A 25-kW SiC-Based Fast DC Charger
  Part 1 Part 2 Part 3
  Part 4 Part 5 Part 6
- Watch Webinars: 25 kW DC Fast Charging
  Session 1 Session 2 Session 3 Session 4

Uninterruptible Power Supplies (UPS)

onsemi' Silicon Carbide (SiC) MOSFETs, diodes, and modules together with versatile Gate Drivers, power conversion, sensing, and protection IC families address requirements of high-power UPS designs. Combined with **onsemi**'s long-term expertise in power management and conversion, customers can deploy **onsemi** MOSFETs to develop UPS systems that maximize power quality and reliability.

UPS 3 Phase with a Full SiC Approach



Demystifying Three-Phase PFC Topologies

Evaluation Boards

Three-phase On Board Charger (OBC) PFC-LLC Platform

The SEC-3PH-11-OBC-EVB is a modular platform that serves as a learning environment for three-phase AC/DC power conversion in an OBC application. It includes a performance 1200 V SiC MOSFET, 6A SiC MOSFET Gate Driver, and a SiC Diode 650 V.

Part number: SEC-3PH-11-OBC-EVB

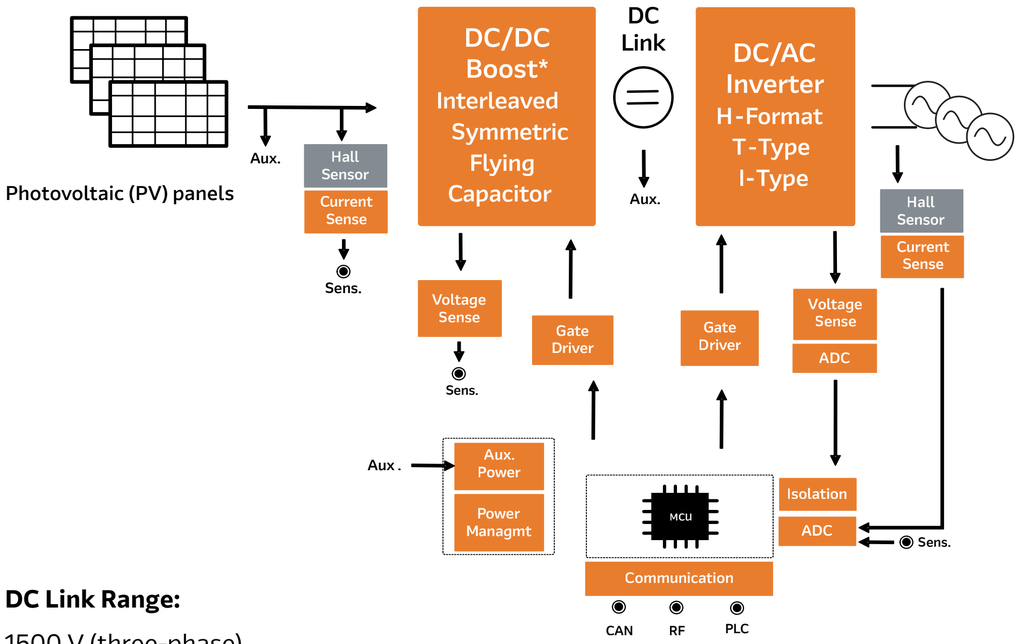
Gate Drivers Plug-and-Play Ecosystem

SECO−GDBB−EVB is the baseboard for the Gate Driver plug-and-play ecosystem, which allows for the comparison of the dynamic performance and capabilities of different Gate Drivers and technologies.

Part number: SECO-GDBB-GEVB

Solar Inverters

Solar inverters need to deliver high efficiencies, very often above 98%, while also ensuring high reliability. This is even more critical in utility applications, where system downtime adversely affects ROI. System-level cost is also a key factor for consideration when choosing technology underpinnings for solar inverters.



DC Link Range:

1500 V (three-phase)

1100 V (three-phase)

~ 350 - < 600 V (single-phase)

onsemi Solutions for Single and Three-phase Solar Inverters

Grid Tie	Power	DC Link	Power Integrated Modules (PIM)		Discrete	
			DC-DC Boost	DC/AC Inverter	DC-DC Boost	DC/AC Inverter
3-Phase	100 kw - >250 kw	1500 V	3-ch Symmetric (Q2) 3-ch Flying Cap (Q2)	I-NPC-type (Q2)		
	30 kw - 100 kw	1100 V	2-ch Boost (Q0, Q1) 3-ch Boost (Q1) 2-ch Boost (Q0)	I-NPC-type (Q2)		
				T-type (Q0) Split T-type (Q1, Q2) Split T-type (Q2)		
	8 kw - 30 kw	1100 V		3-ch T-type (Q1)		
Single Phase				H6.5 / Q1		

- SiC (including hybrid)
- IGBT Trench
- SJ MOSFET

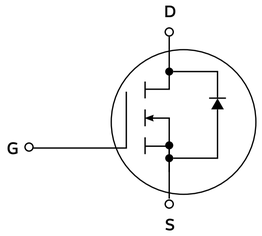
Q0 Q1 Q2

Resource: Solar Power Needs Silicon Carbide

NCP51561 5KV Isolated SiC Gate Driver

Type A (3LD)

N-CHANNEL MOSFET

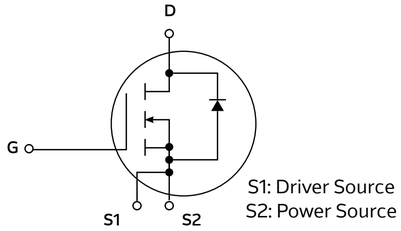


NTHL020N120SC1
1200V SiC (22mΩ)

TO-247-3L

Breakdown Voltage:	SiC: TO-247-3LD
	$R_{DS(on)}$ Range (25C)
1200 V	20mΩ to 160mΩ
900 V	20mΩ to 60mΩ
650 V	12mΩ to 57mΩ

Type B (4LD)



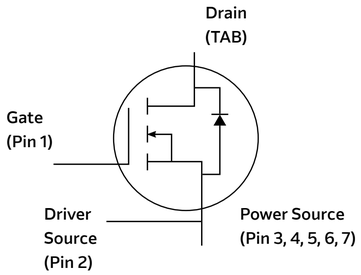
N-CHANNEL MOSFET

NTH4L022N120M3S
1200V SiC (22mΩ)

TO-247-4L

Breakdown Voltage:	SiC: TO-247-4LD
	$R_{DS(on)}$ Range (25C)
1200 V	20mΩ to 160mΩ
900 V	20mΩ to 60mΩ
750 V	13.5mΩ
650 V	12mΩ to 57mΩ

Type C (7LD)



N-CHANNEL MOSFET

NTBG020N120SC1
1200V SiC (20mΩ)

D2PAK7L

Breakdown Voltage:	SiC: TO-247-7LD
	$R_{DS(on)}$ Range (25C)
1200 V	20mΩ to 160mΩ
900 V	20mΩ to 60mΩ
650 V	12mΩ to 43.5mΩ

Getting Started Resources

Evaluation Boards

- Evaluation Board: Three-phase On Board Charger (OBC) PFC-LLC Platform (SEC-3PH-11-OBC-EVB)
- Evaluation Board: 6.6kW OBC SiC model (SEC-6D6KW-OBC-SiC-GEVB)
- Evaluation Board: A 6.6kW OBC Evaluation Board using Totem Pole Topology (SEC-6D6KW-OBC-TTP-GEVB)

White Papers and Application Notes

- White Paper: Physically Based, Scalable SPICE Modeling Methodologies for Modern Power Electronic Devices
- White Paper: SiC MOSFETs: Gate Drive Optimization
- Application Note: **onsemi** Gen 1 1200 V SiC MOSFETs & Modules: Characteristics and Driving Recommendations
- Application Note: Mounting Instructions for PIM Modules (Q0, Q1, Q2, F1, F2)

Simulation Models

- SiC MOSFETs: Simulation Models for Silicon Carbide (SiC) MOSFETs
- SiC Diodes: Simulation Models for Silicon Carbide (SiC) Diodes

Reach out to your local Arrow sales or technical contacts for evaluation boards, samples, and design support.

Contact Information

Online: www.arrow.com

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Five Years Out