FOR ENERGY EFFICIENT INNOVATIONS

THINK ON.

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车载充电器(OBC)及DC-DC转换器应用中的SiC MOSFET及门极驱动器方案

Power Solution Group

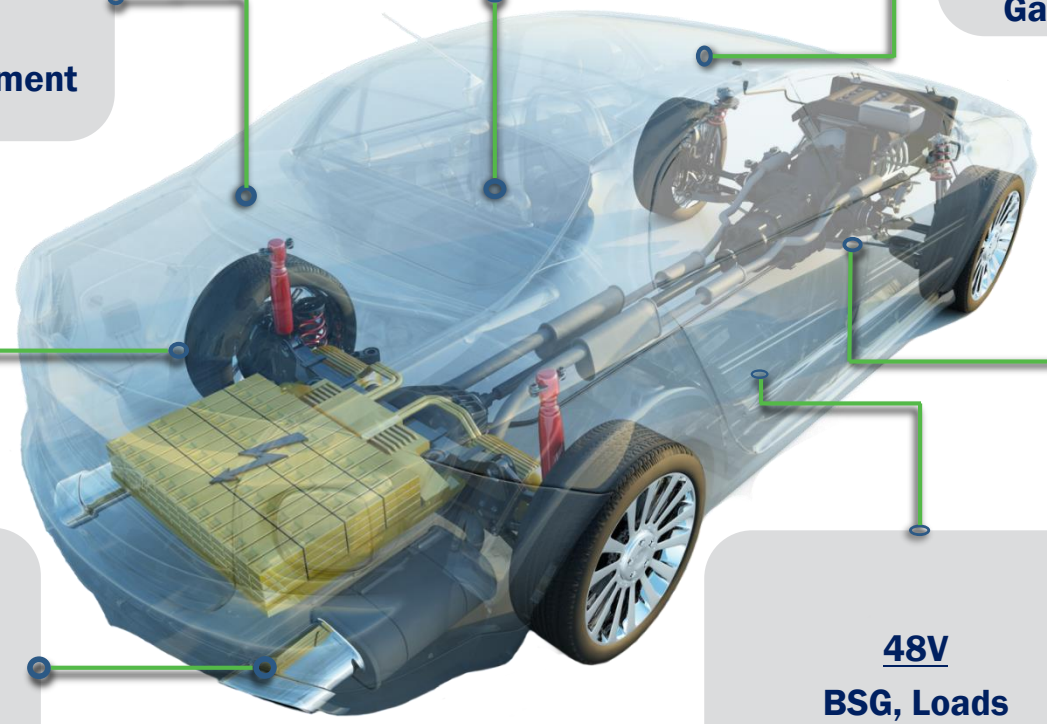
Public Information

A Leader in Vehicle Electrification

Body Electronics
Doors, Seating, Keyless entry, Gateway Modules

PHEV, EV
ON Board Chargers, HV Loads Battery Management

ADAS, Infotainment, HUD
Doors, Seating, Keyless entry, Gateway Modules



DC/DC
HV-LV, 48V-12V

Powertrain
xEV Traction, ECU, TCU, Safety (Braking, Parking)

Lighting
Rear, Front, Interior

48V
BSG, Loads

ON Semiconductor Technologies Enabler

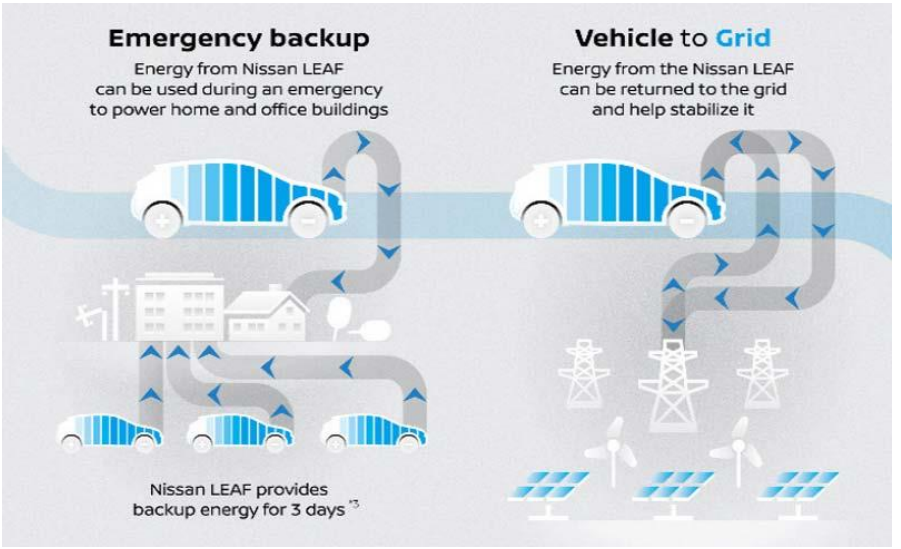
- 650 - 1200 V SiC MOSFET
- 650 – 1200 V SiC JBS Diode
- 100 – 650 V GaN
- 650 – 1200 V IGBT
- Low – Mid – High Voltage FET
- High Voltage Gate Driver

Source: ON Semiconductor Corporate Marketing

ON Board Charger Trend

G2V(Grid to Vehicle)

V2X(Vehicle to Grid, Home, Vehicle..)



Uni-directional Charging

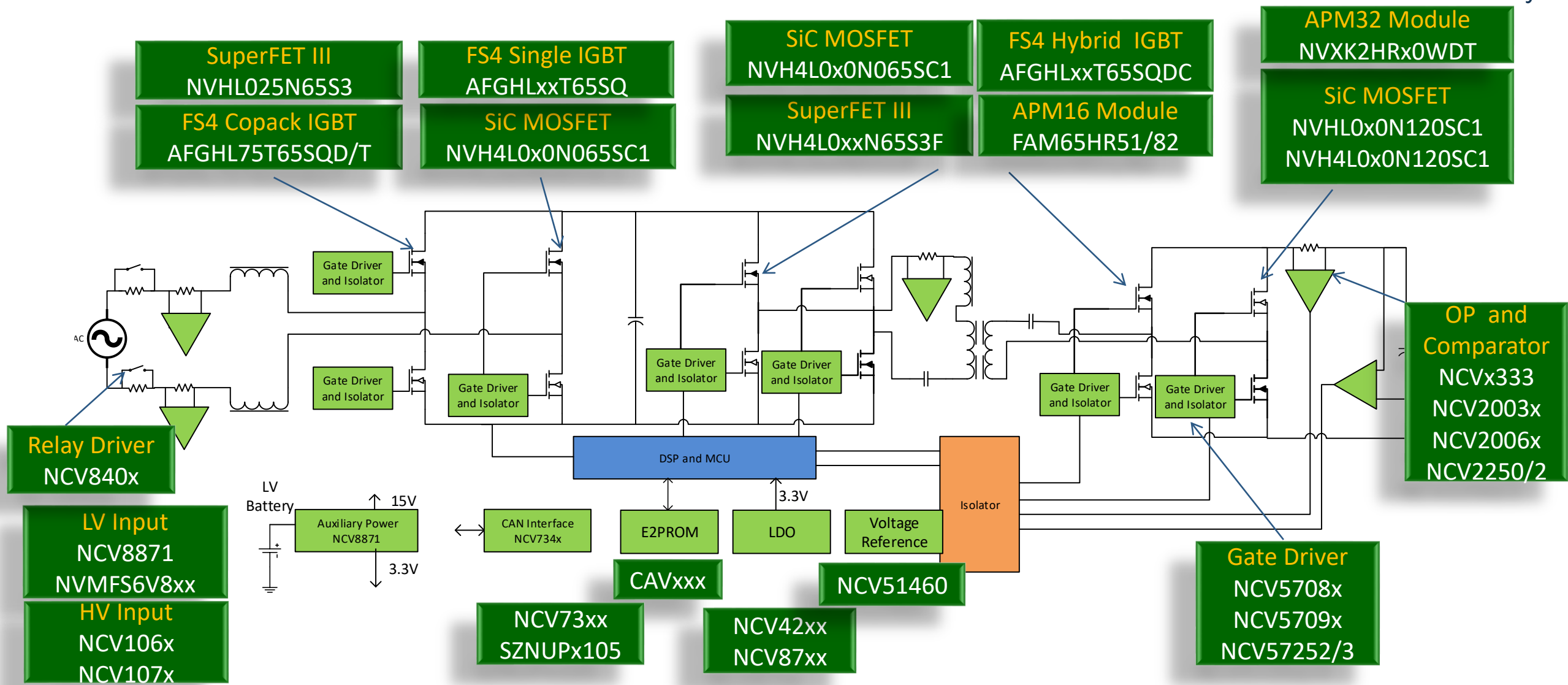
PFC (AC→DC) | LLC, 1st DC→AC | LLC. 2nd AC→DC | Battery

Bi-directional Charging

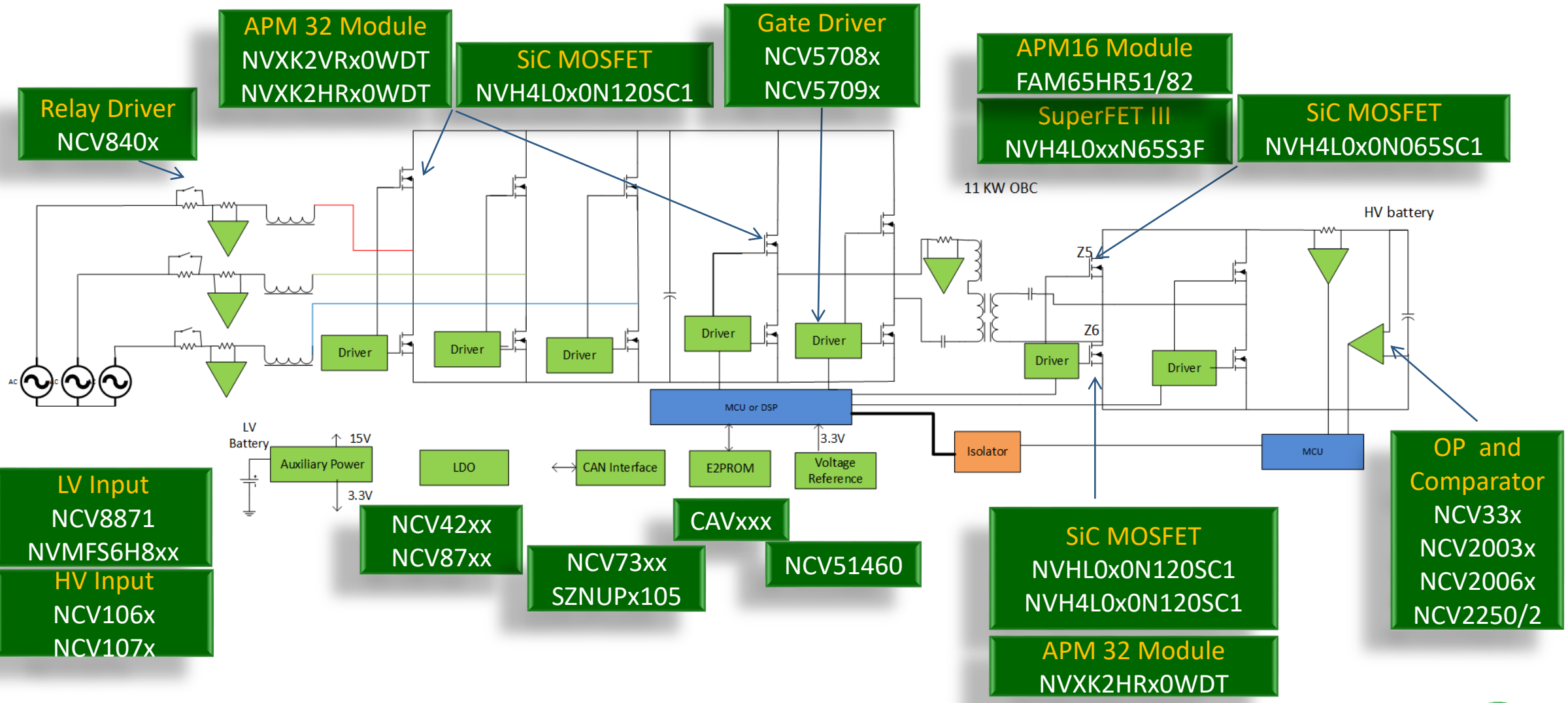
Inverter (AC←DC) | LLC,2nd DC←AC | LLC, 1st AC←DC | Battery

6.6KW bidirectional OBC block diagram

For 500V to 800V battery

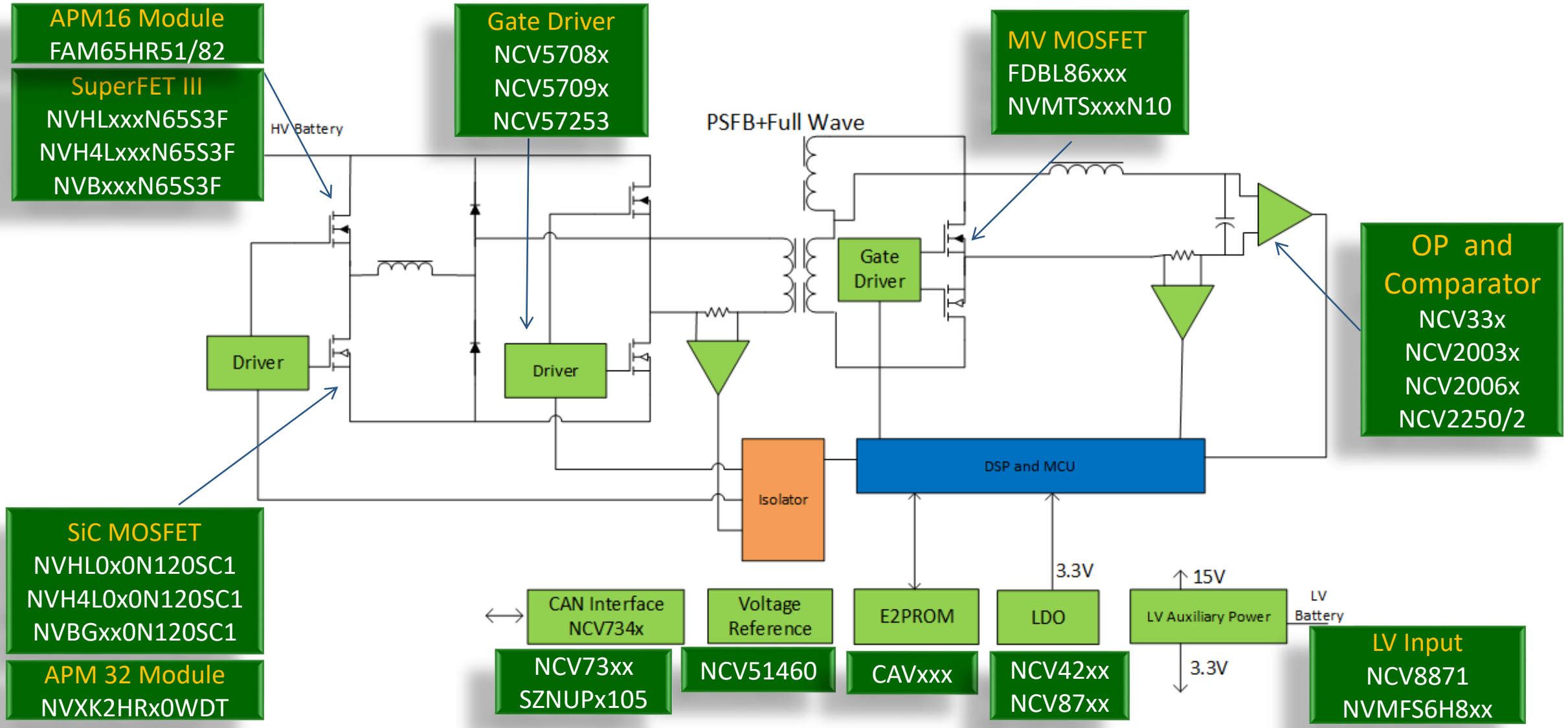


11KW bidirectional OBC block diagram



For 500V to 800V battery

1.8KW to 3KW HV to LV DCDC converter block diagram



For 500V to 800V battery

Automotive SiC Discretes

WBG Supply Chain

Substrate Supply	Epi Growth	Wafer Fab (6 inch)	Solderable Top Metal	Wafer Dicing and Assembly/Test
• Internal (*) • External	• Internal (Multiple)	• Internal (Bucheon, KR)	• Internal (Multiple)	• Internal (Multiple)

GT Advanced Technologies (GTAT) and **ON Semiconductor** announced the execution of a five-year agreement, valued at a potential of $50 million. With this agreement, GTAT will produce and supply its CrystX™ silicon carbide (SiC) material to ON Semiconductor.

Cree and ON Semiconductor Announce Multi-Year Silicon Carbide Wafer Supply Agreement

AUGUST 6, 2019

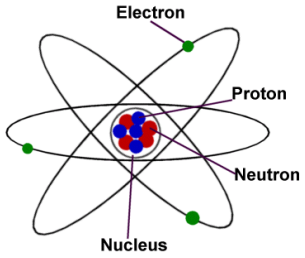
Agreement to boost commercial expansion of SiC in automotive and industrial applications

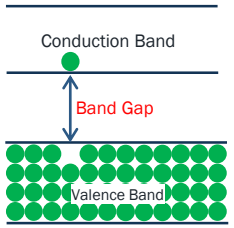
Introduction to Wide Band Gap (WBG)

Bandgap = Energy required to move an electron from it's outer shell, so it can move freely inside the material

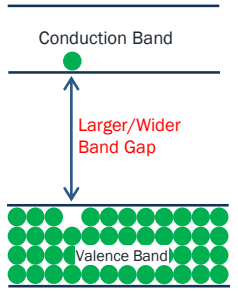
Material	Symbol	Bandgap Energy (eV)
Geranium	Ge	0.7
Silicon	Si	1.1
Gallium Arsenide	GaAs	1.4
Silicon Carbide	SiC	3.3
Zinc Oxide	ZnO	3.4
Gallium Nitride	GaN	3.4
Diamond	C	5.5

Wide band gap





Energy required to move electron from Valence band to Conduction band



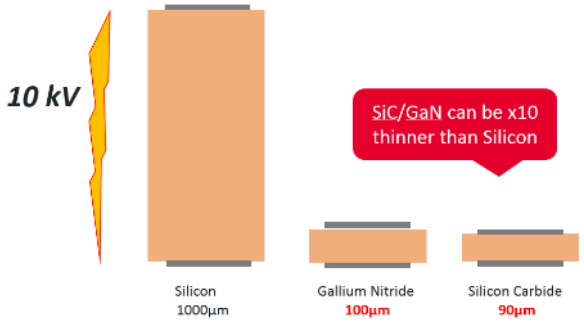
More energy required to move electron

- **Silicon Carbide compared to Silicon**
  - 10x higher dielectric breakdown field strength
  - 2x higher electron saturation velocity
  - 3x higher energy bandgap
  - 3x higher thermal conductivity

Wide Band Gap Technology Benefits

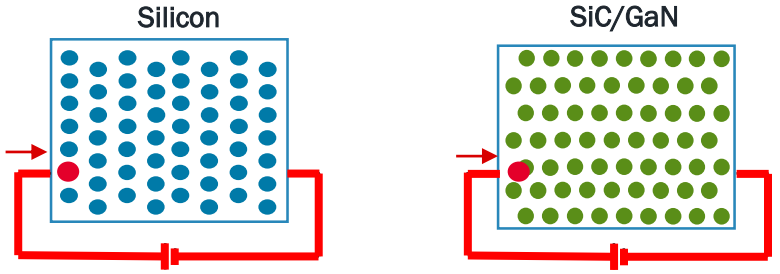
10x higher dielectric breakdown field strength

- SiC/GaN thickness can be reduced
- Reduces electrical & thermal resistance = Lower Power Losses



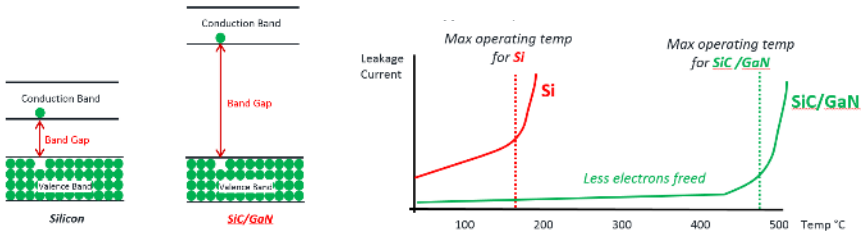
2x higher electron saturation velocity

- Higher switching speeds can be achieved
- Electron Saturation Velocity = max speed of electron



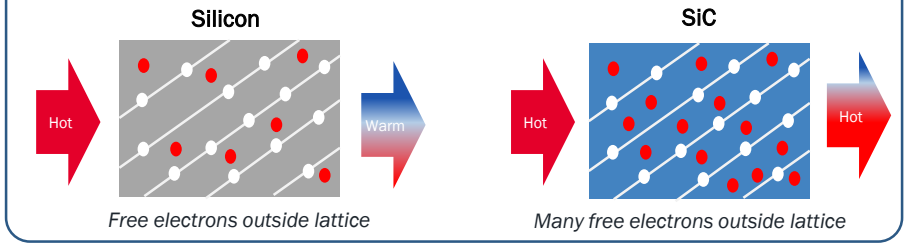
3x higher energy bandgap

- Provides a stable/low leakage over large temperature range
- Higher energy required to 'free' electrons



3x higher thermal conductivity

- High dissipation of heat from SiC results in lower operating temperature and thermal stress
- SiC allows faster transfer of excited electrons (heat)

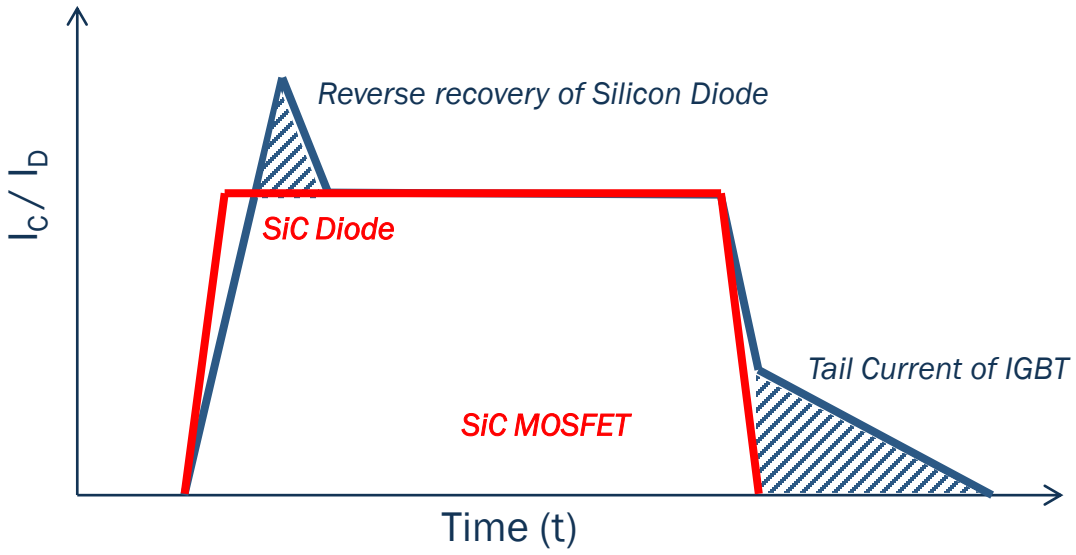


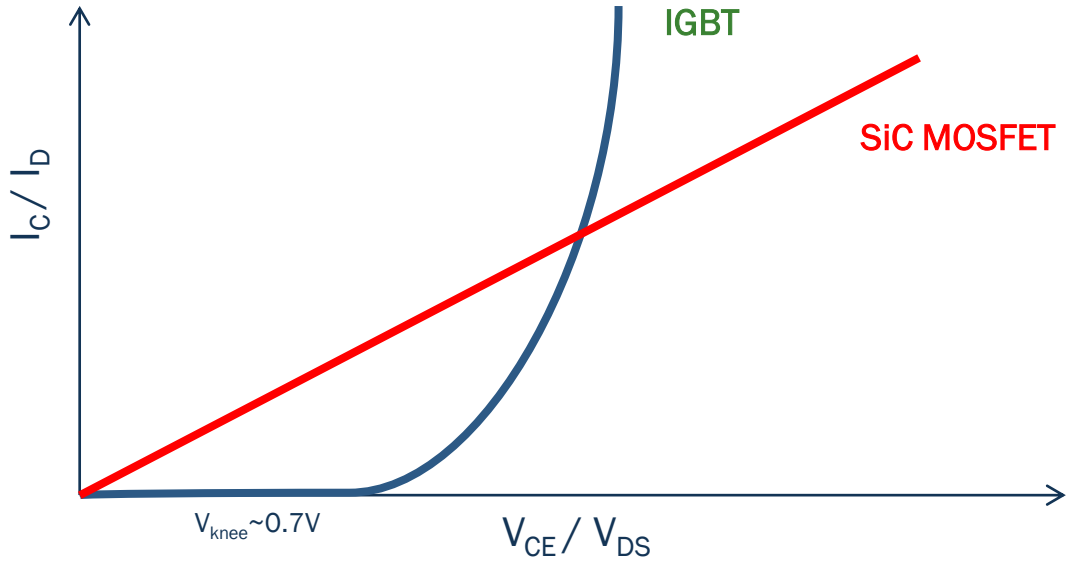
Source: Yole 2016, IHS

Silicon IGBT & Diode vs SiC MOSFET

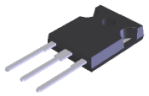
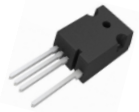
- Lower switching losses
  - Low reverse recovery
  - Fast turn-off due to unipolar charge
  - Fast turn-on due to low gate-charge & low reverse recovery

- Lower conduction losses
  - Absence of knee voltage
  - Lower temperature coefficient





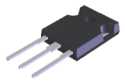
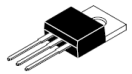
1200V Gen1.0 SiC MOSFETs

$R_{DS(ON)}$ TYP (mΩ)	TO247-3	TO247-4	D2PAK-7L
			
20	NVHL020N120SC1	NVH4L020N120SC1	NVBG020N120SC1
40	NVHL040N120SC1	NVH4L040N120SC1	NVBG040N120SC1
80	NVHL080N120SC1A	NVH4L080N120SC1	NVBG080N120SC1
160	NVHL160N120SC1	NVH4L160N120SC1	NVBG160N120SC1

Devices in green – RTM
Wafers and Bare Die sales upon request

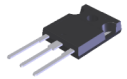
650V SiC Diodes

Automotive grade includes “–F085” OPN suffix

I (A)	VF (V)	Die	TO-247-3L // Die	TO-247-2L	TO-220-2L	TO-220-3L	D2PAK	DPAK	PQFN 88
									
50	1.35			FFSH5065B					
40			FFSH4065BDN			FFSP4065BDN			
30				FFSH3065B	FFSP3065B		FFSB3065B		
20			FFSH2065BDN	FFSH2065B	FFSP2065B	FFSP2065BDN	FFSB2065B FFSB2065BDN	FFSD2065B	FFSM2065B
10				FFSH1065B	FFSP1065B		FFSB1065B	FFSD1065B	FFSM1065B
8					FFSP0865B		FFSB0865B	FFSD0865B	FFSM0865B
6					FFSP0665B		FFSB0665B	FFSD0665B	FFSM0665B

1200V SiC Diodes

Automotive grade includes “–F085” OPN suffix

I (A)	VF (V)	Die	TO-247-3L // Die	TO-247-2L	TO-220-2L	D2PAK	DPAK
							
50	1.45	PCFFS50120AF		FFSH50120A			
40		PCFFS40120AF	FFSH40120ADN	FFSH40120A			
30		PCFFS30120AF	FFSH30120ADN	FFSH30120A			
20		PCFFS20120AF	FFSH20120ADN	FFSH20120A	FFSP20120A	FFSB20120A	
15		PCFFS15120AF	FFSH15120ADN	FFSH15120A	FFSP15120A		
10		PCFFS10120AF	FFSH10120ADN	FFSH10120A	FFSP10120A	FFSB10120A	FFSD10120A
8		PCFFS08120AF			FFSP08120A		FFSD08120A
5		PCFFS05120AF			FFSP05120A		

Automotive Power Modules

ON Semiconductor Power module offer to OBC & DCDC solution needs

Power Ratings

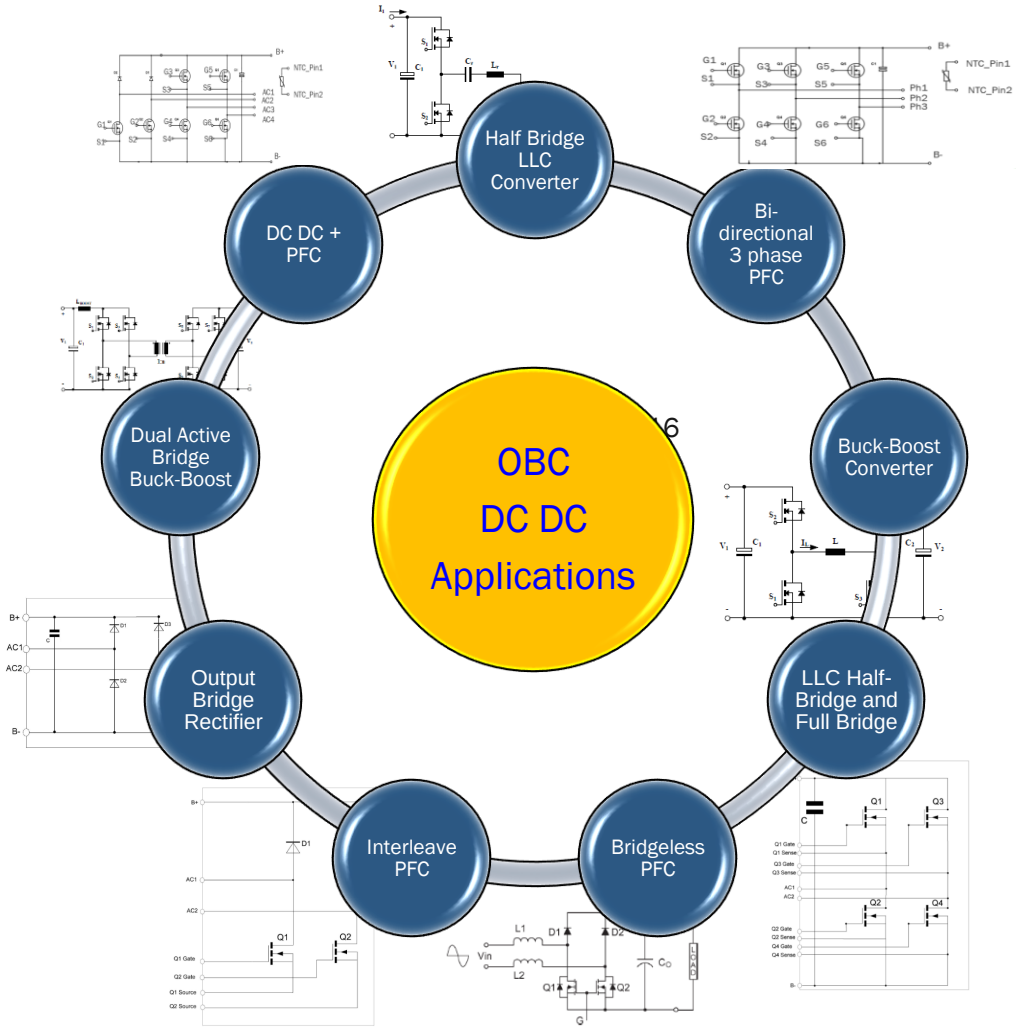
3.6kw

7.2kw

11 kw

22 kw

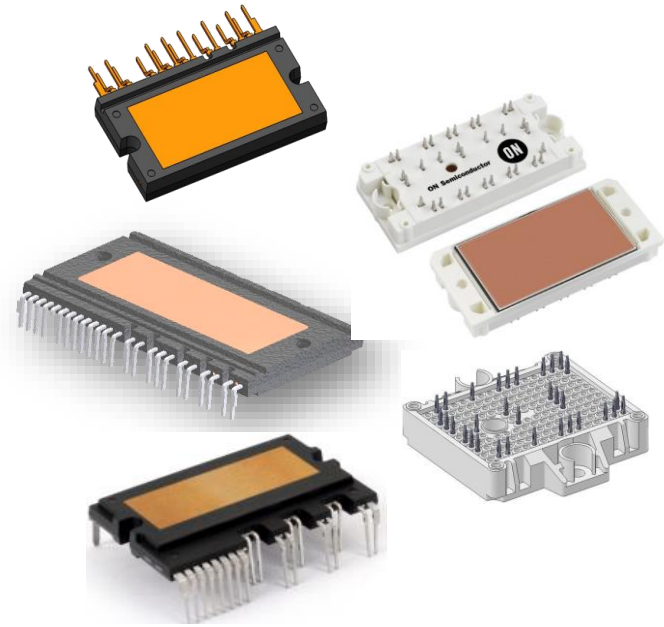
Topologies



FETs

Sic FET / Superfet Mosfet / IGBT / Rectifier

Feasible Offer by APM solutions



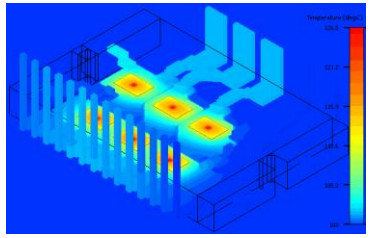
Customer Selections of module solution per
- Price / Auto Reliability / Size / System Assembly (pressfit vs soldering)

Benefits of ON Semiconductor APM

High Power Applications

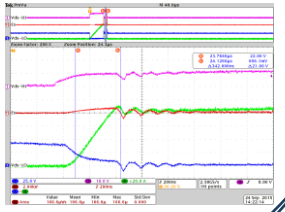
Performance

Low Thermal Resistance



Electrical Performance

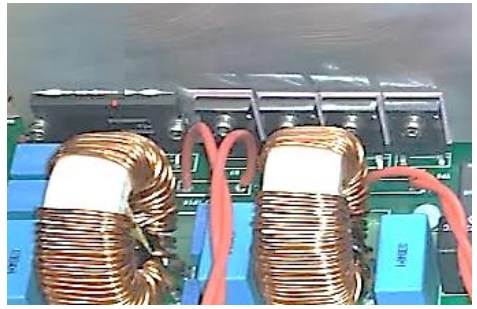
- High Current Capa
- Low Inductance
- Low Resistance
- EMI performance by snubber
- HV Isolation inside



Low Power Loss & Low Tj

Power Density ↑

Compact Size, Lighter Weight



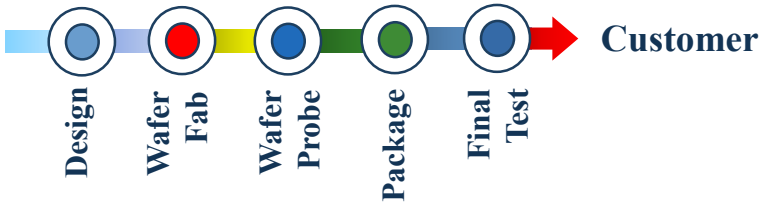
Total Cost ↓

Total system manufacturing cost Saving
+
Quality Cost

Quality

Field Proven Reliability

Fab + Assembly

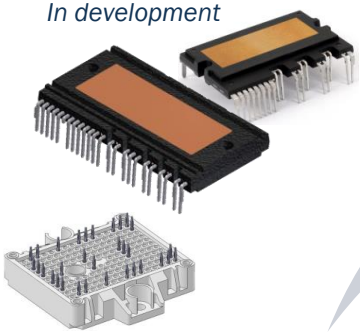


All ON Semiconductor In-House Process

HV OBC APM Solution

APM32

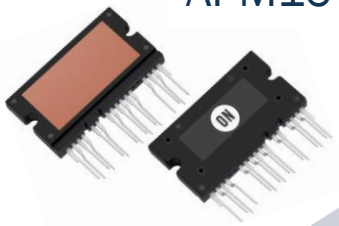
In development



(TBD) Per market demand

- 2020: SiC 1200V & Si FET 650 integration version Release
- 2021~: Proliferations

APM16 Proliferation



- 2018: Platform - Product release for DC DC & PFC
- 2019: Proliferation - ALN DBC - Sic Diode PFC - Bridge Rectifier
- 2020: Proliferation - 900V SIC FET - 82ohm FET options
- 2021~: Next gen Si Tech APM16

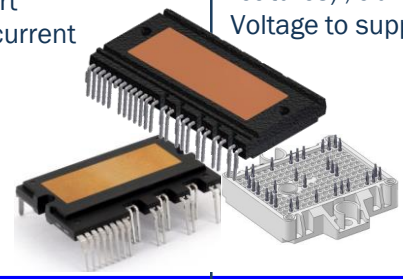
Integration capability

High

Rated @ 650V, highest integration (PFC +DC/DC or Bridge diodes+PFC, possible NTC features). Ability to support complex design with the current SJ technology

In Development

Rated @ 1200V, higher integration (PFC +DC/DC or Bridge diodes+PFC, possible NTC features) , ability to work at higher Voltage to support 800V

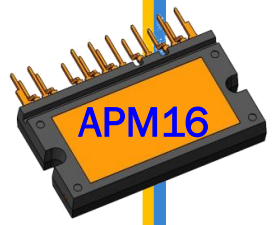


In Development

Low

Current APM16: Rated @650V, relatively low integration possible (PFC or DC/DC or Bridge diodes)

2 Parts were Released per AQG324. Proliferations ongoing



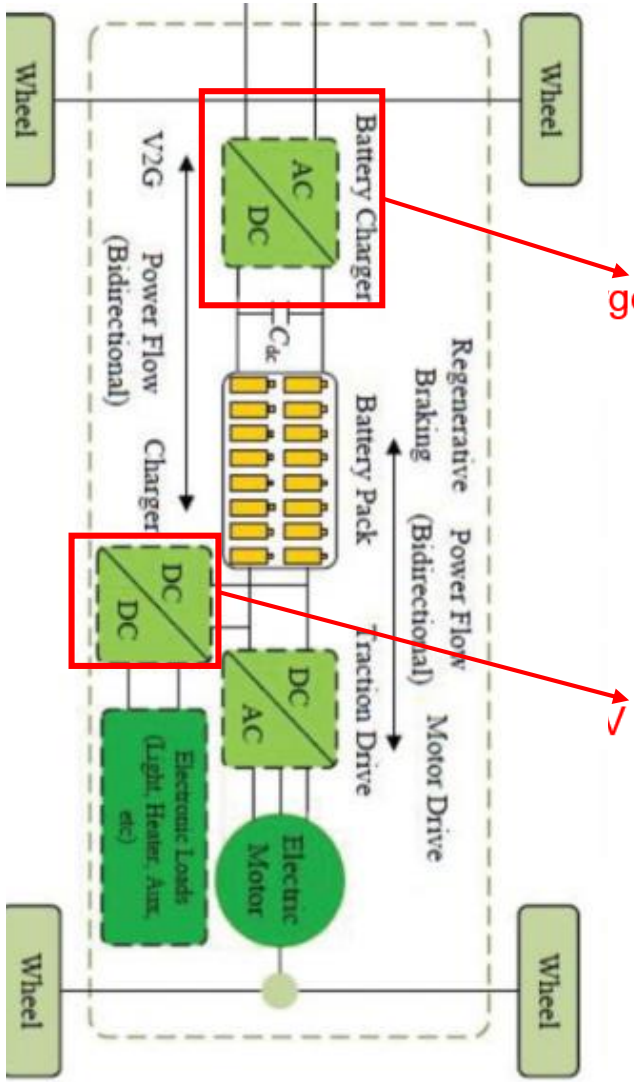
Modified APM16: Rated @900V, low/medium integration possible (PFC or DC/DC or Bridge diodes) compact design with SiC technologies

Concept

Low: 650V

High: 1200V

Existing ON Semiconductor Solution : APM16



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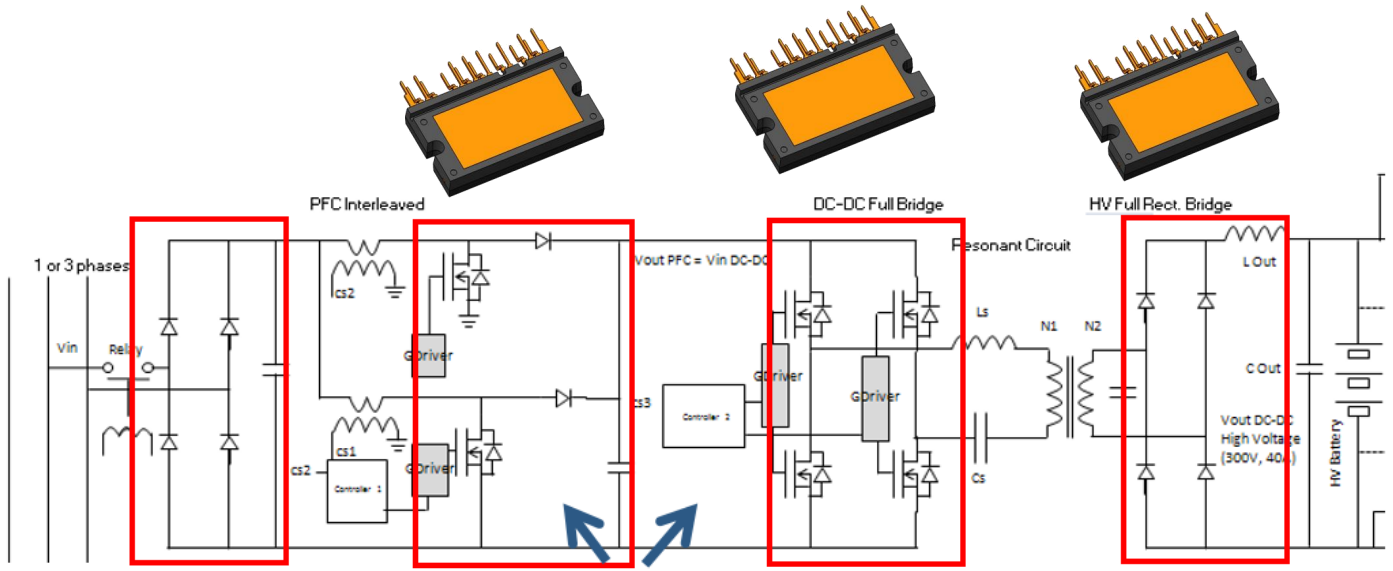
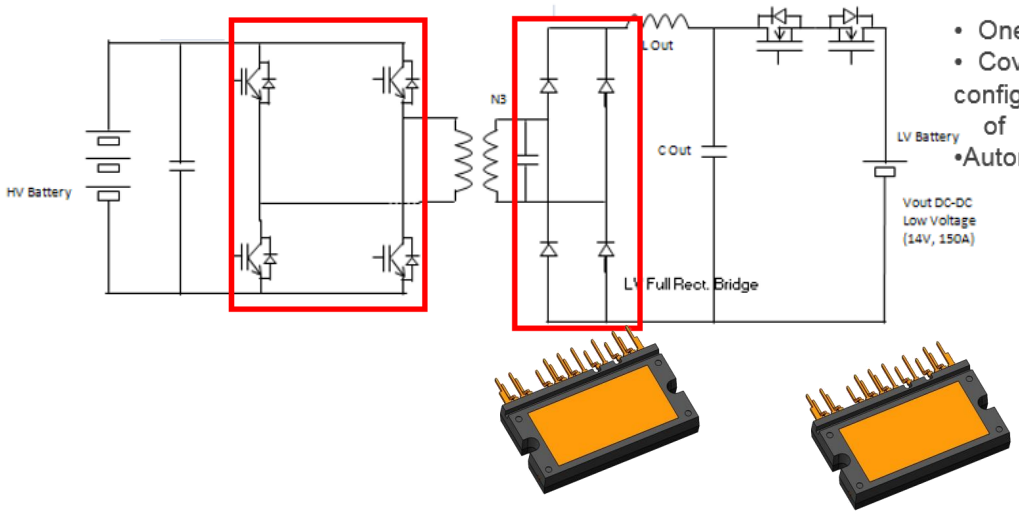
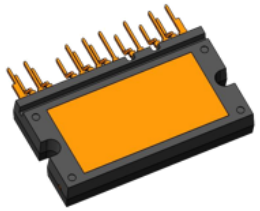


Discrete or APM16 Modules



APM16 Module value proposition:

- One package outline
- Covers all different circuit configurations of OBC and DC/DC
- Automotive qualified



APM1

HV OBC Module - APM16 Platform

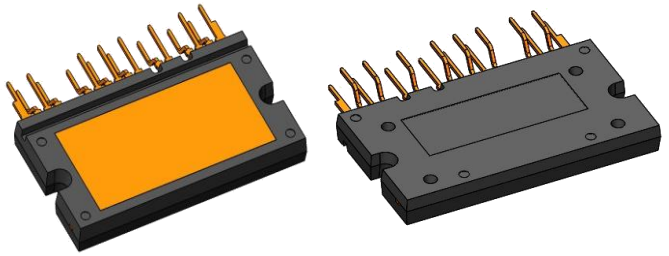
Description

- PFC stage, DCDC converter, Bridge Rectifiers for on-board charger in EV-PHEV
- Creepage and Clearance per IEC60664-1, IEC60950-1
- Low junction-sink thermal resistance
- Highly integrated compact design
- Module flexibility to integrate all technologies Si and SiC and all half Bridge or Full Bridge Circuit topologies
- 5kV/1 sec electrically isolated substrate easy assembly
- Complaint to IEC-60664-1 for functional and reinforced isolation
- Automotive qualified – AQG324

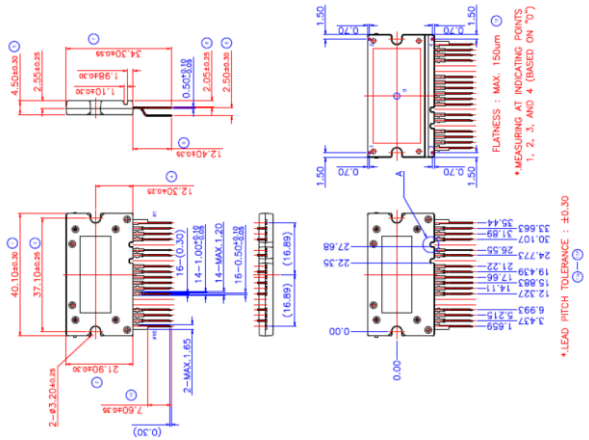
Application

3,3KW	6,6KW	3,3KW	6,6KW
DCDC APM16 Al2O3 Substrate	**DCDC APM16** AlN Substrate	**PFC APM16** Al2O3 Substrate	**PFC APM16** AlN Substrate

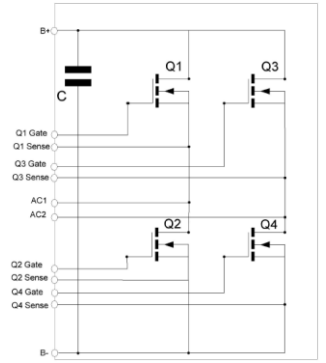
Package : 40.1 mm × 21.9 mm × 4.5 mm



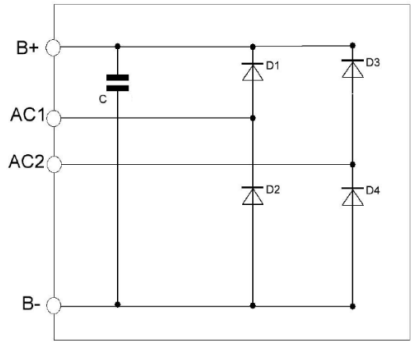
Package Details



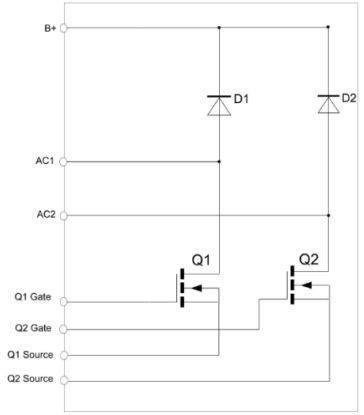
DC DC



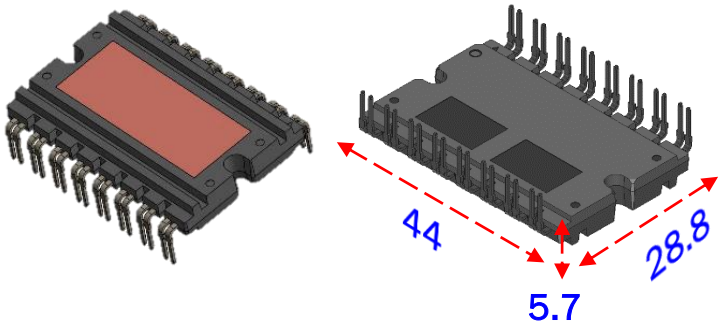
Bridge Rectifier

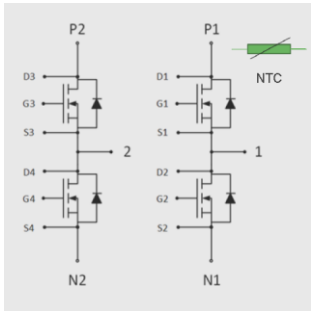


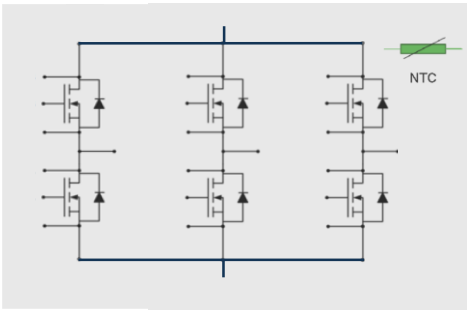
PFC



APM32 1200V SiC Module Development







ADVANCE INFORMATION

ON Semiconductor

Nov 2019-B

NVXK2VR80WDT

Features

- DIP Silicon Carbide H-Bridge power module for on-board charger (OBC) in EV-PHEV
- Creepage and clearance per IEC60664-1, IEC 60950-1
- Compact design for low total module resistance
- Module serialization for full traceability
- Lead free, RoHS and UL94V-0 compliant
- Automotive qualified per AEC Q101 and AQG324 guidelines

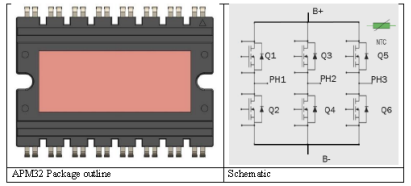
Applications

- PFC for On Board Charger in PHEV-HEV-EV

Benefits

- Enable design of small, efficient, and reliable system for reduced vehicle fuel consumption and CO2 emission
- Simplified assembly, optimized layout, high level of integration, and improved thermal performance

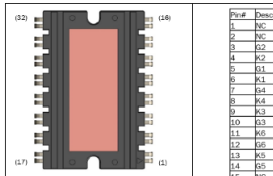
Figure 1. Package view



APM32 Package outline | Schematic

NVXK2VR80WDT APM Automotive Power Module

ADVANCE INFORMATION



Pin#	Description	Pin#	Description
1	NC	17	B-
2	NC	18	B-
3	G2	19	NC
4	K2	20	NC
5	S1	21	PH1
6	K1	22	PH1
7	S4	23	PH2
8	K4	24	PH2
9	K3	25	PH3
10	G3	26	PH3
11	K5	27	NC
12	G5	28	NC
13	K5	29	NTC_1
14	G5	30	NTC_2
15	NC	31	B+
16	NC	32	B+

APM32 Pin-out | Pin-out description

Absolute Maximum Ratings (T_J = 25°C, Unless Otherwise Specified)

Note: Electrical value and Absolute maximum ratings refer to the same die hosted in TO247 NVHL020N120SC1

ABSOLUTE MAXIMUM RATINGS (T_A = 25°C, unless otherwise noted)

Symbol	Parameter		Ratings	Unit
V_{DSmax}	Drain−to−Source Voltage		1200	V
V_{GSmax}	Max. Gate−to−Source Voltage	@ T_C < 175°C	−15 / +25	V
$V_{GSop(DC)}$	Recommended operation Values of Gate − Source Voltage	@ T_C < 175°C	−5 / +20	V
$V_{GSop(AC)}$	Recommended operation Values of Gate − Source Voltage (f > 1 Hz)	@ T_C < 175°C	−5 / +20	V
I_D	Continuous Drain Current	V_{GS} = 20 V, T_C = 25°C	44	A
		V_{GS} = 20 V, T_C = 100°C	31	
$I_{D(Pulse)}$	Pulse Drain Current	Pulse width tp limited by $T_{J\,max}$	106	A
E_{AS}	Single Pulse Avalanche Energy (Note 1)		171	mJ
P_{tot}	Power Dissipation	T_C = 25°C	348	W
		T_C = 150°C	58	
T_J, T_{STG}	Operating and Storage Junction Temperature Range		−55 to +175	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. E_{AS} of 171 mJ is based on starting T_J = 25°C, L = 1 mH, I_{AS} = 18.5 A, , V_{DD} = 50 V, R_G = 25 Ω.

DBC Substrate

0.63 mm Al2O3 with 0.3 mm copper on both sides.
DBC substrate is NOT nickel plated.

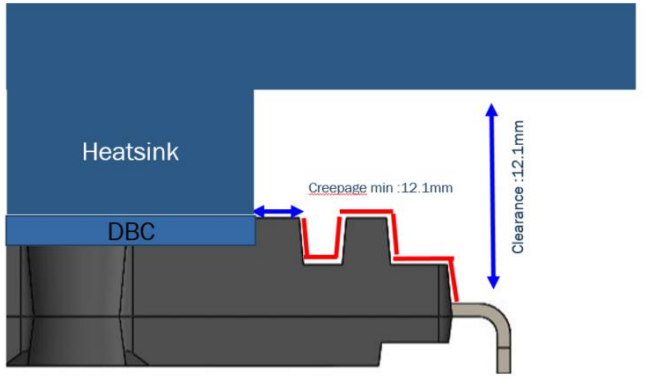
Flammability Information

All materials present in the power module meet UL flammability rating class 94V-0.

Compliance to RoHS directives

The power module is 100 % lead free and RoHS compliant 2000/53/C directive.

NVXK2VR80WDT APM Automotive Power Module

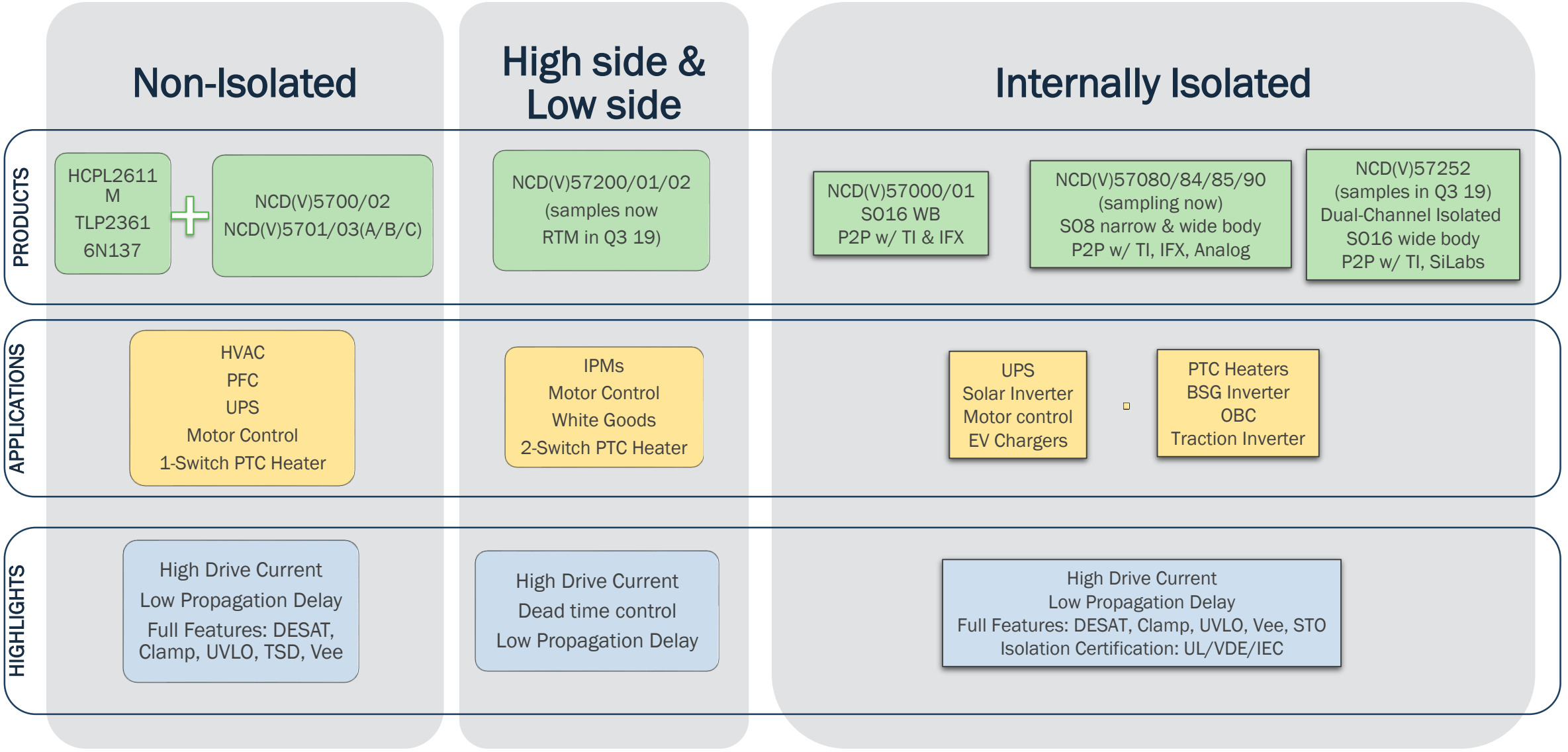


Samples available

Public Information

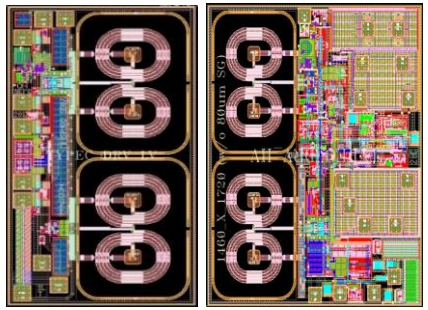
Automotive HV Gate Drivers

High Voltage Gate Drivers Portfolio



Isolated Gate Drivers Technology

A. 5kV UL Recognized Isolation (Robustness)



Features	Inductive
UL 5kV Isolation	√
Reliability/Aging	√
Temp Range	√
EMI	√

Take Aways:

A. Isolation technology that is Safe, Reliable and Certified

B. Drivers improve system efficiency with high drive current

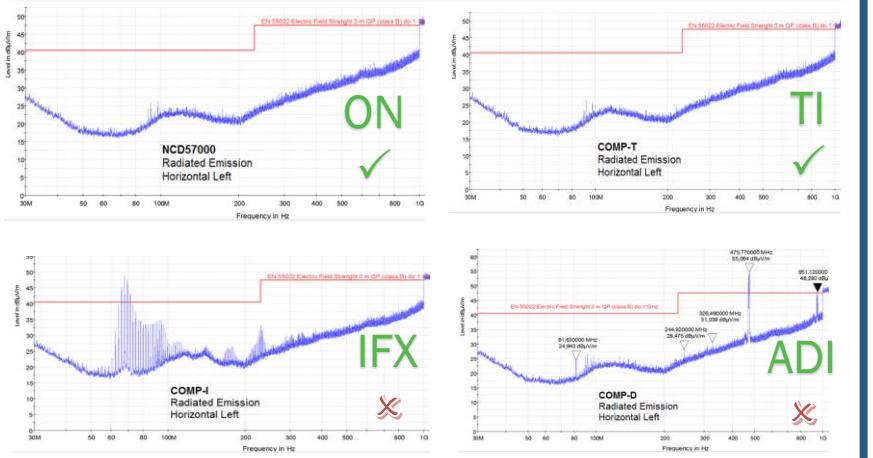
C. Isolation technology that does not generate EMI nor susceptible to system generated EMI

D. Robust Common Mode Transient Immunity against system voltage transients present in high voltage & high power switching applications

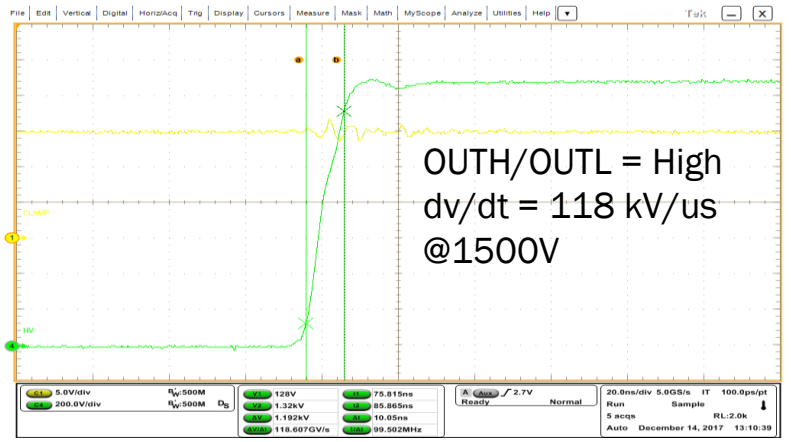
B. Highest Drive Current (improved Efficiency)

	ON	ADI	IFX	TI
I-source Peak	8A	4.6A	4A	2.5A
I-Sink Peak	8A	4.6A	3A	5A
I-Source Miller Plateau	4A	3A	1.1A	2A
I-Sink Miller Plateau	6A	4A	2.9A	4A

C. Best-in-Class EMI (Higher Noise Robustness)



D. Best-in-Class CMTI (Higher Noise Robustness)



Gate Drivers Selector Guide

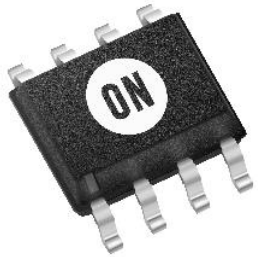
	Specs/Features							
	No. of channels	Isolation	Differential Input	DESAT w/ FLT	Miller Clamp	VEE	Split output	Package Type
NCDV)5700/2	1			V	V	V	V	SOIC-16 Wide
NCD(V)5701/3A	1			V	V			SOIC-8 Wide
NCD(V)5701/3B	1			V		V		SOIC-8 Wide
NCD(V)5701/3C	1			V			V	SOIC-8 Wide
NCD(V)57000/1	1	V	V	V	V			SOIC-16 Wide
NCD(V)57080A	1	V	V		V			SOIC-8 Narrow
NCD(V)57080B	1	V	V			V		SOIC-8 Narrow
NCD(V)57080C	1	V	V				V	SOIC-8 Narrow
NCD(V)57090A	1	V	V		V			SOIC-8 Wide
NCD(V)57090B	1	V	V			V		SOIC-8 Wide
NCD(V)57090C	1	V	V				V	SOIC-8 Wide
NCD(V)57084	1	V		V				SOIC-8 Narrow
NCD(V)57085	1	V		CS w/FLT				SOIC-8 Narrow
NCD(V)57252	2	V						SOIC-16 Wide
NCD(V)57200/1	2							SOIC-8 Narrow

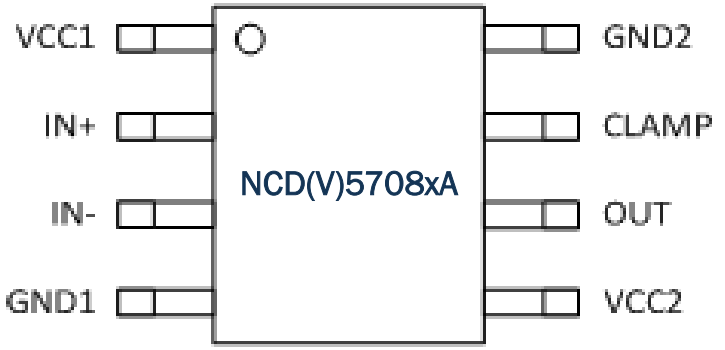
NCD(V)57080/1 8-pin Isolated IGBT/SiC/MOSFET Drivers

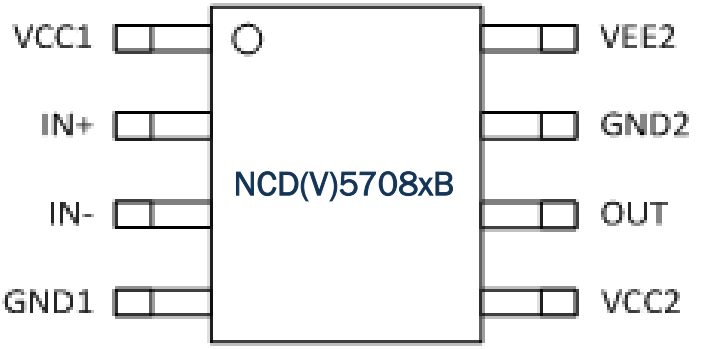
Features

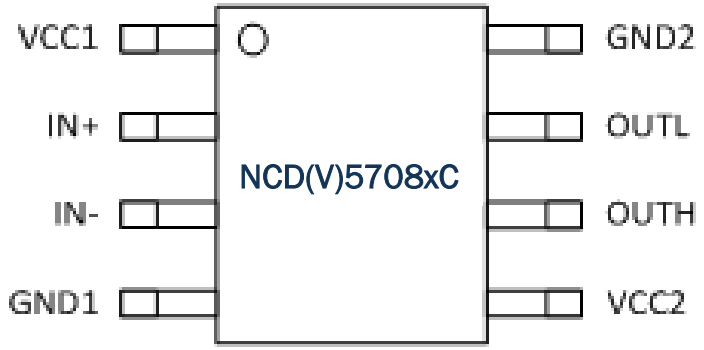
- High current (4.0 A/6.0 A src/snk) at Miller Plateau Voltage
- Galvanic Isolation up to 3.75 kV
- CMTI > 100kV/us @ 1500V
- Typical 60ns propagation delays
- Miller clamp, Negative gate voltage, Split output options
- Tight UVLO(13V) for IGBT/SiC safety – **NCV57080A/B/C**
- Tight UVLO(9V) for MOSFET safety – **NCV57081A/B/C**

P2P w/ TI, Infineon, Analog









Market & Applications

Solar Inverters, Motor Drive, UPS
EV Chargers, Automotive Power Supplies

Packages/Options

SOIC-8 Narrow Body

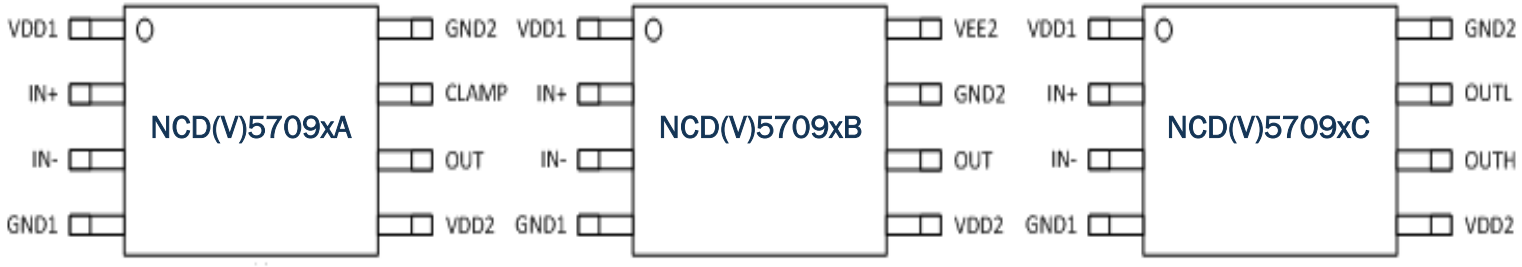
NCD(V)57090/1 8-pin Isolated IGBT/SiC/MOSFET Drivers

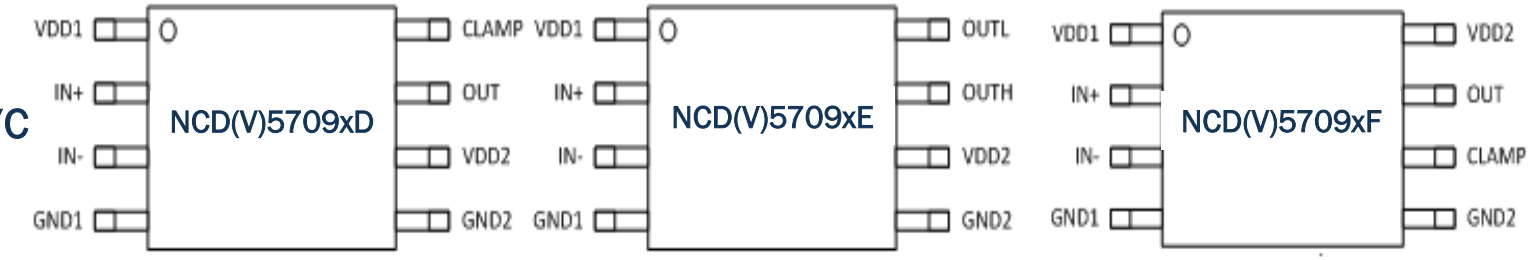
Features

- High current (4.0 A/6.0 A src/snk) at Miller Plateau Voltage
- Galvanic Isolation up to 5 kV
- CMTI > 100kV/us @ 1500V
- Typical 60ns propagation delays
- Miller clamp, Negative gate voltage,

  Split output options
- Tight UVLO(13V) for IGBT/SiC safety
- – **NCV57090A/B/C/D/E/F**
- Tight UVLO(9V) for MOSFET safety - **NCV57091A/B/C**

P2P w/ TI, Infineon, Analog





Market & Applications

Solar Inverters, Motor Drives, UPS
Automotive power supplies, EV Chargers

Packages/Options

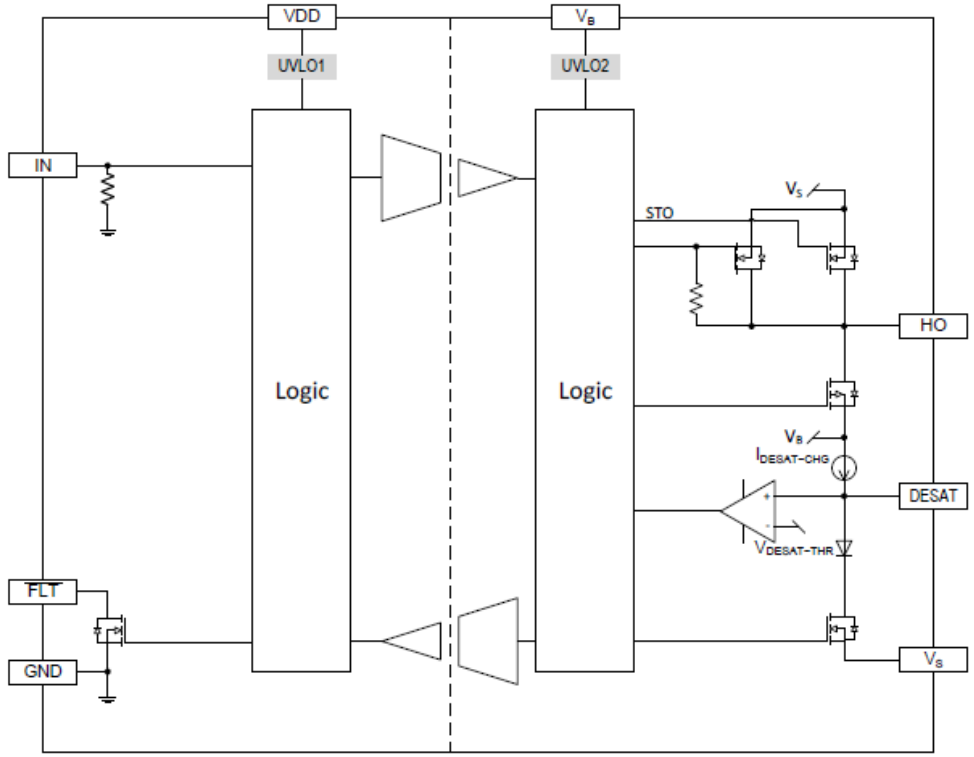
SOIC-8 Wide Body

NCD(V)57084/5 8-pin Isolated IGBT/SiC Drivers

Features

- High current (4.0 A/6.0 A src/snk) at Miller Plateau Voltage
- Galvanic Isolation up to 2.5 kV
- CMTI > 100kV/us @ 1500V
- Typical 60ns propagation delays
- DESAT with FLT - **NCV57084**
- CS with FLT - **NCV57085**
- Tight UVLO(13V) for IGBT/SiC safety

P2P w/ AUIRS2127S
AUIRS21271S

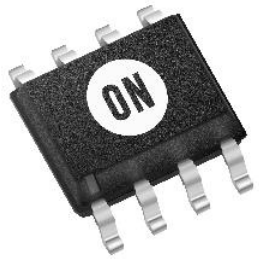


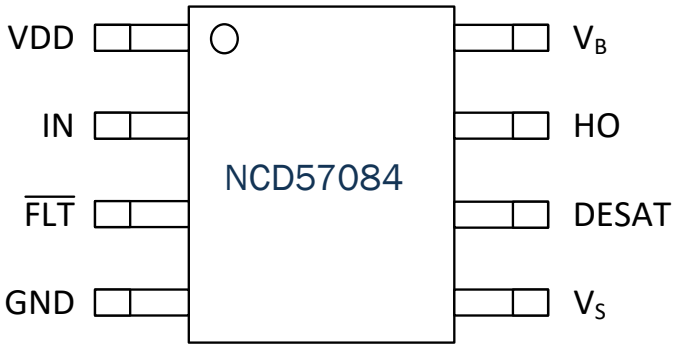
Market & Applications

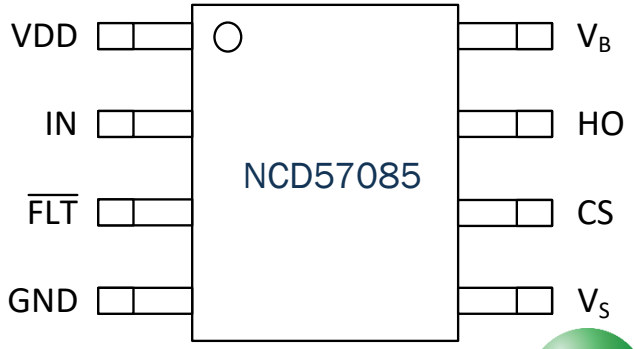
HVAC, IH, Motor Drives, UPS
EV chargers, Automotive Power Supplies

Packages/Options

SOIC-8 Narrow Body







NCD(V)57252/3 Dual Channel Isolated IGBT/SiC/MOSFET Drivers

Features

- High current (4.0 A/6.0 A src/snk) at Miller Plateau Voltage
- Galvanic Isolation up to 5 kV
- CMTI > 100kV/us @ 1500V
- Typical 60ns propagation delays
- Tight UVLO(13V) for IGBT/SiC safety – **NCV57252**
- Tight UVLO(9V) for MOSFET safety – **NCV57253**
- 3.3V, 5V, and 15V Logic inputs
- Configurable for Dual Low-side, Dual high-side or Half-bridge

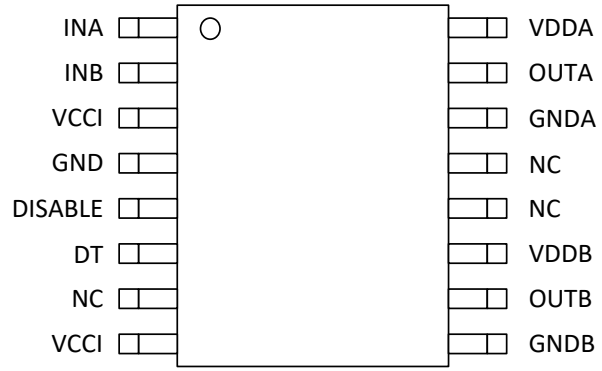
P2P w/ TI, SiLabs

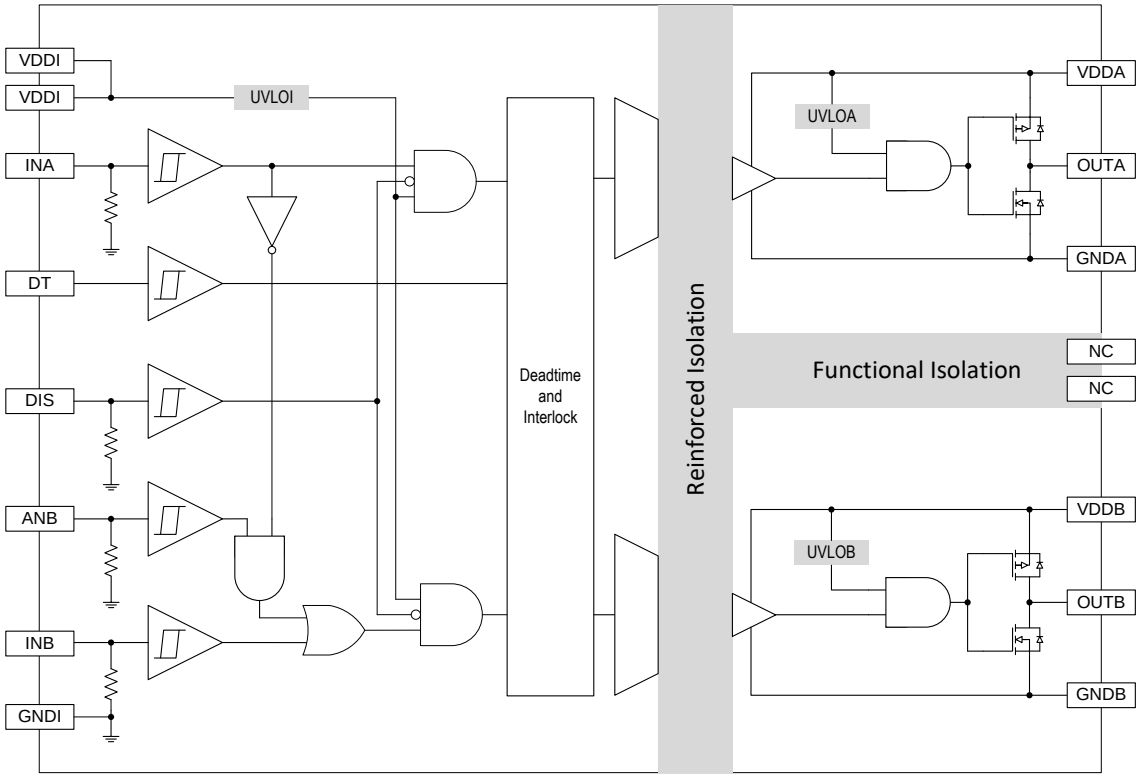
Market & Applications

OBC, EV Chargers, Solar Inverters, Motor Drives, UPS, Automotive power supplies,

Packages/Options

SOIC-16 Wide Body



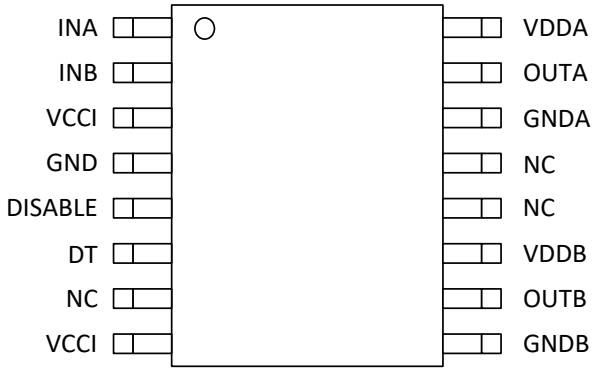


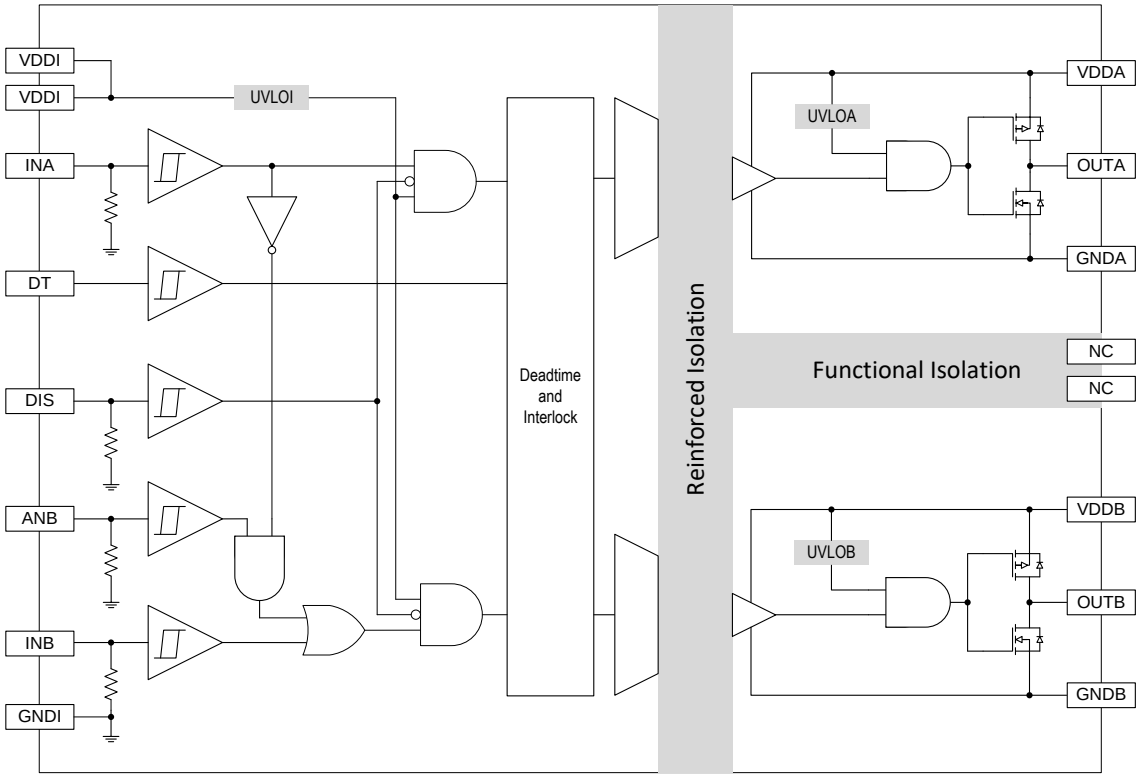
NCD(V)57255/6 Dual Channel Isolated IGBT/SiC/MOSFET Drivers

Features

- High current, +/- 4.0 Apk src/snk
- Galvanic Isolation up to 3 kV
- CMTI > 100kV/us @ 1500V
- Typical 60ns propagation delays
- Tight UVLO(13V) for IGBT/SiC safety – **NCV57255**
- Tight UVLO(9V) for MOSFET safety – **NCV57256**
- 3.3V, 5V, and 15V Logic inputs
- Configurable for Dual Low-side, Dual high-side or Half-bridge

P2P w/ ADI, TI, SiLabs





Market & Applications

OBC,EV chargers, Automotive power supplies
Motor Drives, UPS

Packages/Options

SOIC-16 Narrow Body

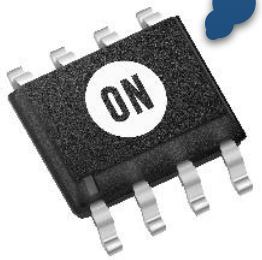
NCD(V)57200/1/2 Half Bridge Gate Driver

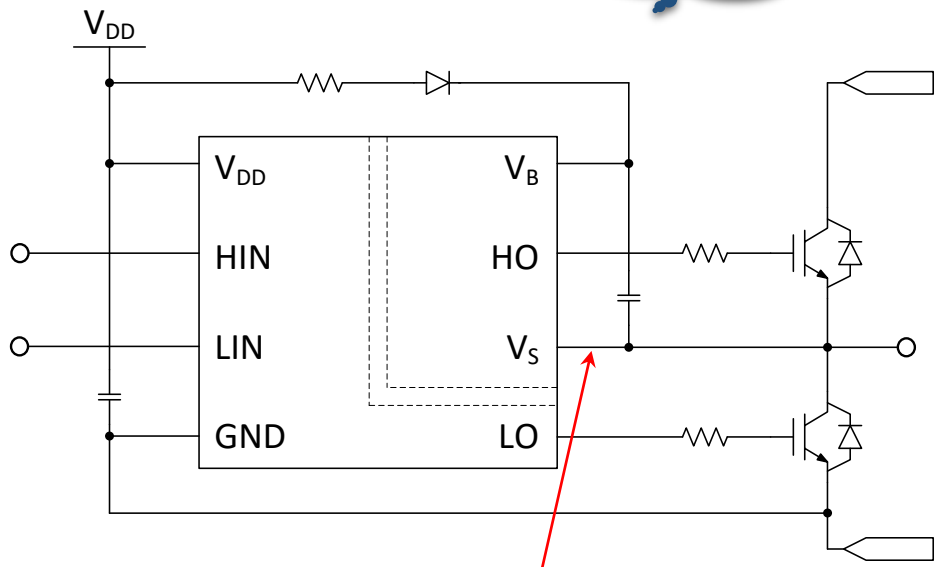
Released

Features

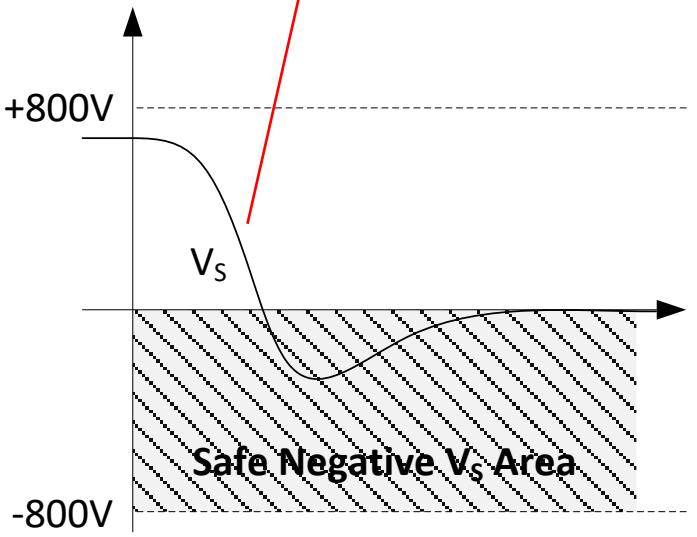
- High current +/- 2 APK
- DC bus operation up to +800V
- **Immunity to negative V_S stress**
- 3.3V/5V/15V logic input
- 100kV/us CMTI
- Asymmetric UVLO protection for both channels
- VCC/VB up to 25V
- Output in phase with input signals

P2P w/ IR2101, IRS2301S, IRS2001





	Interlock	Dead time	Input Filter Time
NCD(V)57200	Yes	300ns	20ns
NCD(V)57201	No, Independent Channels	No	20ns
NCD(V)W57202	Yes	1000ns	600ns ON & 400ns OFF



Applied Topologies

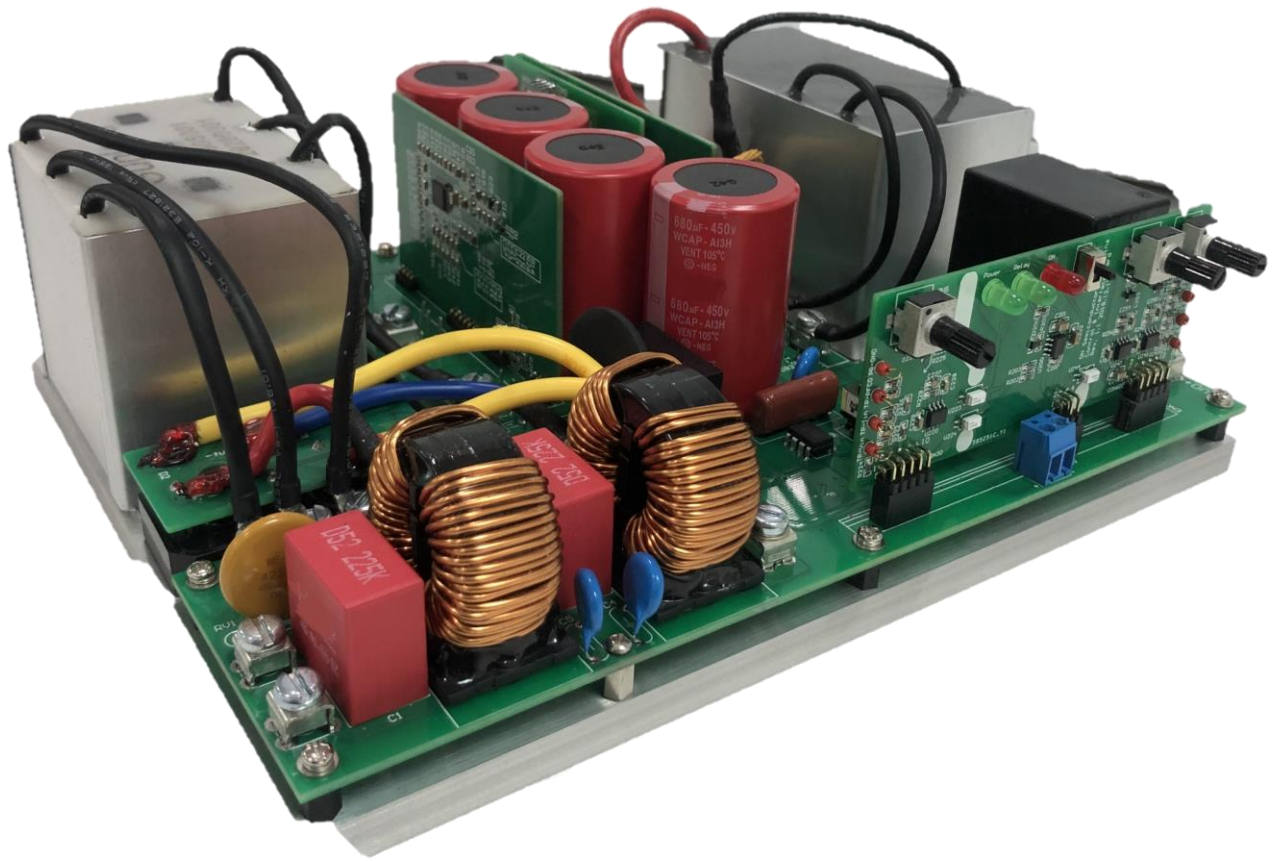
- Bi – Directional Boost
- LLC
- Full & Half Bridges

Packages/Options

- SOIC-8 Narrow Body or die sale for the IPM version

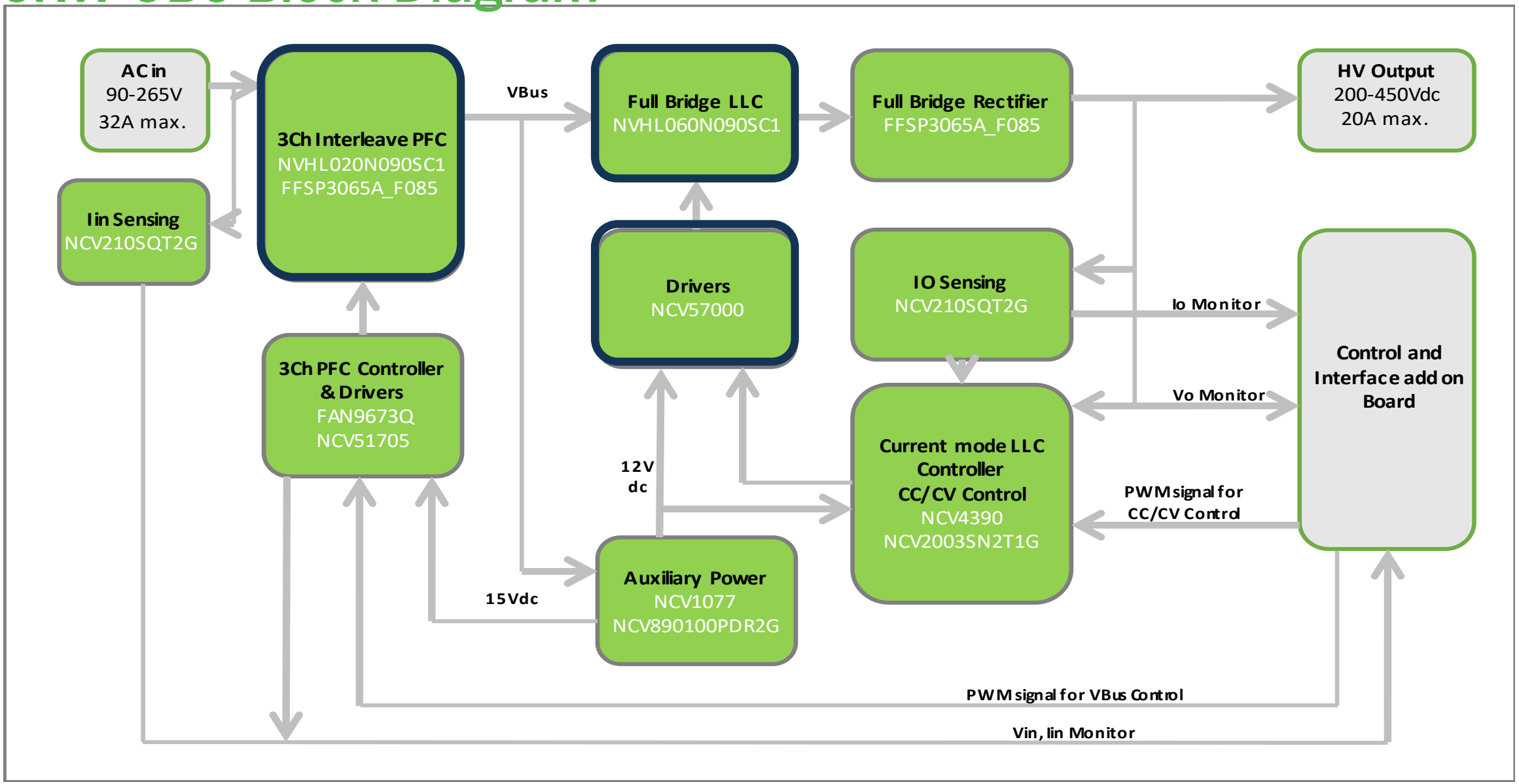
SEC OBC Reference Design

6.6KW OBC Specification



Specificaiton	
Pout	6.6 kW
Vin	Input voltage: 90~264Vac
Topology	3 channel Interleaved PFC LLC resonant
Eff.	Up to 96 %
Vout1	250 – 450 Vdc / 16 A ripple 5%
Vout2	12 Vdc / 0.6 A ripple 5 %
Inrush limit.	48 A
Signal level control	On/Off, CC, CV, Bus Voltage
Size	254 x 198 x 70 mm + Heatsink

6.6KW OBC Block Diagram



6.6KW OBC PFC Test Data

Table 7. EFFICIENCY OF PFC STAGE AT Vin = 90 Vac

Input Current (A)	5	10	15	20	25	32
Vo = 350 Vdc	96.25%	95.35%	95.22%	95.15%	94.93%	94.30%
Vo = 400 Vdc	96.14%	95.18%	94.89%	94.92%	94.81%	94.18%

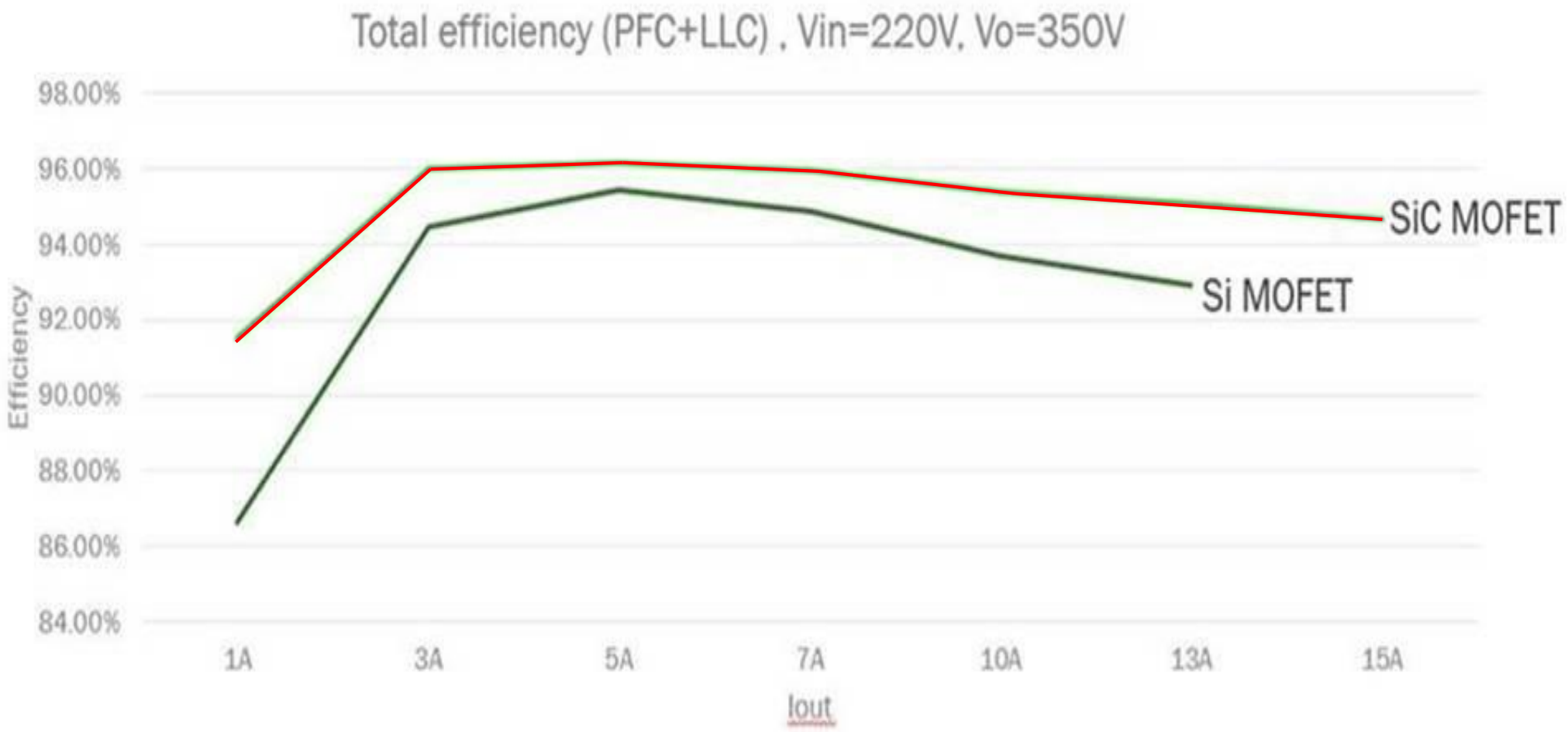
Table 8. EFFICIENCY OF PFC STAGE AT Vin = 110 Vac

Input Current (A)	5	10	15	20	25	32
Vo = 350 Vdc	96.32%	96.16%	96.03%	95.92%	95.66%	95.29%
Vo = 400 Vdc	96.18%	96.13%	95.77%	95.69%	95.50%	95.22%

Table 9. EFFICIENCY OF PFC STAGE AT Vin = 220 Vac

Input Current (A)	5	10	15	20	25	32
Vo = 350 Vdc	97.77%	98.18%	97.80%	97.63%	97.46%	97.30%
Vo = 400 Vdc	97.78%	97.88%	97.76%	97.49%	97.28%	97.17%

Operating efficiency: Si model vs SiC model



Thank You