FOR ENERGY EFFICIENT INNOVATIONS

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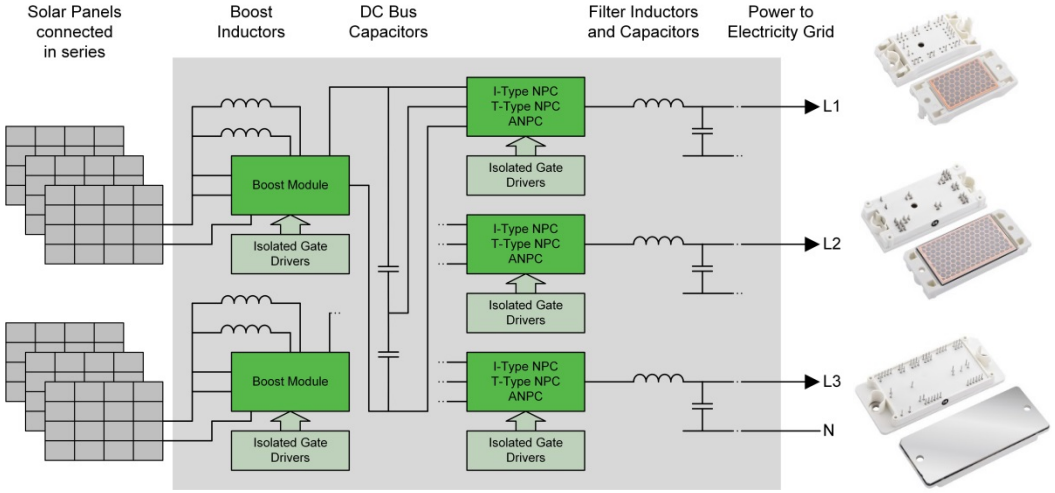
PIM Modules
Energy Infrastructure
Customer Presentation

September 2020

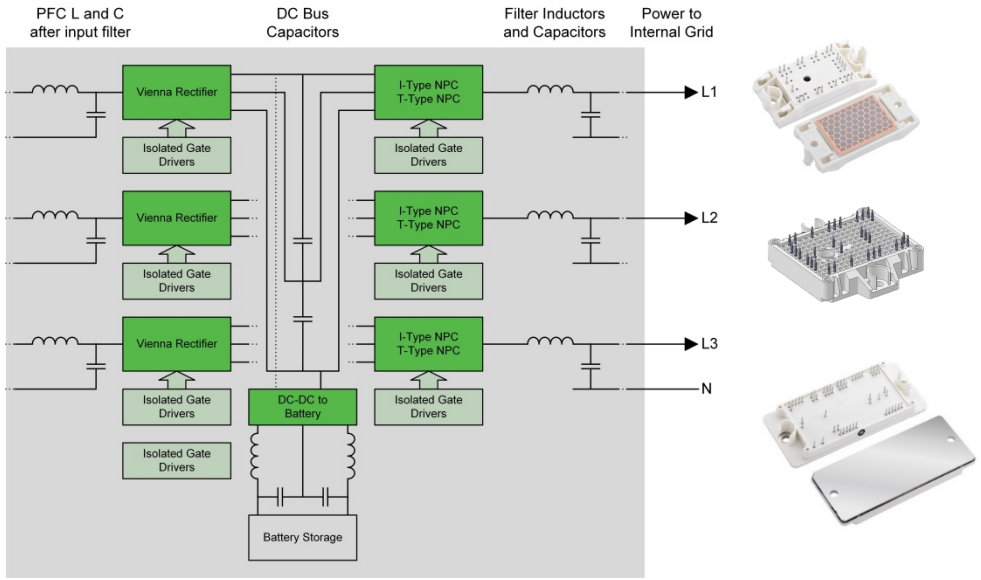
Public Information

PIM Module Markets

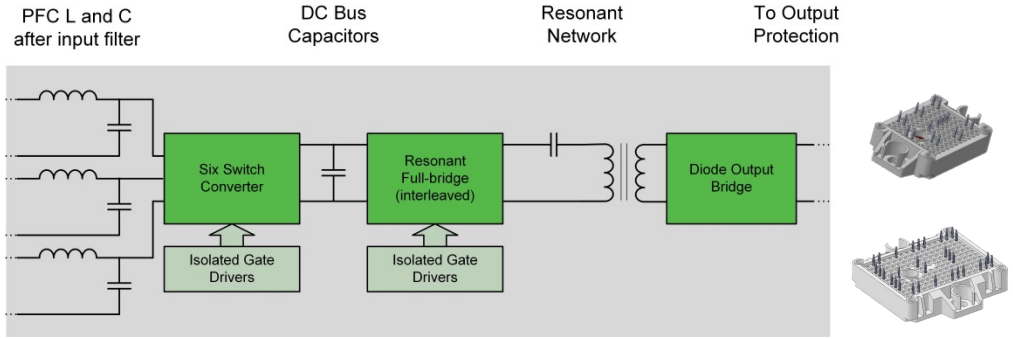
Solar Inverter: 20-250 kVA String Inverters
1 phase Inverters



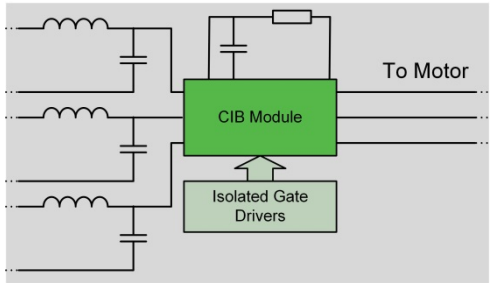
UPS/Storage: 20-50 kVA Modular Blocks

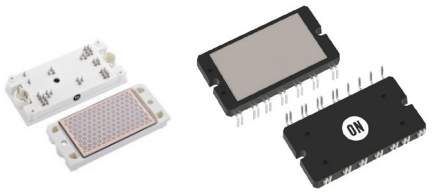


EV Charging Stations



Motor Drive, Servo and Commercial HVAC





Power Discrete and Modules – In-house Semiconductor supply

Roznov, Czechia
IGBT, Diodes

Suzhou, China
IPM, APM, Discretes

Bucheon, Korea
IGBT, SiC, MOSFET, Diode, Drivers

Shenzhen, China
PIM

ON Vietnam
IPM, TMPIM

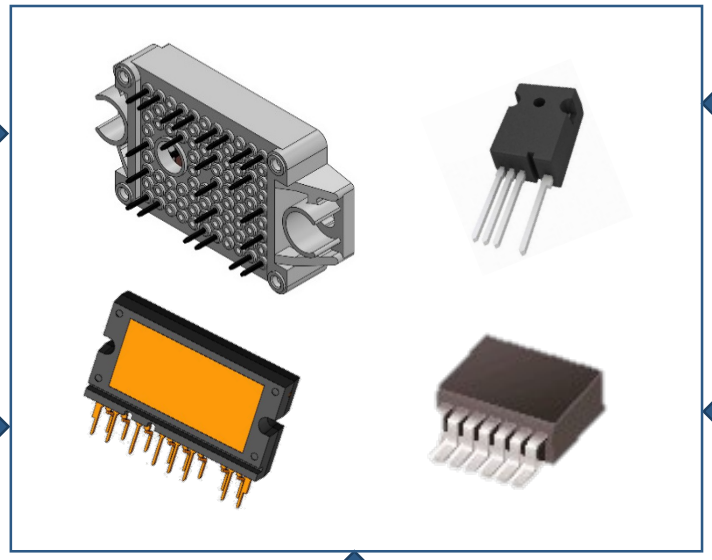
Gresham, USA
Drivers
Mountain Top, USA
MOSFETs

Complete Si & SiC Portfolio

Comprehensive Portfolio of Leading Edge Silicon and SiC Devices

IGBT
650V, 750V
1000V, 1200V, 1700V*
FS3, FS4, FSII, UFS

Diodes
650V, 1000V, 1200V, 1600V
Stealth, HyperFast, UltraFast,
FSII, FSIII



SiC
650V, 1200V, 1700V Diodes
650V*, 750V*, 900V, 1200V,
1700V* MOSFETs

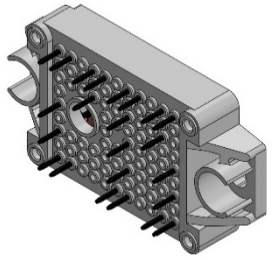
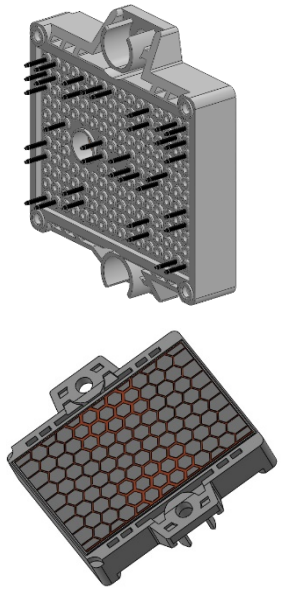
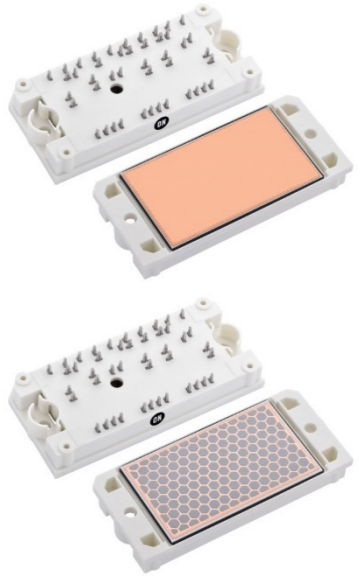
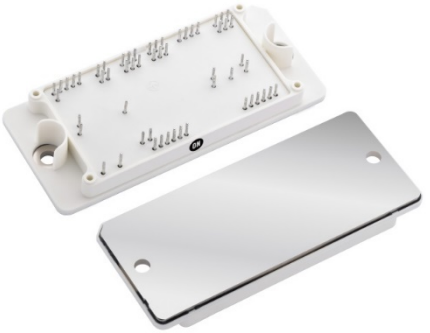
SJ MOSFET
650V, 800V
SuperFET 3
Easy, Fast, Fast Recovery Diode

Passive Components (out-sourced)
Thermistors, Ceramic capacitors, Resistors

* Under development

Review of Packages

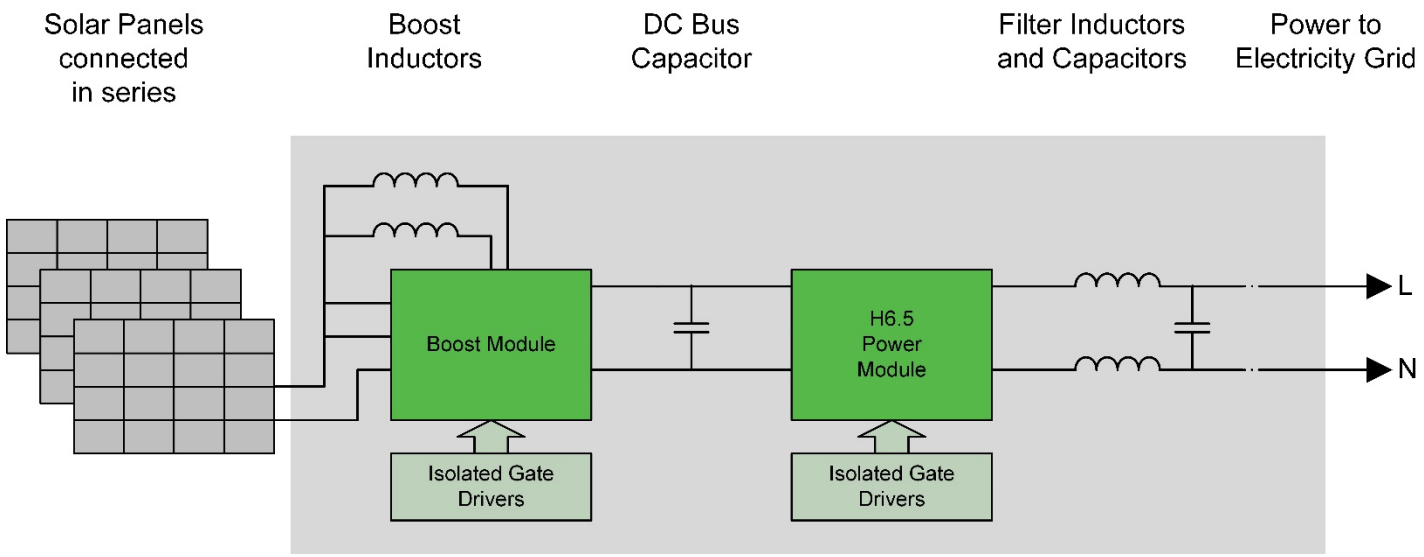
Gel-filled Modules: Available Packages

F1	Q0	F2	Q1	Q2
				 with base plate
1.2 mm press-fit pins Solder pins	1.2 mm press-fit pins 1.6 mm press-fit pins Solder pins	1.2 mm press-fit pins Solder pins	1.2 mm press-fit pins 1.6mm press-fit pins Solder pins	1.6 mm press-fit pins Solder pins
With TIM/no TIM	With TIM/no TIM	With TIM/no TIM	With TIM/no TIM	With TIM/no TIM

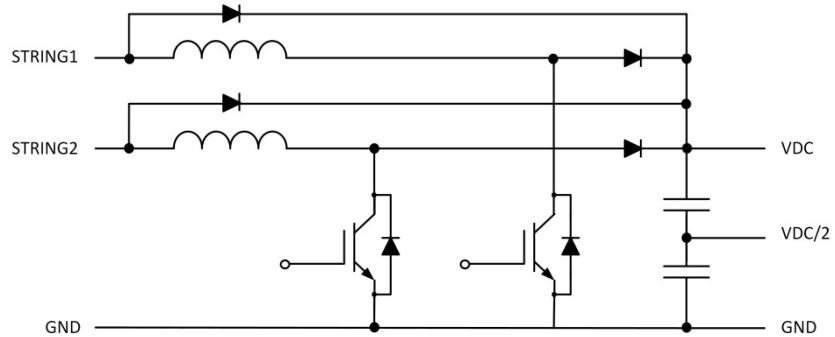
Solar Inverter

Application Example: Solar Inverters - 1 phase

Power Levels: 4kW – 8kW



Interleaved Boost Circuit



Interleaving helps to reduce capacitor ripple current and inductor size

Inductor size can be reduced further by higher switching frequency

Capacitor ripple current influences capacitor size and/or cost. Higher switching frequency reduces ripple current

H6.5 Module Family; single phase residential inverter

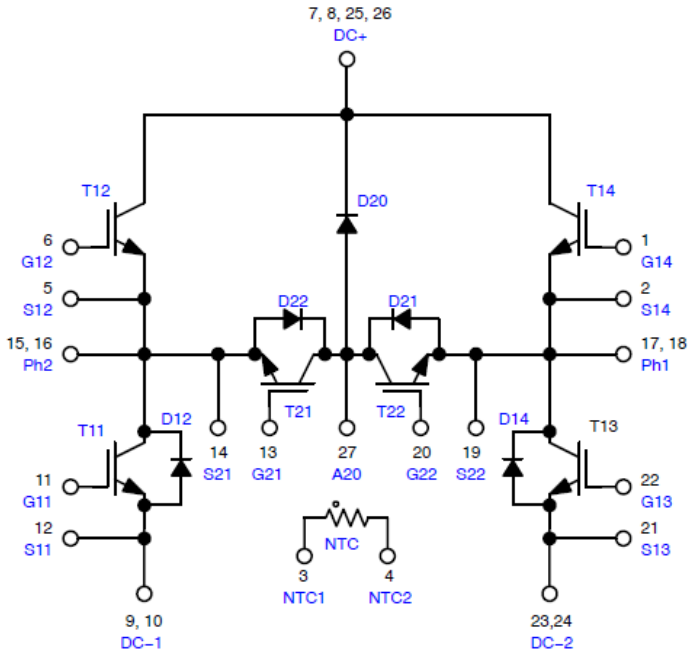
Features

- High-speed FS4 50A/650V and 75A/650V IGBT versions
- 50A/650V Stealth Diodes
- Built-in NTC

Benefits

- Easier mounting with higher reliability than with discrete solutions
- Better efficiency than competitor solution

Block Diagram



Specifications

Product	3-channel T-type components	Configuration
NXH50M65L4Q1SG	50A/650V IGBT, 50A/650V Stealth Diode	no TIM, Solder Pins
NXH75M65L4Q1SG	75A/650V IGBT, 50A/650V Stealth Diode	no TIM, Solder Pins

Applications

- Solar Inverter
- UPS
- Energy Storage

End products

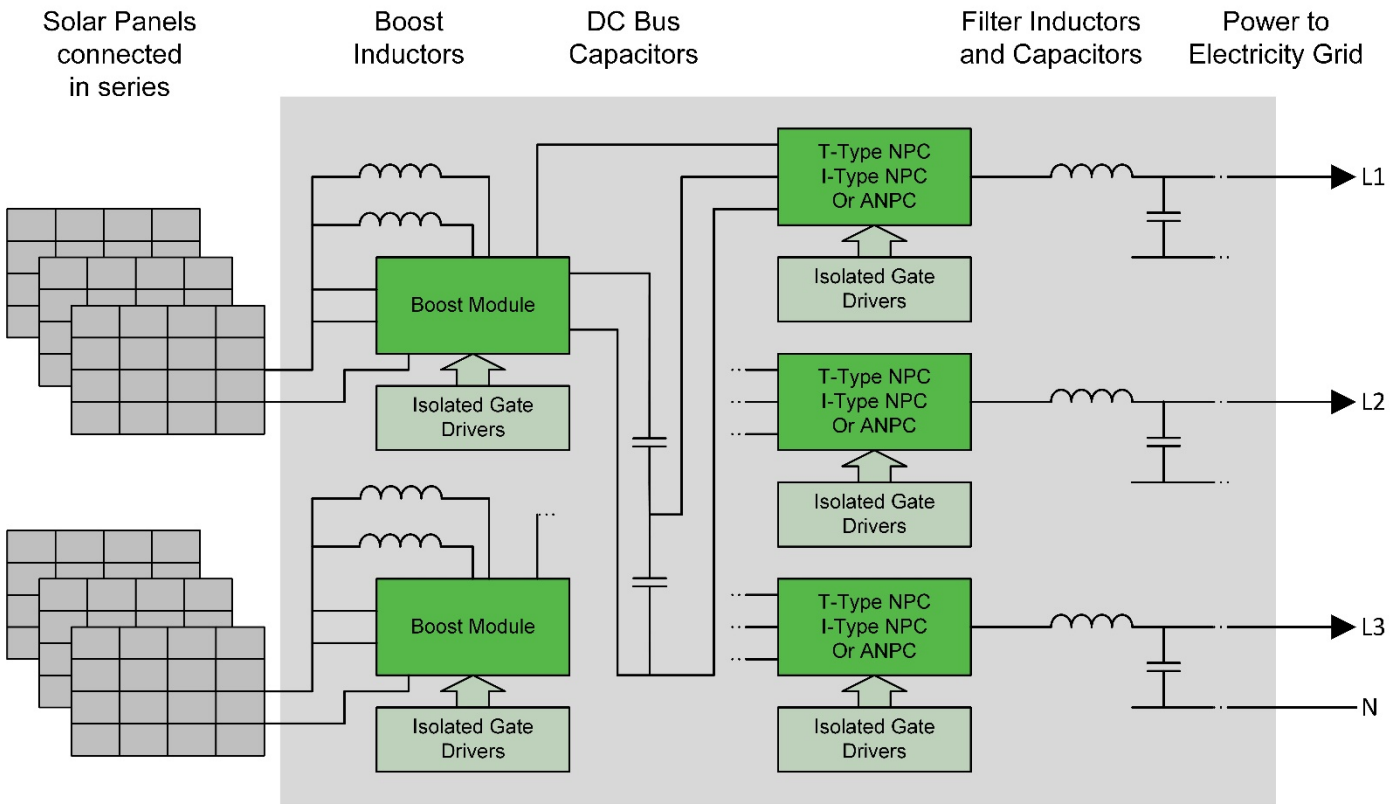
- Solar Inverter

Package

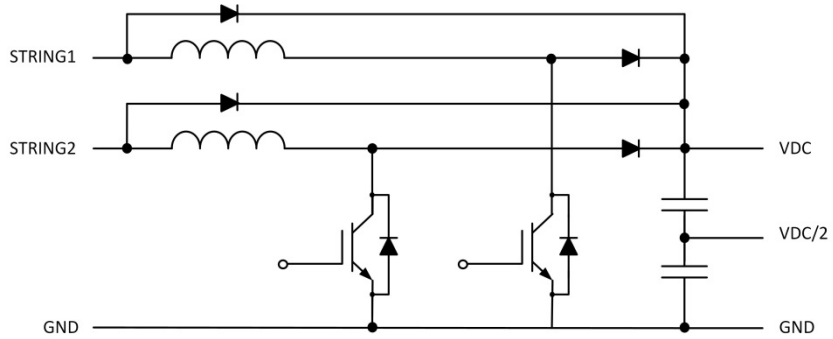
Q1

Application Example: Solar Inverters - 3 phase – 1100V input

Power Levels: 15kW to 200kW



Interleaved Boost Circuit



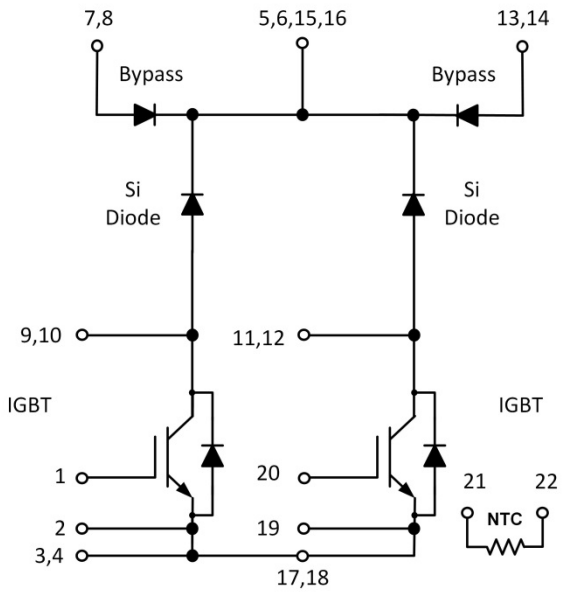
Interleaving helps to reduce capacitor ripple current and inductor size

Inductor size can be reduced further by higher switching frequency

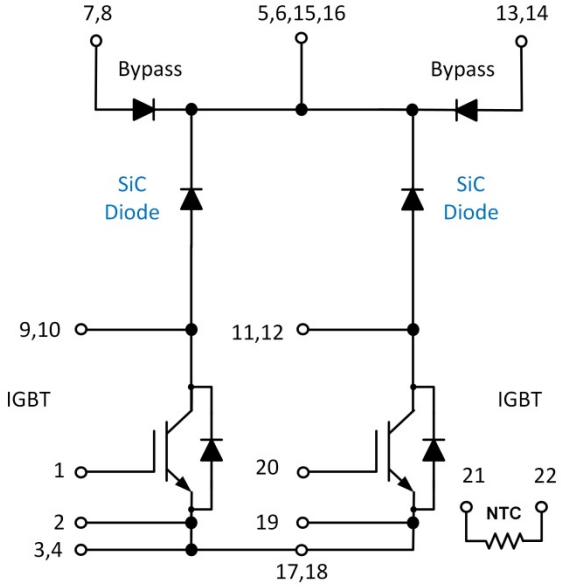
Capacitor ripple current influences capacitor size and/or cost. Higher switching frequency reduces ripple current

Boost Module Block Diagrams

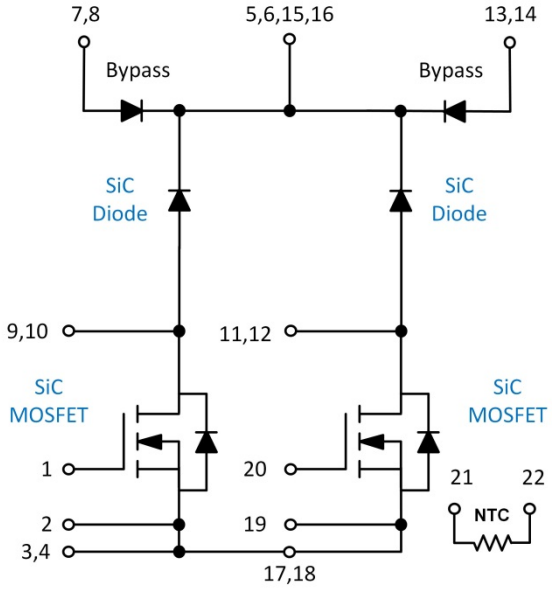
Boost with IGBT + Si Diode



Boost with IGBT + SiC Diode



Boost with SiC MOSFET + SiC Diode



QOBOOST

Faster switching
Lower module losses
Higher module cost
Lower cost inductor/capacitor
More compact end product

2 & 3 Channel SiC Hybrid & Full SiC Boost Module Family

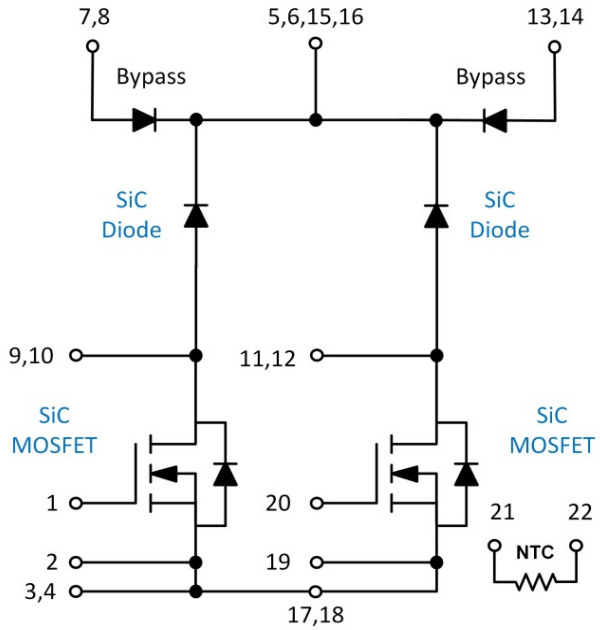
Features

- 2 channel boost module family
  - 50A/1200V IGBT + SiC Diode
  - 40 mohm/1200V SiC MOSFET + SiC Diode
  - 80 mohm/1200V SiC MOSFET + SiC Diode
- 3 channel boost module (different pinouts)
  - 40 mohm/1200V SiC MOSFET + SiC Diode
  - 60A/1200V IGBT, 20A SiC Diode

Benefits

- Easy mounting
- Better efficiency than competitor product
- Range of pin compatible SiC hybrid and full SiC options

Block Diagram (2 channel boost)



Specifications

Product	Dual Boost Components	Pins and TIM
NXH100B120H3Q0	2 channel 50A/1200V IGBT, 20A/1200V SiC Diode	Solder, Press-Fit, TIM Option
NXH40B120MNQ0SNG	2 channel 40mΩ/1200V SiC MOSFET, 40A SiC Diode	Solder pins, Ni plated DBC
NXH80B120MNQ0SNG	2 channel 80mΩ/1200V SiC MOSFET, 20A SiC Diode	
NXH40B120MNQ1SNG	3 channel 40mΩ/1200V SiC MOSFET, 40A SiC Diode	
NXH240B120H3Q1PG	3 channel 60A/1200V IGBT, 20A/1200V SiC Diode	Press-fit pins

Applications

- Industrial Applications

End products

- Solar Inverter
- UPS
- Energy Storage

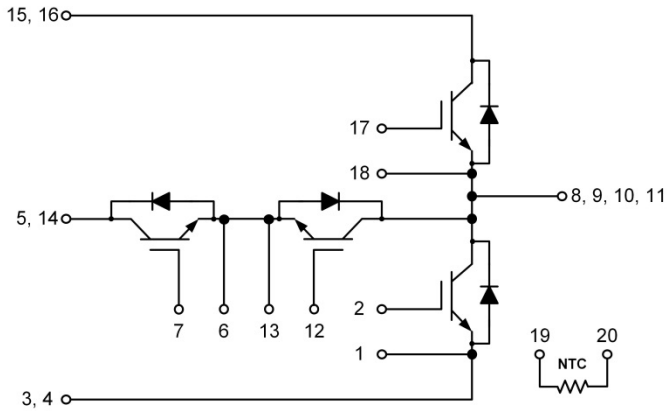
Package

Q0BOOST

Q1

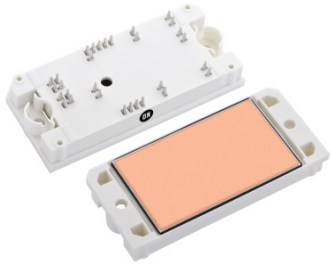
T-Type NPC Module Block Diagrams

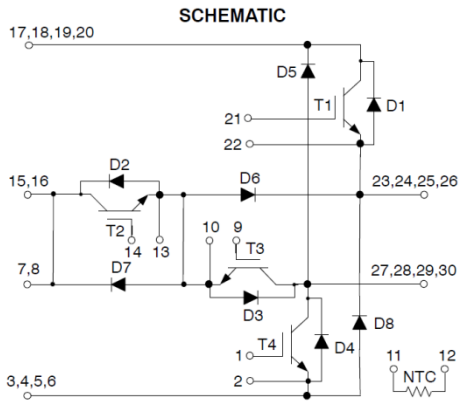
Q0PACK



Higher Power
Larger Size

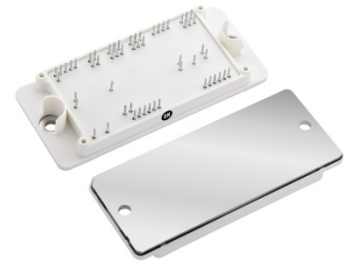
Q1PACK

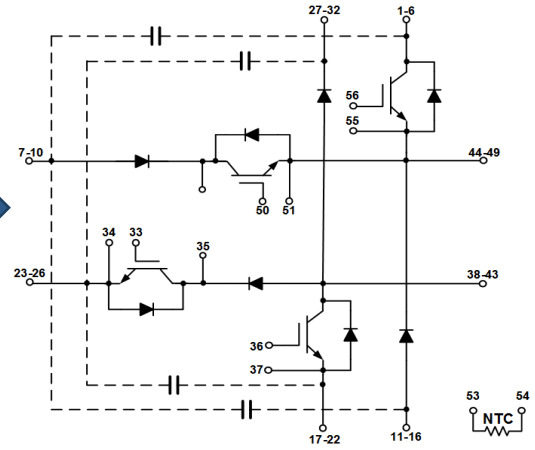




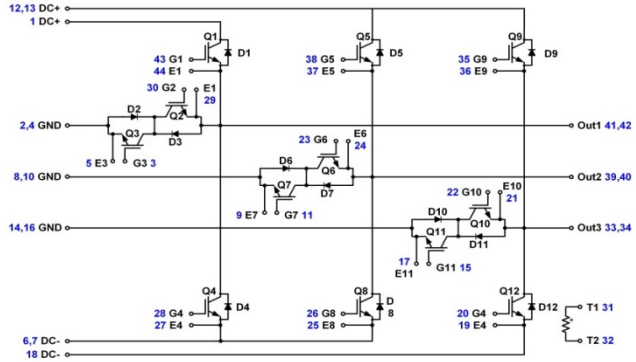
Higher Power
Larger Size

Q2PACK





Lower Power
Smaller Size
1 module replaces 3 modules



Q1-3TNPC

T-Type NPC Module Family

Features

- Full range of power levels in Q0, Q1 and Q2 package
- IGBT versions for medium power levels
- SiC Hybrid version in Q2 package for high power levels
- Built-in NTC

Benefits

- Easy mounting
- Better efficiency than competitor product
- Supports reactive power

Block Diagram

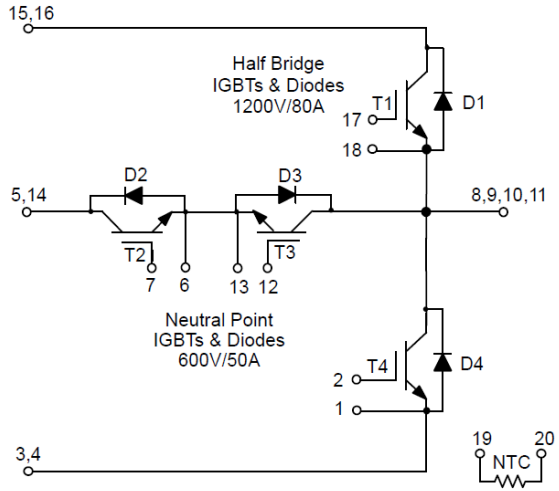


Figure 1. Schematic Diagram

T-Type in Q0 Package

Specifications

Product	Description	Type	Pins and TIM
NXH80T120L2Q0S2/P2	80A/1200V IGBT, 50A/650V IGBT	T-Type NPC	Solder, Press-Fit, TIM Option
NXH80T120L3Q0S2/P2	80A/1200V IGBT, 50A/650V IGBT	T-Type NPC	
NXH160T120L2Q1	160A/1200V IGBT, 100A/600V IGBT	Split T-Type NPC	Solder, Press-Fit, No TIM
NXH160T120L2Q2F2S1G	160A/1200V IGBT, 100A/650V IGBT	Split T-Type NPC	Solder, No TIM
NXH200T120H3Q2F2SG	200A/1200V IGBT, 100A/650V IGBT with SiC diodes	Split T-Type NPC	Solder, No TIM

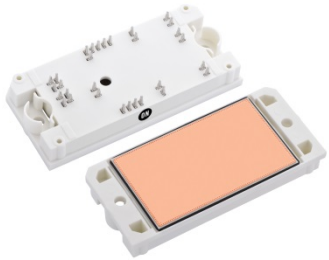
End products

- Solar Inverter
- UPS
- Energy Storage

Package

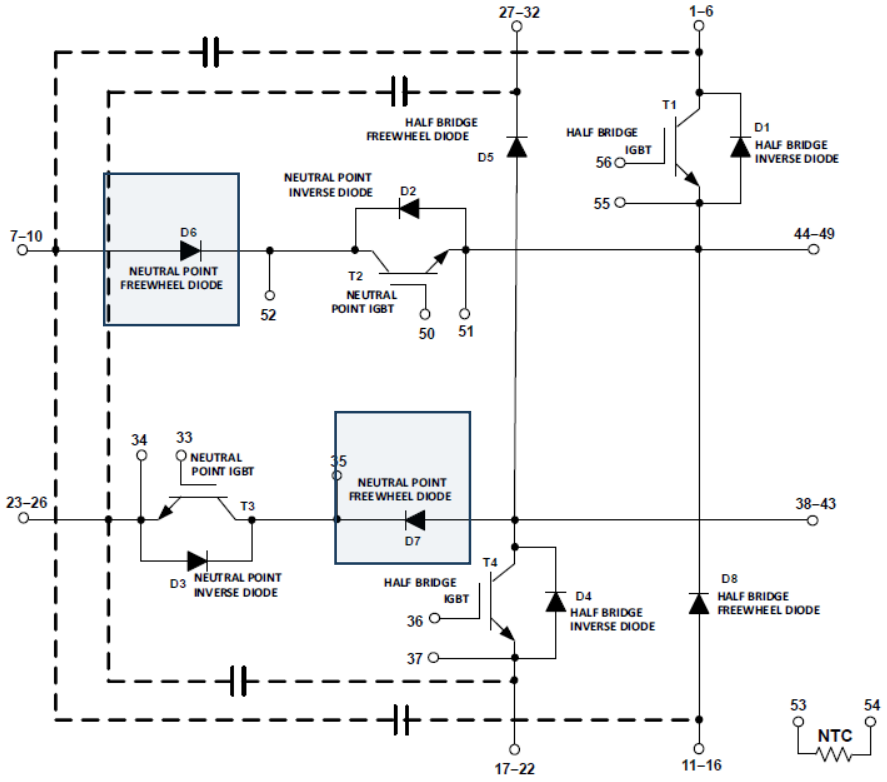
Q0PACK

Q1PACK



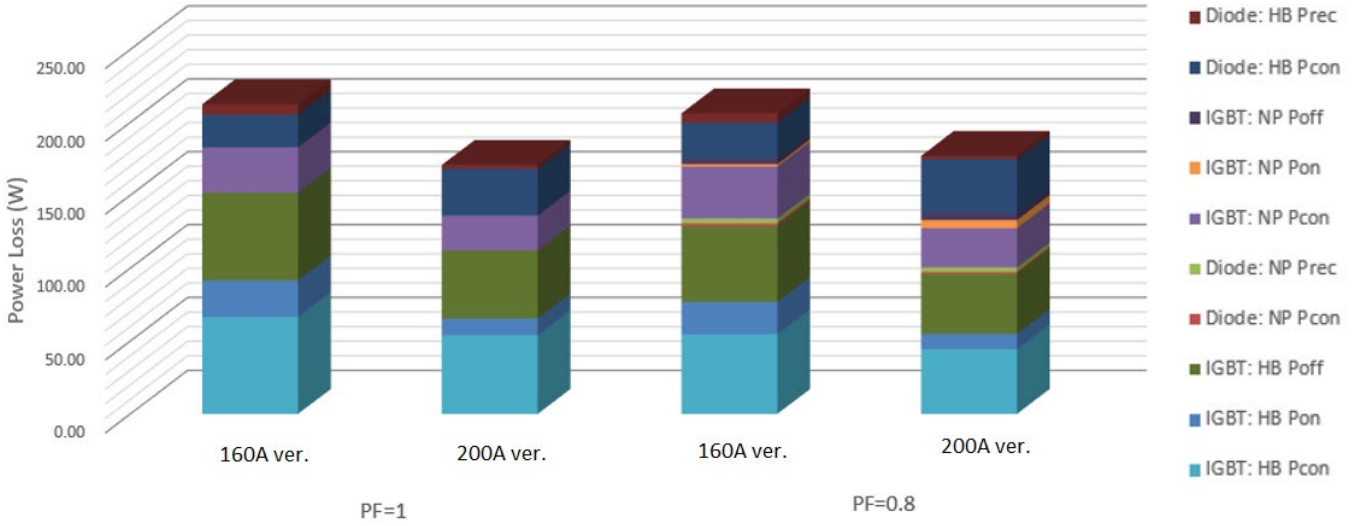
Q2PACK

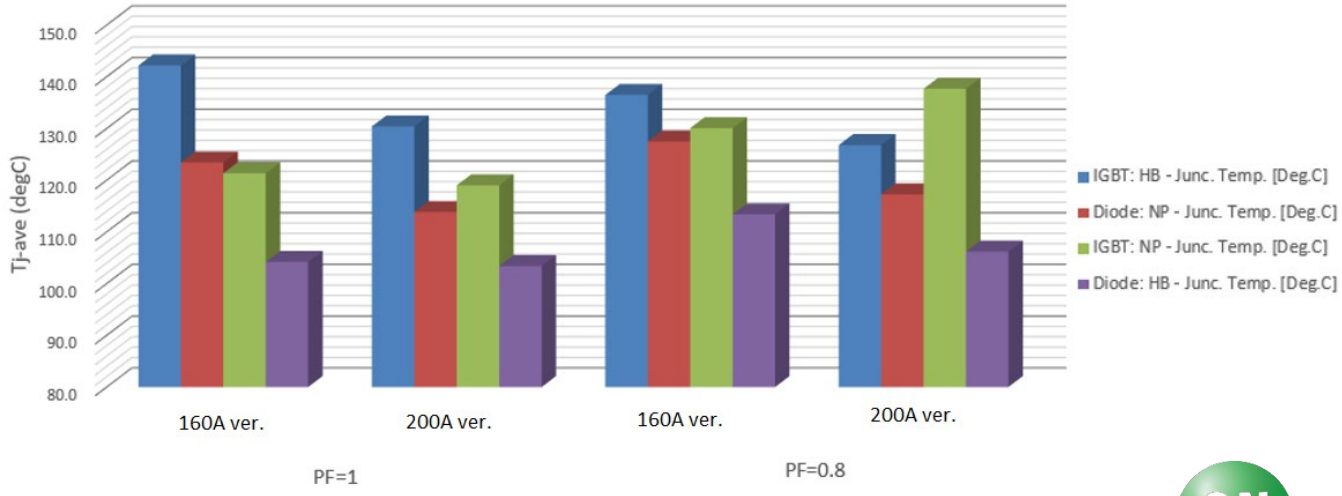
100kW SiC Hybrid T-NPC Performance



Performance improvement with 650V SiC Diodes

V_{dc} 800, V_{phase} 230Vrms, P_{out} 80 kVA, F_{sw} 20kHz, Tc 100°C





3 Channel T-Type NPC Module Family

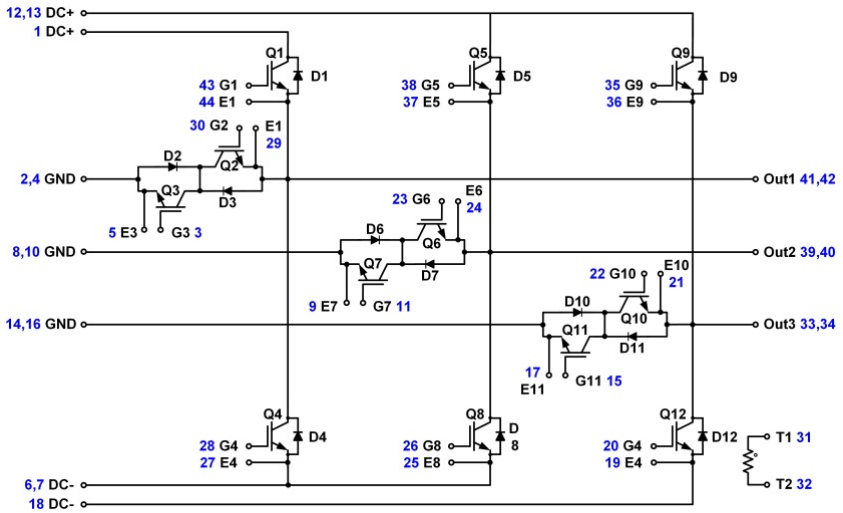
Features

- High-speed FSII/UFS 40A/1200V IGBT
- High-speed 25A/650V IGBT
- Built-in NTC

Benefits

- Easy mounting
- 15% higher power in solar inverter or UPS
- Supports reactive power

Block Diagram



Specifications

Product	3-channel T-type components	Pins and TIM
NXH25T120L2Q1	35A/1200V IGBT, 30A/650V IGBT	Solder, Press-Fit, TIM Option
NXH40T120L3Q1	40A/1200V IGBT, 40A/650V IGBT	Solder, Press-Fit, TIM Option

Applications

- Solar Inverter
- UPS
- Energy Storage

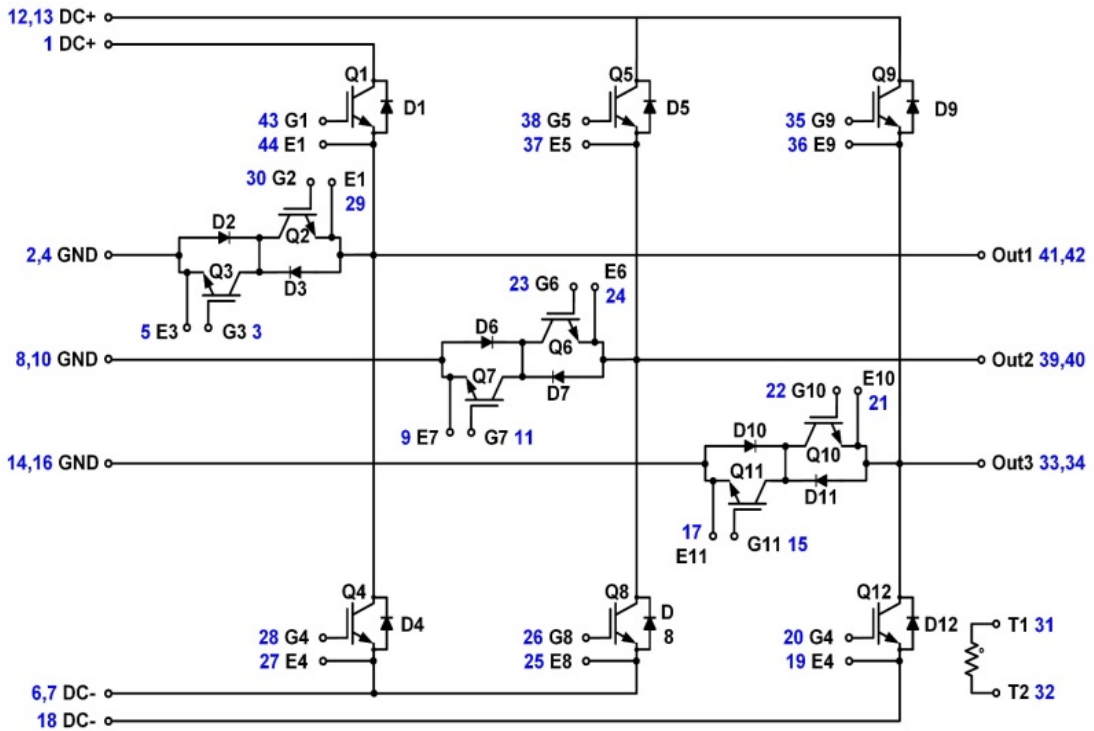
End products

- Solar Inverter

Package

Q1-3TNPC

10-20kW – Q1Pack 3-ph TNPC



▶ System Conditions & Performance :

In/Out Conditions		
Input Voltage	850	[V]
Output Voltage	230	[Vac]
Output Power	6667	[W]
Switching Frequency	16	[kHz]
Line Frequency	50	[Hz]

==>

System Performance at the Con	Power:	6667
Components	Loss [W]	Qty.[EA]	Sum [W]
High-freq. Switch (TF)	32.05	2	64.11
Low-freq. Switch (TL)	6.51	2	13.02
Freewheeling Diode (FD)	15.86	2	31.72
Diode for Reac. Power (	0.00	2	0.00
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [W]			108.85
Calculated Efficiency			98.394%

▶ Detailed Loss and Thermal Performance of Main Devices (TF, TL, FD, RD) for only each 'One'

Details for Loss (TF, RD, TL, FD)	
	Value
TF_Conduction Loss [W]	15.03
TF_Turn-on Loss [W]	4.97
TF_Turn-off Loss [W]	12.06
RD_Conduction Loss [W](Reactive	0.00
RD_Reverse Recovery Loss [W]	0.00
TL_Conduction Loss [W[	6.51
TL_Conduction Loss [W] (Reactiv	0.00
TL_Turn-on Loss [W] (Reactive)	0.00
TL_Turn-off Loss [W] (Reactive)	0.00
FD_Conduction Loss [W]	12.39
FD_Conduction Loss [W] (Reactive)	0.00
FD_Reverse Recovery Loss [W]	3.28
Sum [W]	54.24
Total for one-phase TNPC	108.47

Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
TF - Case Temp. [Deg.C]	90.0
TF - Junc. Temp. [Deg.C]	128.5
RD - Case Temp. [Deg.C]	90.0
RD - Junc. Temp. [Deg.C]	90.0
TL - Case Temp. [Deg.C]	90.00
TL - Junc. Temp. [Deg.C]	102.04
FD - Case Temp. [Deg.C]	90.00
FD - Junc. Temp. [Deg.C]	119.78

Decentralized Utility Inverter Modules – 1100V Input

Features

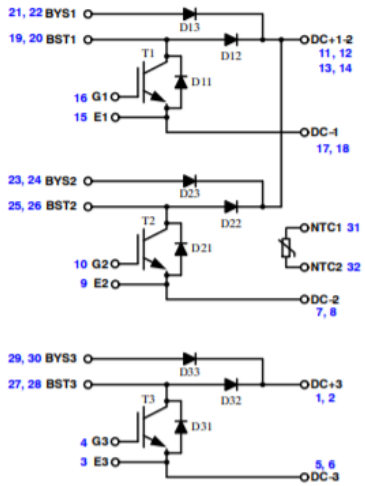
- Family for 1100V Decentralized Inverters
  - 1000V 60A 3-channel Boost
  - 650V 450A I-type NPC
- Thermistor

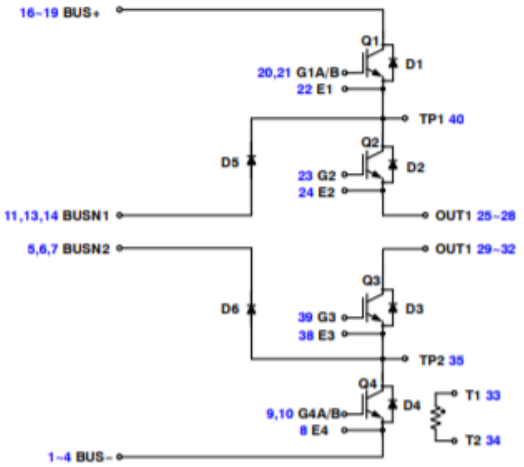
See separate slide for 1500V Input Solar Inverter Family

Benefits

- Better efficiency than 900V SiC based solutions because of high performance 1000V IGBT and diode technology

Block Diagrams: Decentralized 1100V Solar Inverter





Specifications

Product	Description	Pins and TIM
NXH450N65L4Q2	Single 650V 450A I-type NPC	Solder, Press-Fit, No TIM
NXH240B120H3Q1PG	3 channel 60A/1200V IGBT, 20A/1200V SiC Diode	Press-fit pins

Applications

- Decentralized Solar Inverters

End products

- Solar Inverter

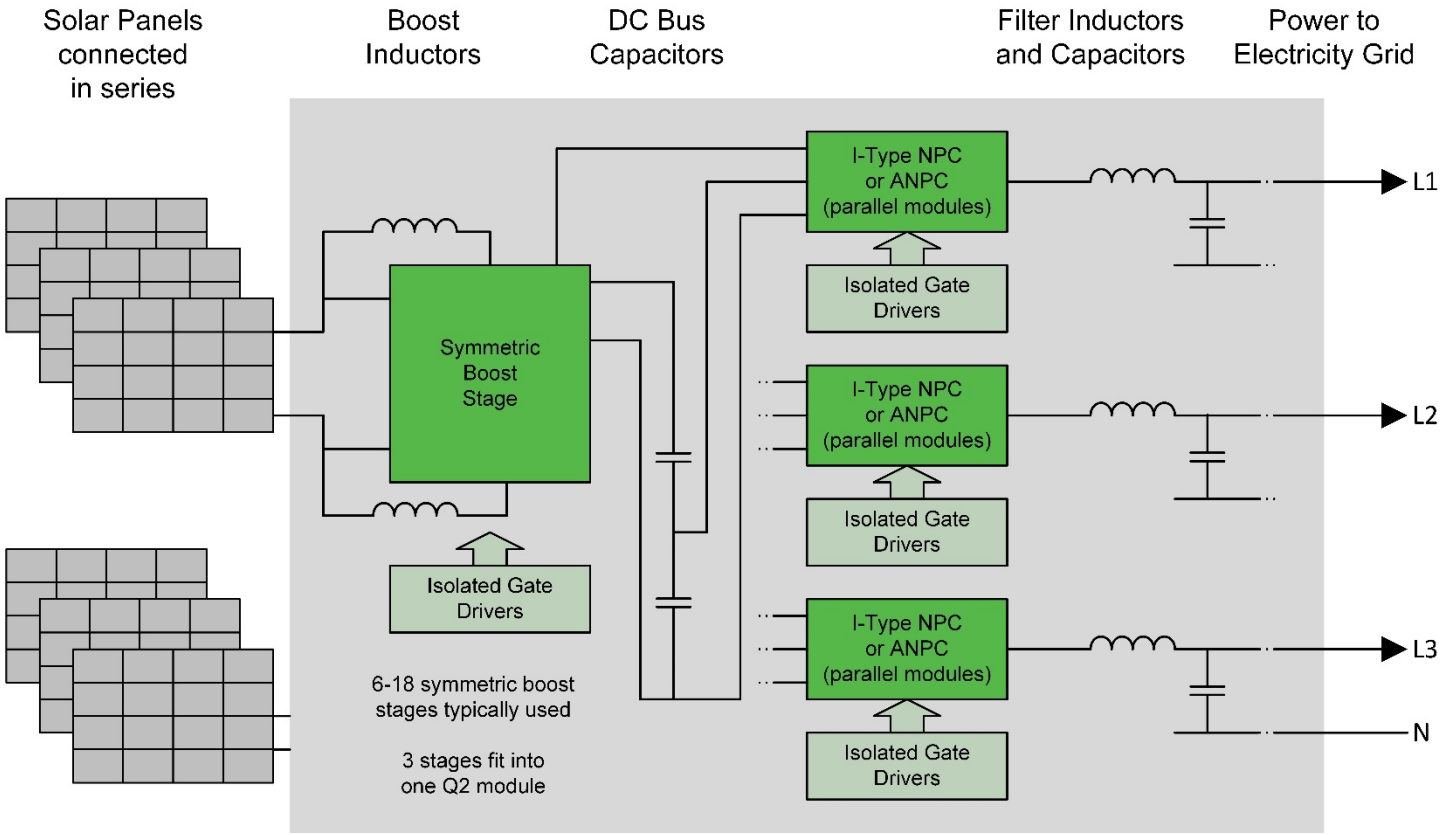
Package

Q1BOOST

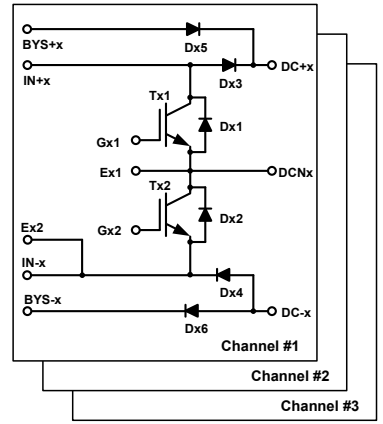
Q2PACK

Application Example: Solar Inverters - 3 phase – 1500V input

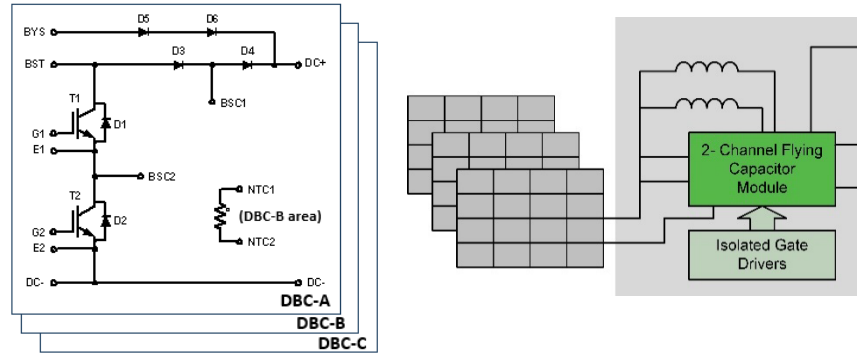
Power Levels: 150kW to 250kW



Symmetric Boost Circuit



Flying Capacitor Boost



Decentralized Utility Inverter Modules – 1500V

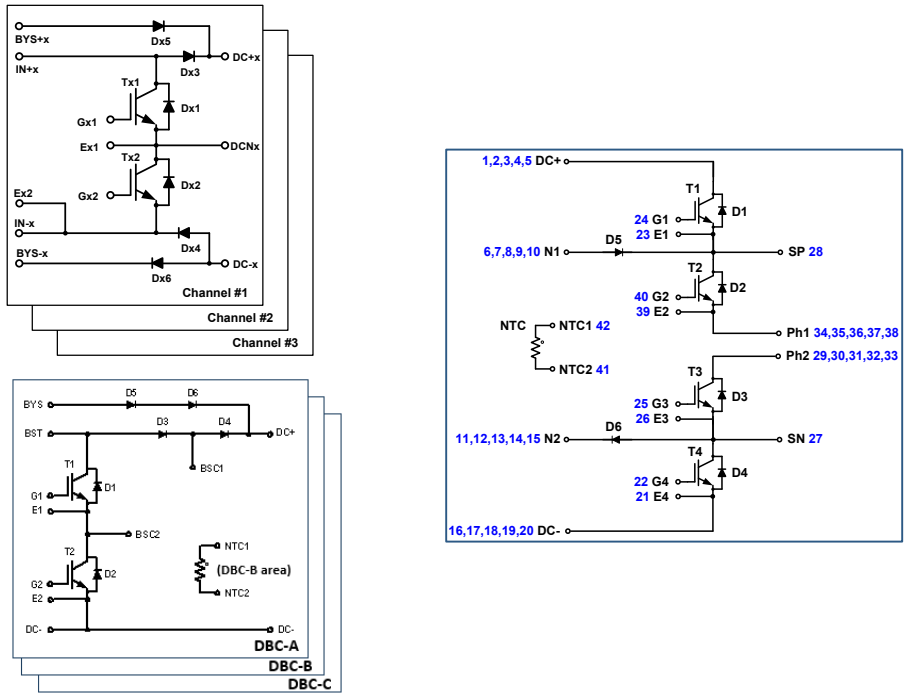
Features

- Family for 1500V Decentralized Utility Inverters
  - 1000V 150A 3-channel Symmetric Boost
  - 1000V 100A 3-channel Flying capacitor Boost
  - 1000V 350A I-type NPC
- SiC Diodes for higher efficiency and power density
- Thermistor

Benefits

- Better efficiency than 900V SiC MOSFET based solutions because of high performance 1000V IGBT and diode technology

Block Diagrams: Solution for 1500V Solar Inverter



Q2BOOST Q2PACK

Specifications

Product	Description	Pins and TIM
NXH450B100H4Q2F2	3 Channel 1000V 150A Symmetric Boost	Solder, Press-Fit, No TIM
NXH300B100H4Q2F2	3 Channel 1000V 100A Flying Capacitor Boost	
NXH350N100H4Q2F2x1	1 Channel 350A 1000V I-type NPC	
NXH400N100H4Q2F2	1 Channel 400A 1000V I-type NPC (Q3 2020)	

Applications

- Decentralized Solar Inverters

End products

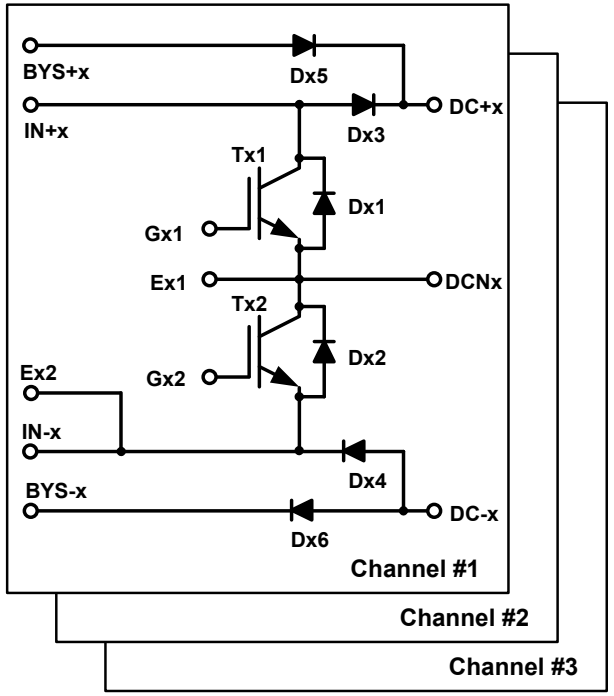
- Solar Inverter

Package

Q2BOOST

Q2PACK

Q2 3-Level Boost for 1500V System



Name	Description	Q'ty/Module
Tx1,Tx2	FS4 1000V/75A, High Speed	12
Dx1,Dx2	1600V/35A, Protection diode	6
Dx5,Dx6	1600V/35A, By-pass diode	6
Dx3,Dx4	1200V/10A, SiC Diode	18
NTC	22kohm, 5% (size 2012)	1

Loss Simulation at 29 kW per Channel

Boost Module Working Condition (per Channel)

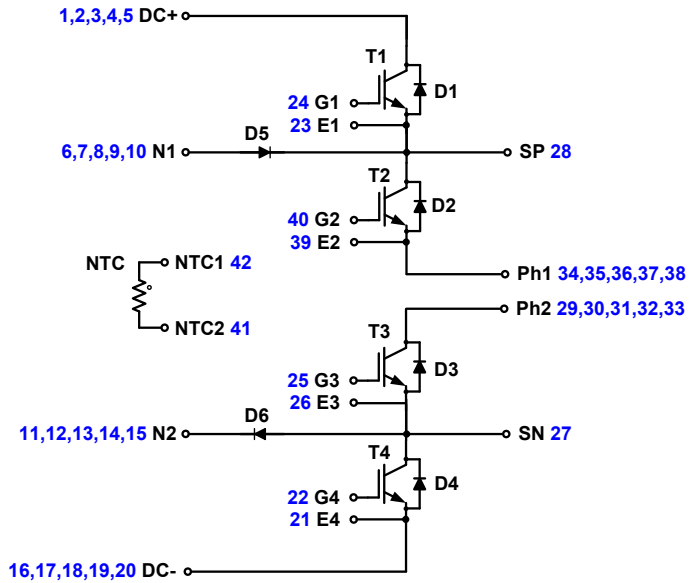
Vin = 830V
Vout = 1170V, or 1300V
Iin = 35A per channel
Fsw = 16kHz (16~18 kHz)
Inductance = *500* uH
Heatsink = 90 degC

Result:

Power (kW)	Vin (V)	Vout (V)	IG Rth-js	Tj-IGBT (^{0}C)	Power loss-FWD (W)	DI-Rth-js	Tj-FWD (^{0}C)
29.1	830	1170	0.5	111.3	52.9	0.7	125.4
29.1	830	1300	0.5	116.0	47.7	0.7	121.9

- **SiC is hotter than IGBT but the its temperature is well below Tjmax.**

Q2 3-Level I-Type NPC for 1500V System



Name	NXH350N100H4Q2F2P1G	Q'ty/Module
T1,T4	FS4 1000V/75A, Middle Speed	10
T2,T3	FS4 1000V/100A, Middle Speed	8
D1,D2,D3,D4	1000V/75A, Diode	8
D5,D6	1200V/20A, SiC Diode	10
NTC	22kohm, 5% (size 2012)	1
DBC	Al_2O_3	

Name	NXH400N100H4Q2F2	Q'ty/Module
T1,T4	FS4 1000V/100A, Middle Speed	8
T2,T3	FS4 1000V/100A, Middle Speed	8
D1,D2,D3,D4	1000V/75A, Diode	8
D5,D6	1200V/20A, SiC Diode	10
NTC	22kohm, 5% (size 2012)	1
DBC	Si_3N_4	

220 kW – NXH350N100H4Q2F2P1G/S1G

Input DC	1200 V
Switching frequency	16.2 kHz
Output AC L-to-L	800 V
Power per channel	73 kVA
ac inductor	65 uH
Max heatsink temperature	90 °C
SVPWM	

Al_2O_3	Rthjh	Rthjc
IGBT TF (T1)	0.21 °C/W	0.12 °C/W
Diode FD (D6)	0.42 °C/W	0.29 °C/W
IGBT TL (T2)	0.23 °C/W	0.13 °C/W
Diode RD (D1)	0.39 °C/W	0.25 °C/W

▶ System Conditions & Performance :

In/Out Conditions		
Input Voltage	1200	[V]
Output Voltage	462	[Vac]
Output Power	73333	[VA]
Switching Frequency	16.2	[kHz]
Line Frequency	50	[Hz]
Power Factor	1	

==>

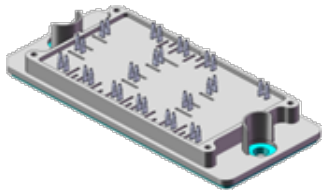
System Performance at the Condit		Power:	73333
Components	Loss [W]	Qty.[EA]	Sum [W]
High-freq. Switch (TF)	196.44	2	392.87
Low-freq. Switch (TL)	103.32	2	206.64
Freewheeling Diode (FD)	26.18	2	52.36
Diode for Reac. Power (RD)	0.00	4	0.00
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [W]			651.88
Calculated Efficiency			99.119%

▶ Detailed Loss and Thermal Performance of Main Devices (TF, TL, FD, RD) for only each 'One'

Details for Loss (TF, RD, TL, FD)	Value
TF_Conduction Loss [W]	89.72
TF_Turn-on Loss [W]	27.82
TF_Turn-off Loss [W]	78.90
RD_Conduction Loss [W](Reactive)	0.00
RD_Reverse Recovery Loss [W]	0.00
TL_Conduction Loss [W]	103.32
TL_Conduction Loss [W] (Reactive	0.00
TL_Turn-on Loss [W] (Reactive)	0.00
TL_Turn-off Loss [W] (Reactive)	0.00
FD_Conduction Loss [W]	22.75
FD_Conduction Loss [W] (Reactive)	0.00
FD_Reverse Recovery Loss [W]	3.43
Sum [W]	325.94
Total for one-phase INPC	651.87775

	Value
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
TF - Case Temp. [Deg.C]	90.0
TF - Junc. Temp. [Deg.C]	131.2
RD - Case Temp. [Deg.C]	90.0
RD - Junc. Temp. [Deg.C]	90.0
TL - Case Temp. [Deg.C]	90.00
TL - Junc. Temp. [Deg.C]	113.76
FD - Case Temp. [Deg.C]	90.00
FD - Junc. Temp. [Deg.C]	101.78

- ❑ Higher output power can be achieved with higher output voltage
- ❑ Outer IGBT is the hottest in most cases



255 kW – NXH400N100H4Q2F2

Input DC	1200 V
Switching frequency	16.2 kHz
Output AC L-to-L	800 V
Power per channel	85 kVA
ac inductor	65 uH
Max heatsink temperature	90 °C
SVPWM	

Si_3N_4	Rthjh	Rthjc
IGBT TF (T1)	0.17 °C/W	0.072 °C/W
Diode FD (D6)	0.36 °C/W	0.237 °C/W
IGBT TL (T2)	0.18 °C/W	0.078 °C/W
Diode RD (D1)	0.32 °C/W	0.152 °C/W

▶ System Conditions & Performance :

In/Out Conditions		
Input Voltage	1200	[V]
Output Voltage	462	[Vac]
Output Power	85000	[VA]
Switching Frequency	16.2	[kHz]
Line Frequency	50	[Hz]
Power Factor	1	

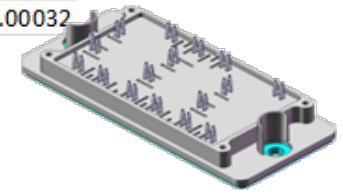
==>

System Performance at the Condit		Power:	85000
Components	Loss [W]	Qty.[EA]	Sum [W]
High-freq. Switch (TF)	235.01	2	470.02
Low-freq. Switch (TL)	126.31	2	252.62
Freewheeling Diode (FD)	32.68	2	65.36
Diode for Reac. Power (RD)	0.00	4	0.00
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [W]			788.00
Calculated Efficiency			99.081%

▶ Detailed Loss and Thermal Performance of Main Devices (TF, TL, FD, RD) for only each 'One'

Details for Loss (TF, RD, TL, FD)	Value
TF_Conduction Loss [W]	109.22
TF_Turn-on Loss [W]	43.54
TF_Turn-off Loss [W]	82.25
RD_Conduction Loss [W](Reactive)	0.00
RD_Reverse Recovery Loss [W]	0.00
TL_Conduction Loss [W]	126.31
TL_Conduction Loss [W] (Reactive	0.00
TL_Turn-on Loss [W] (Reactive)	0.00
TL_Turn-off Loss [W] (Reactive)	0.00
FD_Conduction Loss [W]	28.98
FD_Conduction Loss [W] (Reactive)	0.00
FD_Reverse Recovery Loss [W]	3.70
Sum [W]	394.00
Total for one-phase INPC	788.00032

	Value
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
TF - Case Temp. [Deg.C]	90.0
TF - Junc. Temp. [Deg.C]	129.9
RD - Case Temp. [Deg.C]	90.0
RD - Junc. Temp. [Deg.C]	90.0
TL - Case Temp. [Deg.C]	90.00
TL - Junc. Temp. [Deg.C]	116.52
FD - Case Temp. [Deg.C]	90.00
FD - Junc. Temp. [Deg.C]	101.76



Si_3N_4 decrease Rthjc which allows generating more power

PIM Solar Product Roadmap

Released | Development | Plan

✓ = Full SiC

1500Vdc

- Q2BOOST *custom
- Q2BOOST 450A, 3-CH
- Q2BOOST 300A, 3-CH
- F2 BOOST 200A, 2-CH
- Q2PACK *custom
- Q2PACK INPC, 350A
- Q2PACK INPC, 400A Si3N4 DBC
- Q2PACK INPC, 225A
- Q3Dual HB 600A

1100Vdc

- Q0BOOST 80A, 2-CH
- Q1BOOST 240A, 3-CH
- Q0BOOST 40mΩ, 2-CH ✓
- F2 BOOST 160A, 1-CH
- Q0PACK TNPC 80A
- Q0BOOST 100A, 2-CH
- Q0BOOST 80mΩ, 2-CH ✓
- F2 TNPC 100A
- Q2PACK TNPC 160A
- Q1PACK TNPC 160A
- Q0PACK TNPC 100A
- Q1BOOST 40mΩ, 3-CH ✓
- Q2PACK INPC 450A 175C Tjmax
- F2 BOOST 120A, 3-CH
- Q2PACK INPC, 450A
- Q2PACK TNPC 200A
- Q1PACK H6.5 50 &75A
- F2 Heric 75A
- F2 BOOST 27mΩ, 1-CH ✓
- F2 Heric 75A
- F5 2-level BOOST 3 or 4-CH Hybrid

2018 2019 2020 2021 2022

Full SiC PIMs

Industrial Full SiC PIMs

Module/ Voltage	F2 Half Bridge	F2 Full Bridge	F2 Six Pack	F1 Half Bridge	F1 Full Bridge	F1 Diode Full Bridge		Q0 2x Boost	Q1 3x Boost
1200V	6 mΩ*								
18V – 20V Gate Drive		*12 mΩ*		10 mΩ*					
			20 mΩ	*20 mΩ*	20 mΩ*	*40 A*			
			40 mΩ	*40 mΩ*	40 mΩ*	*20 A*		40 mΩ	40 mΩ
								80 mΩ	
900V				10 mΩ*					
15V – 18V Gate Drive				*20 mΩ*	*20 mΩ*				
				30 mΩ	*30 mΩ*				
650V/ 750V 15V – 18V Gate Drive				*8 mΩ*					
				15 mΩ	*15 mΩ*				
				25 mΩ	*25 mΩ*				

Key:

27 mΩ Released

10 mΩ* Samples built on request

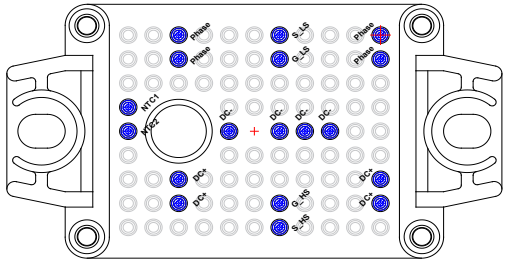
60 mΩ In Design

60 mΩ Roadmap

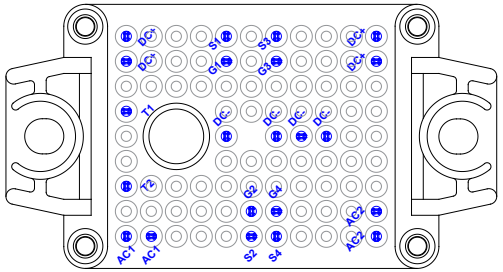
1200V/900V Technology Qualification Complete

Module pinouts

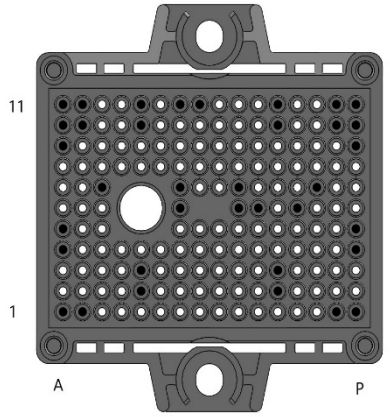
F1 Half Bridge
Same pinout
All power levels

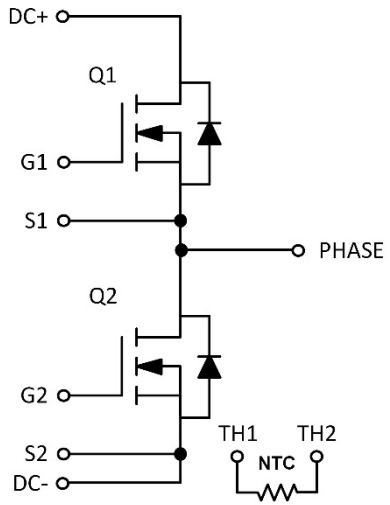


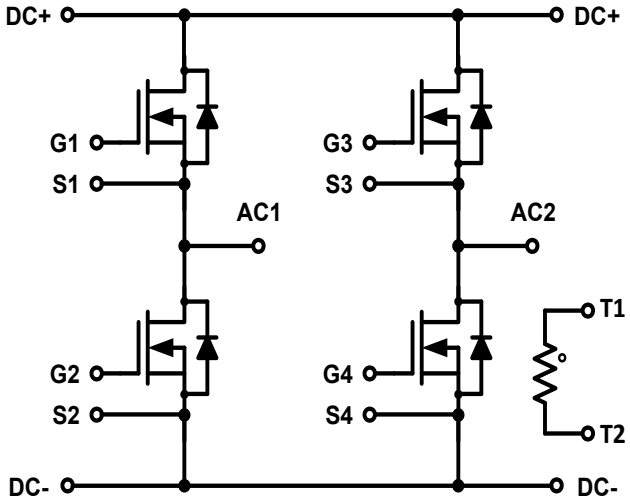
F1 Full Bridge

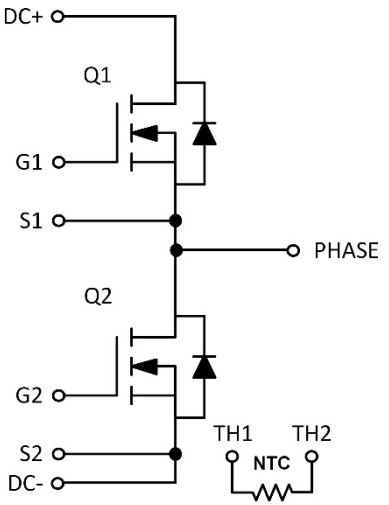


F2 Half Bridge









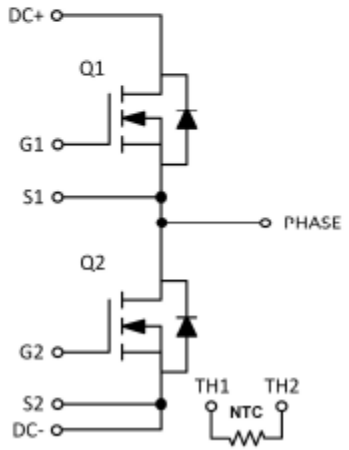
6mohm 1200V Half Bridge Module Summary

Features

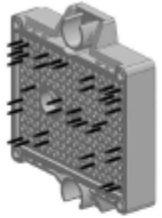
- 6 mohm/1200V SiC MOSFET half-bridge
- Thermistor
- Options with pre−applied thermal interface material (TIM) and without pre−applied TIM
- Options with solderable pins and press−fit pins

Typical Applications

- Solar Inverter
- Uninterruptible Power Supplies
- Electric Vehicle Charging Stations
- Industrial Power



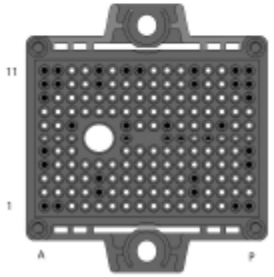
PACKAGE PICTURE



MARKING DIAGRAM

Specific Device Code
YYWW = Year and Work Week Code

PIN CONNECTIONS



See Pin Function Description for pin names

6mohm 1200V Half Bridge Module Summary

ELECTRICAL CHARACTERISTICS
T_J = 25 °C unless otherwise noted

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
SIC MOSFET CHARACTERISTICS						
Drain-Source Breakdown Voltage	V_{GS} = 0 V, I_D = 250 µA	$V_{(BR)DSS}$	1200	–	–	V
Zero Gate Voltage Drain Current	V_{GS} = 0 V, V_{DS} = 1200 V	I_{DSS}	–	10	300	µA
Drain-Source On Resistance	V_{GS} = 20 V, I_D = 200 A, T_J = 25 °C	$R_{DS(ON)}$	–	5.48	9	mohm
	V_{GS} = 20 V, I_D = 200 A, T_J = 150 °C		–	7.1	–	
Gate-Source Threshold Voltage	V_{GS} = V_{DS}, I_D = 80 mA	$V_{GS(TH)}$	1.8	2.83	4.3	V
Gate Leakage Current	V_{GS} = -10/20 V, V_{DS} = 0 V	I_{GSS}	-1000	–	1000	nA
Forward Transconductance	V_{DS} = 10 V, I_D = 200 A	g_{FS}		14		S
Internal Gate Resistance		R_G		–		ohm
Input Capacitance	V_{DS} = 800 V. V_{GS} = 0 V. f = 1 MHz	C_{ISS}	–	6687	–	pF
Reverse Transfer Capacitance		C_{RSS}	–	49	–	
Output Capacitance		C_{OSS}	–	1092	–	
C_{OSS} Stored Energy	V_{DS} = 0 V to 800 V. V_{GS} = 0 V.	E_{OSS}	–	349	–	µJ
Total Gate Charge	V_{DS} = 800 V. V_{GS} = 20 V. I_D = 200 A.	$Q_{G(TOTAL)}$	–	847	–	nC
Gate-Source Charge		Q_{GS}	–	231	–	nC
Gate-Drain Charge		Q_{GD}	–	195	–	nC
Turn-on Delay Time	T_J = 25 °C V_{DS} = 600 V, I_D = 200 A V_{GS} = 18/-5V, R_G = 1.8 Ω	$t_{d(on)}$	–	54	–	ns
Rise Time		t_r	–	21	–	
Turn-off Delay Time		$t_{d(off)}$	–	174	–	
Fall Time		t_f	–	22	–	
Turn-on Switching Loss per Pulse		E_{ON}	–	2.1	–	mJ
Turn off Switching Loss per Pulse		E_{OFF}	–	2.75	–	
Turn-on Delay Time	T_J = 150 °C V_{DS} = 600 V, I_D = 200 A V_{GS} = -5V/20V, R_G = 1.8 Ω	$t_{d(on)}$	–	48	–	ns
Rise Time		t_r	–	19	–	
Turn-off Delay Time		$t_{d(off)}$	–	196	–	
Fall Time		t_f	–	22	–	
Turn-on Switching Loss per Pulse		E_{ON}	–	2.3	–	mJ
Turn off Switching Loss per Pulse		E_{OFF}	–	2.93	–	
Diode Forward Voltage	I_D = 200 A, T_J = 25 °C	V_{SD}	–	4.0	6	V
	I_D = 200 A, T_J = 150 °C		–	3.6	–	
Thermal Resistance - chip-to-case		R_{thJC}	–	0.10	–	°C/W
Thermal Resistance - chip-to-heatsink	Pre-applied TIM version	R_{thJH}	–	0.15	–	°C/W

Module Design In Support

Tools for Customer Design-In

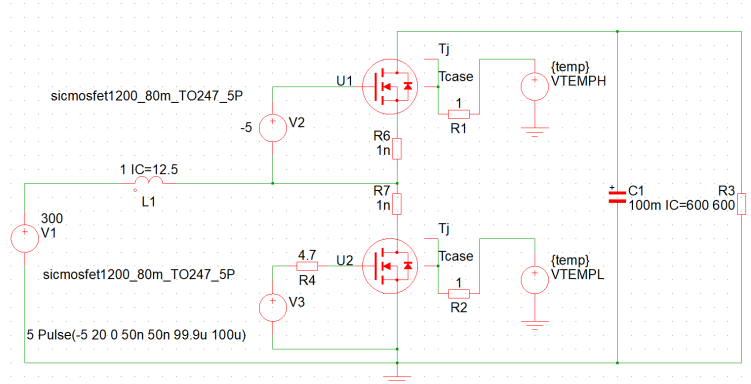
PSPICE model of module

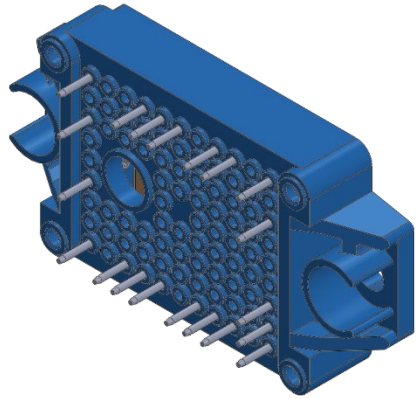
Parasitics estimated before build, then updated

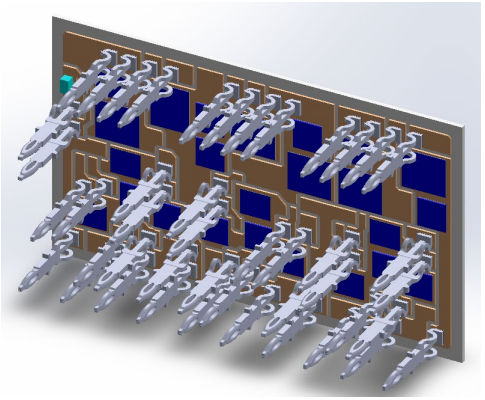
STEP file for module

DBC with die positioning for thermal simulation

We can assess Rth and losses using ANSYS simulation (with simple boundary conditions)







Module Development and Support

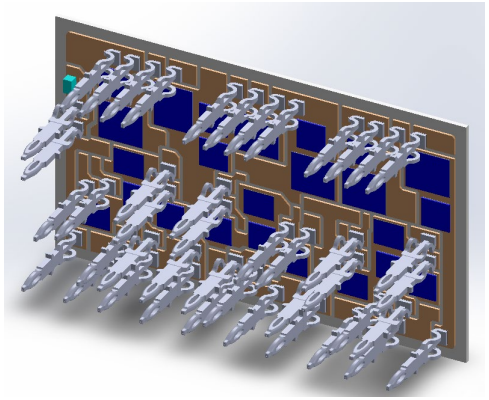
Simulation

Vin (V)	Vout (V)	Freq (kHz)	Power losss -IGBT (W)
850	1170	16	36.6
850	1300	16	41.8
850	1170	20	43.6
850	1300	20	49.6
850	1170	24	50.6
850	1300	24	57.4

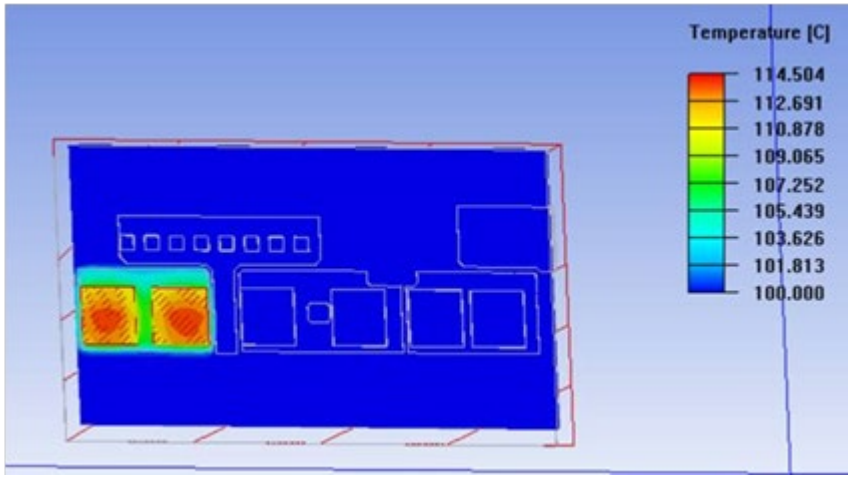
Selection

Description	Target BOM	Pcs
Tx1,Tx2	FS4 1000V/75A, High Speed	2
Dx1,Dx2	1600V/35A, Protection diode	2
Dx5,Dx6	1600V/35A, By-pass diode	2
Dx3,Dx4	1200V/10A, SiC Diode	2
NTC	22kohm, 5% (size 2012)	1

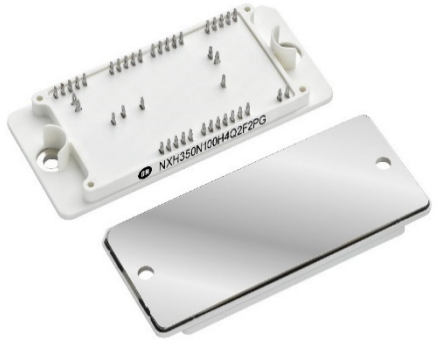
Layout



Optimization, thermal simulation



Prototype and qualification samples



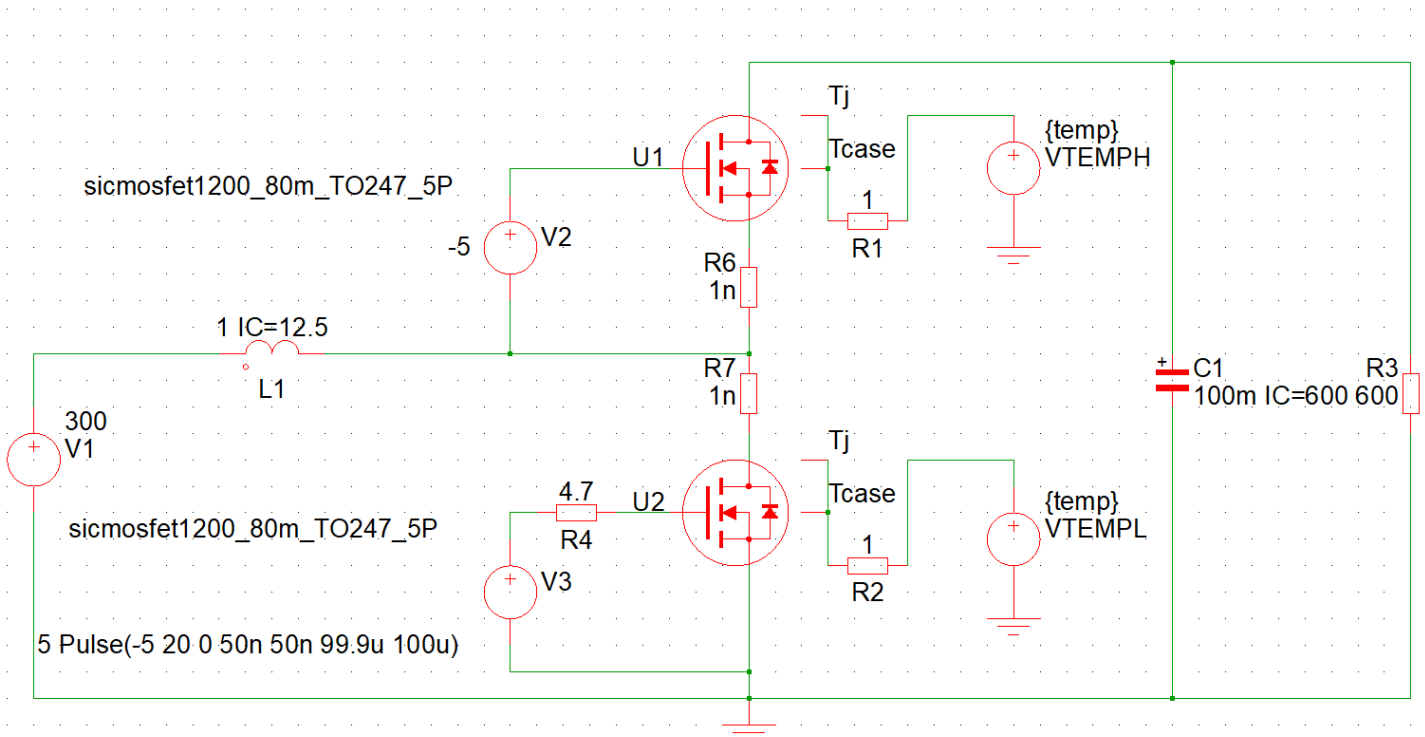
Final implementation

End Customer System

Physical SPICE models - benefits

Closer matching of simulation results to actual circuits

- Thermal simulation – self-heating effects included
- Reverse recovery behaviour
- Effect of parasitics at circuit, module and die level



Thank You