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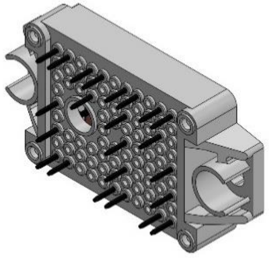
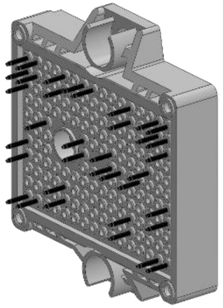
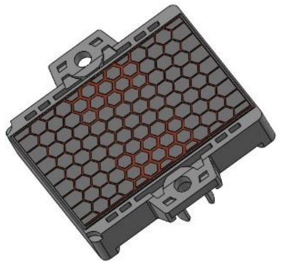
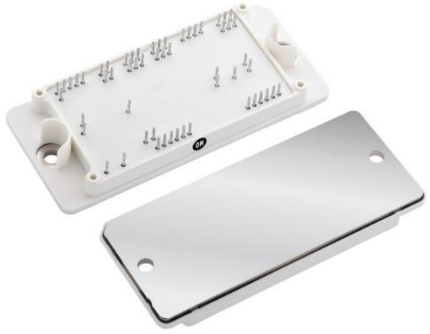
SiC Hybrid Modules for Decentralized Solar Inverters Customer Presentation

June 2020

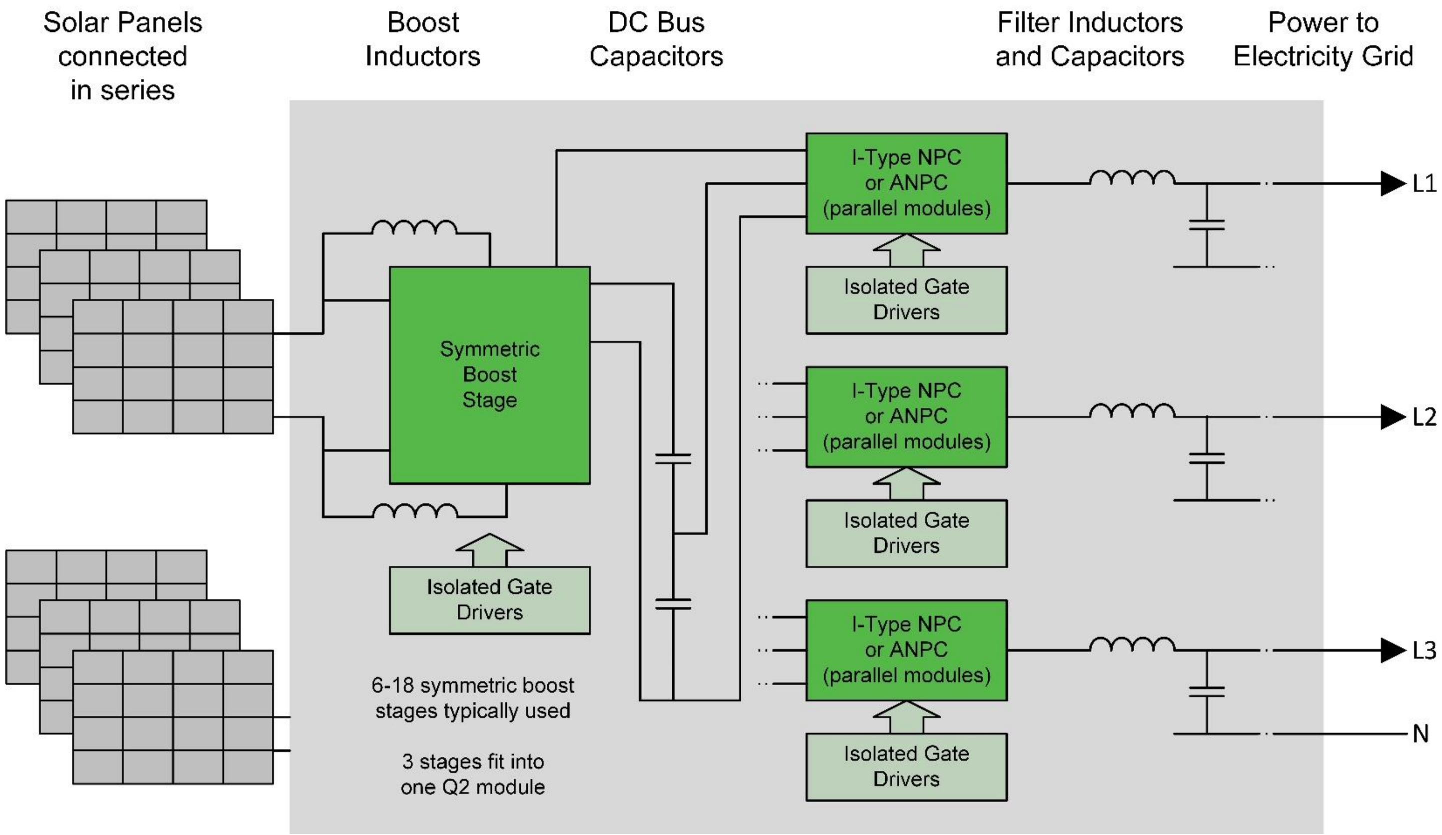
Public Information

Gel-filled Modules: Available Packages

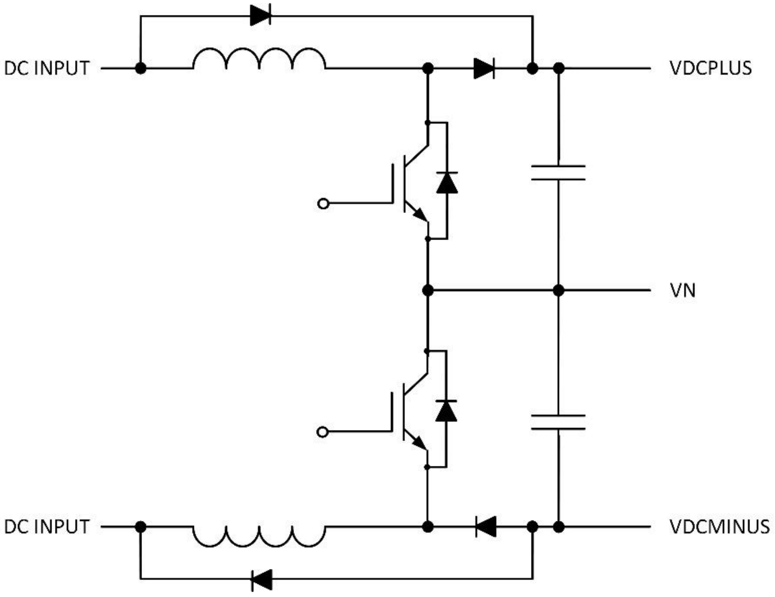
F1	Q0	F2	Q1	Q2
	 	 	 	 **with base plate**
1.2 mm press-fit pins Solder pins	1.2 mm press-fit pins 1.6 mm press-fit pins Solder pins	1.2 mm press-fit pins Solder pins	1.2 mm press-fit pins 1.6mm press-fit pins Solder pins	1.6 mm press-fit pins Solder pins
With TIM/no TIM	With TIM/no TIM	With TIM/no TIM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

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

Power Levels: 150kW to 250kW



Symmetric Boost Circuit



Symmetric boost circuit allows higher DC input voltage than standard boost

Decentralized Utility Inverter Modules

Features

- Family for 1500V Decentralized Utility Inverters
  - 1000V 150A 3-channel Symmetric Boost
  - 1000V 350A I-type NPC
- Family for 1200V Decentralized Inverters
  - 1000V 60A 3-channel Boost
  - 650V 450A I-type NPC
- Thermistor

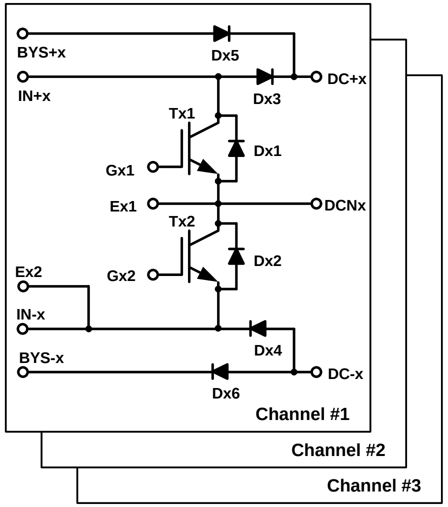
Benefits

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

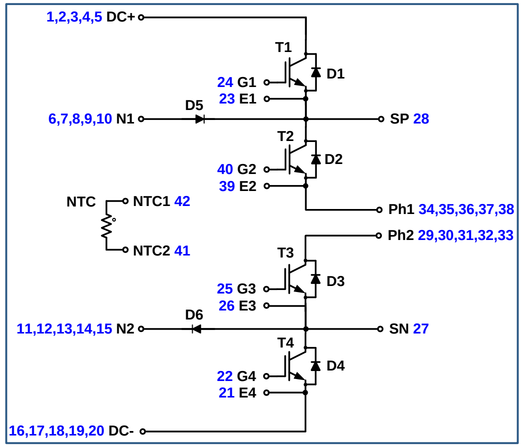
Specifications

Product	Description	Status
NXH450B100H4Q2F2x	3-Channel 1000V 150A Symmetric Boost	Released
NXH350N100H4Q2F2x	Single 1000V 350A I-type NPC	Released
NXH240B100H3Q1PG	3-Channel 1000V 60A Boost	Released
NXH450N65L4Q2F2SG	Single 650V 450A I-type NPC	Released

Block Diagrams: Solution for 1500V Solar Inverter



Q2BOOST



Q2PACK

Applications

- Decentralized Solar Inverters

End products

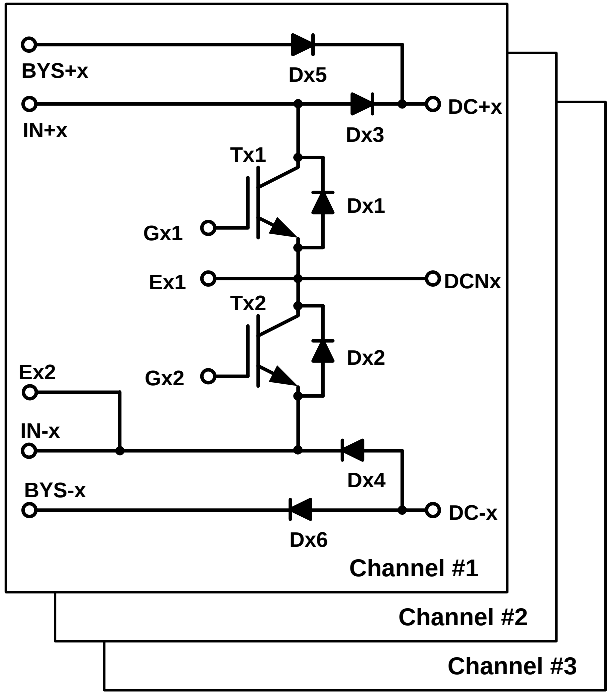
- Solar Inverter

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

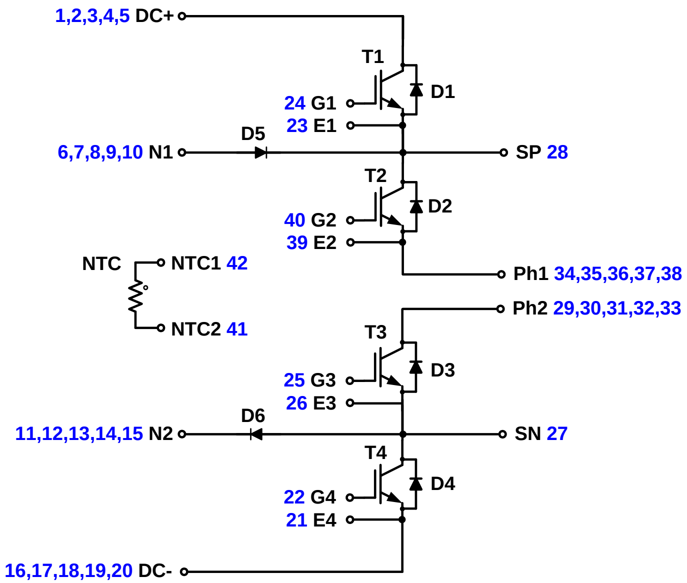
Heatsink = 90 degC

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

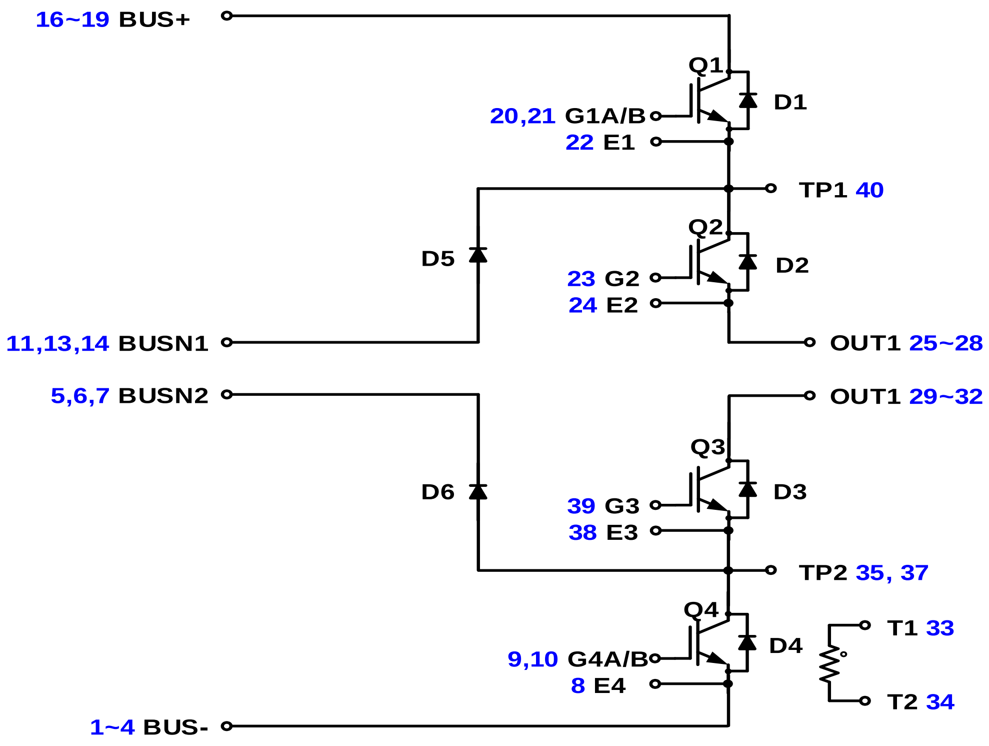
- **SiC is hotter than IGBT but the its temperature is well below Tjmax.**

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



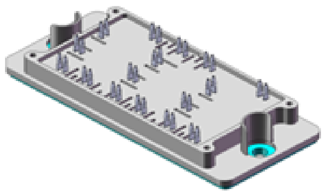
Name	Description	Q'ty/Module
T1,T4	FS4 1000V/75A, High Speed	10
T2,T3	FS4 1000V/75A, Low Vce(sat)	8
D1,D2,D3,D4	1000V/75A, Diode	8
D5,D6	1200V/20A, SiC Diode	10
NTC	22kohm, 5% (size 2012)	1

120-150kW – Q2 INPC



Vbus 850V, fsw 16.2kHz, Tsink 100℃, Rg_on/off 15Ω							
Condition	Vo[V]	kVA	PF	Tj_Q1 [°C]	Tj_D1 [°C]	Tj_Q2 [°C]	Tj_D5 [°C]
1	230	100	1	129.6	100.0	125.1	114.2
2	230	110	1	133.6	100.0	128.5	116.0
3	230	111	0.9	132.1	100.5	129.8	118.1
4	230	125	0.8	135.2	101.5	136.0	123.0
5	230	121	1	138.3	100.0	132.4	118.1
6	230	122	0.9	136.5	100.3	133.9	120.5
7	230	137	0.8	140.3	101.3	141.1	126.0
8	230	132	1	143.2	100.0	136.5	120.2
9	230	132	0.9	140.7	100.4	137.7	122.6
10	230	150	0.8	145.6	101.4	146.4	129.2
11	288.7	126	1	132.1	100.0	125.1	109.1
12	288.7	139	1	136.5	100.0	128.5	110.2
13	288.7	140	0.9	134.7	100.6	129.8	112.7
14	288.7	158	0.8	138.1	101.7	135.9	117.1
15	311.8	136	1	133.2	100.0	125.1	107.1
16	311.8	150	1	137.7	100.0	128.5	107.9
17	311.8	152	0.9	135.9	100.6	129.9	110.6
18	311.8	170	0.8	139.4	101.9	136.0	114.9

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



Loss Simulation at 195kW, PF =0.8

Inverter Working Condition

VDC = 1170V
Vout L-L = 800Vrms
Fsw = 16kHz
Inductance = 83uH
Heatsink = 90 degC
Pf = 0.8

Details for Loss (TF, RD, TL, FD)	Value
TF_Conduction Loss [W]	61.34
TF_Turn-on Loss [W]	42.21
TF_Turn-off Loss [W]	60.57
RD_Conduction Loss [W] (React	1.86
RD_Reverse Recovery Loss [W	1.20
TL_Conduction Loss [W]	74.71
TL_Conduction Loss [W] (React	5.21
TL_Turn-on Loss [W] (Reactive	6.60
TL_Turn-off Loss [W] (Reactive)	19.91
FD_Conduction Loss [W]	39.72
FD_Conduction Loss [W] (Reactive)	**8.25**
FD_Reverse Recovery Loss [W]	2.68

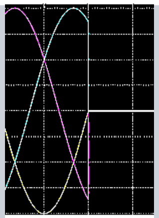
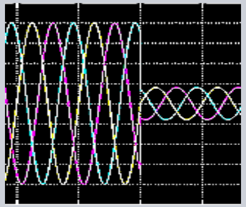
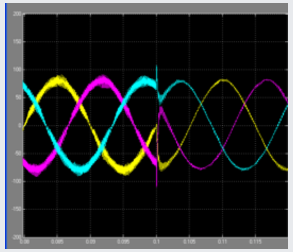
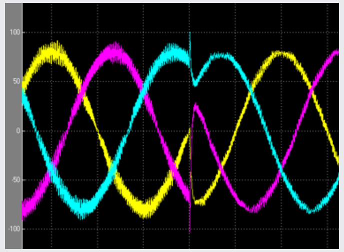
	Value
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
TF - Case Temp. [Deg.C]	90.0
TF - Junc. Temp. [Deg.C]	122.8
RD - Case Temp. [Deg.C]	90.0
RD - Junc. Temp. [Deg.C]	92.3
TL - Case Temp. [Deg.C]	90.00
TL - Junc. Temp. [Deg.C]	112.35
FD - Case Temp. [Deg.C]	90.00
FD - Junc. Temp. [Deg.C]	106.71

AC condition under simulation

IGBT-O : Out IGBT T1/T4
(Vce= 600V; Rg= 15 Ω; Vge= +15V/ -8V)

160 kW LVRT – Low Voltage Ride Through

LVRT Simulation

	LVRT voltage : 0 pu, ~ 150ms	LVRT voltage : 0.2 pu, ~625 ms	*Comments*
Phase Voltage, Vout	Vout: 0V (*46.1V* in practice**) 	Vout: *92V* (0.2*461) 	***At 0 pu, Vout =0V theoretically, in practice Vout = 40V ~ 50V (0.1pu)*
Phase Current, Iout	Lag 90 deg 	Lag 90 deg 	*Magnitude: 121A (105%*In)* *Phase angle: shift 90^0* *P → Q (reactive)*

Result

Per Device	Loss & Tj	
	Power Loss (W) ~up to **625ms**	max Tj (^0C)
IGBT-O	52.3	99.9
IGBT-I	173.4	126.4
Diode-NP	132	133.6
Protection Diode D1,D4,D5,D6	9.24	96.9

Thank You