Smart GaN-Based Inverters for Grid-tied Energy Storage Systems

DOE/OE Peer Review, 09/26/2018

InnoCit

Innovation City, Power and Energy Solutions

DOE SBIR Phase II

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

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Acknowledgement

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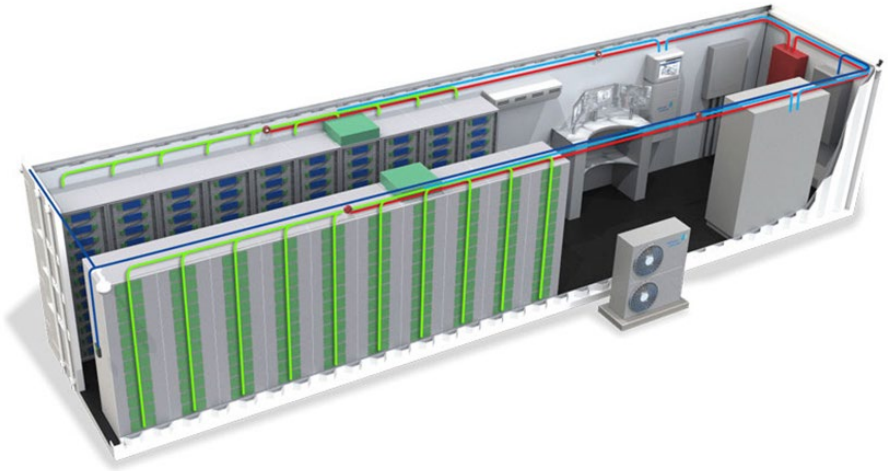
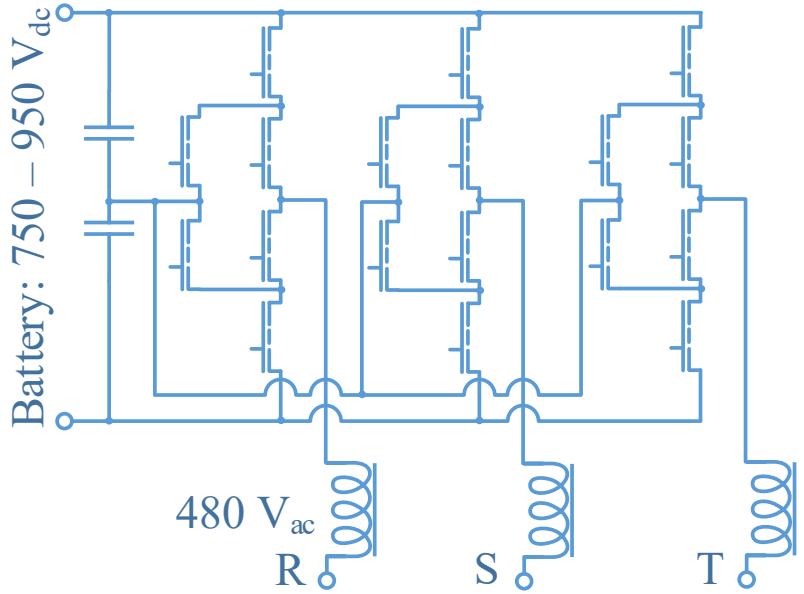
InnoCit

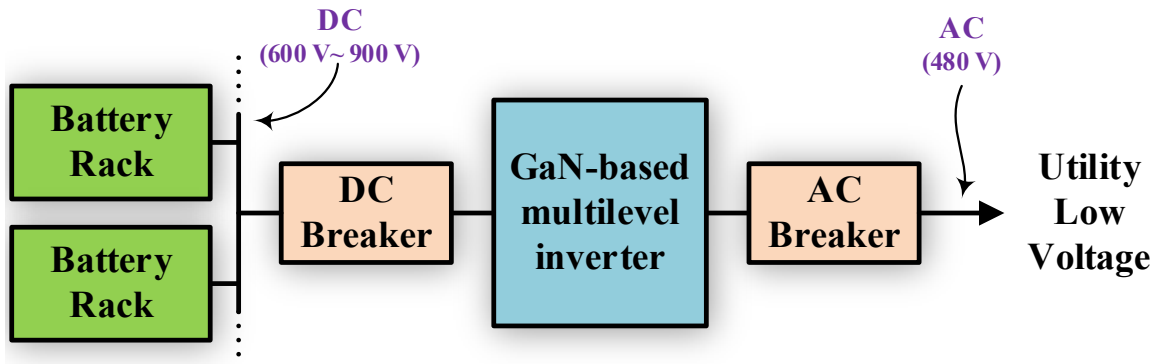
- Founded in 2014
- Tech Transfer Startup
- 4,000 sq. ft. research facility, 10 acre campus, solar farm, based in Missouri
- DOE SBIR Phase I & II, NSF SBIR Phase I
- Costume manufacturing

System Specifications

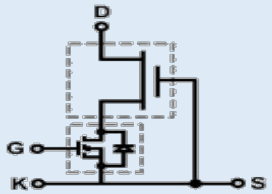
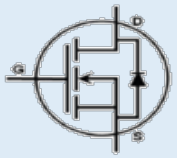
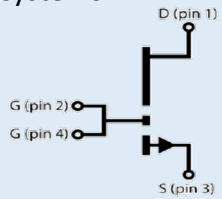
- **GaN-based multilevel inverter**
- **Nominal input voltage: 900V**
- **Output voltage: 3-phase 480V**
- **Power rating: 75kW and 100kVA**



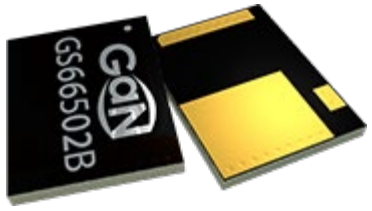




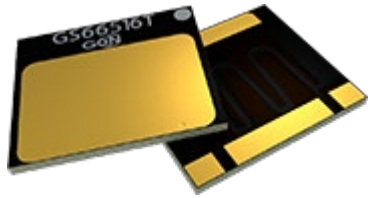
Fast-Paced Technology

Technology / manufacturer	Transphorm 	EPC 	GaN systems 
Switch topology	Cascode: GaN JFET + Si MOSFET	Enhancement mode FET	Enhancement mode FET
Material	GaN + Si	GaN	GaN
Part number	TPH3205WS	EPC2034	GS66508T
Voltage	600 V	200 V	650 V
Current	36 A	31 A	30 A
Rds-on @ 150°C	0.10 Ω	0.015 Ω	0.050 Ω
CRSS (Reverse transfer)	17.5 pF	5 pF	2 pF (this is the fastest power GaN commercialized capable of operating up to 100MHz)
Heatsink Plate		no	Yes

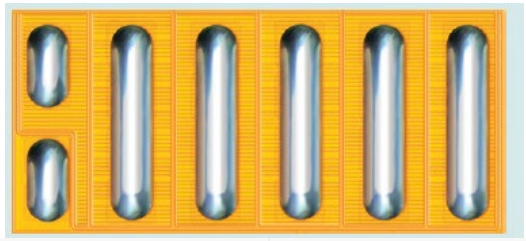
Available GaN Switches



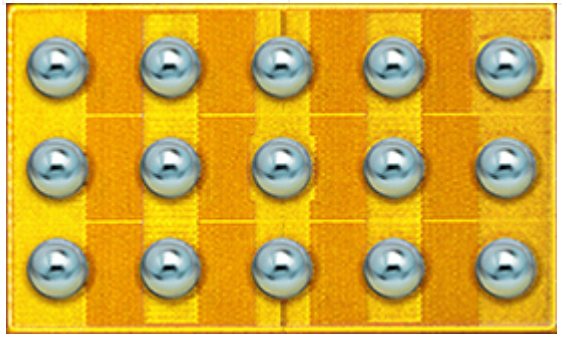
V_{DS}	650 V E-HEMT
I_{DS}	7.5 A
$R_{DS(ON)}$	200 mΩ
Q_G	1.5 nC
DIMENSIONS (MM)	5.0 x 6.6 x 0.51
COOLING	Bottom-Side



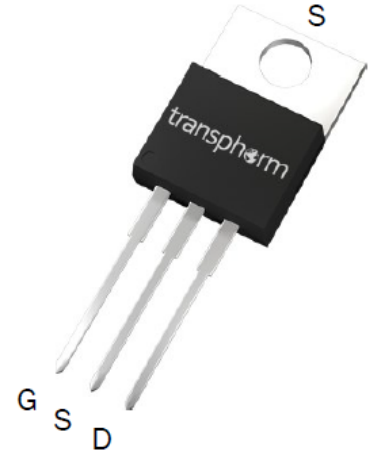
V_{DS}	650 V E-HEMT
I_{DS}	60 A
$R_{DS(ON)}$	25 mΩ
Q_G	12.1 nC
DIMENSIONS (MM)	9.0 x 7.6 x 0.54
COOLING	Top-Side



V_{DS}	200 V
I_{DS}	22 A
$R_{DS(ON)}$	15 mΩ
Q_G	3.7 nC
DIMENSIONS (MM)	3.6 x 1.6
COOLING	Top & Bottom



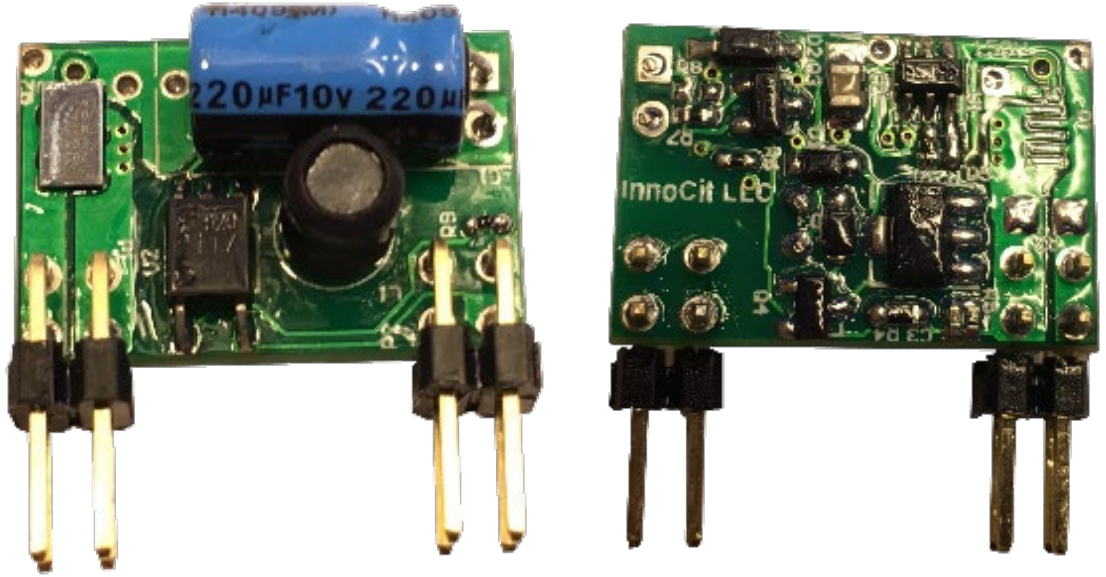
TPH3212PS
TO-220
(top view)



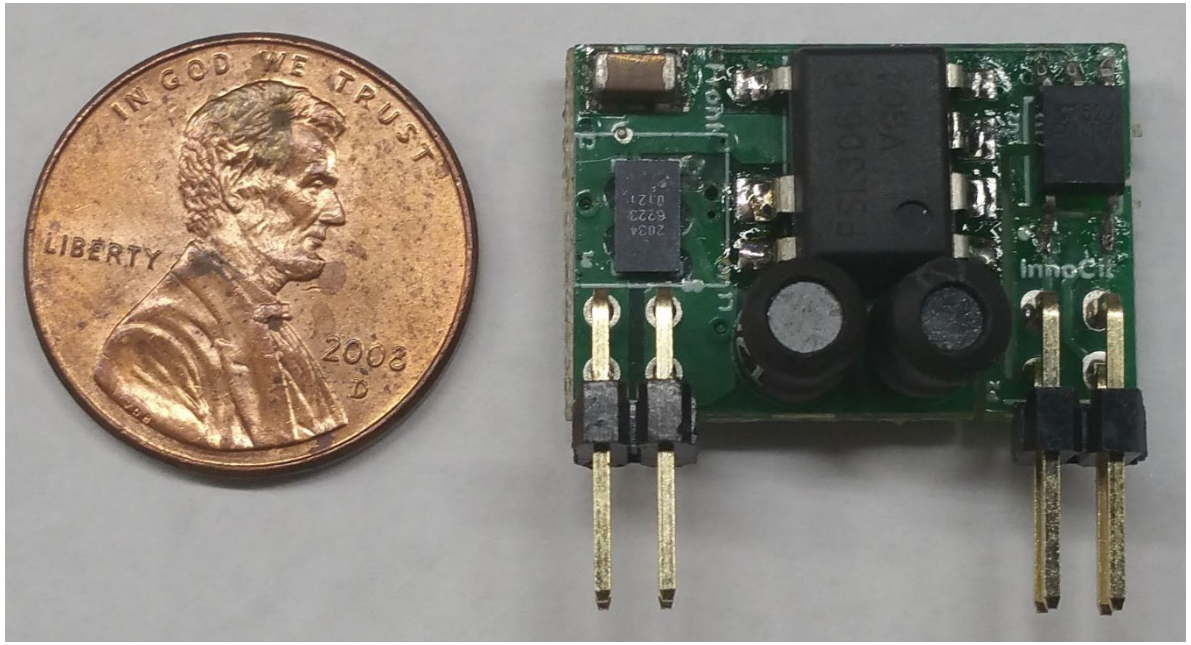
V_{DS} (V) min	650
$V_{(TR)DSS}$ (V) max	800
$R_{DS(on)eff}$ (mΩ) max*	85
Q_{RR} (nC) typ	90
Q_G (nC) typ	14

Achievements

- **First ever floating supply integrated GaN gate driver + switch (commercialized)**
- **First ever modular GaN-based 7.5-kW inverter (TRL-4)**



PCBs


IN GOD WE TRUST
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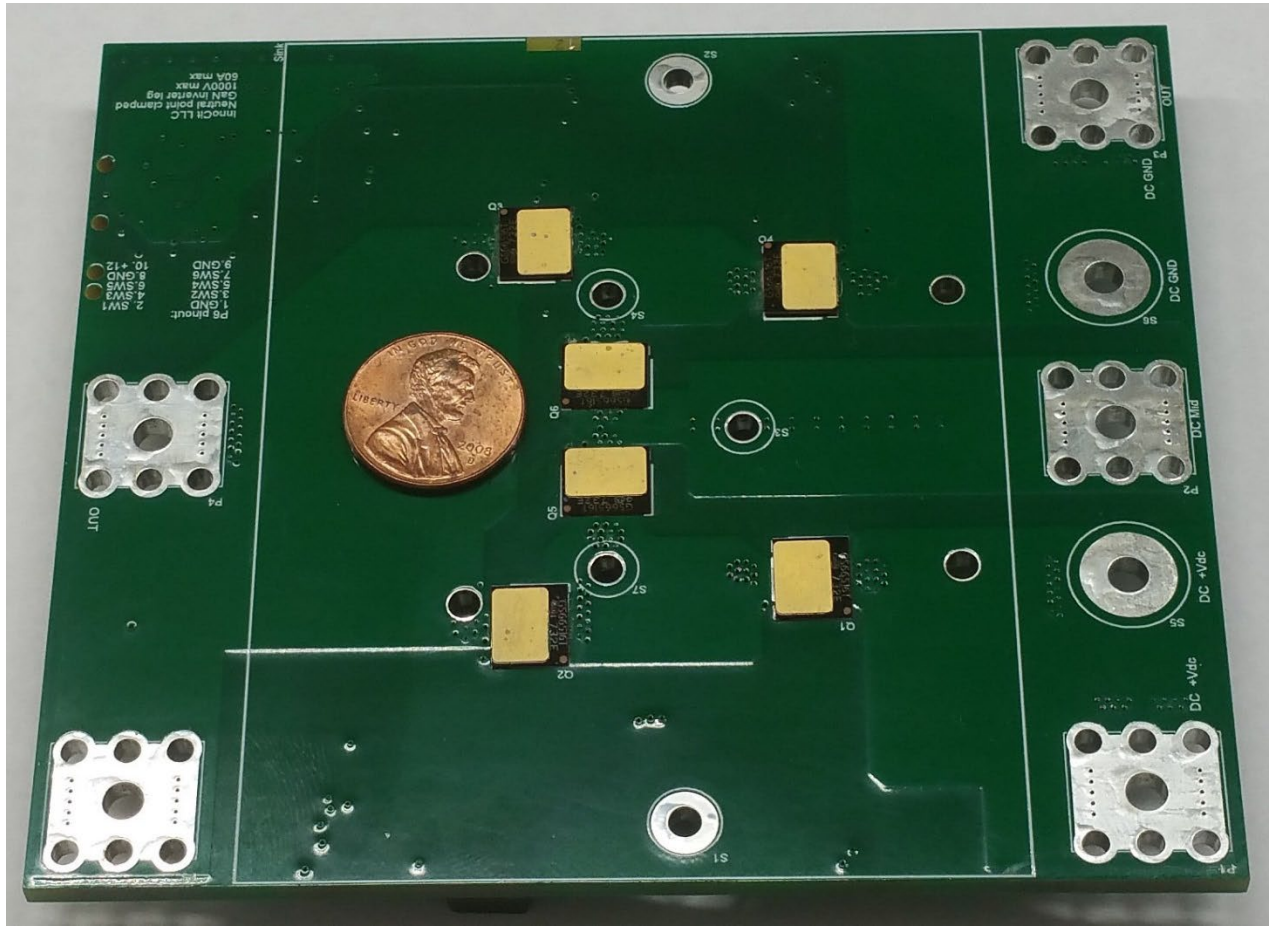
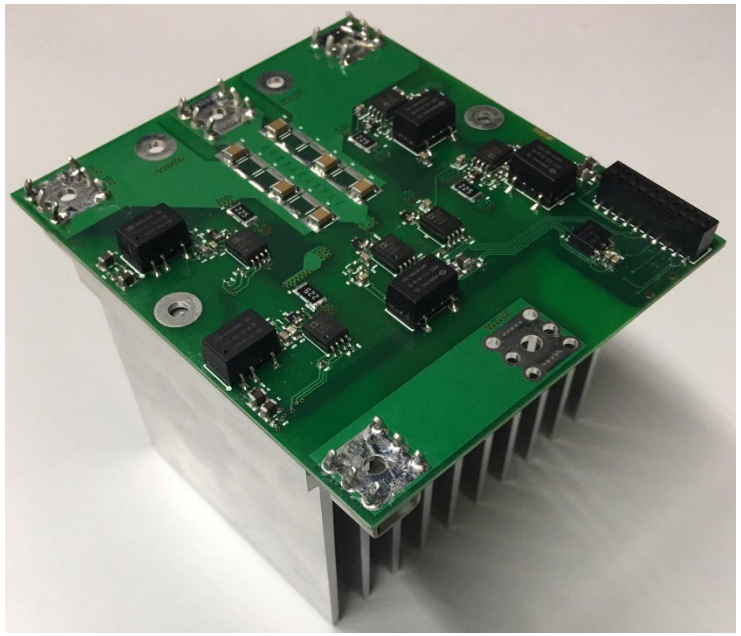
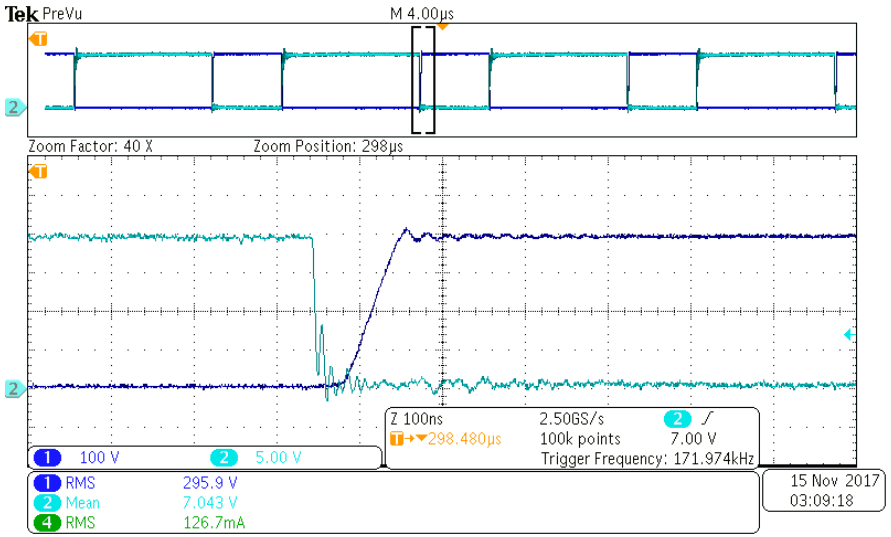
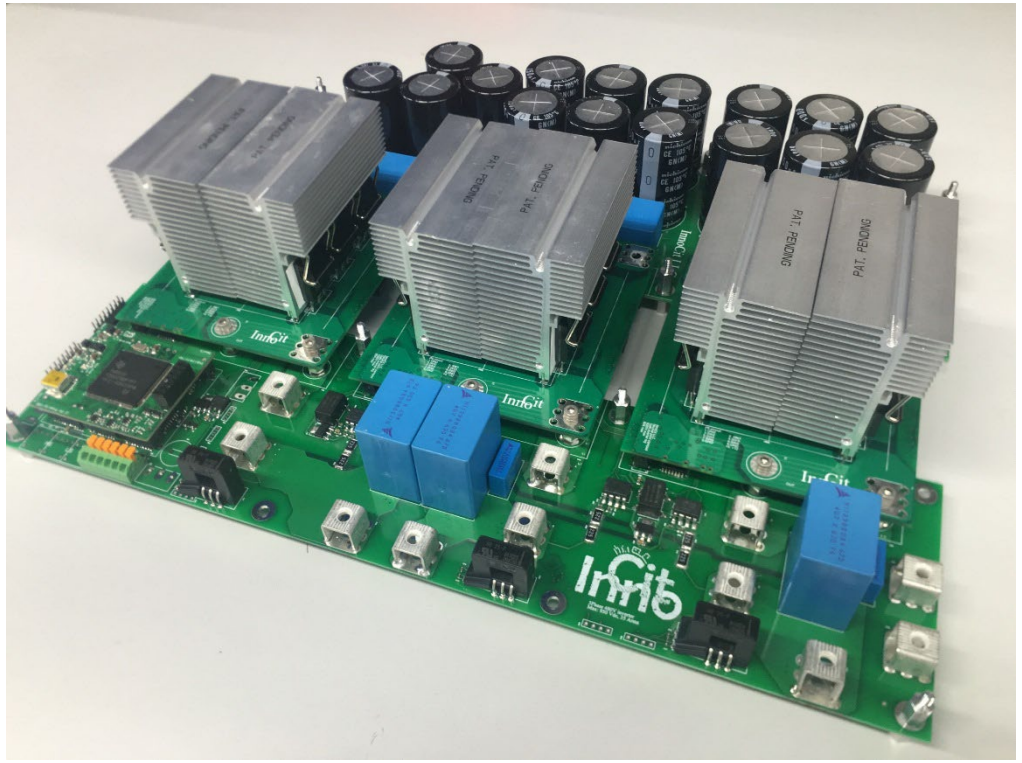
InnoCit

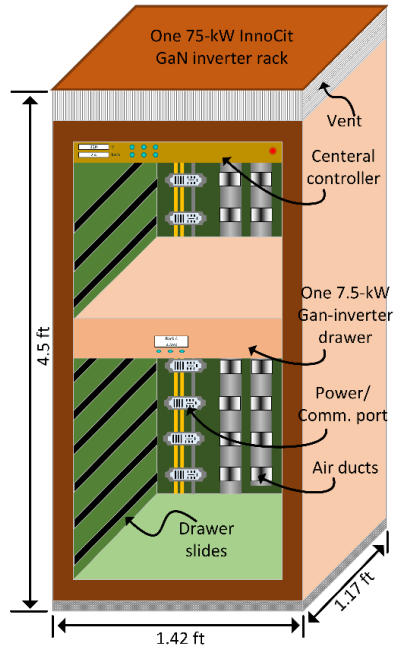

InnoCit LLC
Neutral point clamped
GaN inverter leg
1000V max
60A max
PB pinout:
1.GND
2.SW1
3.SW2
4.SW3
5.SW4
6.SW5
7.SW6
8.GND
9.GND
10. +12
OUT
DC GND
DC Mid
DC +Vdc
Q1
Q2
Q3
Q4
Q5
Q6

Final System









Commercial Competitiveness

Features	InnoCit's GaN Inverter	GTIB-100 Princeton Power	MPS-100 Dynapower	EssPro c250 ABB
Peak Efficiency	>99.1%	>96.5%	>96.5%	>96%
CEC Efficiency	>98.5%	>94.5%	>94%	93.9%
End-user Price	$15,500 $0.205/w	$37,000 $0.296/w	$58,000 $0.58/w	$130,000 $0.65/w
Modularity at 7.5-kW level	Yes	No	No	No
Noise (dBA)	<45	<75	<60	<80
Weight (lb)	300	1,020	1,545	2,100
Volume (ft^3)	7.5	28	48	41
Material	GaN	Si	Si	Si

Lessons Learned

- Gate driver design is very critical
- Requires isolated gate drivers and isolated dc-dc power supplies for driving the gate
- When selecting the isolated gate driver and gate power supply, one should ensure that they can withstand the high dv/dt stress due to faster turn ON and OFF times
- With the fast switching of GaN E-HEMTs, any parasitic inductances in the gate switching loop will give rise to ringing which leads to losses and EMI problems - keep the PCB gate-source loop as small as possible
- Best switching performance can be achieved with proper selection of gate resistor

Lessons Learned

- Poor thermal conductivity of GaN semiconductor calls for special attention to thermal design
- GaN E-HEMTs have tiny packaging compared to SiC. Therefore, the heat generated within the device has to be dissipated fast and effectively to keep the junction temperature within allowable limits
- Also, the maximum junction temperature of the GaN E-HEMT selected is low compared to the SiC device
- If using a single heat sink for multiple GaN devices, they have to be aligned flat with the surface of heat sink
- Using thermal grease along with thermal tape will provide the best thermal conductivity

Contact Information

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