

The benefits of GaN for solar inverters

Design with higher power
density & efficiency

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GaN | Higher power density and efficiency in solar inverters

Higher efficiency

Smaller passive components

Integrated protection and driver with TI GaN

Benefits of GaN over silicon

- Overall efficiency **~98%**
- Higher switching frequency allows for **smaller magnetics**, allowing for **40% size reduction**
- Over **2x the power density** of equivalent Si-based designs



20cm x 20cm x 4cm

Decrease the size of your overall design while increasing power density and efficiency!

1.6kW bidirectional micro inverter

[TIDA-010933](#)

7.2kW single-phase string inverter

[TIDA-010938](#)

400W MPPT charge controller

[TIDA-010042](#)

TI's new 100V integrated GaN power stages



**Top side cooled (exposed pad) with extended ground pads at the bottom for effective cooling*

	GaN half-bridge with gate-driver	Single GaN FET with gate-driver
GPN	LMG2100R044	LMG3100R017
Package details	QFN 4.5 x 5.5mm	QFN 6.5 x 4.0mm
V_{DS} (max.)	100V	100V
Protection Features	UVLO	UVLO
Advanced features	Integrated bootstrap	Integrated bootstrap
< 1kW	4.4mΩ Sampling now, RTM April '24	
1kW – 2kW		1.7mΩ Sampling now, RTM Jul'24

LMG2100R044 100V integrated GaN half bridge overview

Features

- **GaN half-bridge with integrated gate-driver, level-shifter and synchronous bootstrap diode**
 - >200V/ns CMTI and 10MHz switching frequency
- 100V AbsMax (100ms, 1k pulse), 90V operational
- 35A (operational), 125A (100us pulse)
- Only single V_{dd} supply 4.5V to 5.5V
- 3.3V or 5V logic inputs
- UVLO protection
- **4.4m Ω typ 5.7m Ω max $R_{DS(on)}$ drain to source at 25°C**
- **Package:** QFN with top-side cooling: 5.5mm x 4.5mm

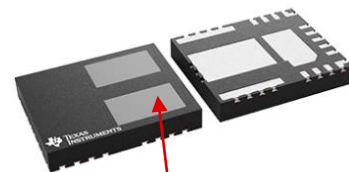
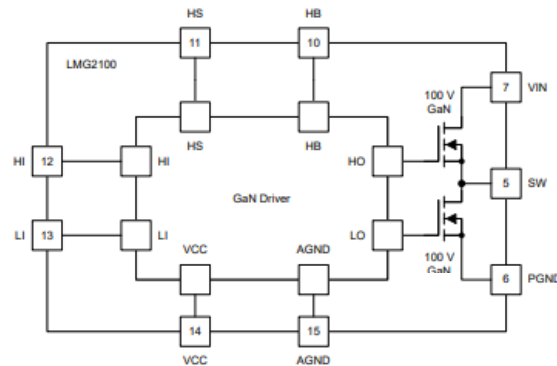
Applications

- 48-V DC-DC converters in server and telecom power
- Solar inverters
- Class D audio
- Test and Measurement power supplies and DC sources
- Motor drives

Benefits

- Easy to use complete power solution
- Does not need separate GaN gate-driver or bootstrap switch
- Easy layout, less dependence on board parasitics
- In-built protection features

Functional block diagram & package



Exposed GaN dies for heat sink

LMG3100R017 100V integrated GaN power stage overview

Features

- **100V GaN FET with integrated driver**
 - >200V/ns CMTI and 10MHz switching frequency
 - Only single V_{dd} supply 4.5V to 5.5V
 - 1.8V, 3.3V or 5V logic inputs
 - UVLO protection
- **Level shift to high-side and bootstrap included**
 - Low-side LMG3100 provides bootstrap supply and level shifted input to high-side LMG3100
 - Mix and match R044 and R017 for asymmetric buck/boost
- 100V AbsMax (100ms, 1k pulse), 90V operational
- R017: **1.7m Ω** typ **2.2m Ω** max $R_{DS(on)}$ drain to source at 25°C
- **Package:** QFN with top-side cooling: 6.5mm x 4.0mm

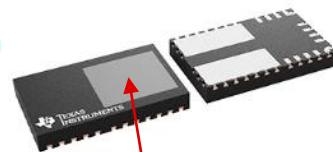
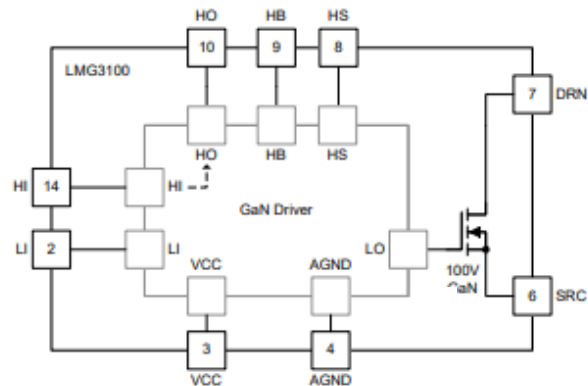
Applications

- 48-V DC-DC converters in server and telecom power
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- Automotive power
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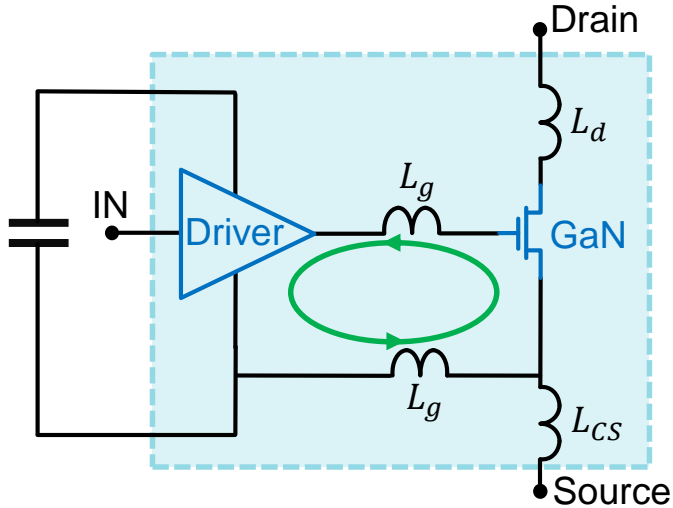
Functional block diagram & package



Exposed GaN dies for heat sink

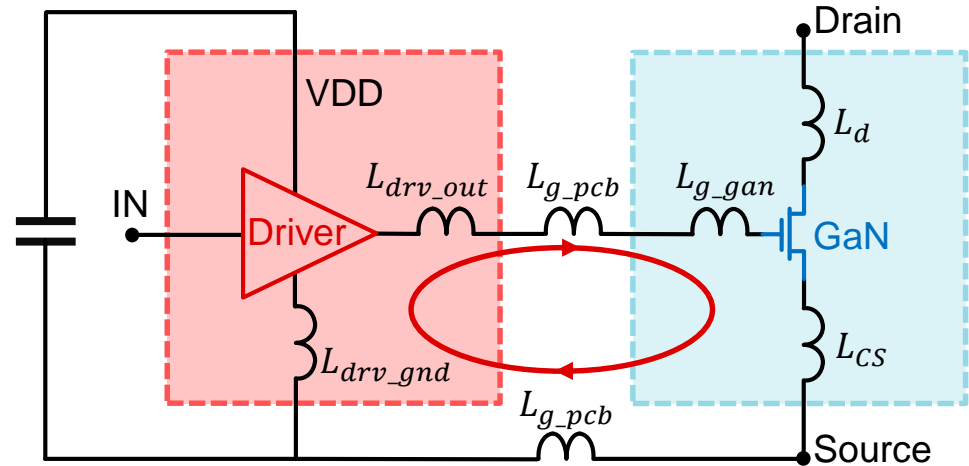
Integrated gate driver

TI driver + GaN



Minimized switching loop, maximum efficiency
Faster turn-on and turn-off

Discrete GaN with external driver

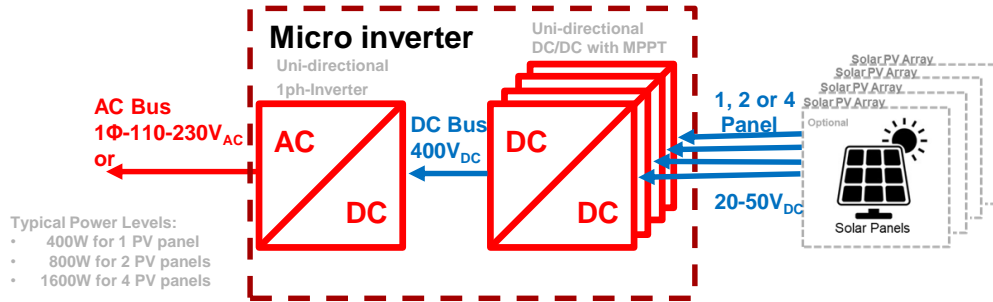


Large parasitic inductances, increased switching losses

Micro inverter reference design

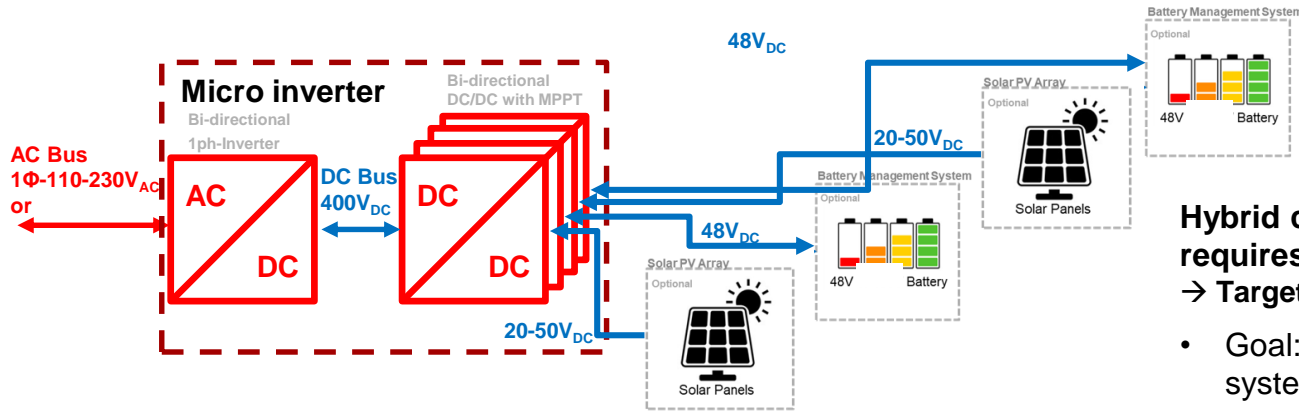
TIDA-010933

Solar micro inverter configurations



These are configurations with PV-panel support only.
Often CSI with flyback topology

- Pros: low cost
- Cons: big magnetics, less efficient



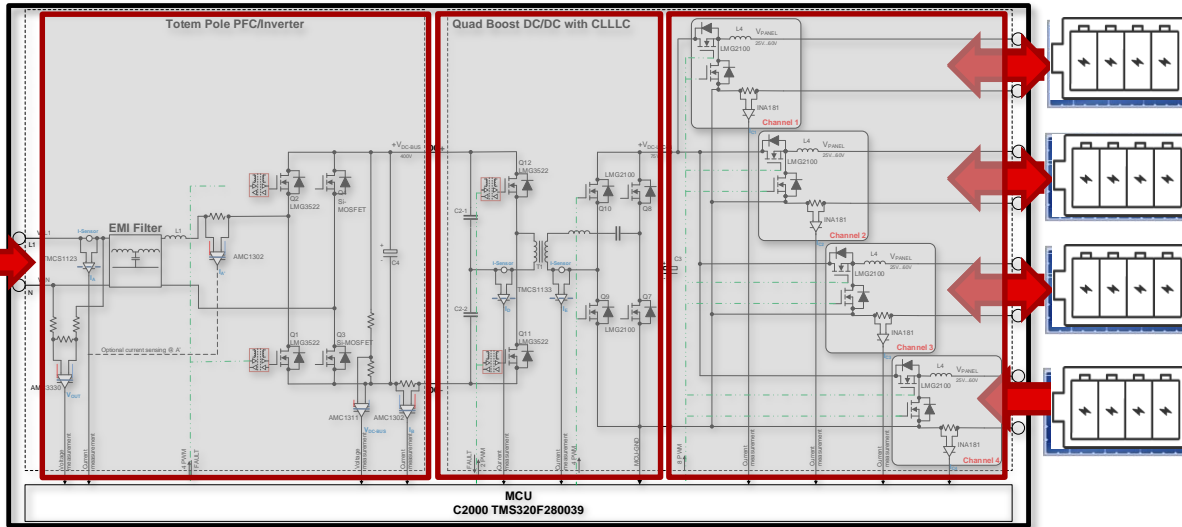
Hybrid configuration (solar with ESS) which
requires bi-directional operation (VCS)
→ Target for TIDA-010933

- Goal: high efficiency & power density @ low system cost

1.6kW GaN based single phase micro inverter

Block diagram

$230V_{AC}$ \leftrightarrow $400V_{DC}$ \leftrightarrow $75V_{DC}$ \leftrightarrow $30V_{DC} \dots 60V_{DC}$



Operating principle:

Configurable inputs and outputs:

- PV-Panel input each up to $400W$ @ $14A_{MAX}$
- Battery Energy Storage In/Output up to $400W$ @ $48V$ each

Single phase AC line able to sink & source $1600W_{MAX}$ at $230V_{AC}$

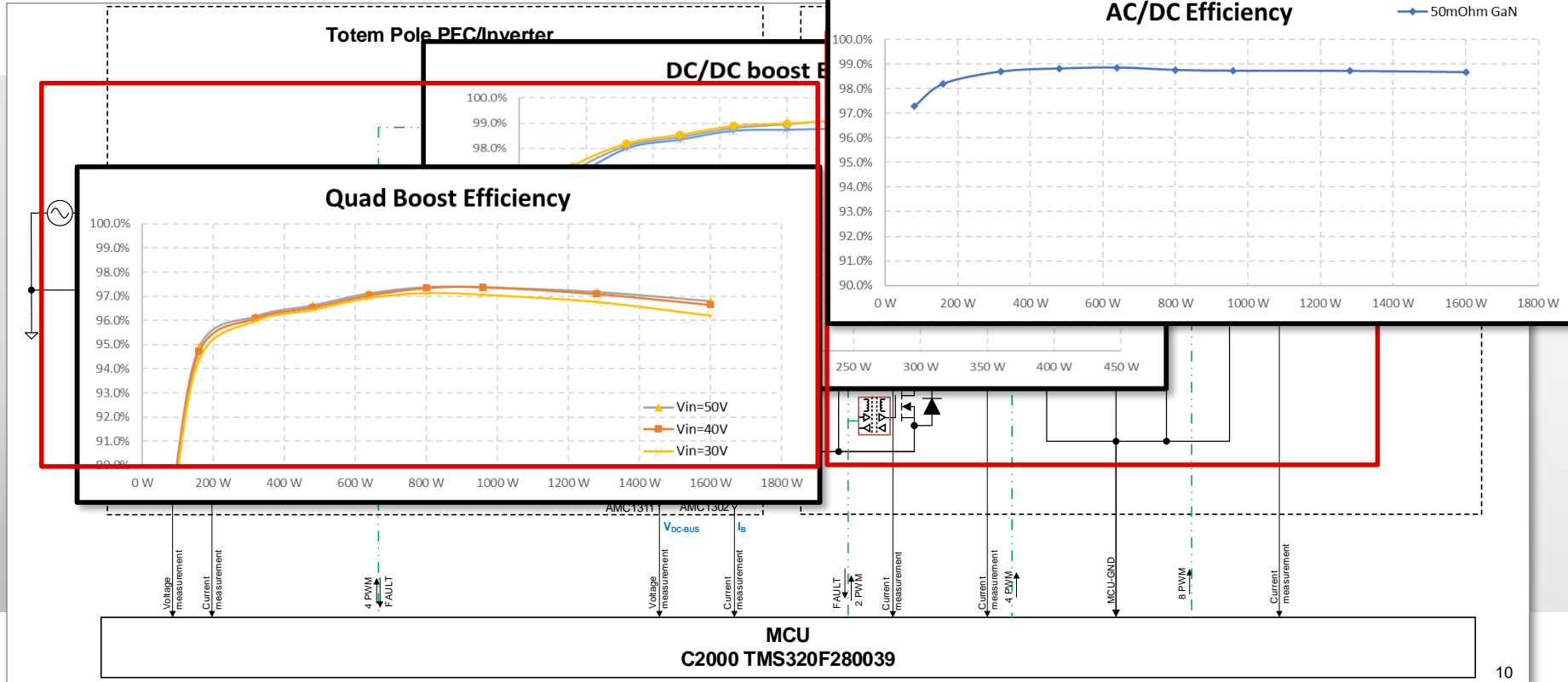
Three stage converter:

$230V_{AC} \leftrightarrow 400V_{DC} \leftrightarrow 75V_{DC} \leftrightarrow 30V_{DC} \dots 60V_{DC}$

Design challenges

- Bi-directional operation on all stages
- High power density $>1kW/L$
- High efficiency

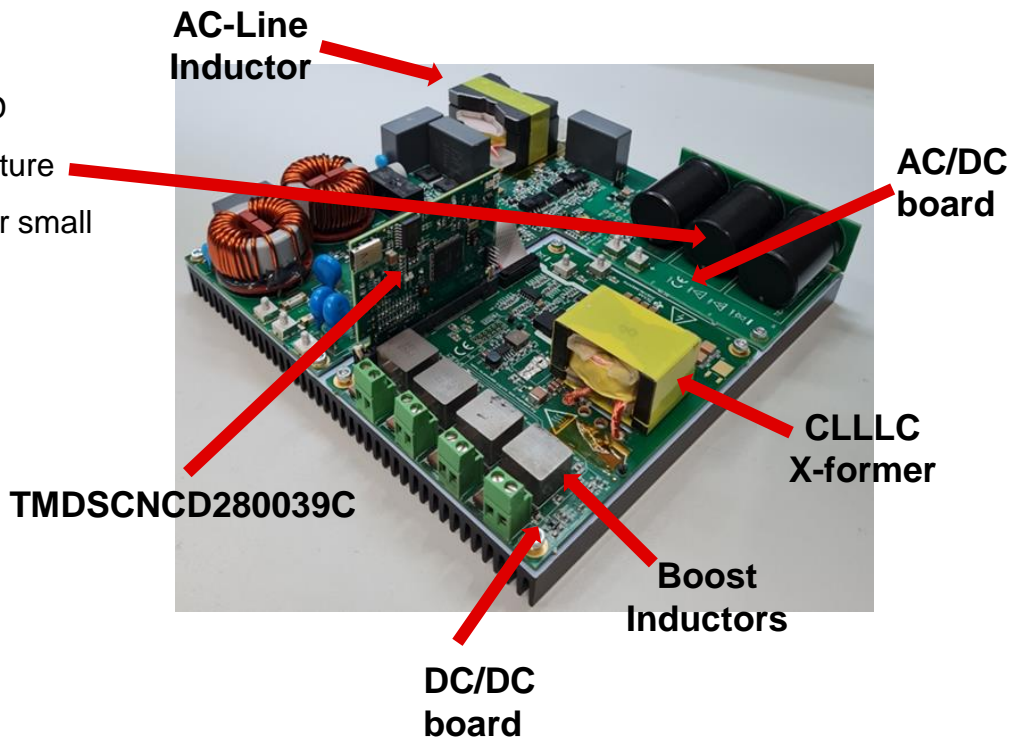
Micro inverter topology for single-phase inverter/PFC with four PV/BAT-inputs



TIDA-010933 reference design highlights

- 2 PCBs: AC/DC & DC/DC board (total 20cm x 20cm)
- TMS320F280039C control card referenced to PV-GND
- No need for huge electrolytic caps because of architecture
- GaN enables high switching frequency which allows for small sized magnetic components
- **High power density: 1kW/L**

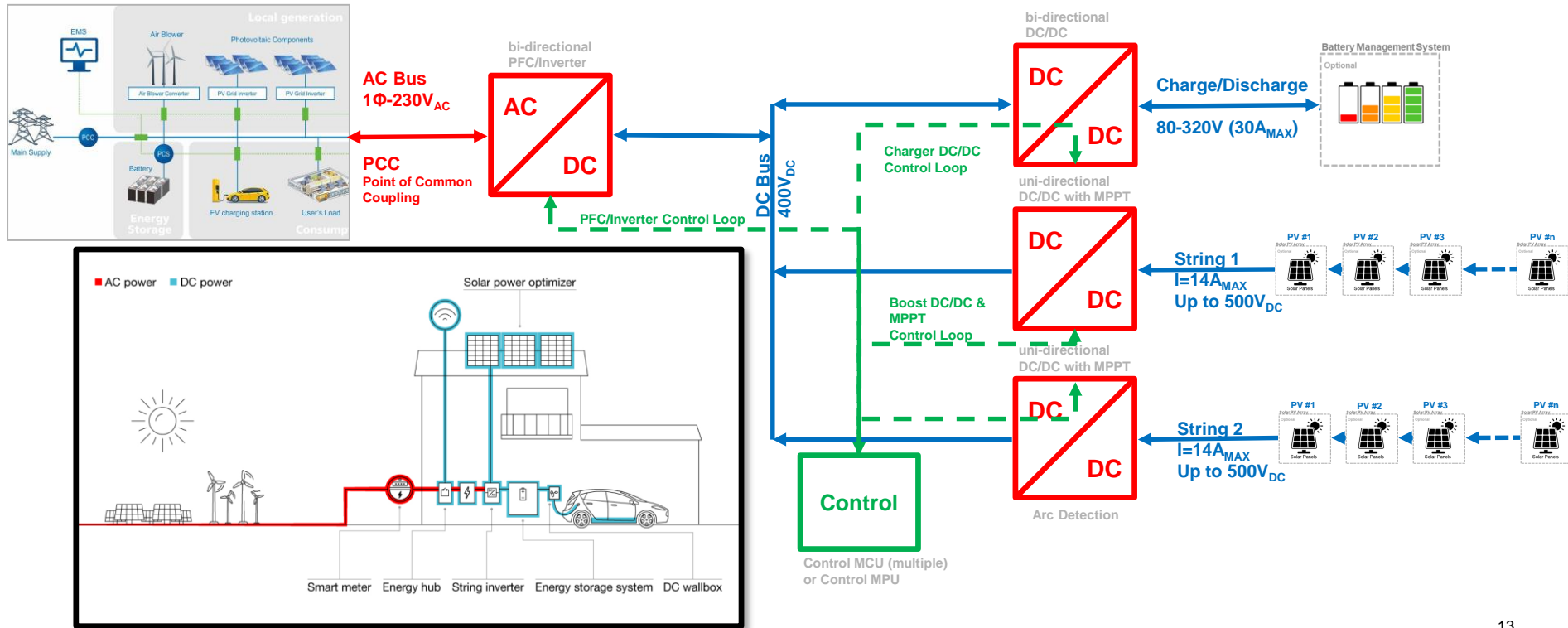
Micro Hybrid Inverter Specifications	Value
DC PV/Bat voltage range	30V to 60V
Maximum input DC current	14A
DC/DC Boost converter switching frequency	250kHz
CLLLC switching frequency	500kHz
Nominal DC link voltage	400V
Maximum DC link current	4A
Nominal output AC voltage	230VAC
Output AC current	7A
DC/AC stage switching frequency	125kHz



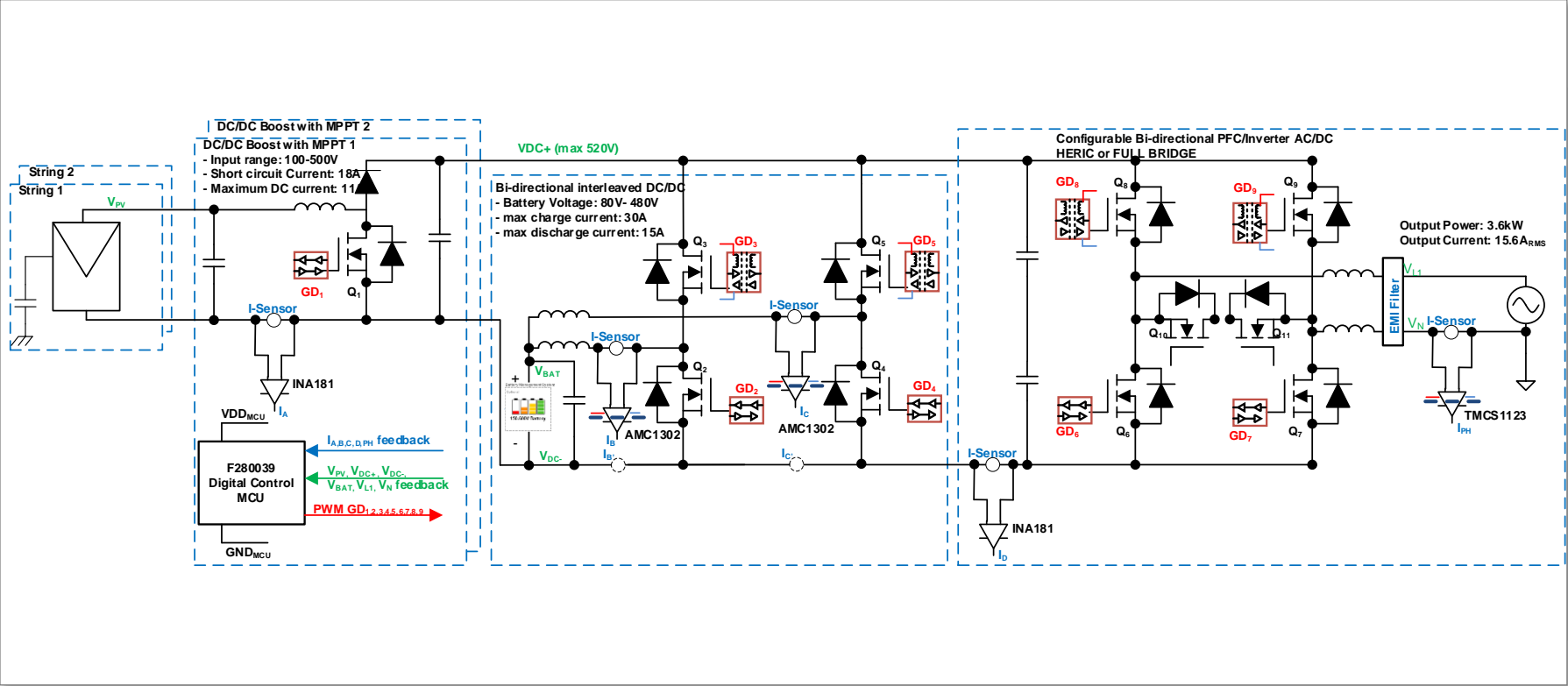
String inverter reference design

TIDA-010938

7.2-kW, GaN-based single-phase string inverter with battery energy storage system reference design

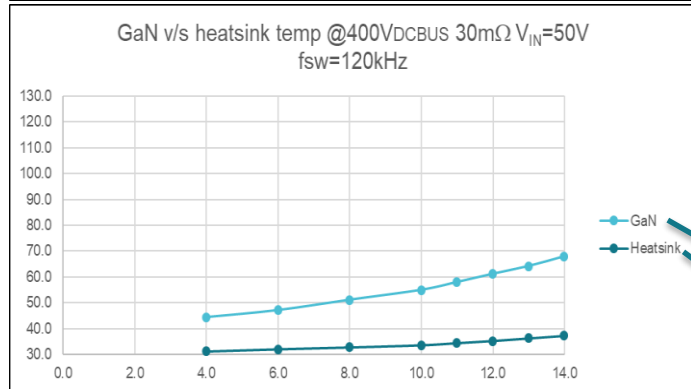
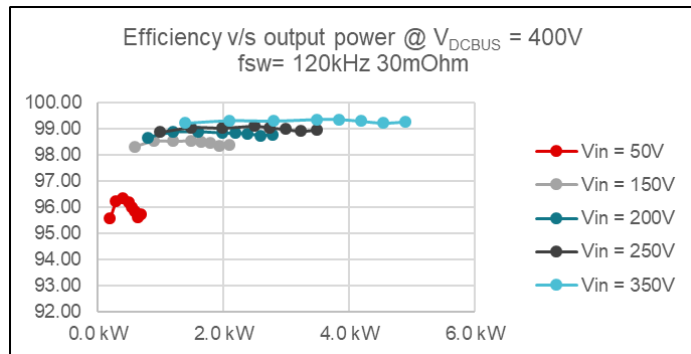


Single phase string inverter topology with BESS support

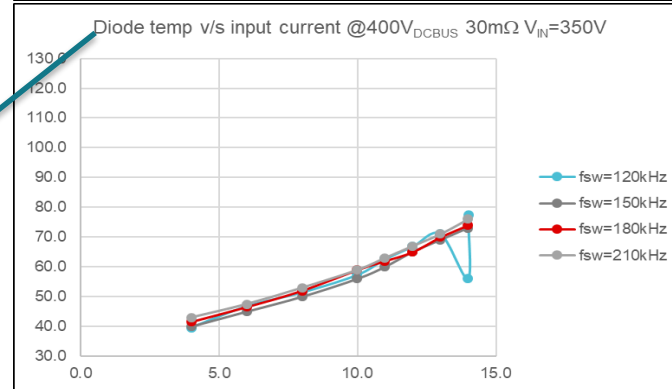
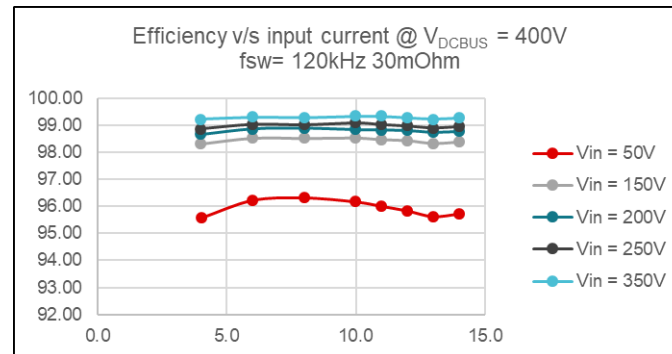
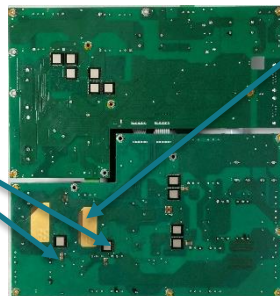
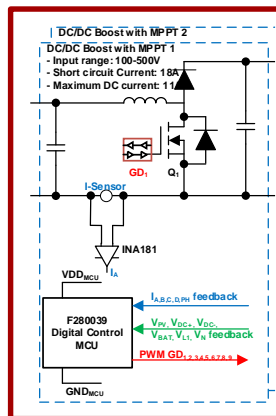


DC/DC boost efficiency for one input

➤ Very high efficiency over wide load range

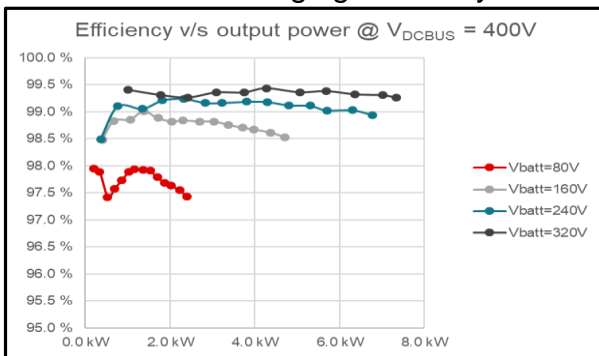


➤ Very high efficiency over wide input current (from PV panel)

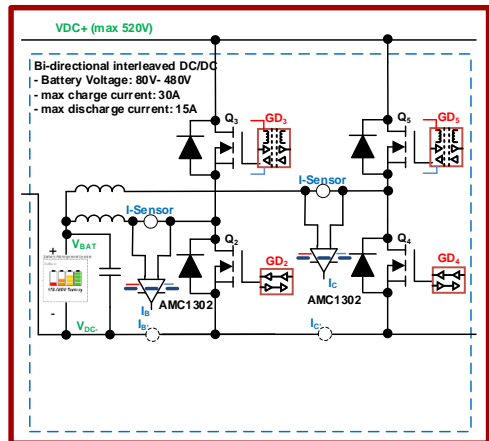
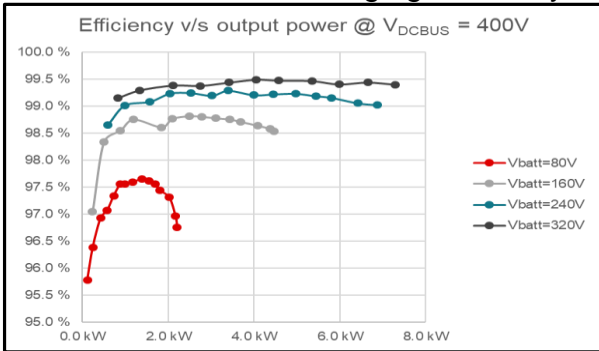


DC/DC bidirectional efficiency for interleaved stages

BUCK mode: charging of battery

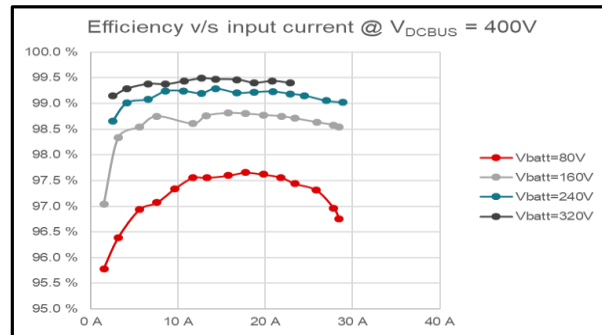
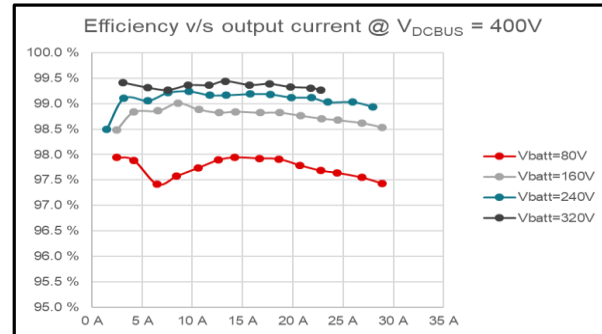


BOOST mode: dis-charging of battery



- $f_{PWM} = 60kHz$ (resulting in 120kHz interleaved)
 - very high efficiency over wide voltage range
 - Charge/Discharge current as high as 29A over wide battery voltages
- Design is able to operate at 320V_{BATT} -> 9kW possible

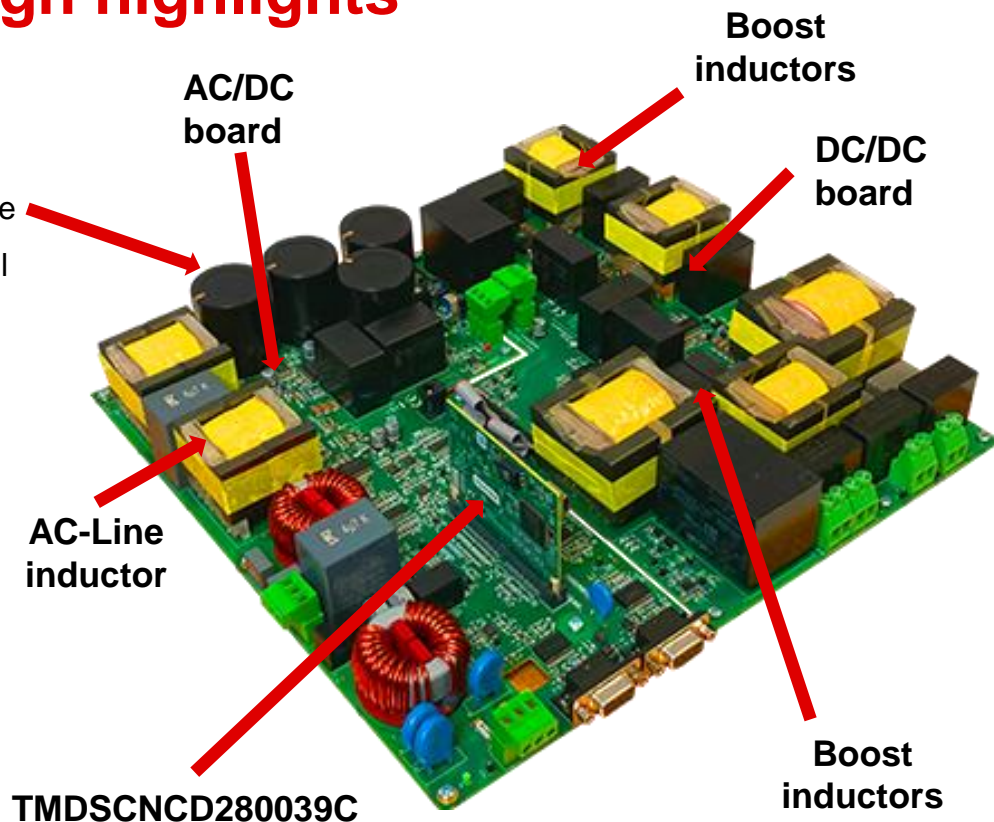
Data points to be measured for discharging mode



TIDA-010938 reference design highlights

- 2 PCBs: AC/DC & DC/DC board (total 29cm x 28cm)
- TMS320F280039C control card referenced to $-V_{DC-link}$
- No need for huge electrolytic caps because of architecture
- GaN enables high switching frequency which allows small sized magnetic components

String hybrid inverter specifications	Value
Maximum Nominal DC link voltage	520V 400V
Rated AC output voltage	230V
Rated AC output power	3.6kW
AC/DC switching frequency	100kHz
Power factor	\pm Active, \pm Reactive
String input voltage	50V to 500V (up to 10 panels per string)
String short circuit current	18A
Nominal DC current	14A string
Rated output power	7.2kW with 2 strings
PV boost switching frequency	120kHz
Battery charging Discharging current	30A 30A
Battery voltage range	80V to 500V
Maximum charge/discharger power @ battery	7.2kW
Battery ESS switching frequency	60kHz each leg
Ambient temperature range	-40°C to +60°C
Cooling	Static cooling or natural convection



Conclusion

- Microinverters and string inverters are trending to bidirectional for BESS and higher power density, and smaller (lower-cost) passive components
- GaN can enable bidirectional topologies and increase power density and efficiency at equivalent cost to Si MOSFET solutions
- TI GaN's integrated gate driver, overtemperature and short circuit protections allows simple system integration



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