Empowering Zero Carbon Unleashing the Potential of Navitas GaN in Solar and Energy Storage Systems

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Solar and energy storge system

PV Inverter

Residential Installations

Typical <10kW


Micro Inverter

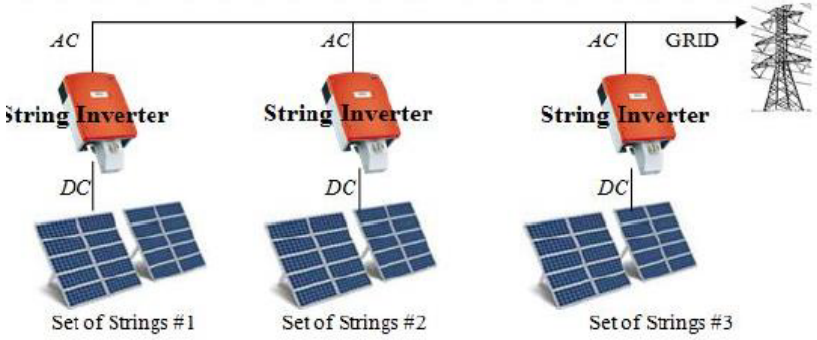


Residential Inverter

Commercial and industrial building installations

500kW-1MW

Block size 15kW – 150kW

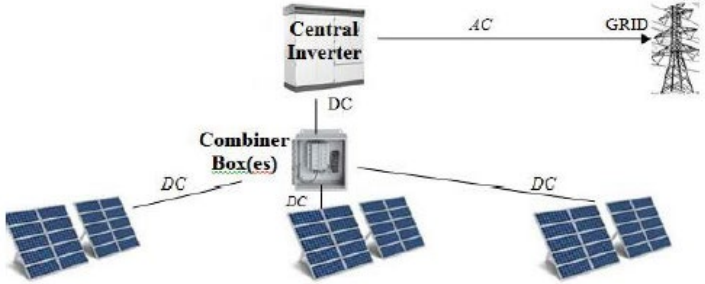
String Inverter

- ✓ Widely used / Up to 98% efficiency
- ✓ Higher flexibility & scalability / Harvesting
- × Moderate system cost

Ground-mounted power plant

1MW-100MW

Block size 150kW - 300kW

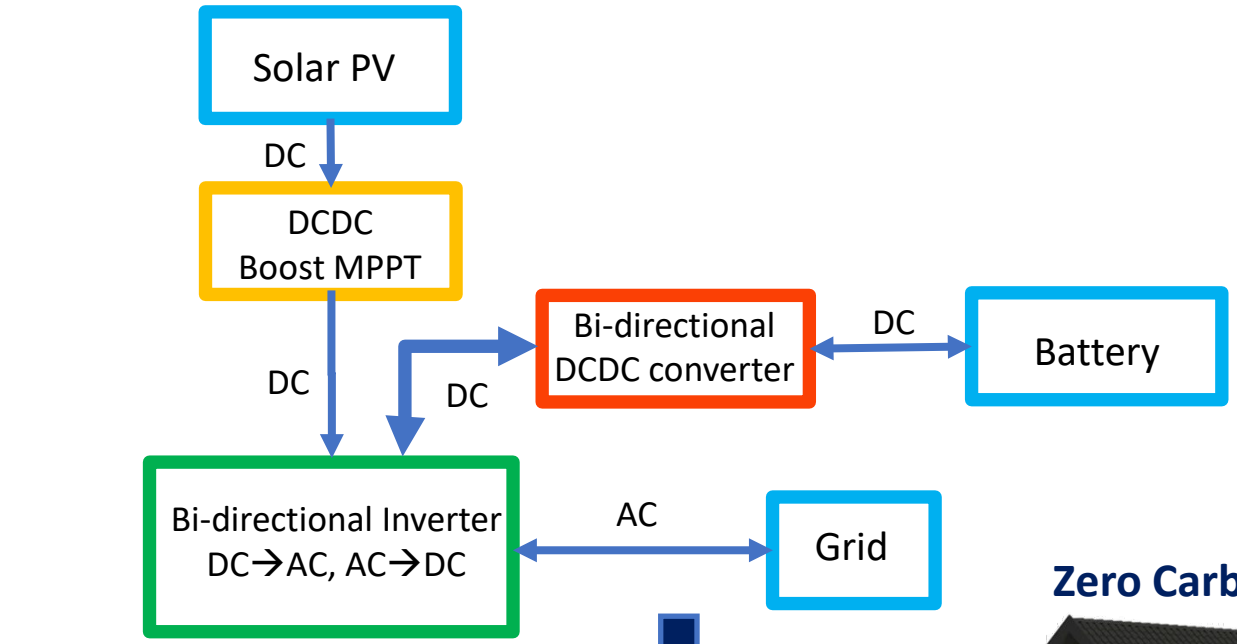
Central Inverter

- ✓ Highest efficiency up to 99%
- ✓ Lower system cost
- × Low flexibility & scalability / Harvesting

Residential Energy Storage

Navitas

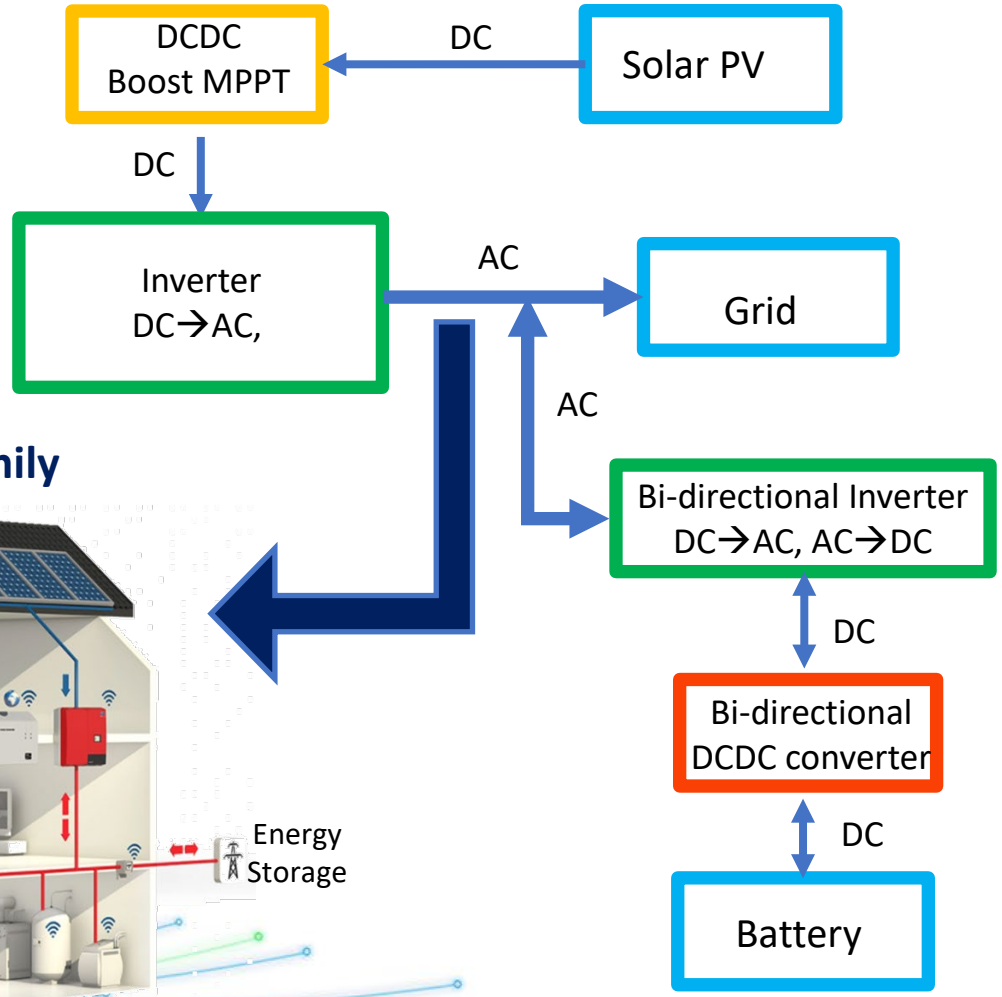
DC Coupled



- ✓ Less DC-to-DC conversion steps from primary power→ More efficient
- × Cannot be added to an existing solar installation

AC Coupled

- ✓ Can be added to an existing solar installation
- × Two conversion steps from primary power→ Less efficient



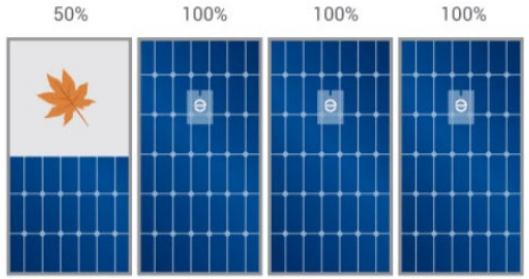
Zero Carbon family

Why Module Level Power Electronics?

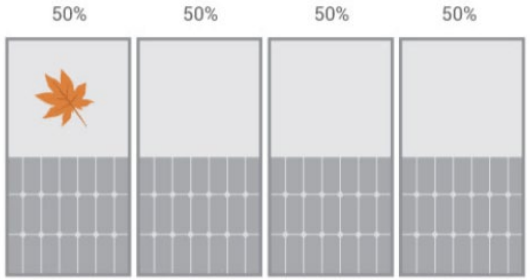
NEC 2017 & 2020

Module-level rapid shutdown requirements

MLPE

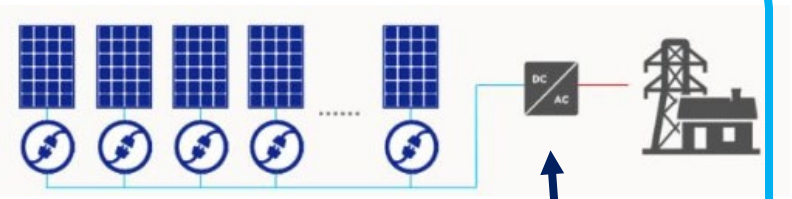


String Inverter

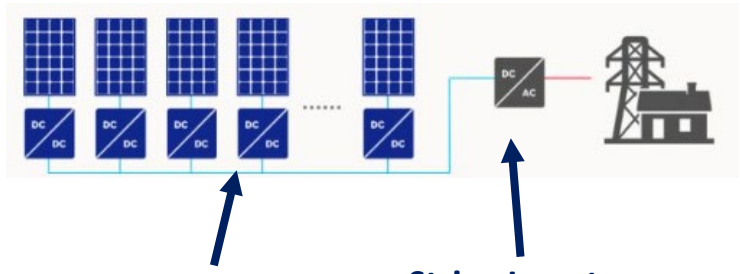


- ✓ Extra electricity yield the energy production of the system ~15%
- ✓ Safer
- ✓ Long year warranties
- ✓ Flexible and simple system design

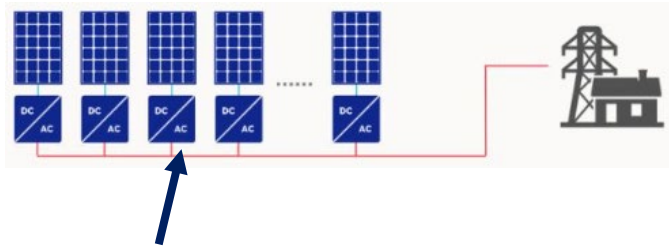
String Inverter + RSD



String Inverter + Optimizer



Micro inverter



MLPE PV Inverter Comparison (<30kW)

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Features	String Inverter + RSD	String Inverter + Optimizer	μ-Inverter
Eliminate electric shock hazard	✓	✓	✓
Eliminate fire hazard	✗	✗	✓
Module level MPPT **(More Electricity)**	✗	✓	✓
Maintenance cost	Medium	Low (Panel level)	Low (Panel level)
Investment Return rate	Low	Medium	**High**
		Preferred when cost difference is acceptable compared with the RSD one.	

- String inverter + Optimizer and μ-Inverter are preferable.
- <20kW, μ-Inverter price is lower.
- 20kW~30kW, string inverter + Optimizer has lower price.

Cost Comparison based on two type of price

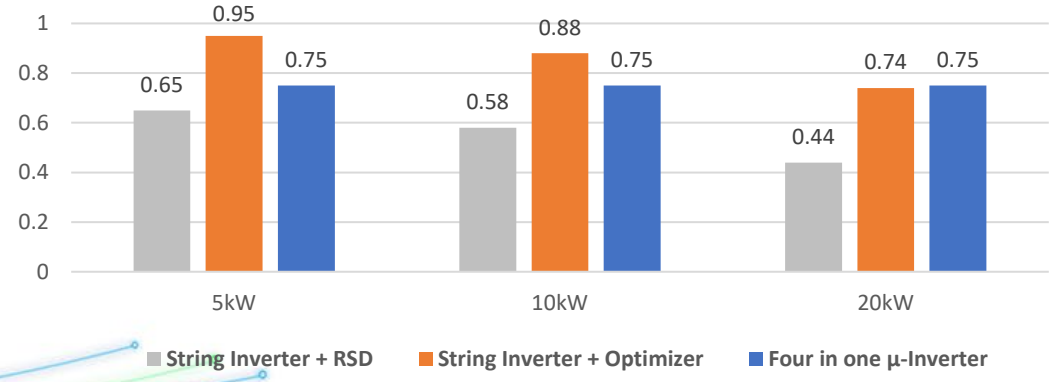
- **MLPE cost**

MLPE Type	Price/Watt (¥)
4 in one μ-Inverter	0.75
RSD	0.15
Optimizer	0.45

- String Inverter per Watt cost VS. power level

Power Level	5kW	10kW	20kW
Price/Watt (¥)	0.5	0.43	0.29

- Comparison Result



Micro-inverter Topologies to Enhance Price Benefit

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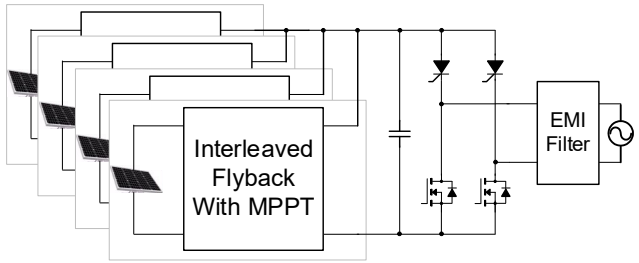
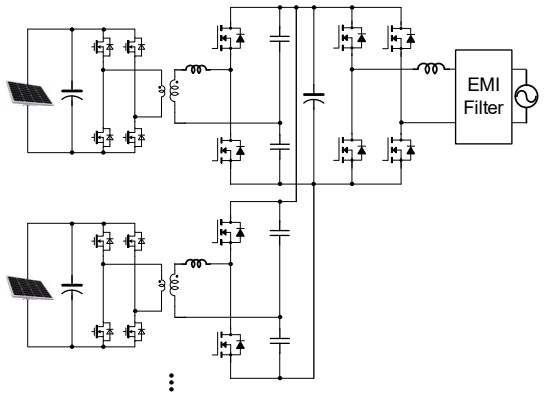
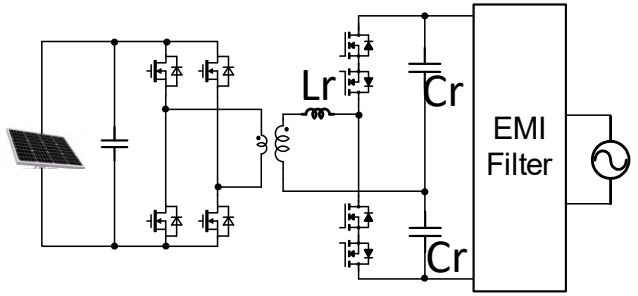
Quasi-Single stage



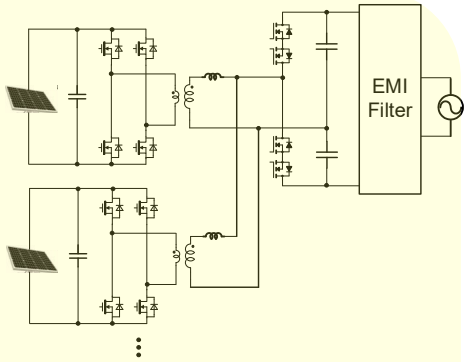
Two stage



Single stage resonant



Single stage Phase-shift



	Quasi-Single stage	Two stage	Single stage resonant	Single stage Phase-shift
Typical Company	H company	A company	X company	Z company
Peak Efficiency	~96.5%	~97.3%	~97.6%	~97.1%
System cost	☺☺☺☺	☺	☺☺	☺☺☺☺
Power density	☹	☺	☺	☺
THD at Non-unity PF	✗	☺	☺	☺
Compatible with N in One	☺	☺	✗	☺

Combine single-stage & N in idea & THD
Promising to be the lowest cost scheme

High Fsw N in One Micro-inverters

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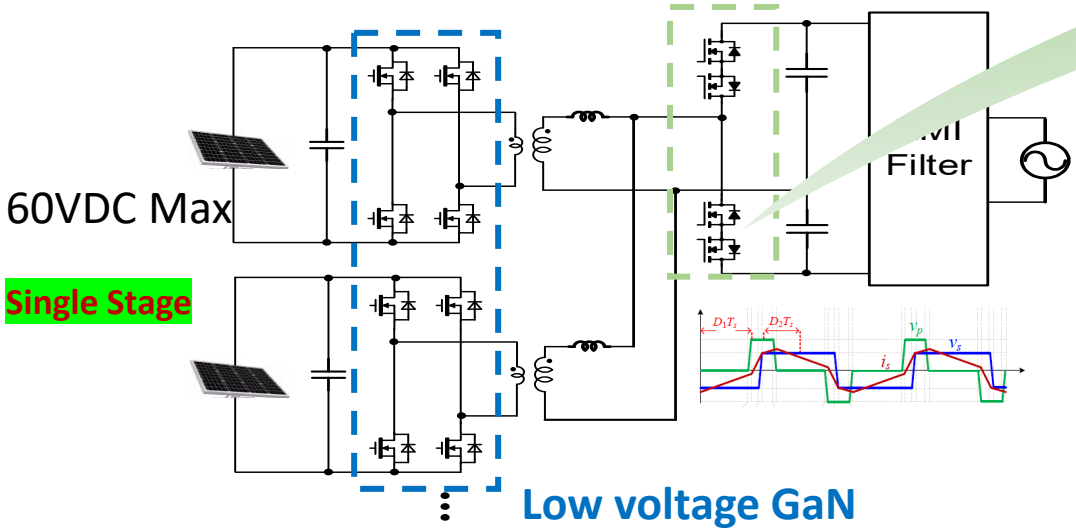
Full-bridge Stage with MPPT

AC/AC Matrix converter Phase shift control

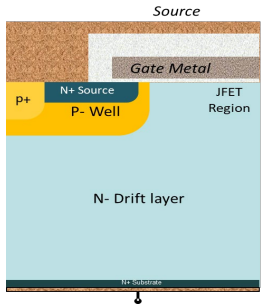


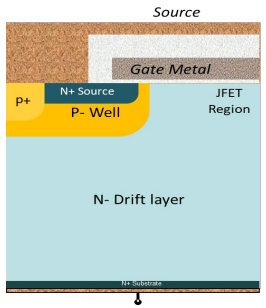
Low voltage GaN

- ✓ Only one integrated power magnetics
- ✓ Reduced BOM, preferably lower cost
- ✓ High efficiency
- × Large electrolytic capacitor at PV side
- × Higher design complexity

Bi-directional switch

Si/SiC MOSFET: Vertical structure





GaN HEMT: Planar structure

Easily be merged in one die

Bi-directional GaN HEMT

Common Source VS Common Drain

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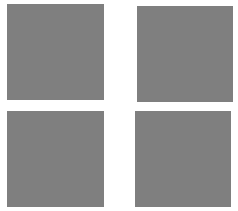
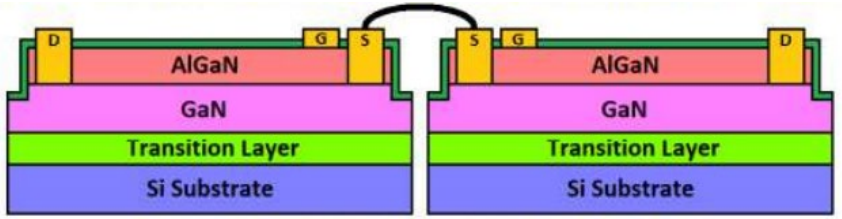
Ratio die area

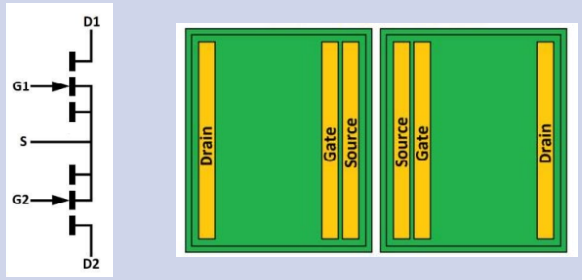


2xUni-directional GaN HEMT



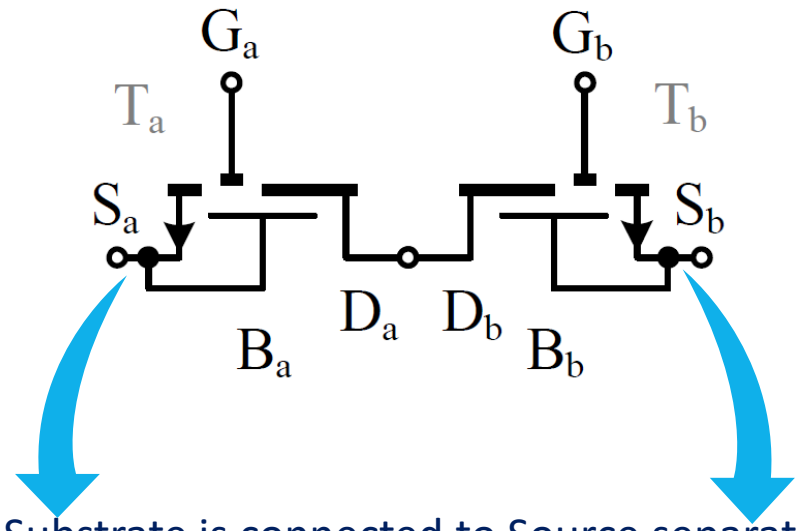
Bi-directional GaN HEMT

Ratio die area

4QS Device	Common Source	Common Drain
Internal structure		 • Sharing drift region • Two gates
Advantage	✓ Simple Aux power supply ✓ Simple gate driver control	✓ Smaller die size ✓ Almost equal Rdson to single device with bi-directional ✓ Lower switching loss
Disadvantage	× Large die size, two dies × Almost double Rdson to single device with bi-directional	× Complicate Aux power supply × Complicate gate driver control × Substrate termination design

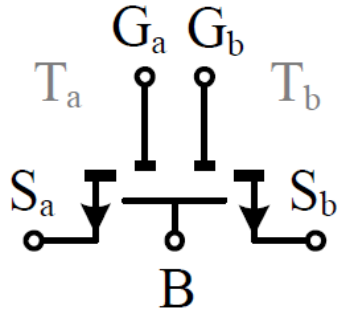
Challenge in Common Drain Bi-directional GaN

2 x Uni-directional GaN

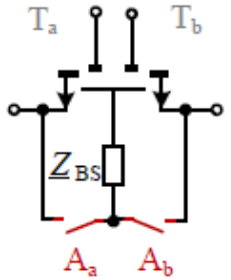


Substrate is connected to Source separately
to minimize back gating effect!

Bi-directional GaN



How to do substrate clamping for bi-directional GaN

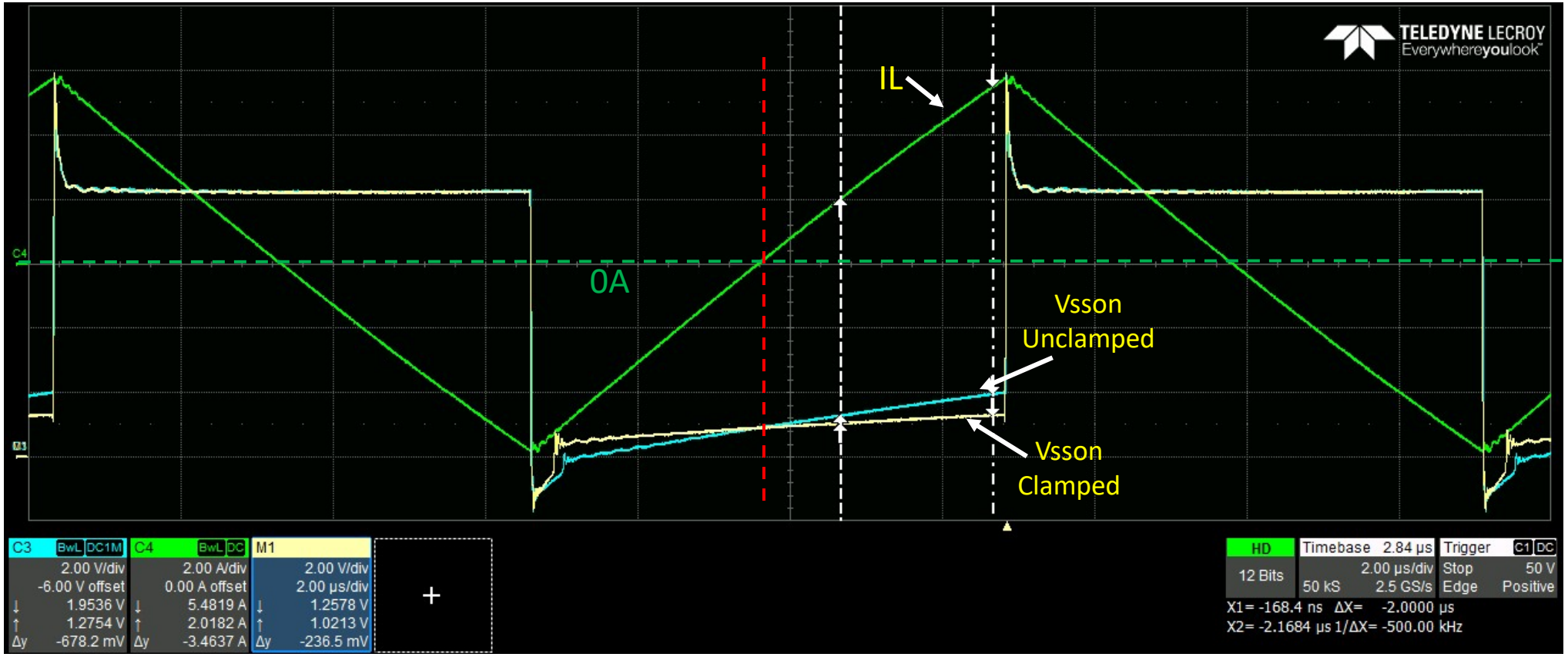


Substrate is clamped based on current flow direction through internal switch

BDS with Integrated Substrate Clamp

Test Conditions:

- V_{IN} = 400V
- F_{SW} = 80kHz
- Duty Cycle = 50%
- I_{L_PEAK} = 6A
- dV/dt = ±14 V/ns
- No probe on substrate



$R_{SS(ON)}$ comparison:

- **Unclamped: 196mΩ**
- **Clamped: 68mΩ**

T_{CASE} comparison (10 min. soak, continuous switching):

- **Unclamped: 76 ^{0}C**
- **Clamped: 61 ^{0}C**

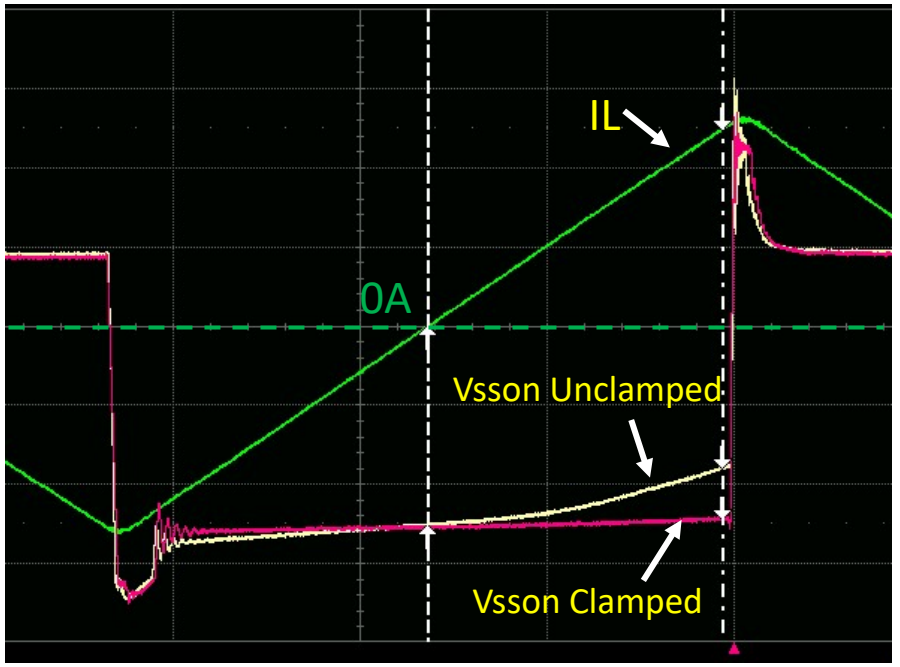
4QS with Integrated Substrate Clamp

ZVS HTOL Test Condition:

- V_{IN} = 520V and I_{L_PEAK} = 3A
- F_{SW} = 150kHz and Duty Cycle = 50%
- Oven Temp = 125 ^{0}C
- No Scope Probe on substrate

Prelim Result / Root Cause:

- Five 70mΩ parts with integrated substrate clamp passing 500+ Hrs
- 5/5 failures for floating substrate parts prior to 168 Hrs checkpoint
- Floating substrate parts experience thermal runaway and degradation

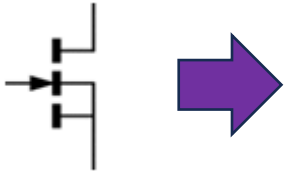


GaNFast™ creates a functional 4QS, overcoming Back-Gate Effect

The Revolution… in GaN

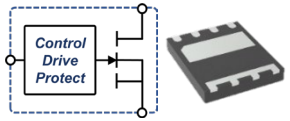
Navitas

Unprotected GaN



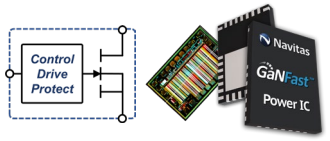
- Exposed gate
- External gate drive
- dV/dt sensitivity
- Layout sensitivity
- ESD sensitivity
- Unknown reliability
- Unknown robustness

GaNFast™ Gen1.0



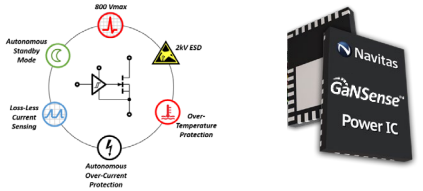
- ✓ Integrated gate drive
- ✓ dV/dt immunity
- ✓ Layout insensitive
- ✓ 2KV ESD rating
- ✓ Proven reliability
- ✓ Proven robustness

GaNFast™ Gen2.0



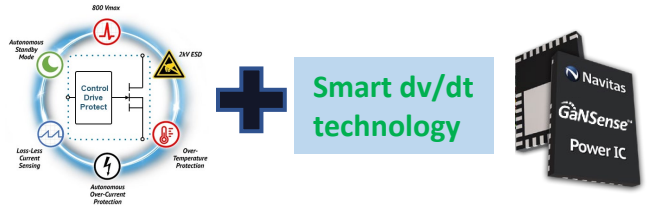
- ✓ Integrated gate drive
- ✓ dV/dt immunity
- ✓ Layout insensitive
- ✓ 2KV ESD rating
- ✓ Proven reliability
- ✓ Proven robustness
- ✓ Larger cool pad&package

GaNSense™ Gen3.0



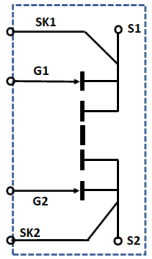
- ✓ Autonomous standby
- ✓ Autonomous protection
- ✓ Loss-less current sensing
- ✓ High precision for current sensing
- ✓ High efficiency

GaNSense™ Gen4.0

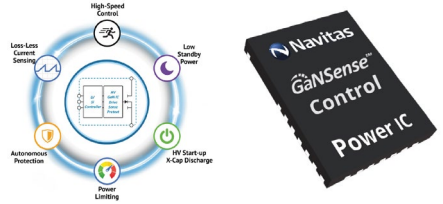


- ✓ Autonomous standby
- ✓ Autonomous protection
- ✓ Loss-less current sensing
- ✓ High precision for current sensing
- ✓ High efficiency
- ✓ EMI improvement

4 Quadrant Switch GaN

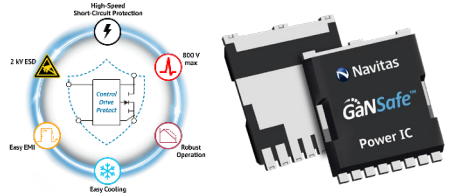


GaNSense™ Control Gen4.0



- ✓ Loss-less current sensing
- ✓ Autonomous protection
- ✓ High efficiency
- ✓ < 20mW stby power
- ✓ Multi-mode CCM/DCM + variable freq ctrl
- ✓ Fewest external components
- ✓ Smart dv/dt control easy EMI

GaNSafe™ Gen4.0



- ✓ Autonomous standby&protection
- ✓ Thermal-enhcnced with larger package TOLL PWM
- ✓ GaN safe
  - ✓ OTP setpoint 170C , SCP<=200ns dv/dt immunity , 2kv for all pin

GaNSense Half-Bridge Gen4.0

- ✓ Highest integration
  - ✓ integrated HS and LS FETs
  - ✓ Integrated level-shift isolation
  - ✓ integrated boot-strap
  - ✓ Shoot-through protection
  - ✓ Enlarged cooling pads
- ✓ Fastest switching
- ✓ Highest efficiency

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