From Back-to-Back to Monolithic: The Role of GaN BDS in Next-Generation Power Electronics

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Bodo's Wide Bandgap Event 2025

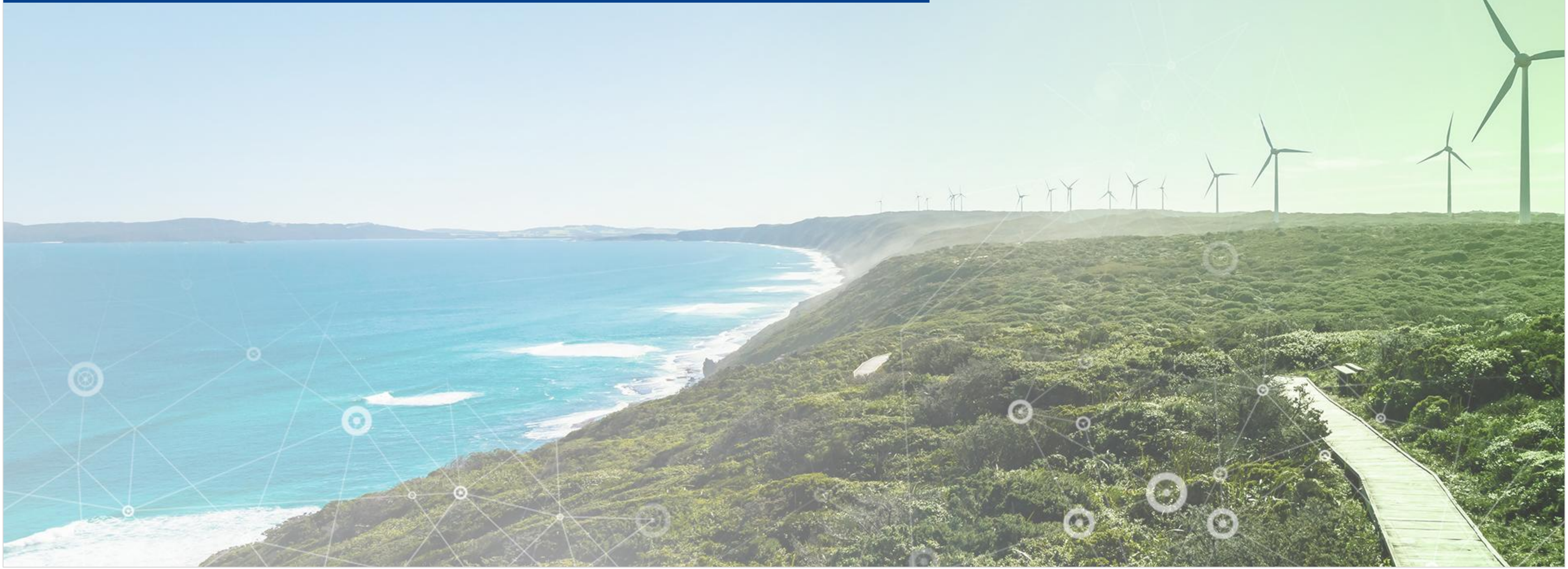
Making WBG Designs Happen

GaN

AGENDA

- INTRODUCTION: BDS GaN OVERVIEW
- BDS GaN BASED MICRO-INVERTER
- BDS GaN BASED VIENNA RECTIFIER
- CONCLUSION

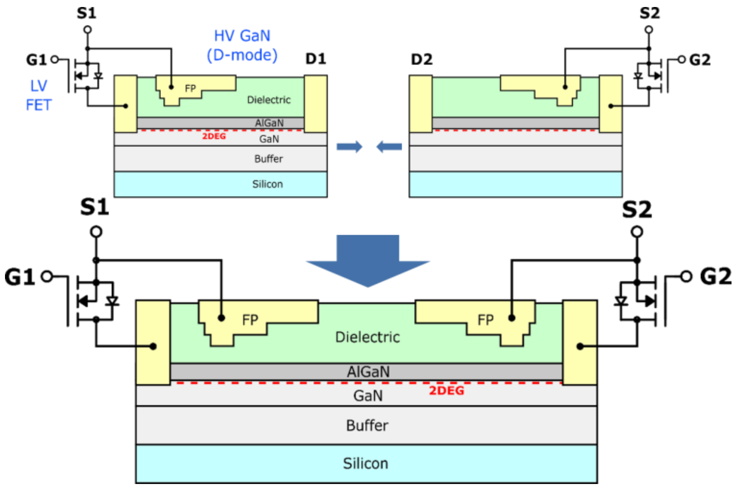
INTRODUCTION: BDS GAN OVERVIEW

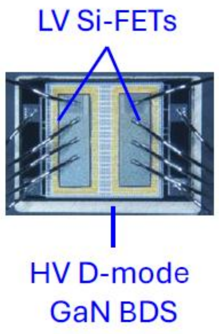


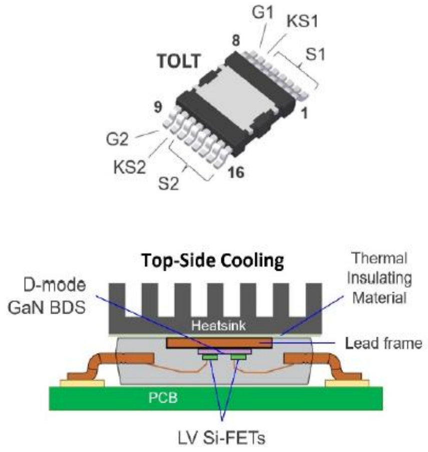
MONOLITHIC BDS WITH D-MODE GAN OVERVIEW

Bidirectional GaN Cascode enables:

- Monolithic HV GaN achieving low $R_{on,sp}$
- High and stable V_{th} (3V)
- AC and DC blocking capability
- High di/dt & dV/dt immunity

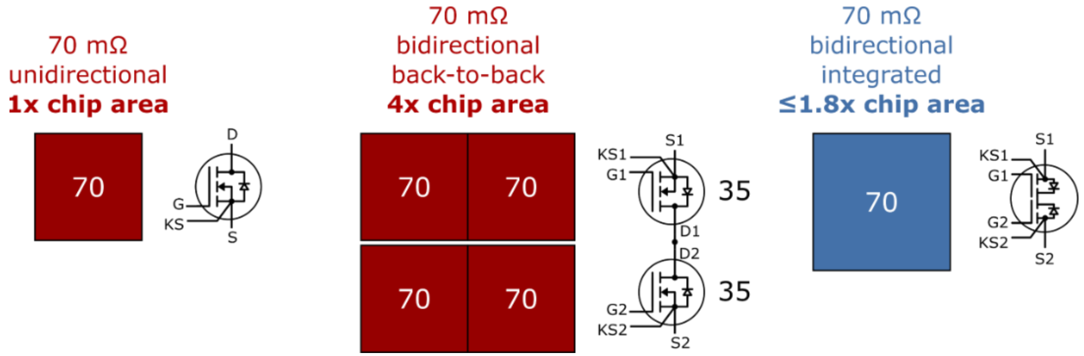




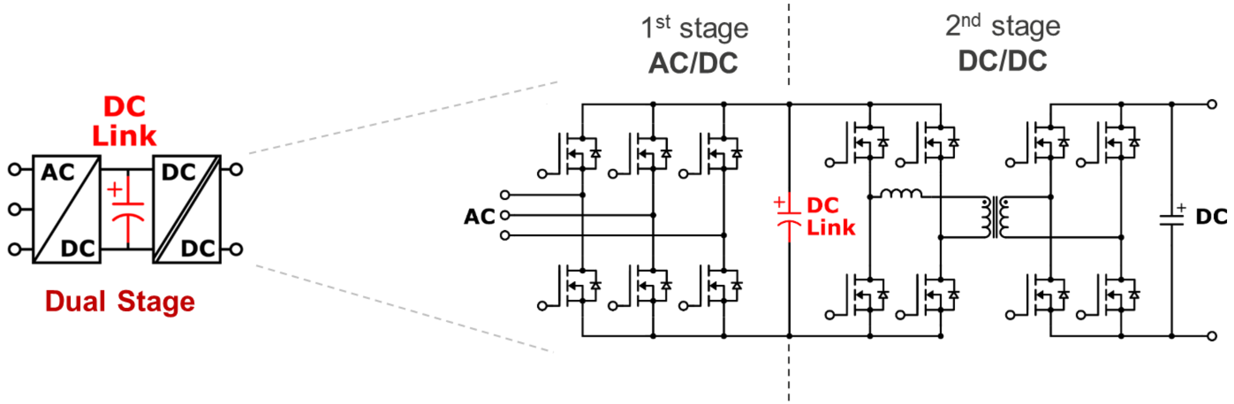


System Level Benefits:

- Improve solution size and cost
- Improve reliability by reducing number of active components
- Improve system efficiency



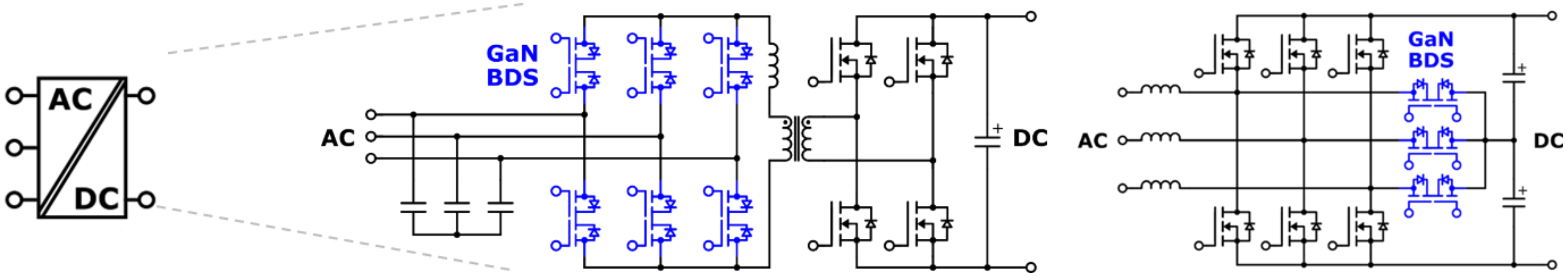
BIDIRECTIONAL GAN ENABLES SINGLE-STAGE CONVERTERS



Bi-Directional GaN enables Single-Stage Power Conversion

- **Reduced System BoM and Cost**
- **Higher Conversion Efficiency**

Single Stage (isolated)

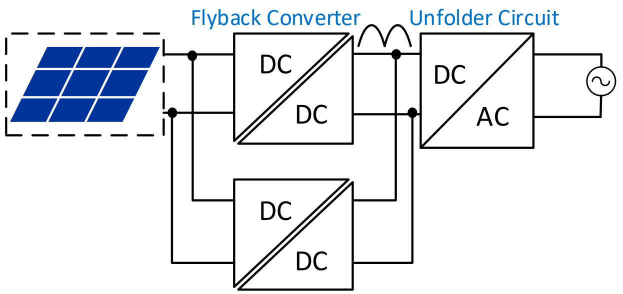


BDS GAN REDUCING NUMBER OF CONVERSION STAGES - MICROINVERTER

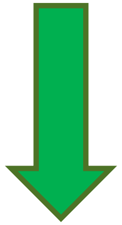
- **Minimizing Power Conversion stages to:**
  - reduce the BOM size and cost
  - increase the power density
  - maximize the system efficiency

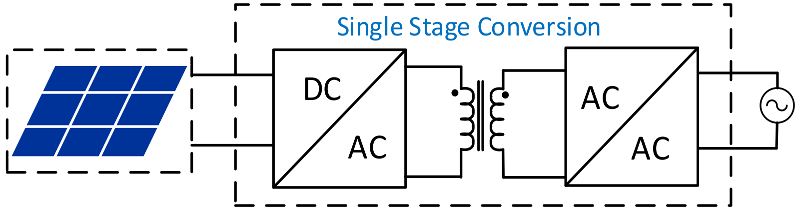
- Today most common solution for Microinverter consists of one or multiple Flyback converter stages followed by unfolder DC-AC converter
  - Disadvantages:
    - poor efficiency figures
    - higher BOM size and cost
    - low power density compared to most advanced/trending topologies

- Future trend focuses on DAB based single stage solutions.
  - **Advantages**:
    - improving BOM cost and size
    - system Efficiency and power density.



Flyback + unfolder based Microinverter





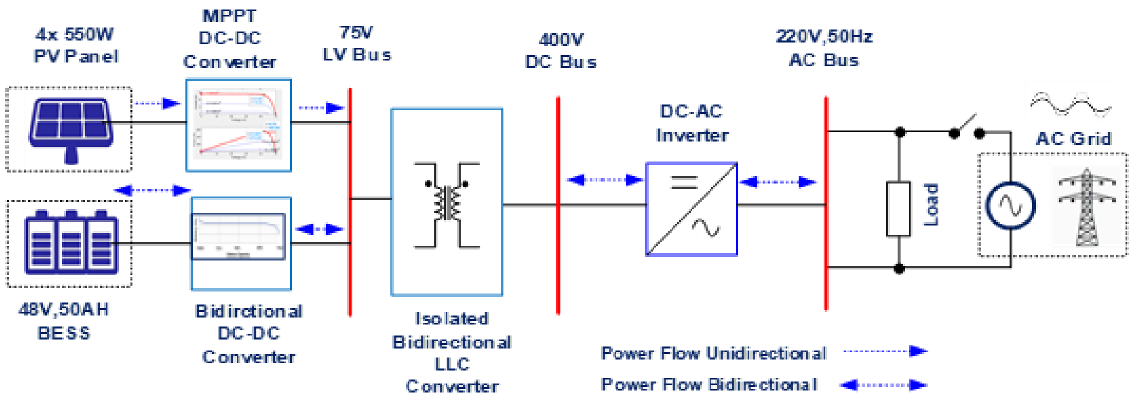
Single stage DAB based Microinverter

BDS GAN REDUCING NUMBER OF CONVERSION STAGES – HYBRID INVERTER

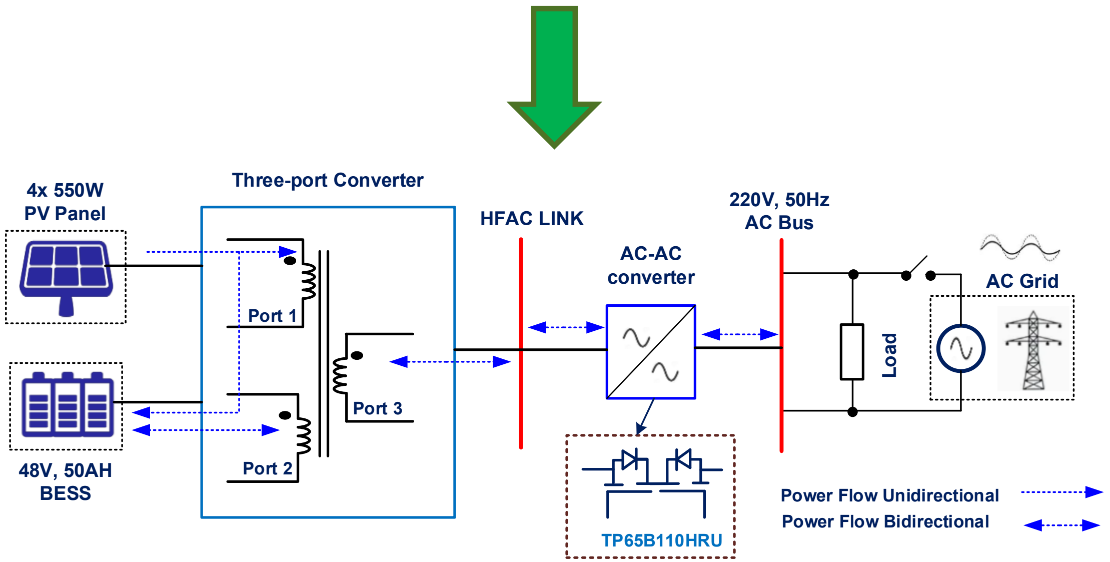
- **Minimizing Power Conversion stages to:**
  - reduce the BOM size and cost
  - increase the power density
  - maximize the system efficiency

- Today most common solution for Hybrid-Inverter consists of Intermediate Bus architecture, with multiple DC Bus, first from PV and ESS to ~75V, second 400V HV isolated rail
  - Disadvantages:
    - Multiple power conversions lower system efficiency
    - higher BOM size and cost
    - low power density compared to most advanced/trending topologies

- Future trend focuses on Multiport single DC-DC stage solutions.
  - **Advantages**:
    - improving BOM cost and size
    - Increasing system Efficiency and power density.



Intermediate Bus- based Hybrid Inverter



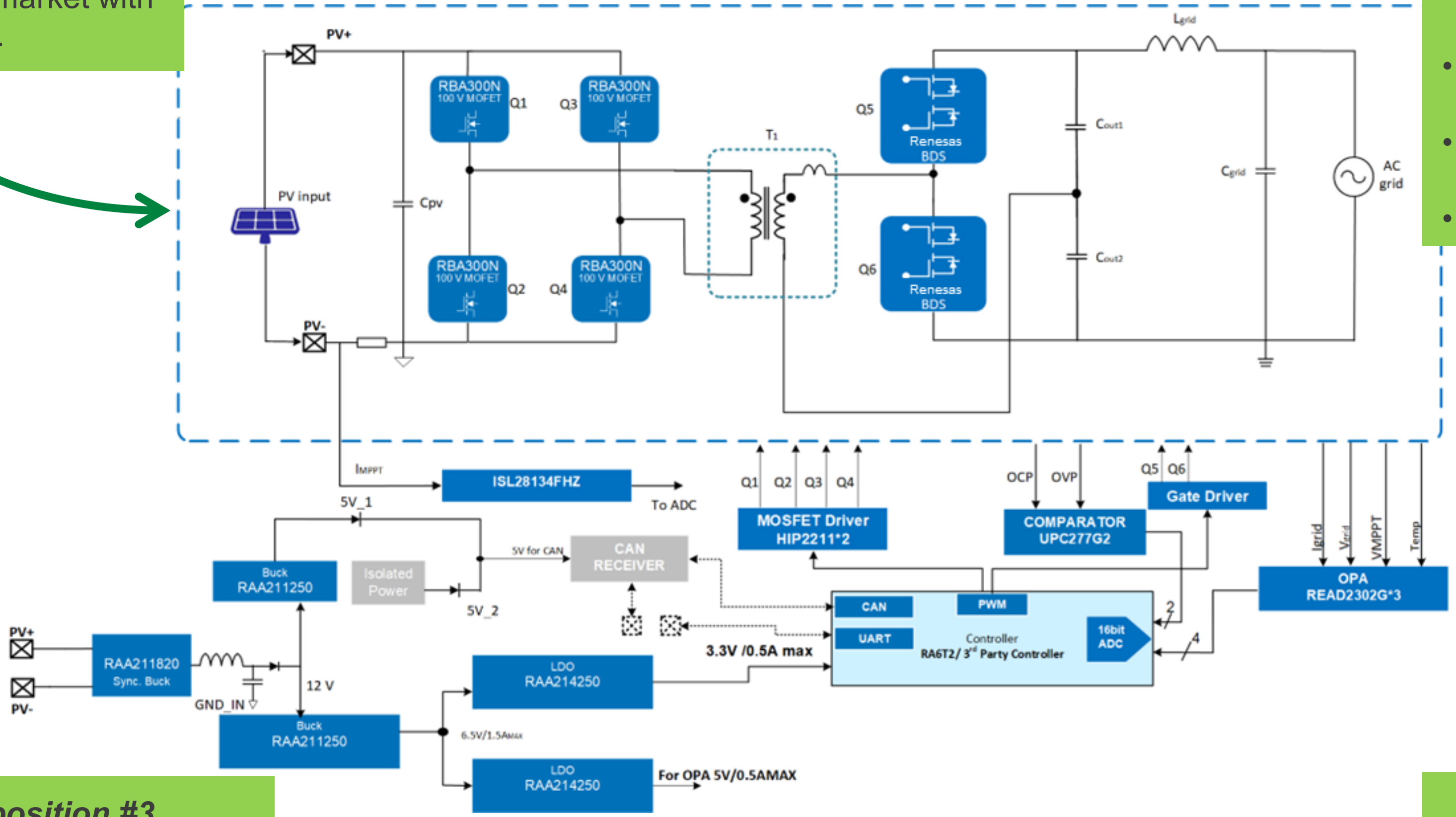
Multiport Hybrid inverter

BDS GAN BASED MICROINVERTER

500W DAB-BASED MICROINVERTER: SYSTEM BLOCK DIAGRAM

Value Proposition #1
Faster solution to market with Renesas HW+SW.

Value Proposition #2
- 40 % Reduction in weight and volume in comparison with Flyback based solutions.
- Reduced BOM cost with single stage conversion.
- High Efficiency operation with peak efficiency upto 97%.
- High power density >4.5 W per in^3



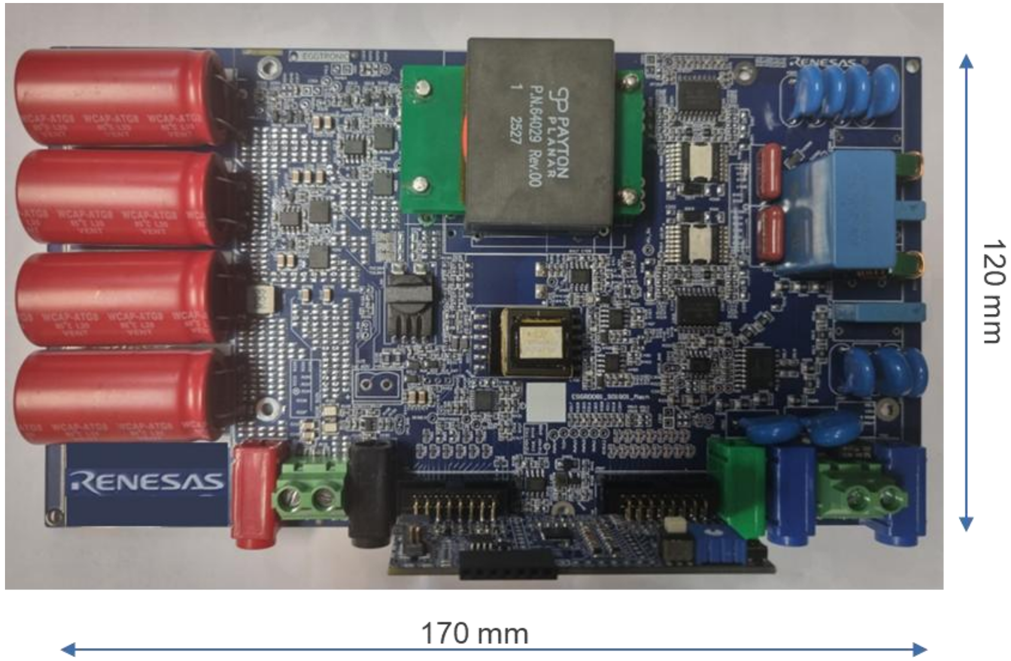
Value Proposition #3
Compact design with Renesas GaN operating at 200 kHz to 800 kHz.

Value Proposition #4
Single stage low power solution serving residential on grid/ off grid loads.

500W MICROINVERTER PROTOTYPE WITH BDS GAN AND 80V REXFET

Single Stage Microinverter Prototype Features

- DAB-based topology capable of operating in on grid/off grid mode through Single PV panel as a source.
- Operates with high efficiency (Target peak efficiency: 97%).
- High F_{SW} operation ensures compact Magnetics and ensures high power density.
- Zero Voltage Switching (ZVS) operation throughout the operating range.
- Low Ron REXFET forms primary bridge and GaN BDS forms the AC-AC secondary bridge network.
- Includes Over current protection, over voltage protection, over temperature protection.
- Improved Efficiency at light load with burst mode operation.



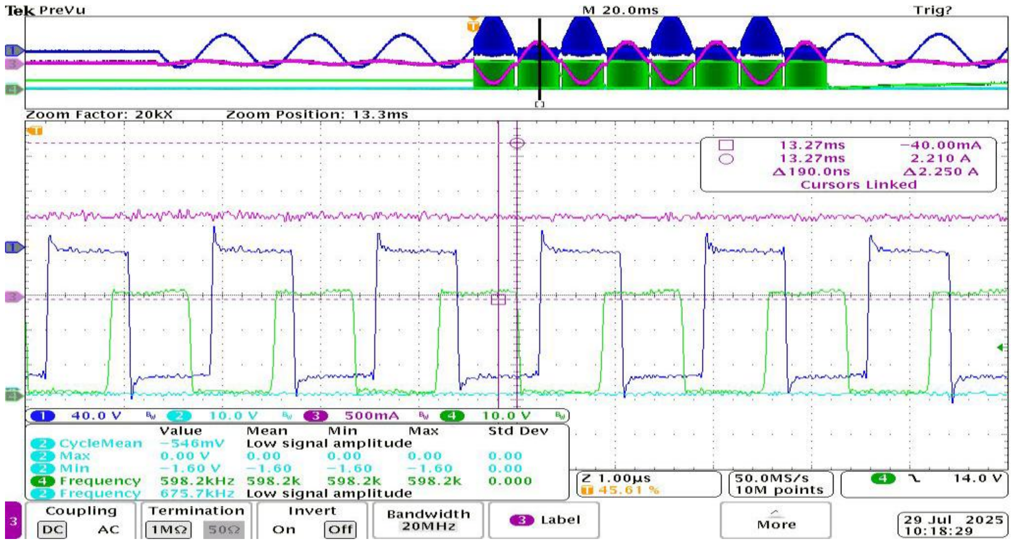
Specifications	
VAC	1 phase, 240VAC rms
IAC	2.2A rms
Power	500 W
Switching Frequency	200 kHz to 800 kHz
Controller	RA6T2 or EPIC2 (Eggtronic)

Renesas Power BoM	
TP65B110HRU	650V BDS GaN, 140mΩ, TOLT
RBE024xxxxx	80/100V REXFET MOSFET
HIP2210	100V, 3A Source, 4A Sink, High Frequency Half-Bridge Drivers
RAA211820	Integrated FET 75V, 2A Synchronous Buck Regulator
RAA211250	Integrated FET 30V, 5A Synchronous Buck Regulator

500W MICROINVERTER POC PERFORMANCES

Microinverter Switching Waveforms

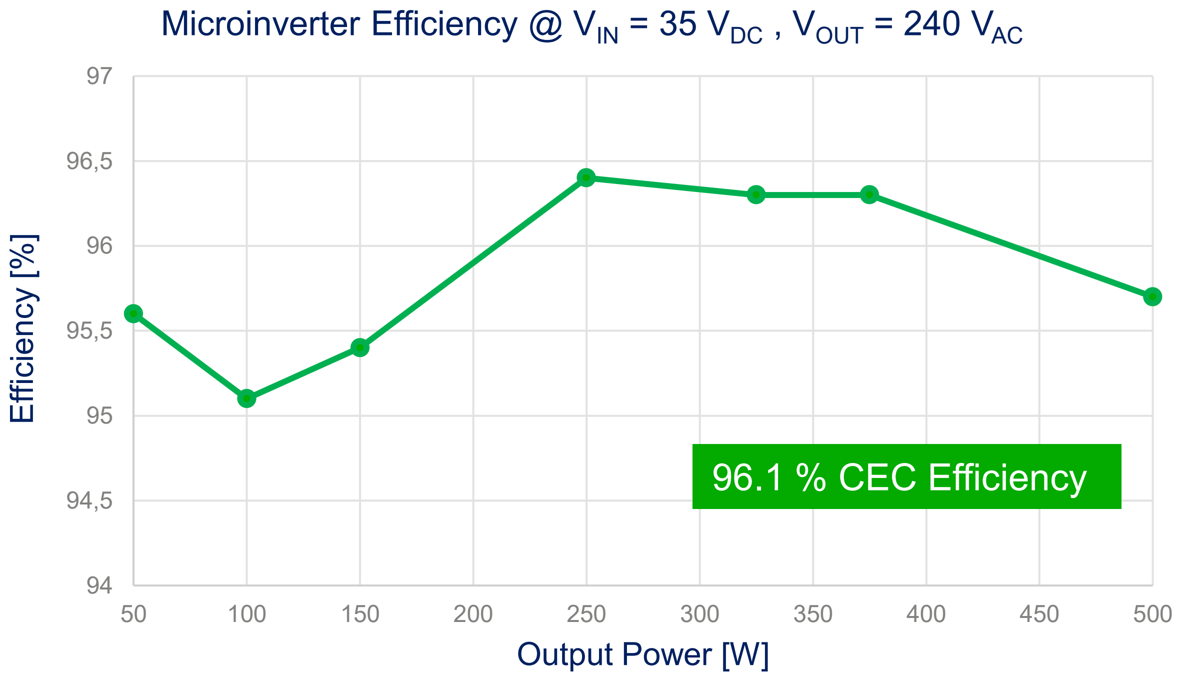
Transformer Secondary Voltage (Blue); Grid Current (Magenta), Primary MOSFET switching signal (Green)



- PLL is synched with grid, with observable transformer secondary voltage.
- Phase shift is maintained between primary and secondary bridges to deliver required power to the grid.
- The switching frequency is varied from 200 kHz to 800 kHz to reduce the harmonics and maintain the continuous conduction even at zero crossing.
- GaN BDS enables high frequency operation achieving high power density

Preliminary Efficiency Measurements

Single-Stage converter efficiency outperforms existing dual-stage solutions

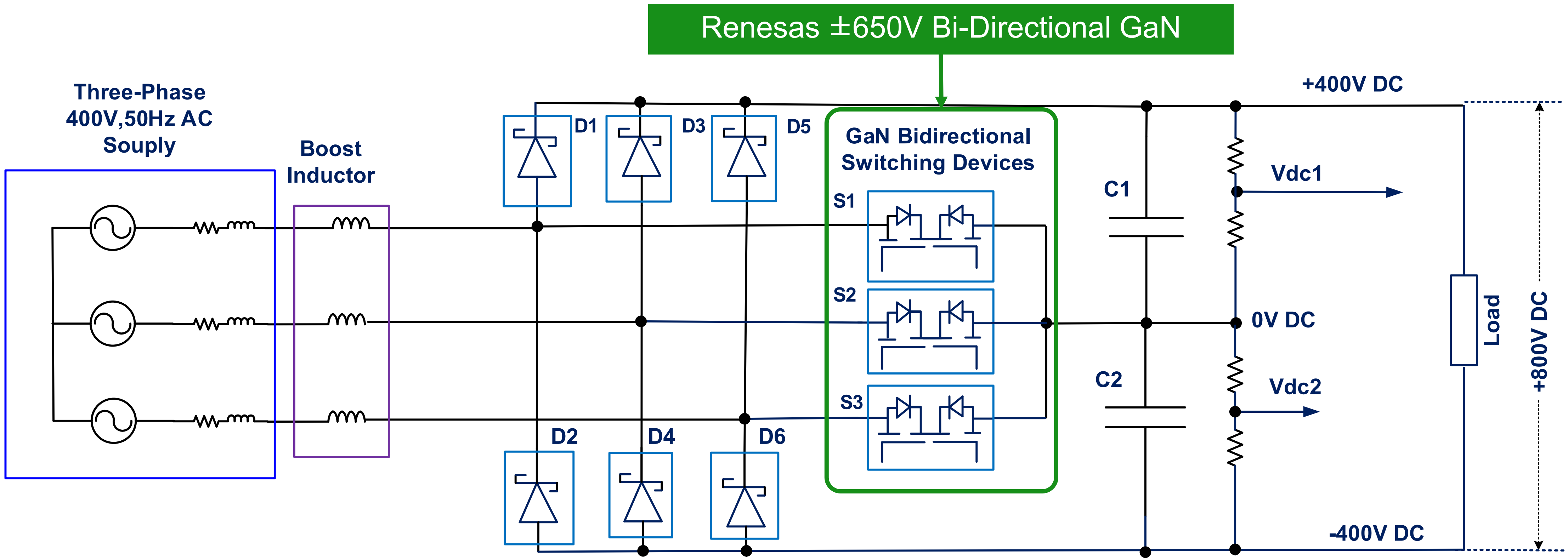


Preliminary Results:
the ongoing optimization process is expected to further improve efficiency performance

BDS GAN BASED VIENNA RECTIFIER

3-PH VIENNA RECTIFIER: TOPOLOGY OVERVIEW

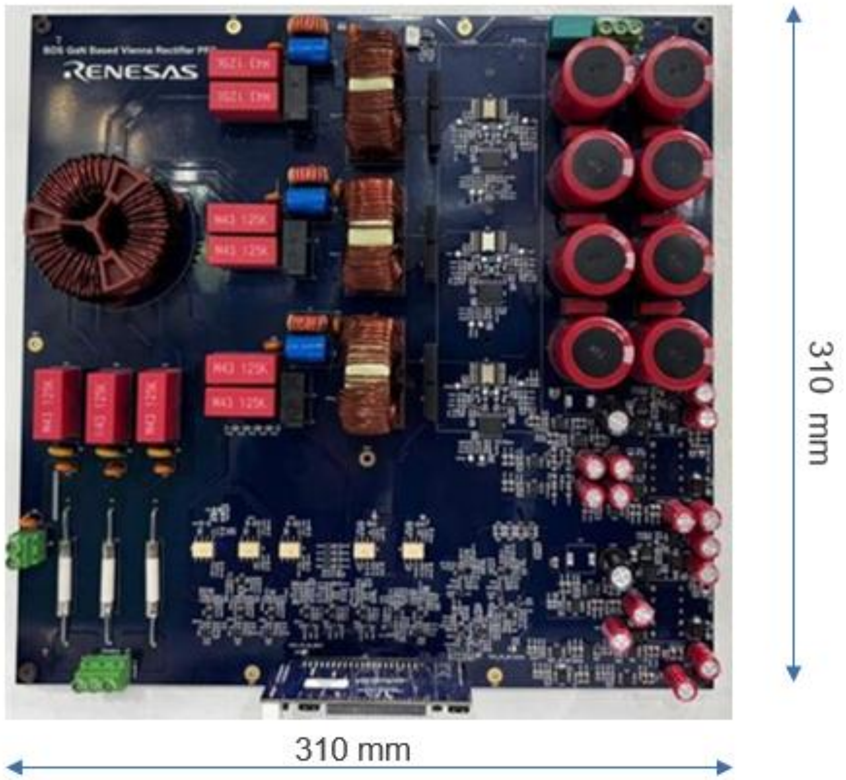
- Vienna rectifier is a unidirectional three-level AC-DC converter, which is widely used in AC-DC PFC applications.
- Three bidirectional GaN switches one per phase employing two gates.
- Voltage stress on the power switches is only half of the output voltage.
- A single GaN BDS device replace 2x switches in back-to-back configuration, reducing BoM size and cost



3.6 KW VIENNA RECTIFIER PROTOTYPE WITH BDS GAN

Vienna Rectifier Prototype Features

- The Vienna Rectifier is a non-isolated PFC converter which rectifies a 3ph AC Input to a ±400V or 800V DC Bus
- This PoC delivers up to 3.6 kW power to the DC Bus in a compact form factor. Higher power can be achieved by exploiting lower $R_{ds,on}$ BDS GaN device
- Bi-Directional HV GaN devices replace the back-to-back structure by enhancing system performance while reducing BoM size and cost
- The RX26T Renesas core MCU is used as Digital Power Controller
- Switching frequency up to 100kHz w/ cycle-by-cycle PWM update
- RX26T includes fast analog comparators for fast current protection
- Enhanced reliability guarantee by single BDS GaN device



Specifications	
VAC	3 phase, 460 VAC rms
IAC	2.2A rms
Output Power	3.6 kW
Switching Frequency	Up to 100 kHz
Controller	RX26T (Renesas-Core MCU)

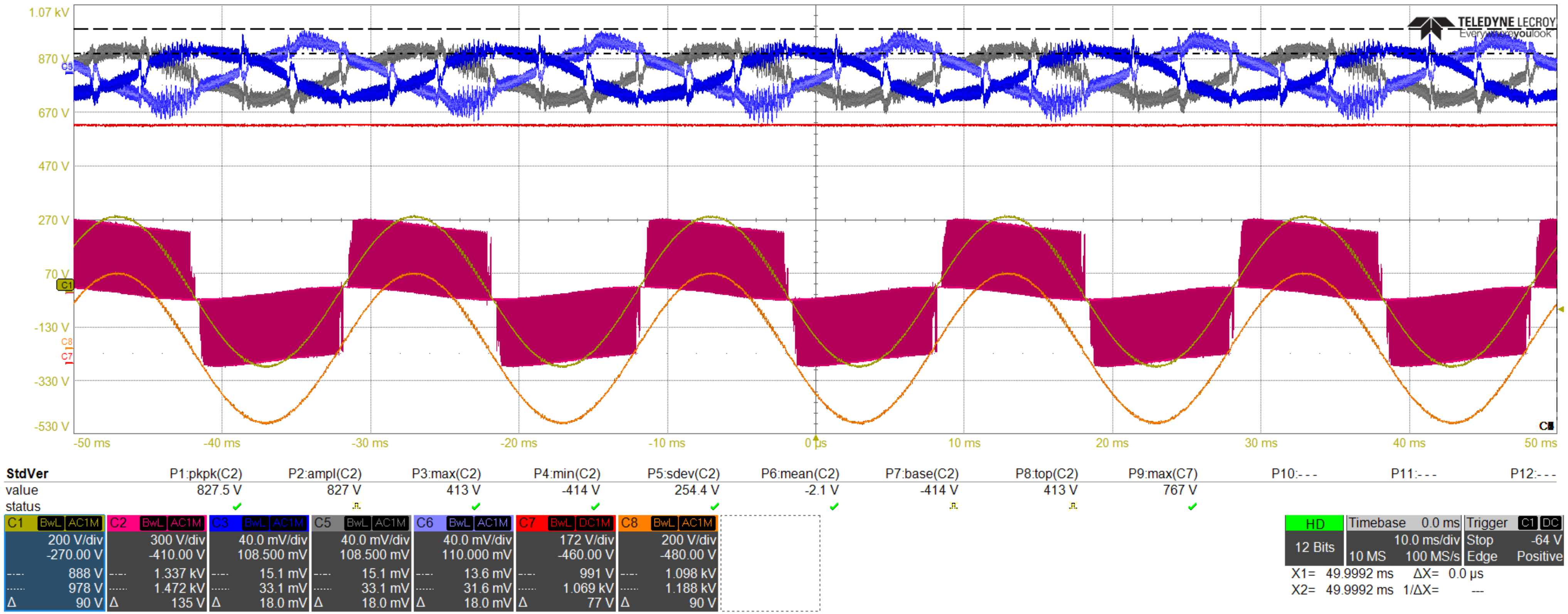
Renesas Power BoM	
TP65B110HRU	650V BDS GaN, 140mΩ, TOLT
RAA223021	700V AC/DC Regulator with Ultra-Low Standby Power and up to 12W Output Power
RAA214250	20V, 500 mA, Linear Regulator

3-PH VIENNA RECTIFIER: SWITCHING WAVEFORMS

Switch voltage (phase A), **Supply voltage** (phase A) **DC Bus voltage** (Closed loop operation)

i_IN,PhaseA, **i_IN,PhaseB**, **i_IN,PhaseC**

Preliminary Results:
Control Loop optimization ongoing



CONCLUSION

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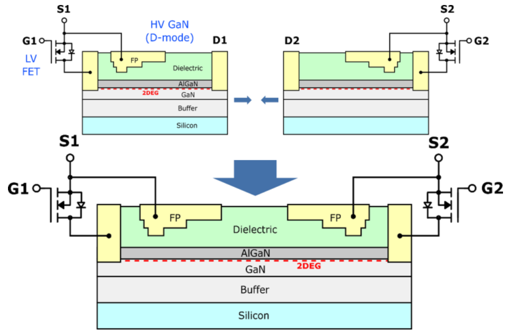
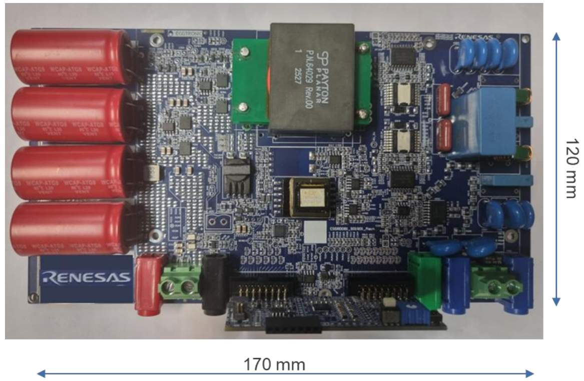
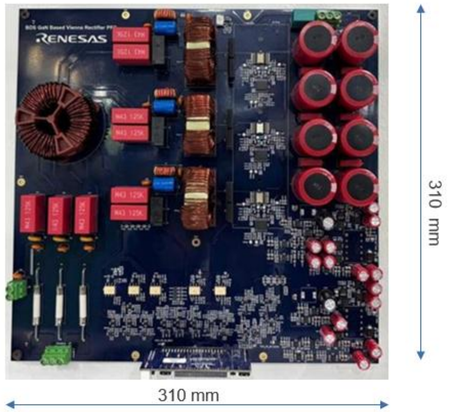
- Power Conversion System Design and Definition is moving towards smaller, highly efficient solutions, hence increasing power density while reducing losses
- Renesas ±650V Bidirectional GaN switch allows single-stage topologies, supporting system designers meeting todays and future challenges
- **Renesas Bi-Directional GaN technology enables Microinverter, Hybrid-Inverter, Vienna Rectifier and Single-Stage OBC architectures that outperforms existing solutions in terms of efficiency and power density**
- **Future Work**:
  - Optimize Microinverter design aiming at further enhancing efficiency
  - Optimize Vienna Rectifier Performance
  - Proof the advantages of Single-Stage topologies in other applications, such as OBC







THANK YOU!

"Investing in renewable energies is investing in a bright future.“

\- Anonymous

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