Compact Three-Level GaN Power Module Suitable for Active-Neutral-Point-Clamped (ANPC) Three-Level Converter

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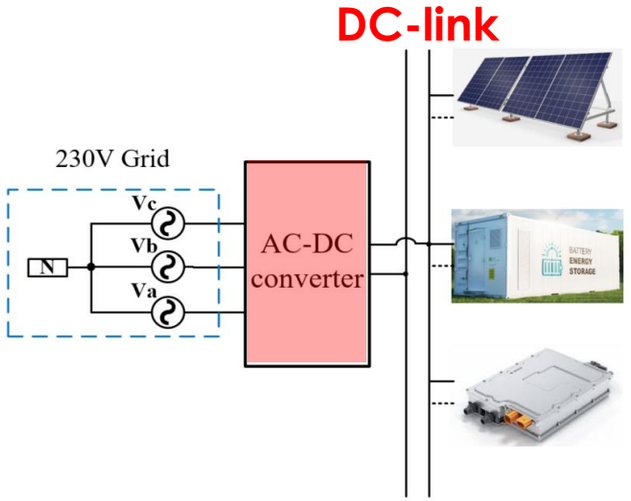
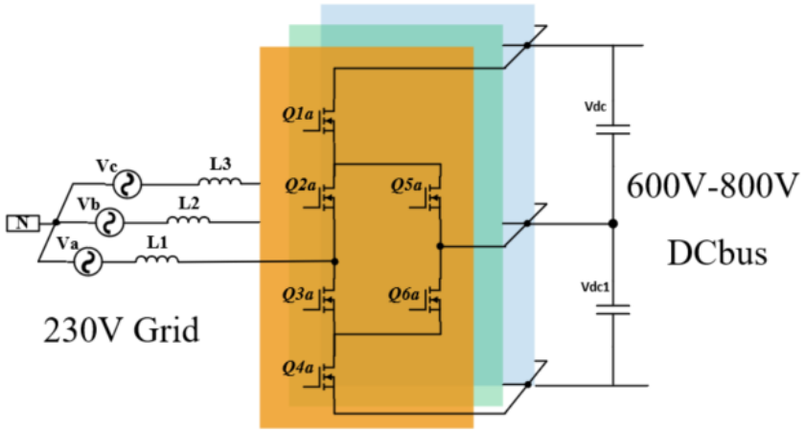
Introduction



- **GaN vs SiC vs Si:**
  1) Lower $R_{ds(on)}$ and Q_g
  3) Smaller size
  4) Faster switching capability
  5) Excellent reverse recovery

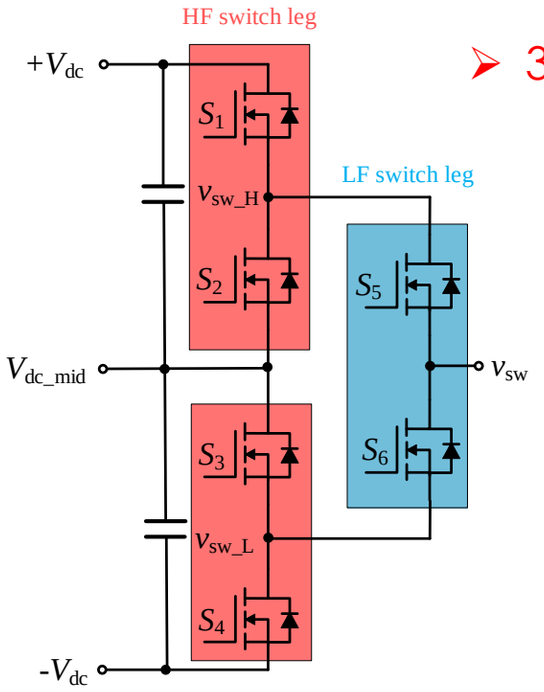


- For grid-connected systems, the DC-link voltage should be **above 600V** in order to connect to the **$230V_{phase}$** three-phase grid.
- Based on two-level structure, device voltage rating should be larger than 800V.

- Three-level ANPC converter is good candidate for employing the 650V GaN device in such AC-DC converter.
- Halved voltage stress can make sure the 650V GaN HEMTs operate at the Safe Operating Area (SOA).

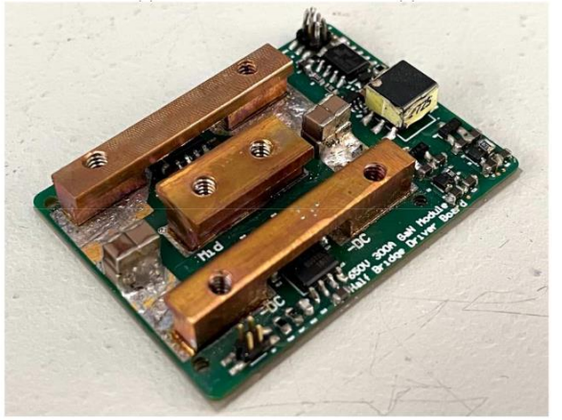
Three-level GaN power module

- Two-level vs Three-level GaN power module:

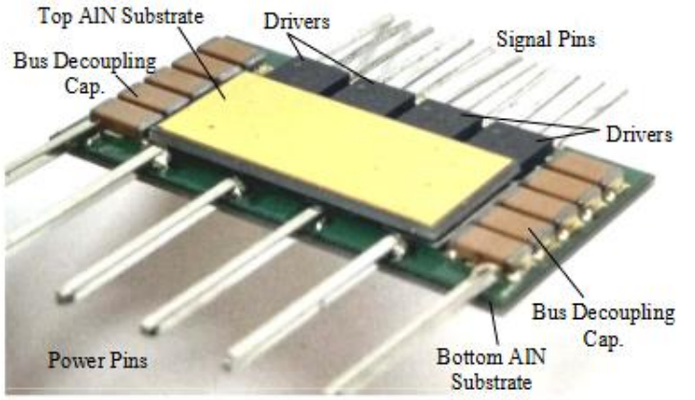


➢ 3×Two-level module

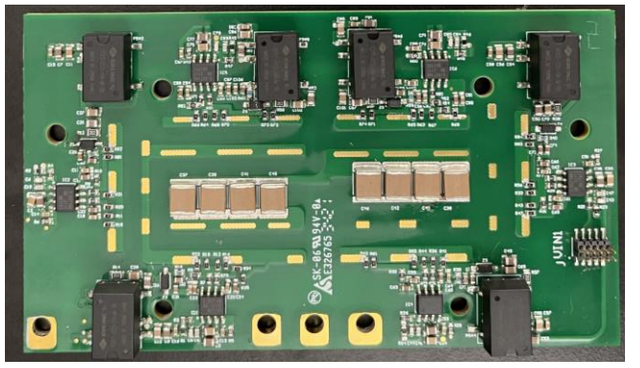
➢ 1× Proposed three-level module



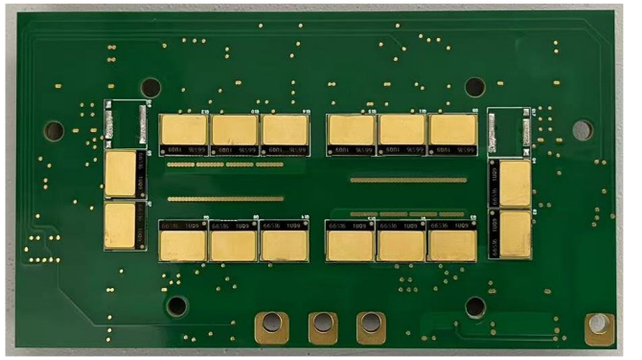
[1] Yu Yan et al.



[2] K. Wang et al.



[3] Z. Liang et al.



Three-level GaN power module

- Proposed Three-level GaN power module:

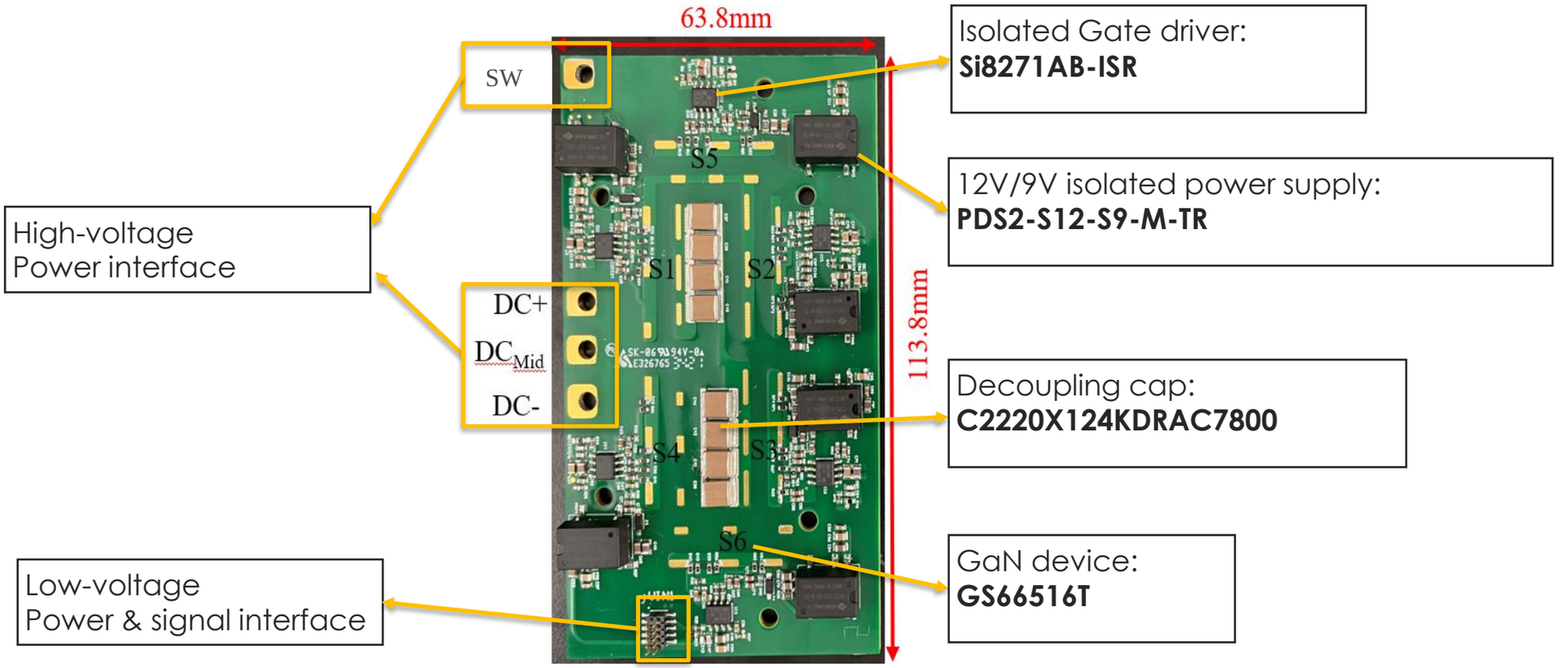
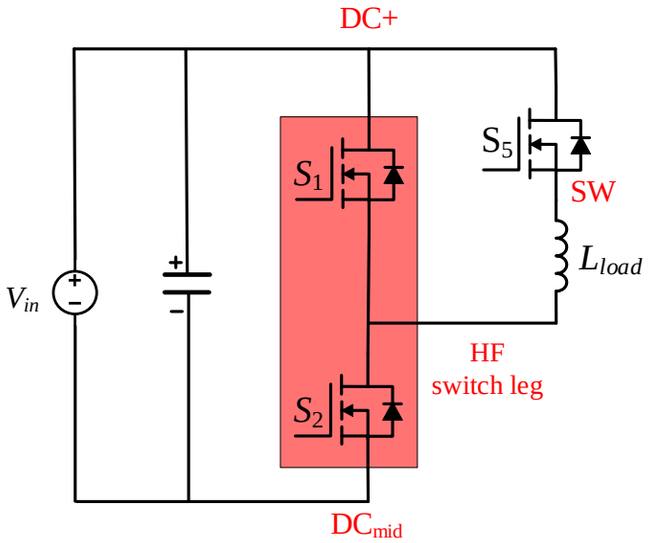


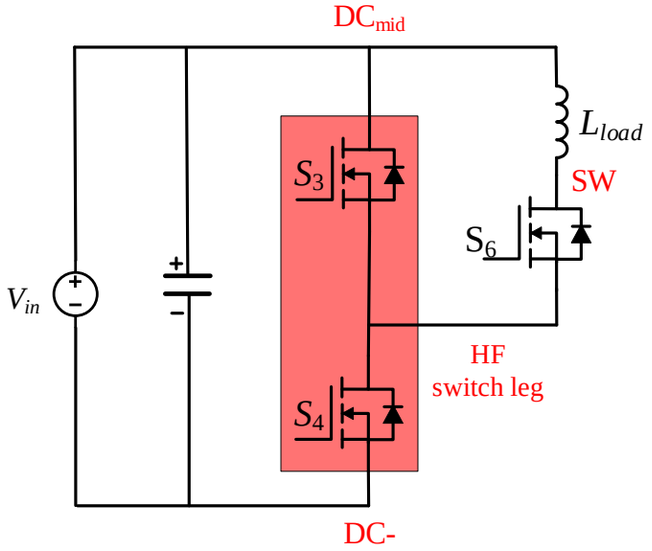
Fig.1 Proposed three-level ANPC phase leg.

Experiments

- DPT:



(a) Higher HF switch leg.



(b) lower HF switch leg.

Fig.2 Schematic of the DPT for the HF switch legs.

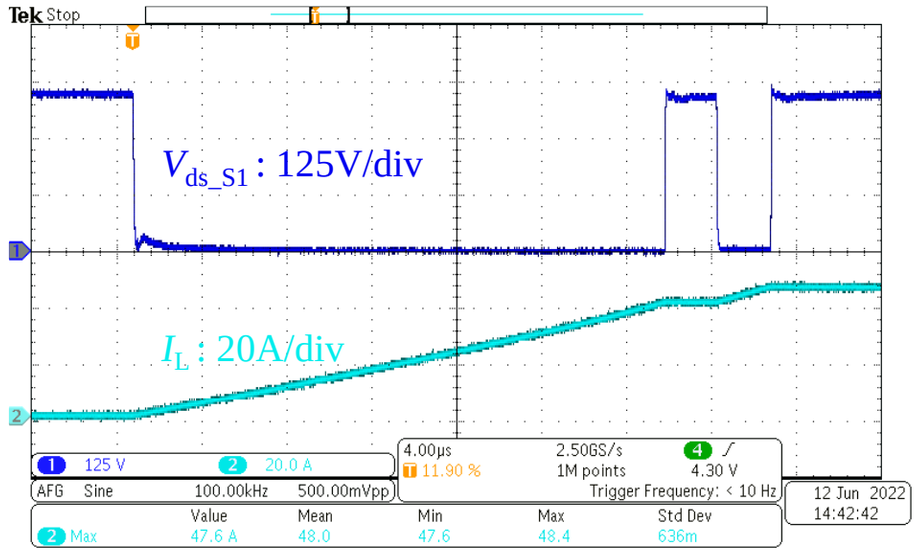
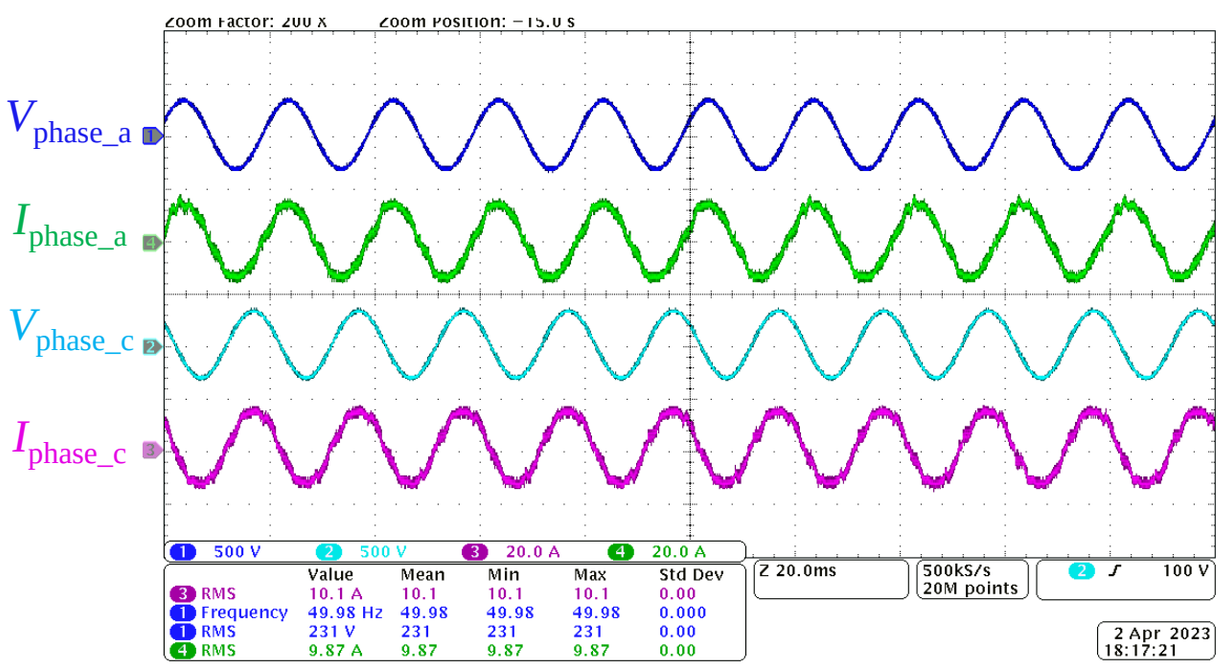


Fig.3 DPT test waveform @ 350Vdc/42A.

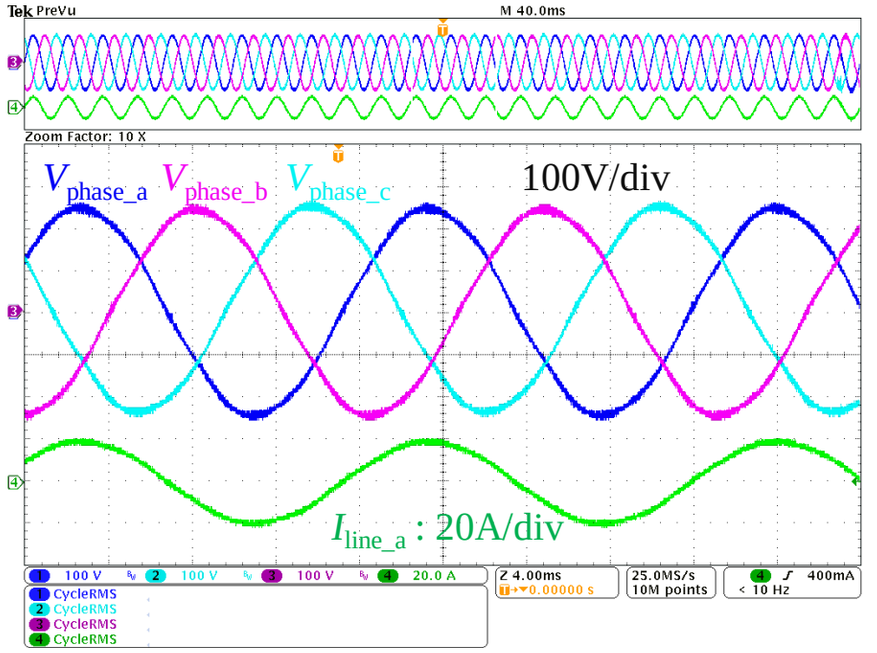
- Two high-frequency (HF) witch legs are tested separately. The low-frequency devices are also involved .
- The overshoots on drain-to-source voltage at **$350V_{dc}$ / 42 A DPT** are **4.3% and 5%** for higher and lower HF switch leg.

Experiments

- Converter test:



(a) PFC mode @7kW.



(b) Inverter mode @8kW.

Fig.4 Converter power test.

- One bidirectional three-phase 3L ANPC converter is built to verify the proposed power module.
- **7kW PFC mode** and **8kW inverter mode** are tested and >98.5% peak efficiency is achieved.

Conclusion

- Such three-level GaN power module **employs the 650V GaN devices in an 230V_{phase} AC/DC converter with >600V_{DCbus}** successfully.
- By utilizing the eight-layer PCB and good PCB layout, the **low parasitic inductance and compact design** are achieved and verified by DPT and converter tests.
- Based on such structure, it’s possible to build a more compact three-level ANPC phase leg power package by employing the **smaller GaN dies**.