Paralleling 650 V/150 A GaN HEMTs for Cryogenically Cooled Solid-State Circuit Breaker Applications

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Background and Motivation

- Light-weight, highly efficient, fast, and reliable protection is needed for future aviation;
- Cryogenically cooled power electronics with wideband gap devices can benefit future electrified aircraft propulsion (EAP) where the power density and efficiency are must, and clean fuels such as liquid hydrogen and liquified natural gas can be duel used as the coolant.

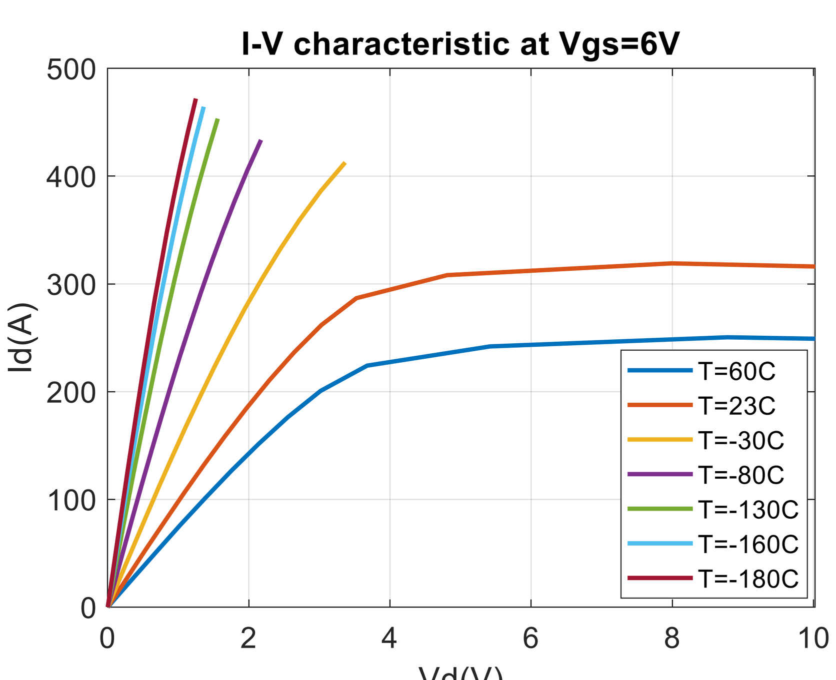
GaN HEMTs offer large reduction in $R_{ds(on)}$ at cryogenic temperatures → Low conduction loss, suitable for SSCB application

GaN HEMTs have positive temperature coefficient of on-resistances → Good for paralleling to increase current rating and reduce conduction loss

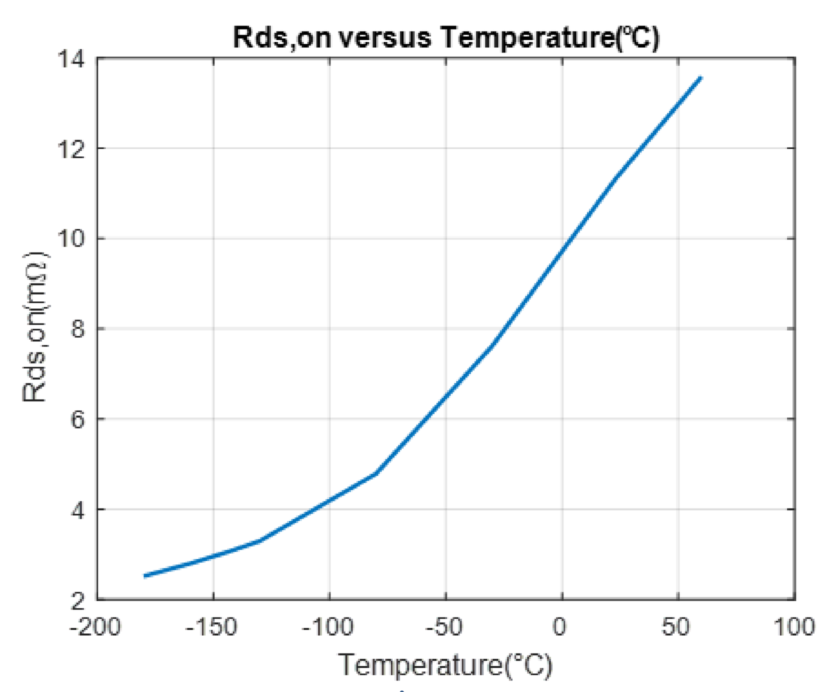
→ SSCB are desirable to have low conduction loss and be capable of interrupting high current (e.g., 5~10x) during faults.

GaN HEMTs at Cryogenic Temperature

- GaN HEMTs exhibit positive temperature coefficient of on-resistances $R_{ds(on)}$. The $R_{ds(on)}$ is about one-fifth at -180°C of that at the room temperature.



(a)

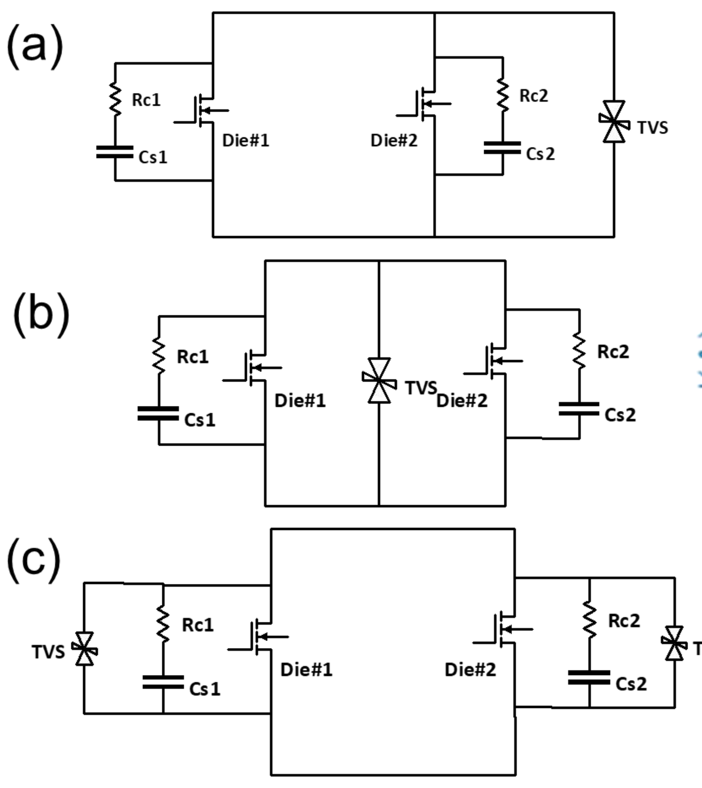


(b)

Fig. 1. Characteristics of GaN HEMTs GS-065-150
(a) I-V at different temperature, (b) $R_{ds(on)}$ versus temperature.

SSCB Module Design

- A RC snubber is added to each die to mitigate the parasitic ringing issue in both high current and high voltage turn-off process.
- The power-loop inductance between the device and the TVS can induce transient voltage spike, which could lead to possible failure. Paralleled TVS with each GaN devices ensures lower power loop inductance.



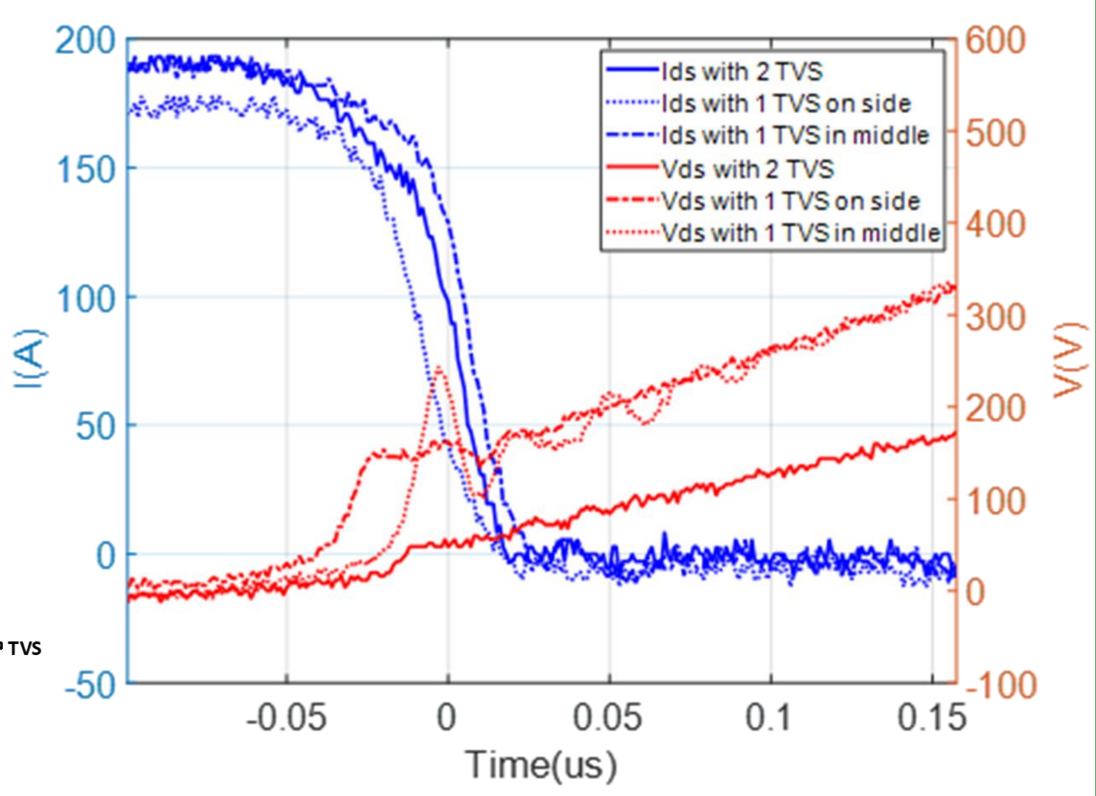
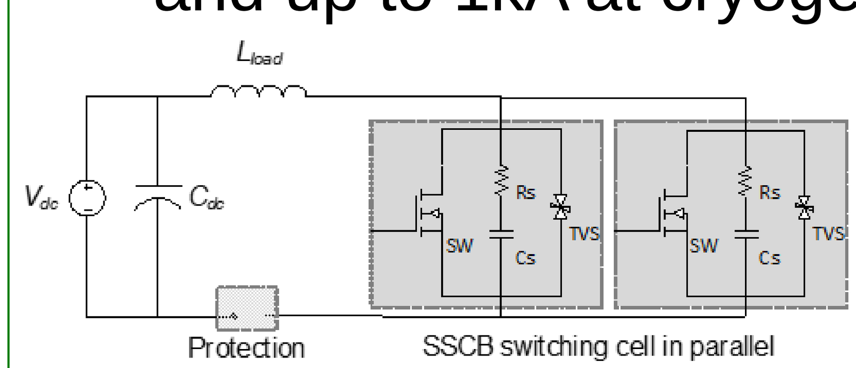


Fig. 2. Different configuration of TVS and turn-off performance comparison. (a) On single side (b) In between (c) Parallel with each die,

Experimental Results

- The paralleled GaN HEMTs are tested to interrupt 100A, 400A at both room and cryogenic temperature and up to 1kA at cryogenic temperature (-180°C).



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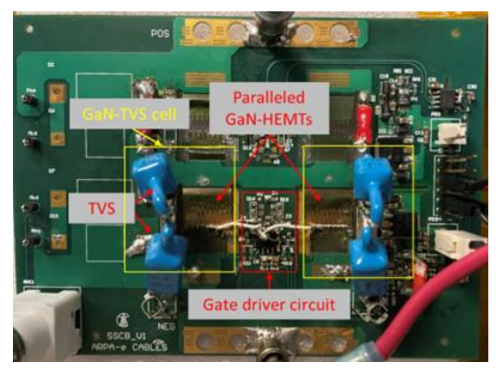

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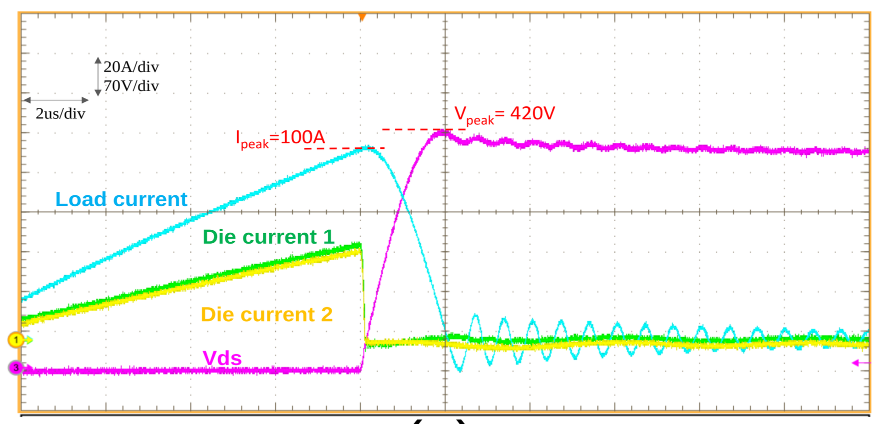
(c)

Fig. 3. Test configuration and setup
(a)Test setup diagram (b)SSCB module (c)Test bench setup



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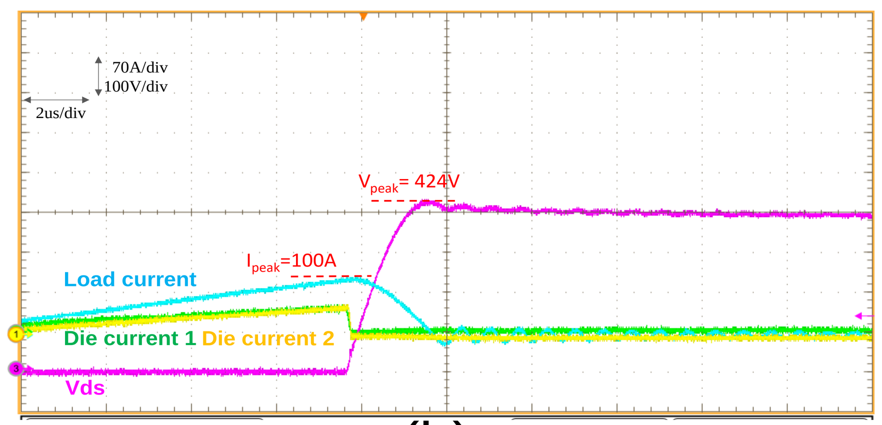

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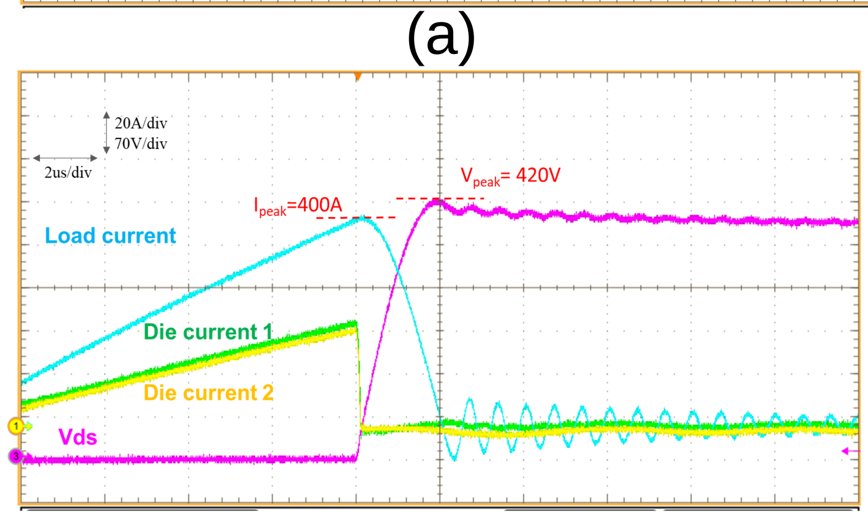

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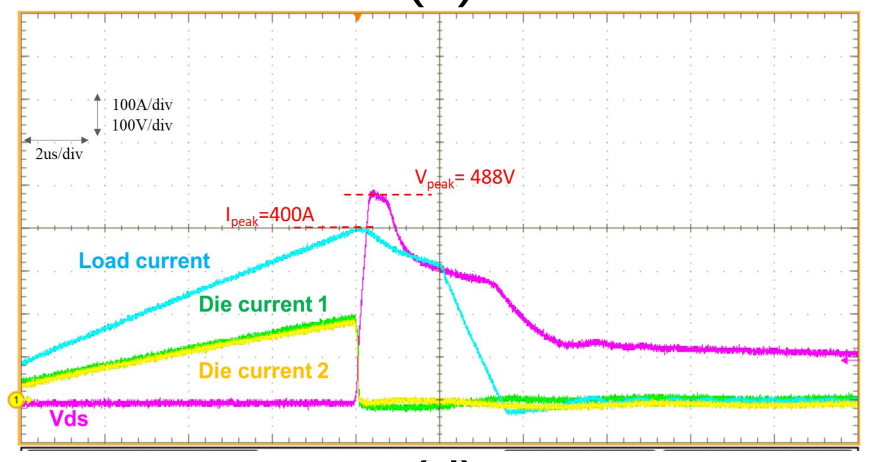
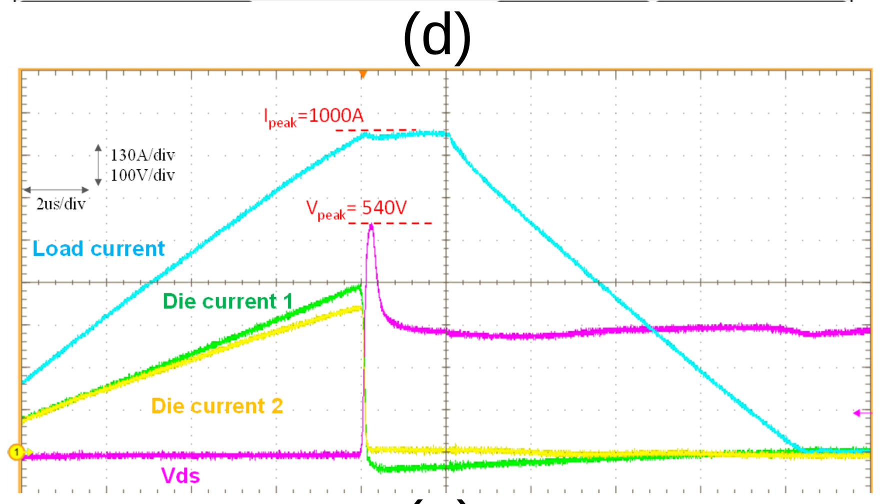


(d)

Fig. 4. Test result of the paralleled GaN SSCB module turning off :
(a)100A at room temperature
(b)100A at -180°C
(c) 400A at room temperature
(d)400A at -180°C
(e)1kA at -180°C



(e)

Conclusion

- Achieved paralleling two 650V/150A GaN HEMTs and interrupting high current up to 1kA at cryogenic temperature.
- TVS configurations is also critical to the high current turn-off capability.