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Virgiliu Botan

Design and Reliablity Considerations for 3.3kV SiC Modules for Traction

Date
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Public

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Subtitle

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HE Semiconductors enabling sustainability from generation, transmission…

… to consumption

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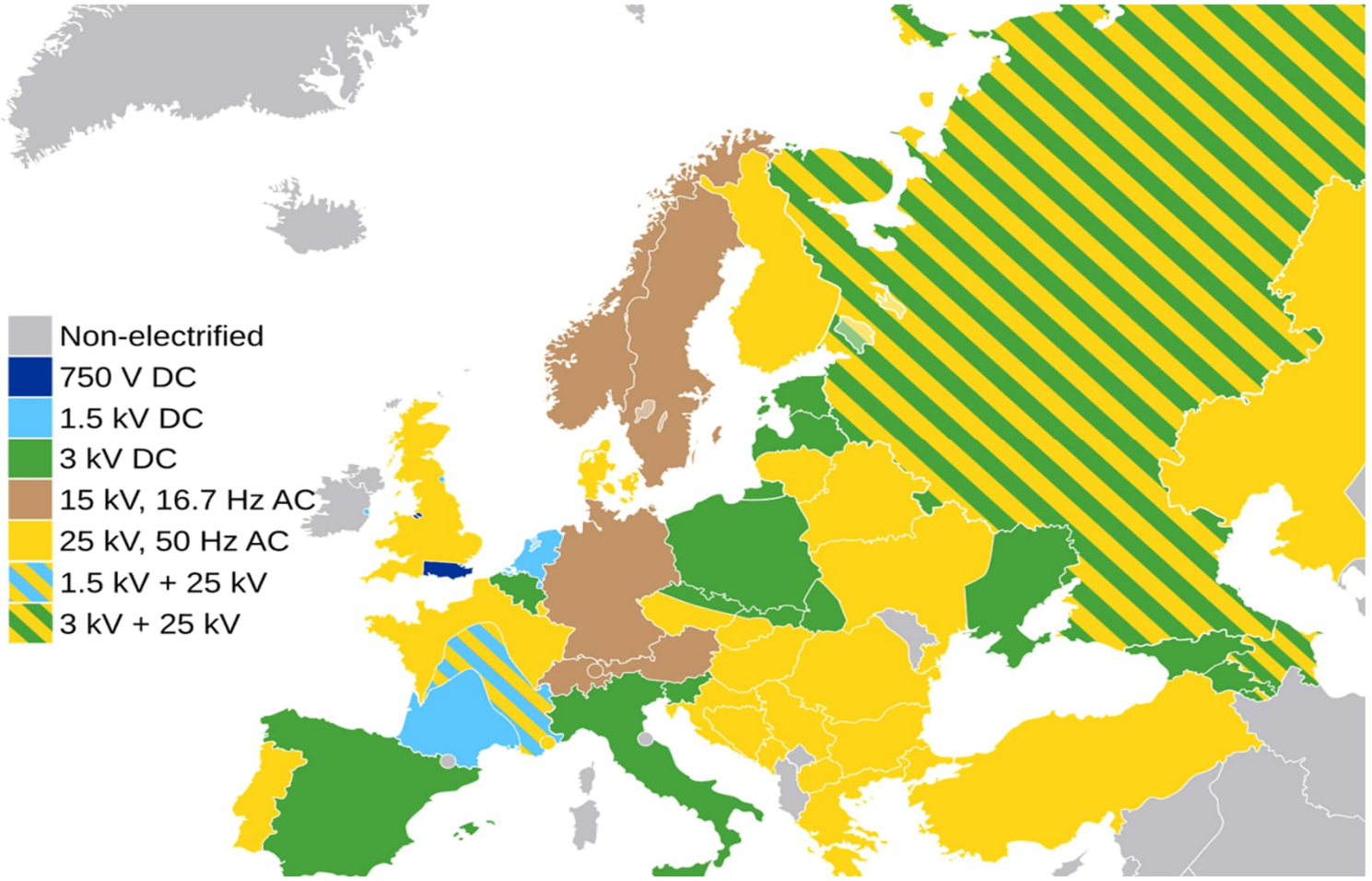
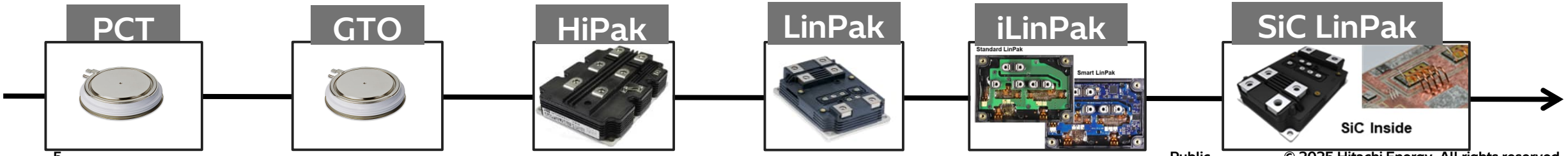
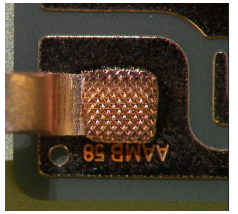
Rail Network in Europe, A wild mix of Challenges

- **Variety of voltages (AC & DC)**
- **Most difficult power cycling requirements**
- **Environmental robustness**
- **30 Year lifetime required**





LinPak, next standard in Traction



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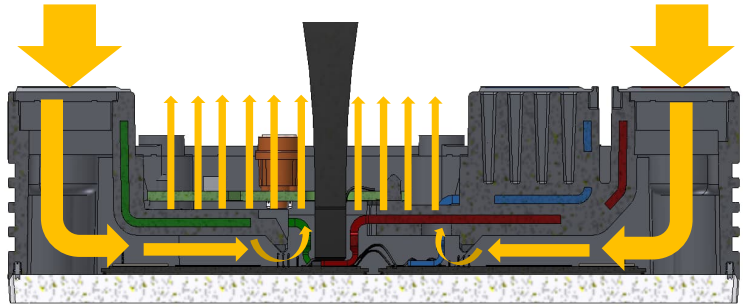
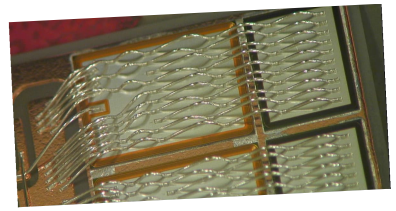
LinPak advantages:

- Compact phase leg design
  - Module optimized for compact converter design
    - Ideal for paralleling, no derating
      - Used with both Si and SiC
        - Same footprint over broad voltage range (1200V to 6500V)
          - **Unmatched reliability: welded terminals, sinter chips, optimized bonding…**

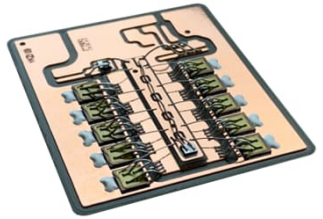
Welded Terminals



Air Blade against particles

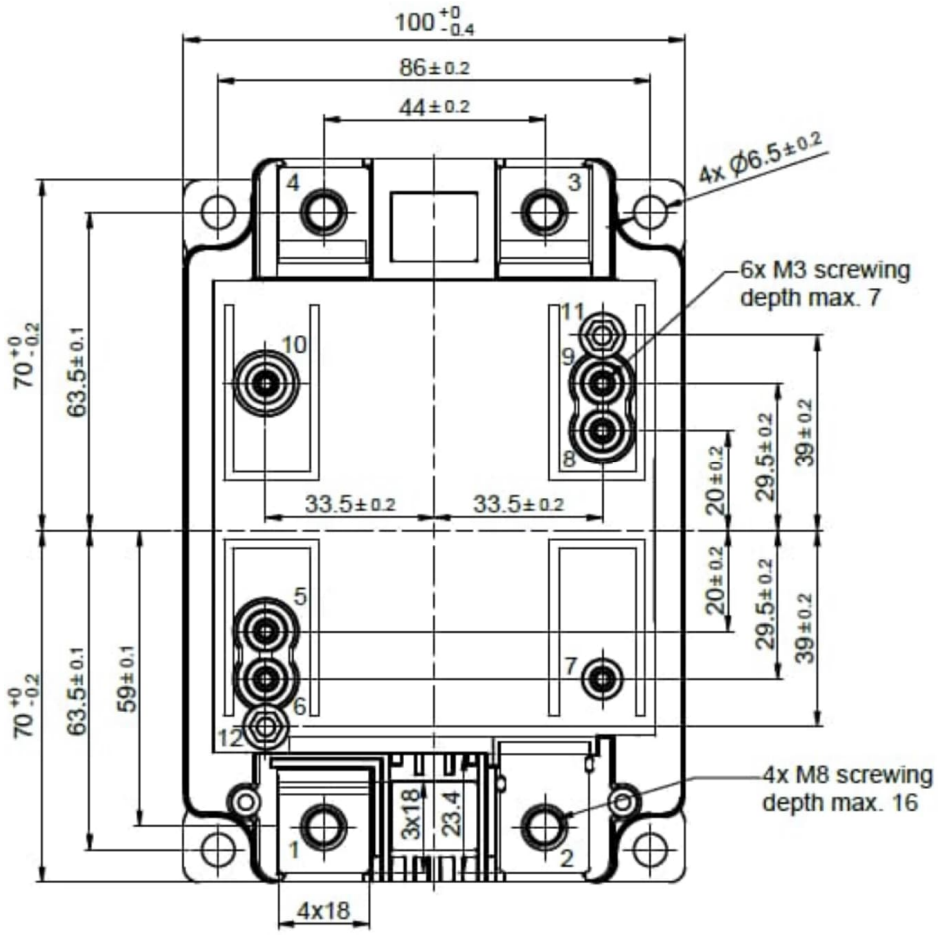


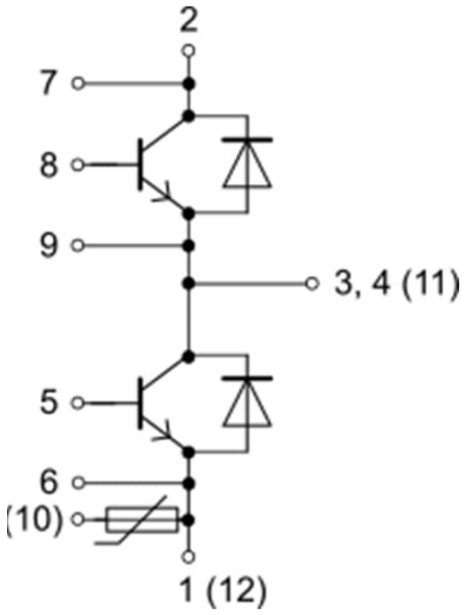
Sintered chips, optimized bond layout



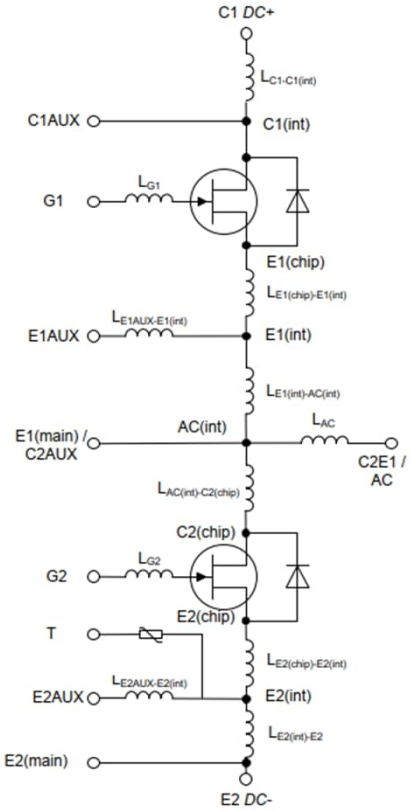
Uses Si and SiC

Placement of Optional NTC

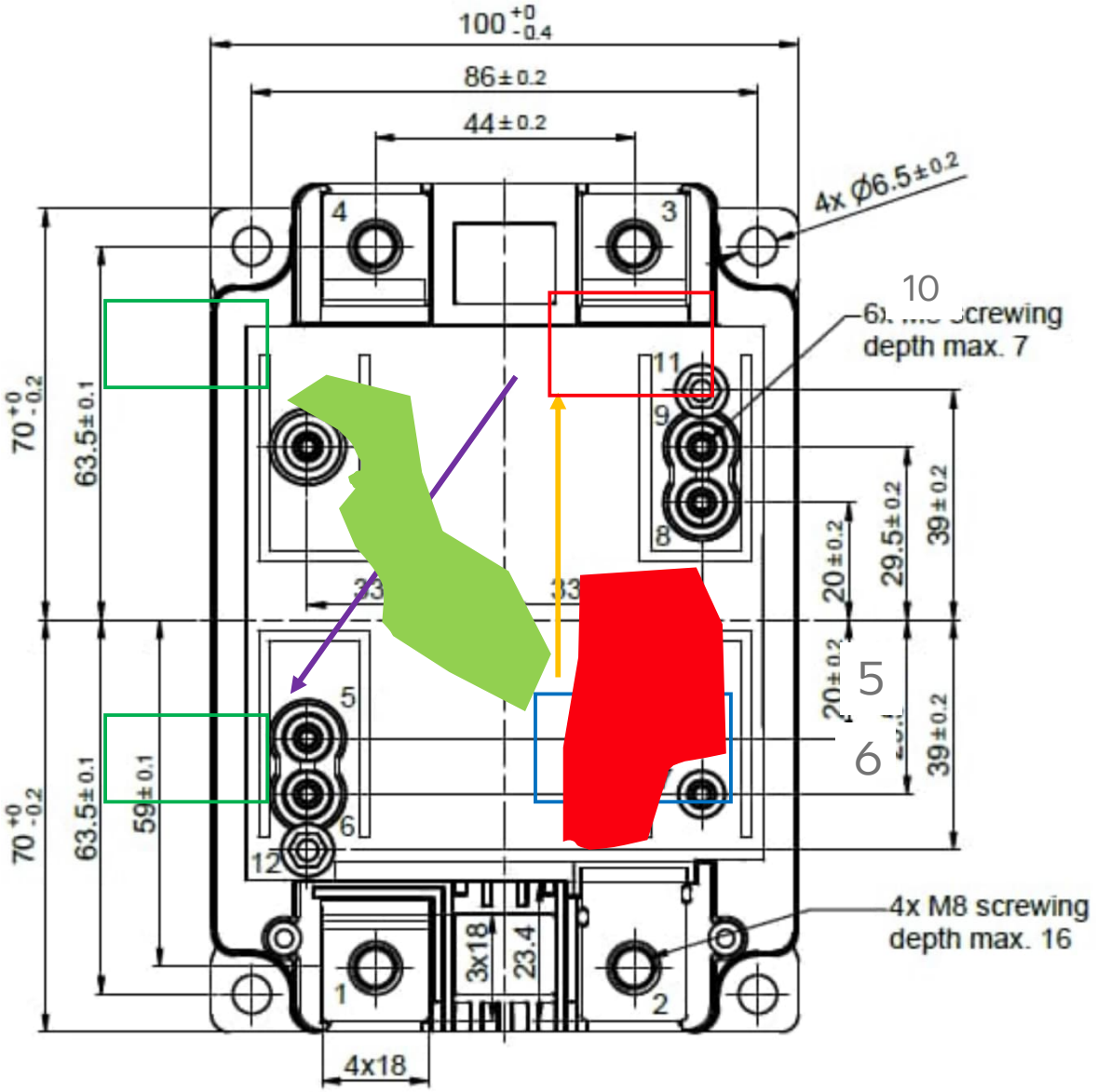


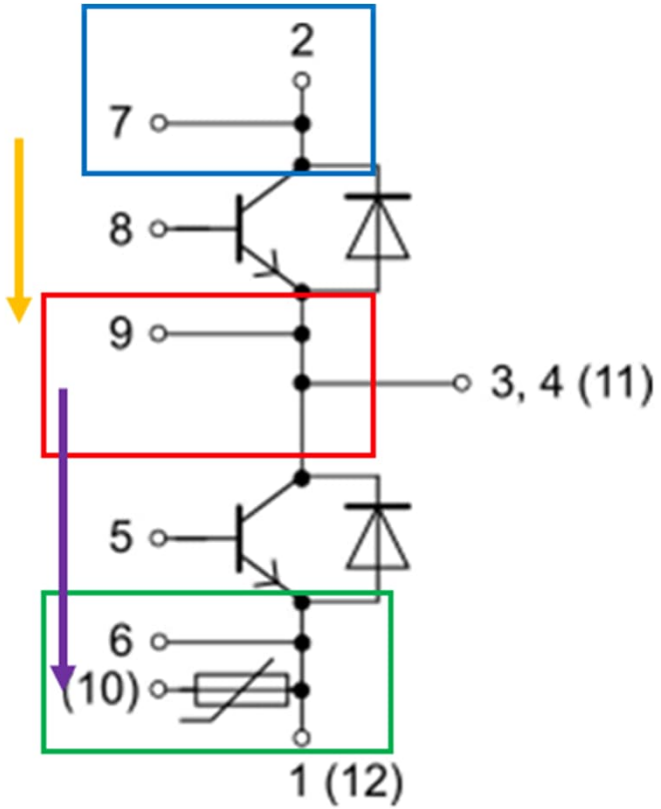


Roll2Rail Specification



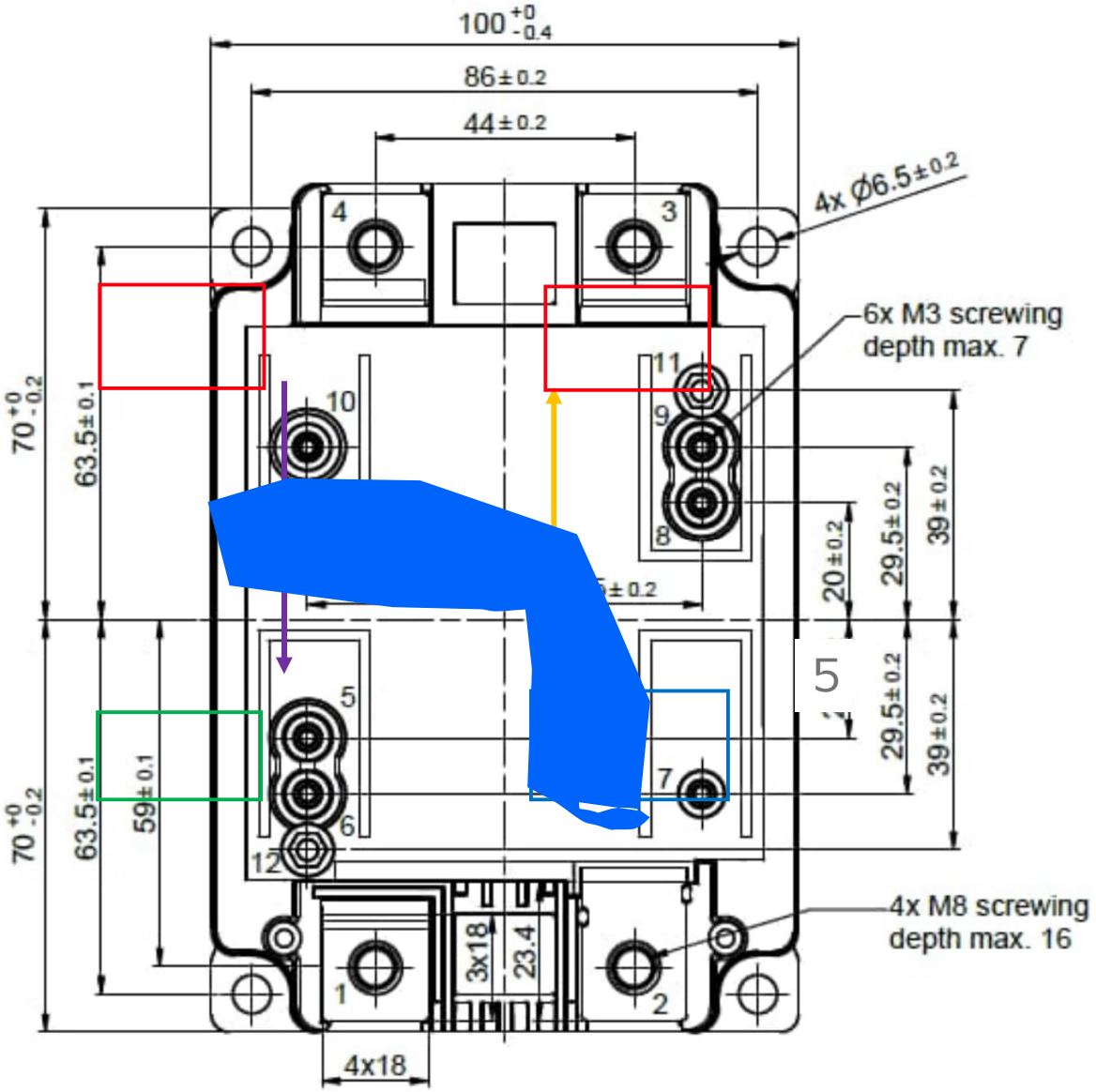
NTC at DC- potential

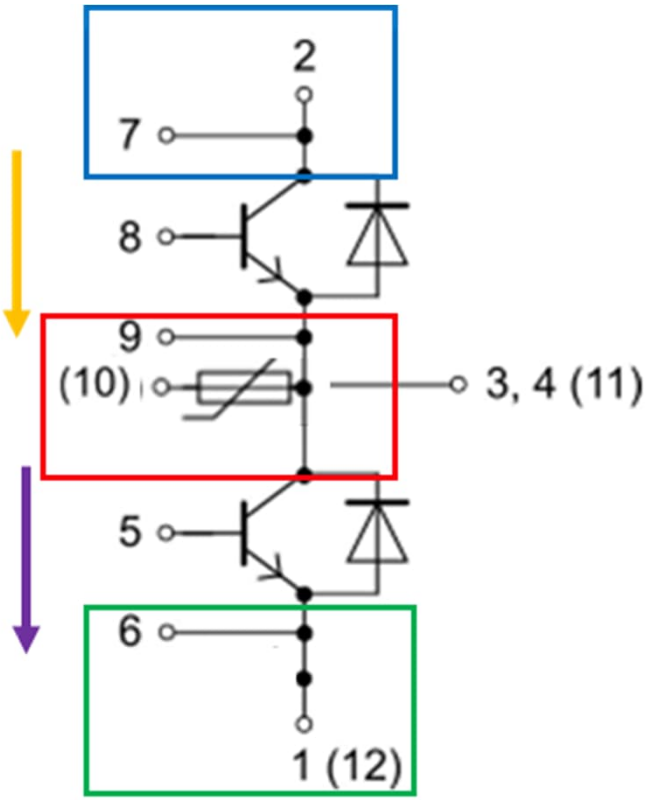




7 -> 9: Vce,sat-measurement high side
9 -> 6: Vce,sat-measurement low side

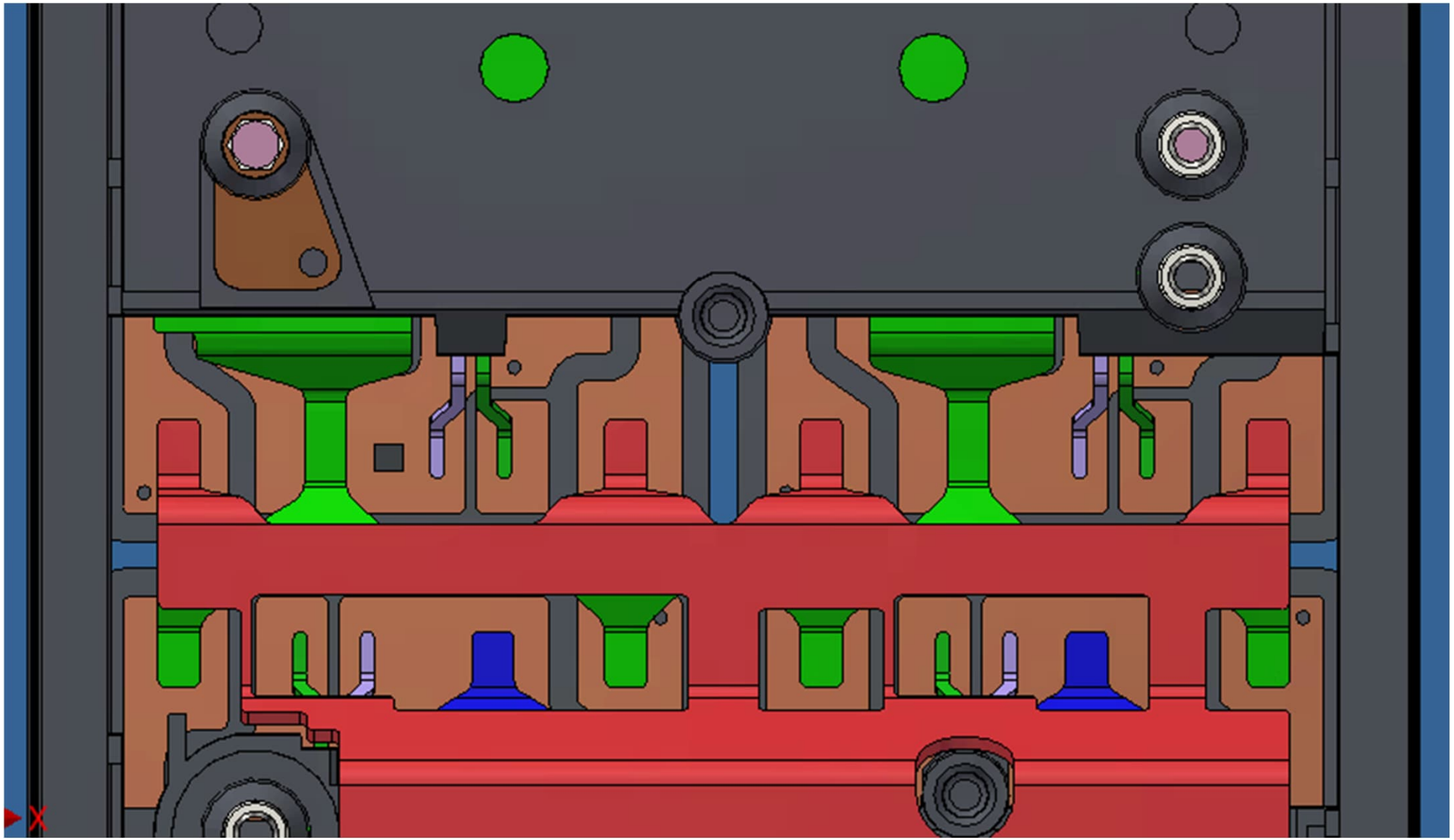
NTC at the AC potential



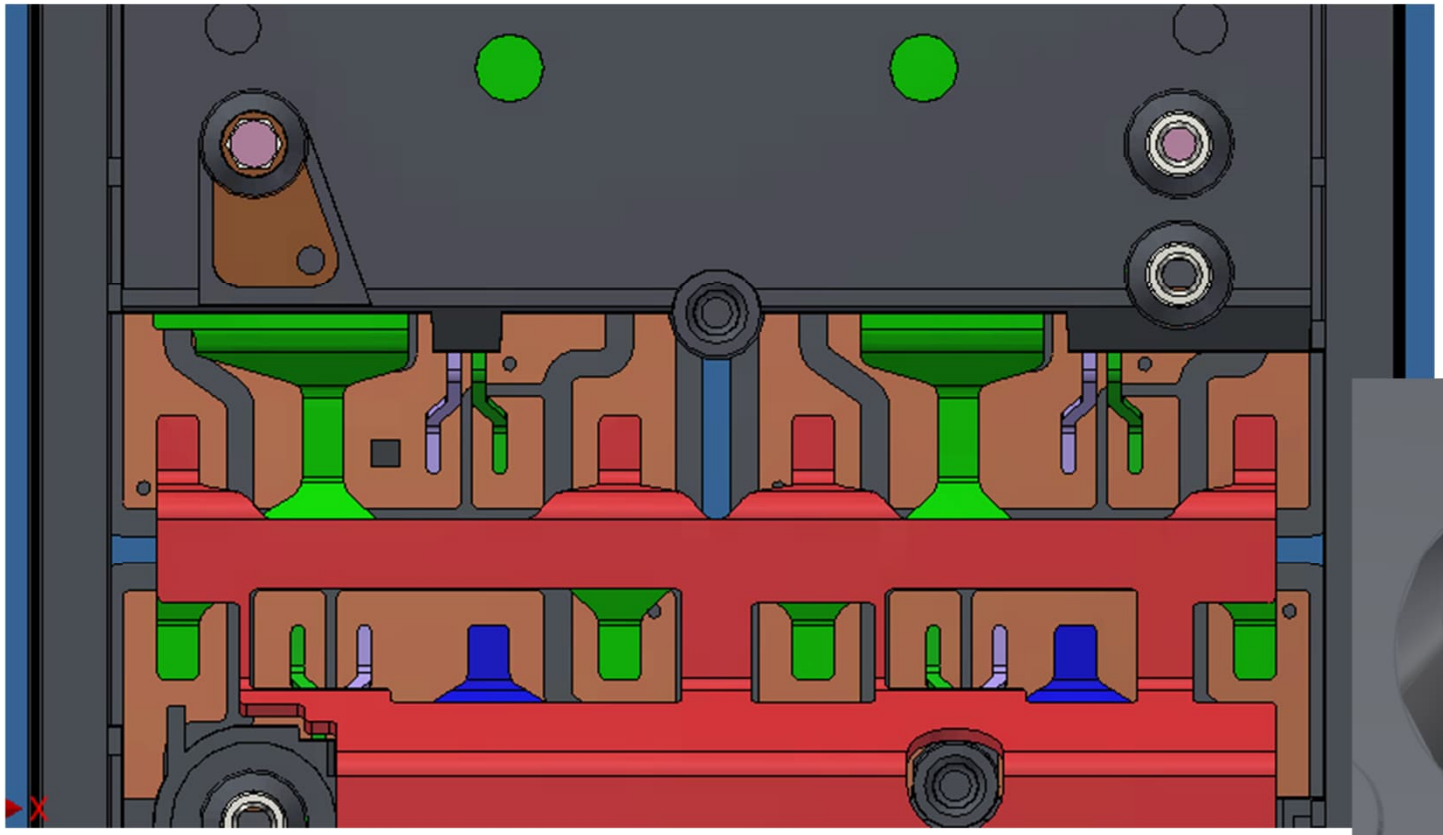


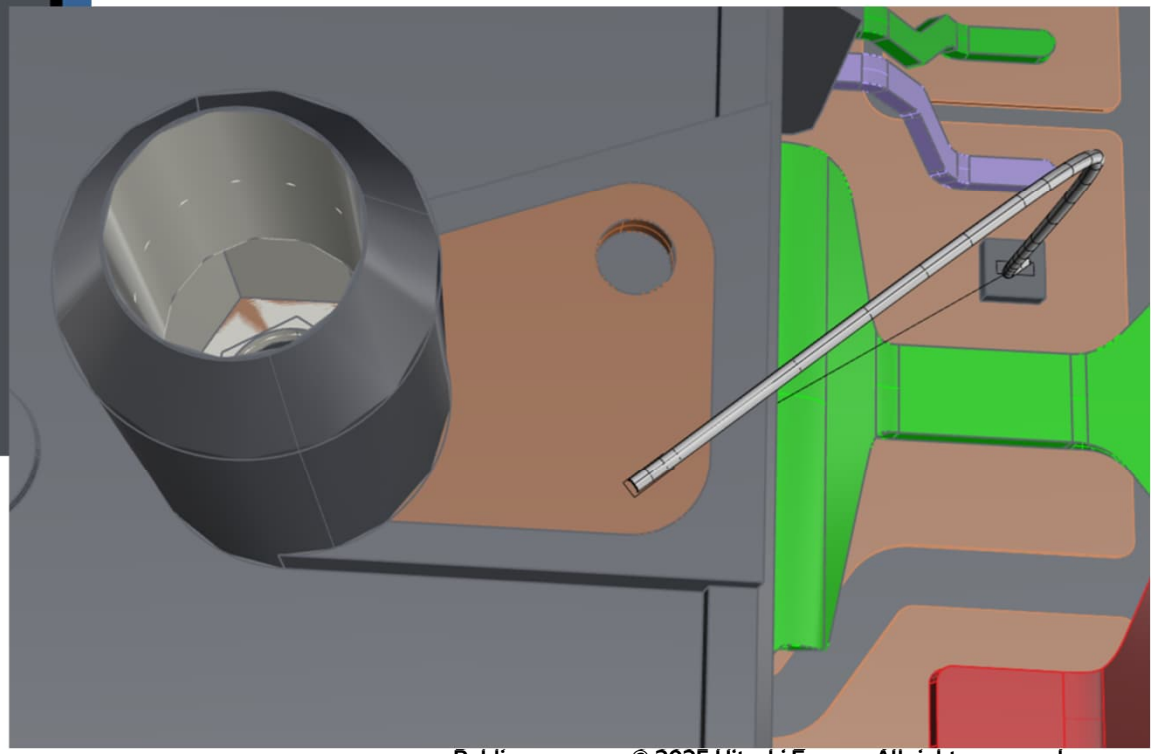
7 -> 9: Vce,sat-measurement high side
10 -> 6: Vce,sat-measurement low side

Change of NTC on the AC Terminal



Change of NTC on the AC Terminal





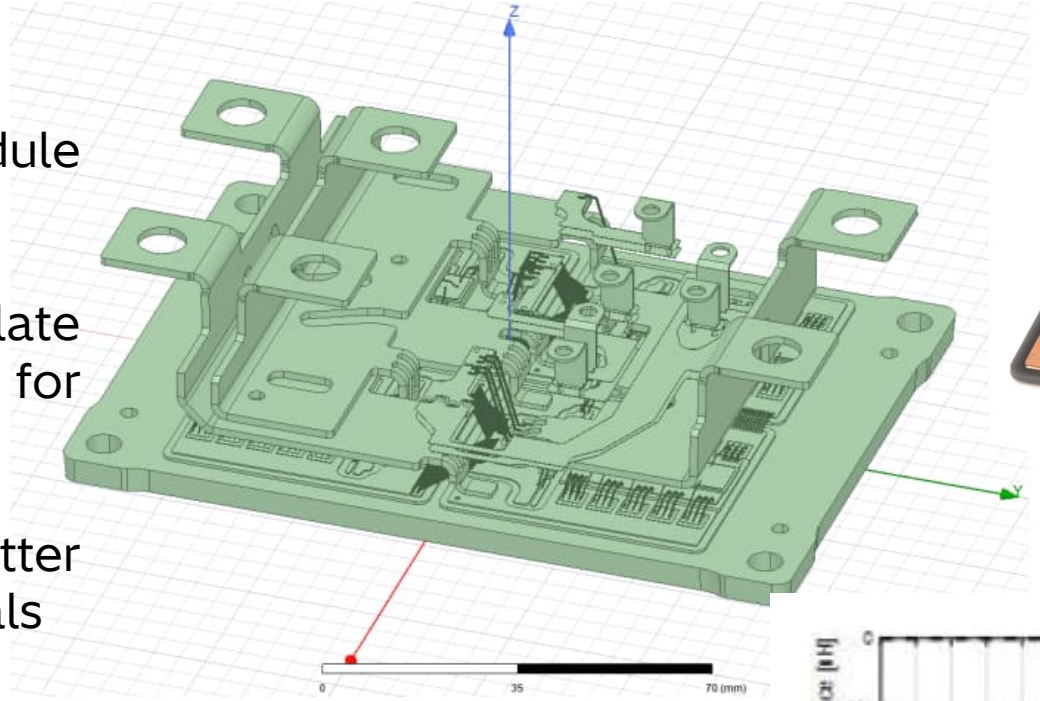
Module Design – SiC LinPak

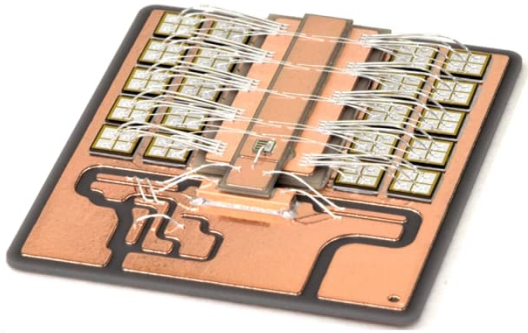
Having so many chips inside the module (up to 80pcs) is very challenging.

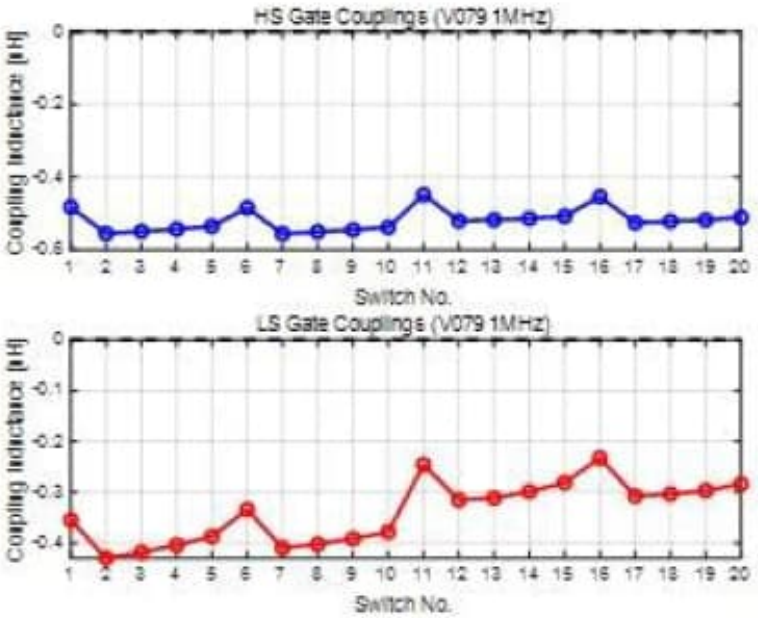
1. build up SPICE model to simulate the swithing behaviour for optimization

2. special substrate design for better distribution of Gate and Source signals

3. Optimization of electromagnetic couplig for faster switching and optimized paralleling







Comparison of Switching Behavior Si IGBT vs. SiC MOSFET HV LinPak

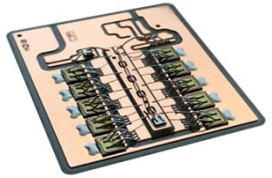
Si IGBT Hv LinPak 3.3kV 600A

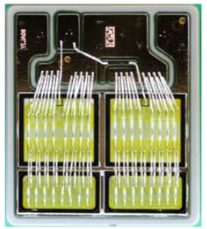
SiC MOSFET HV LinPak 3.3kV 480A

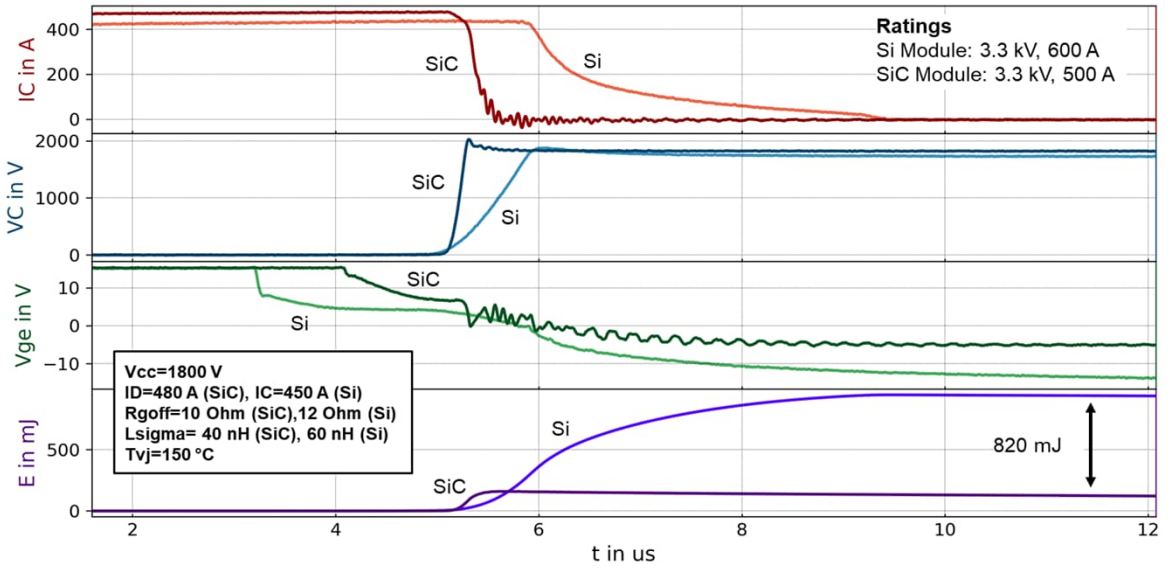
V_{CC}=1800V, I_D=480A I_C=450A, T_j=150°C

$E_{offIGBT}$-$E_{offMOSFET}$=820mJ

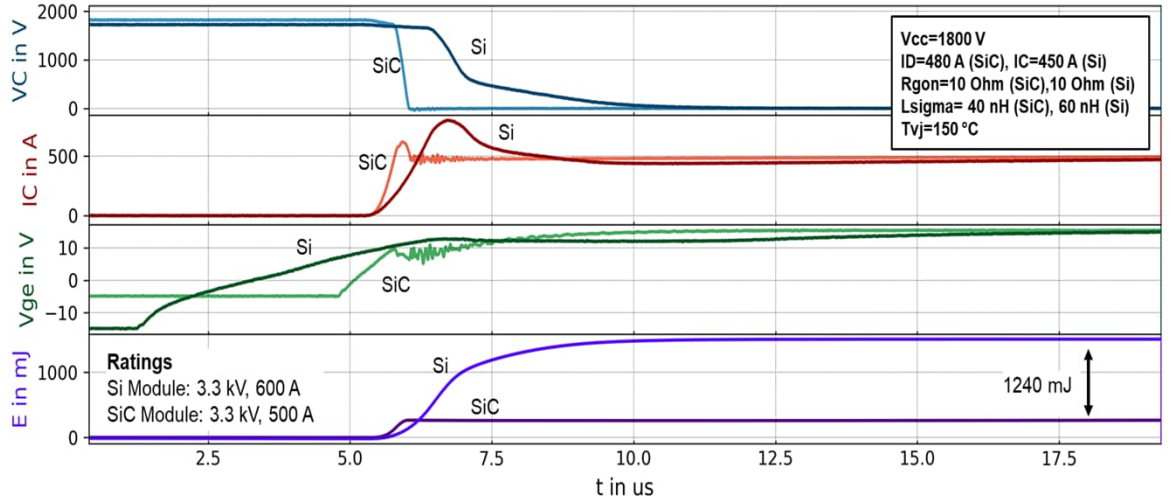
E_{onIGBT}-$E_{onMOSFET}$=1200mJ







Turn-off



Turn-on

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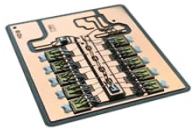
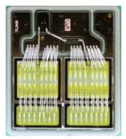
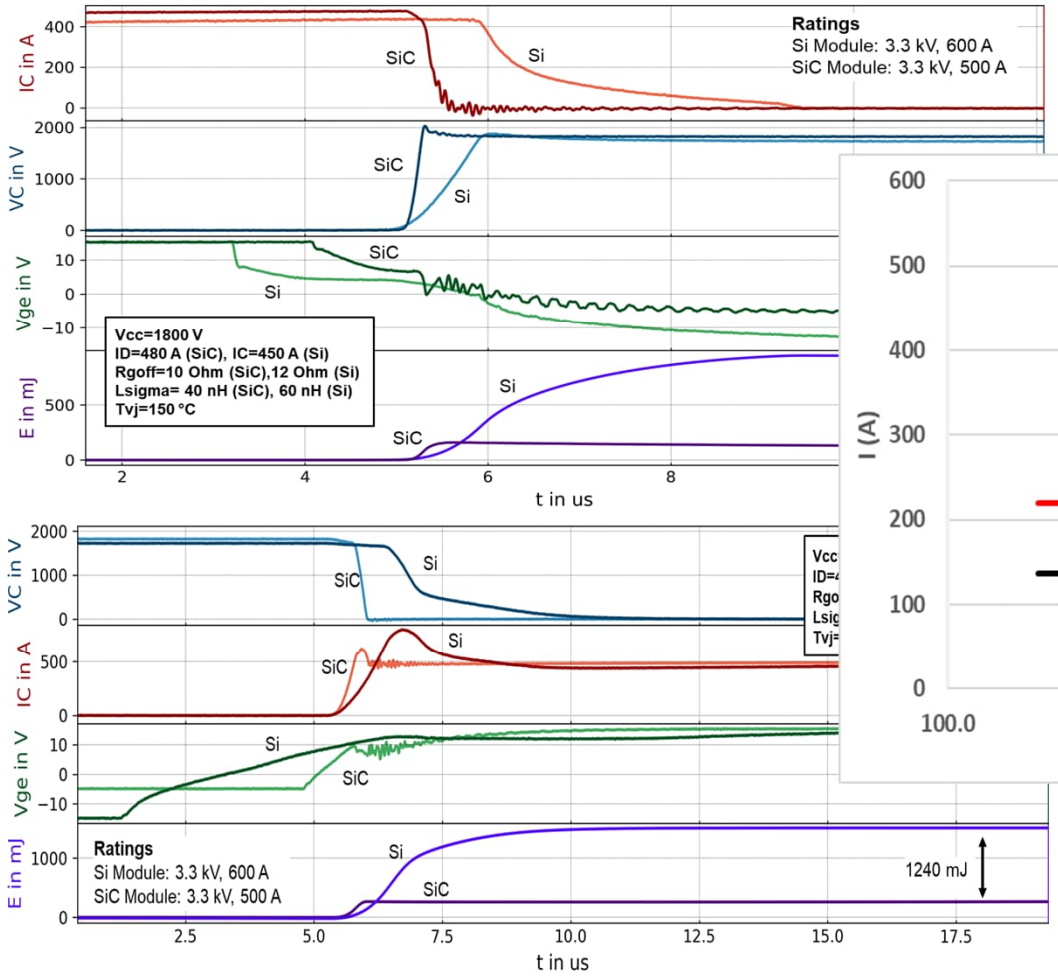
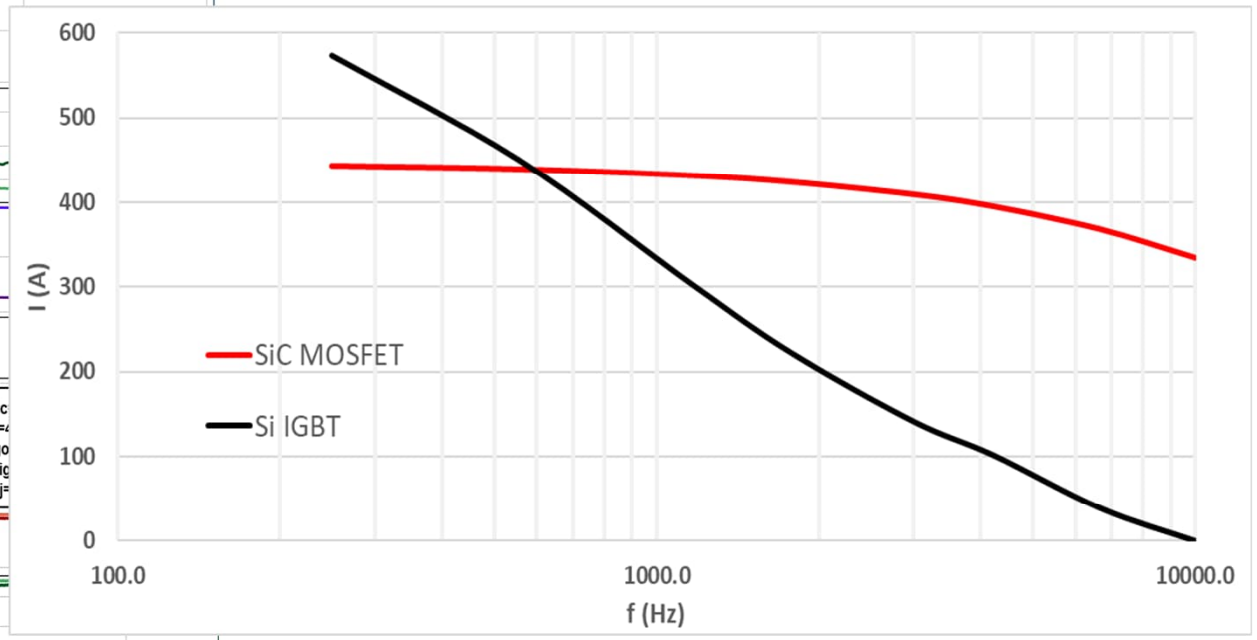






Current output

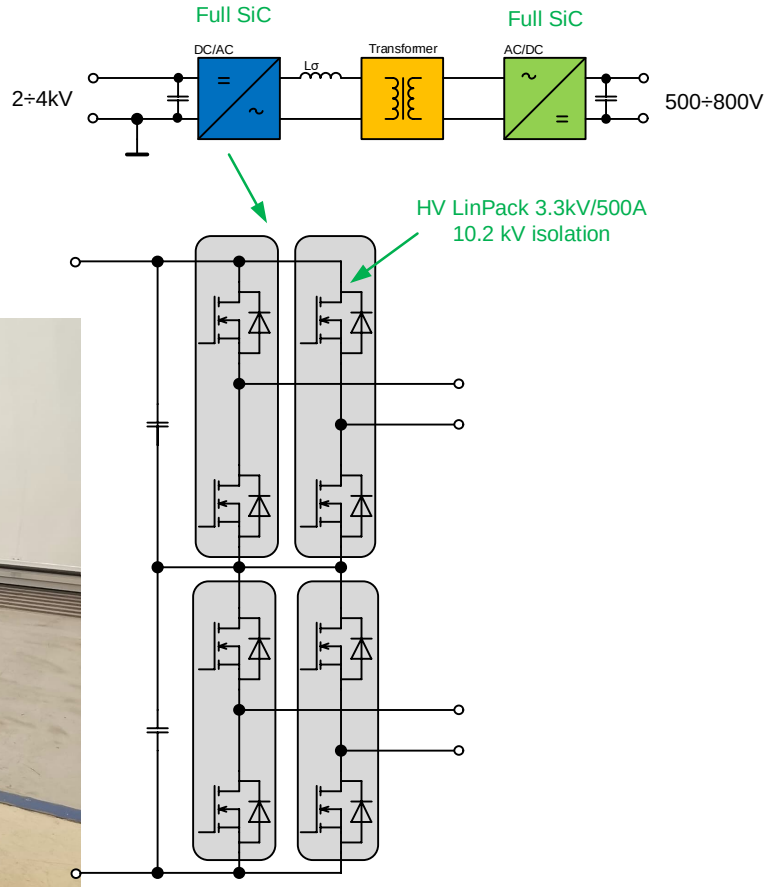


Going from Si to SiC

Going for SiC for the galvanically isolated DC-DC converter

The goal is to reduce dimensions and weight with increasing frequency

SiC 5SFG 0480Z330100
3.3 kV, 2x480 A
10.2 kV isolation



HV-H_3TRB according to ECPE Guideline

- Voltage is not seen as an accelerator, typical catenary voltage is used (i.e. 1950V)
- Test humidity and temperature 85%, 85°C
- Acceptance criteria In-test: $I_{DSS} < 10 \times I_{DSS\_initial}$
- Acceptance criteria after the test V_{SD}, $R_{DS(on)}$, $V_{GS,th}$ with less than 10% change and I_{DSS}, I_{GSS} less than factor 10 change, and V_{ISO} minimum within 80% of original

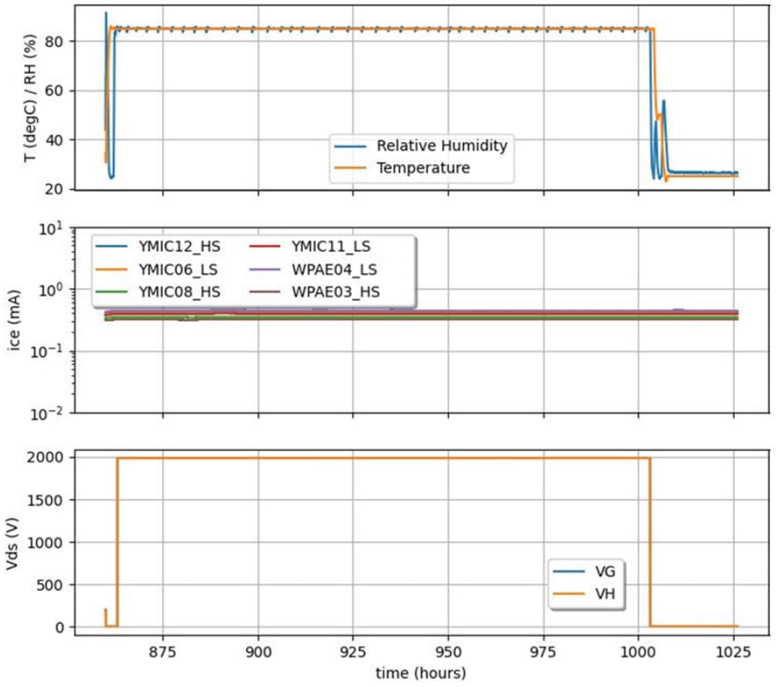
ECPE Guideline PSRRA 01

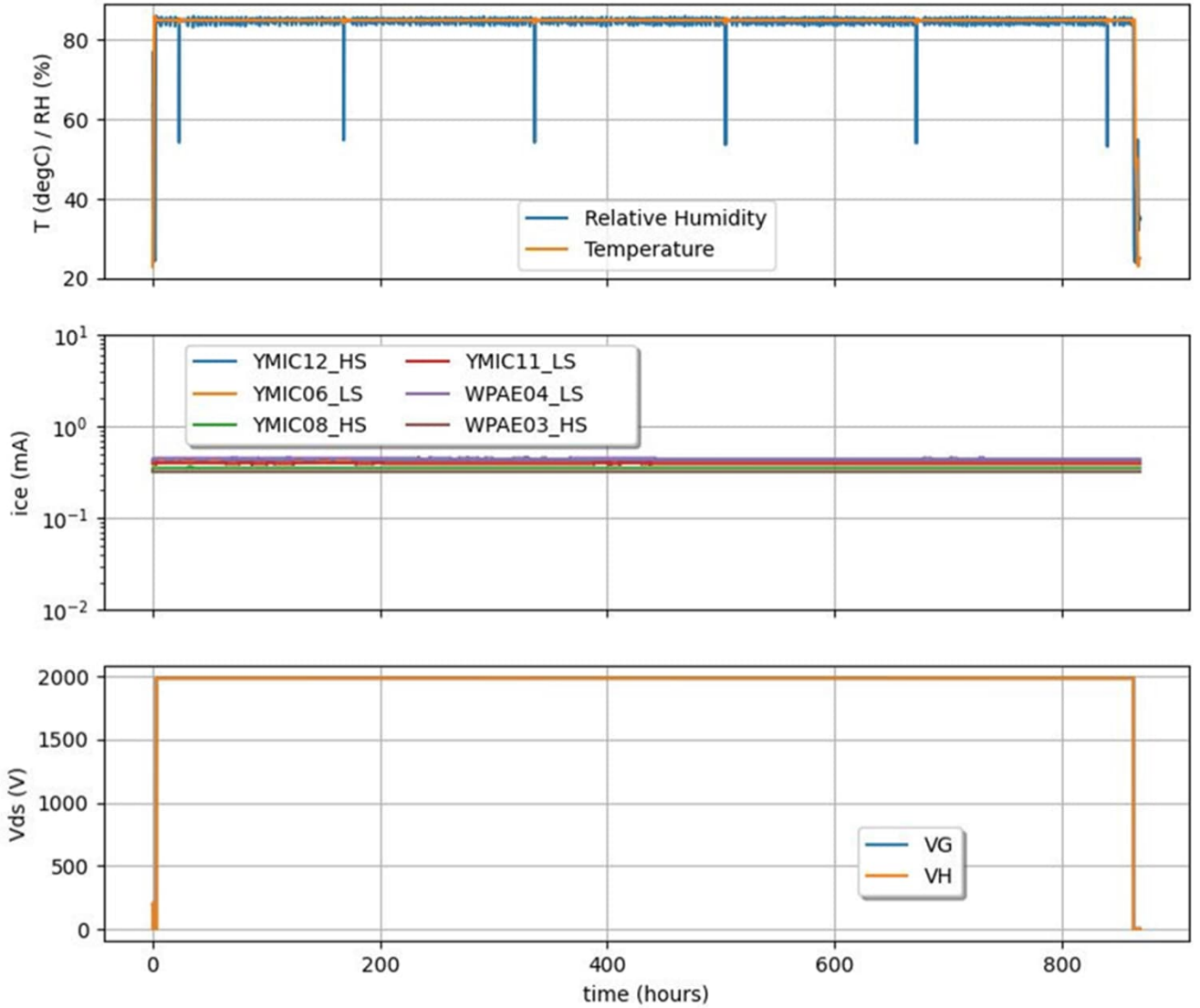
Railway Applications

HV-H3TRB tests for Power Semiconductor

HV-H_3TRB according to ECPE Guideline

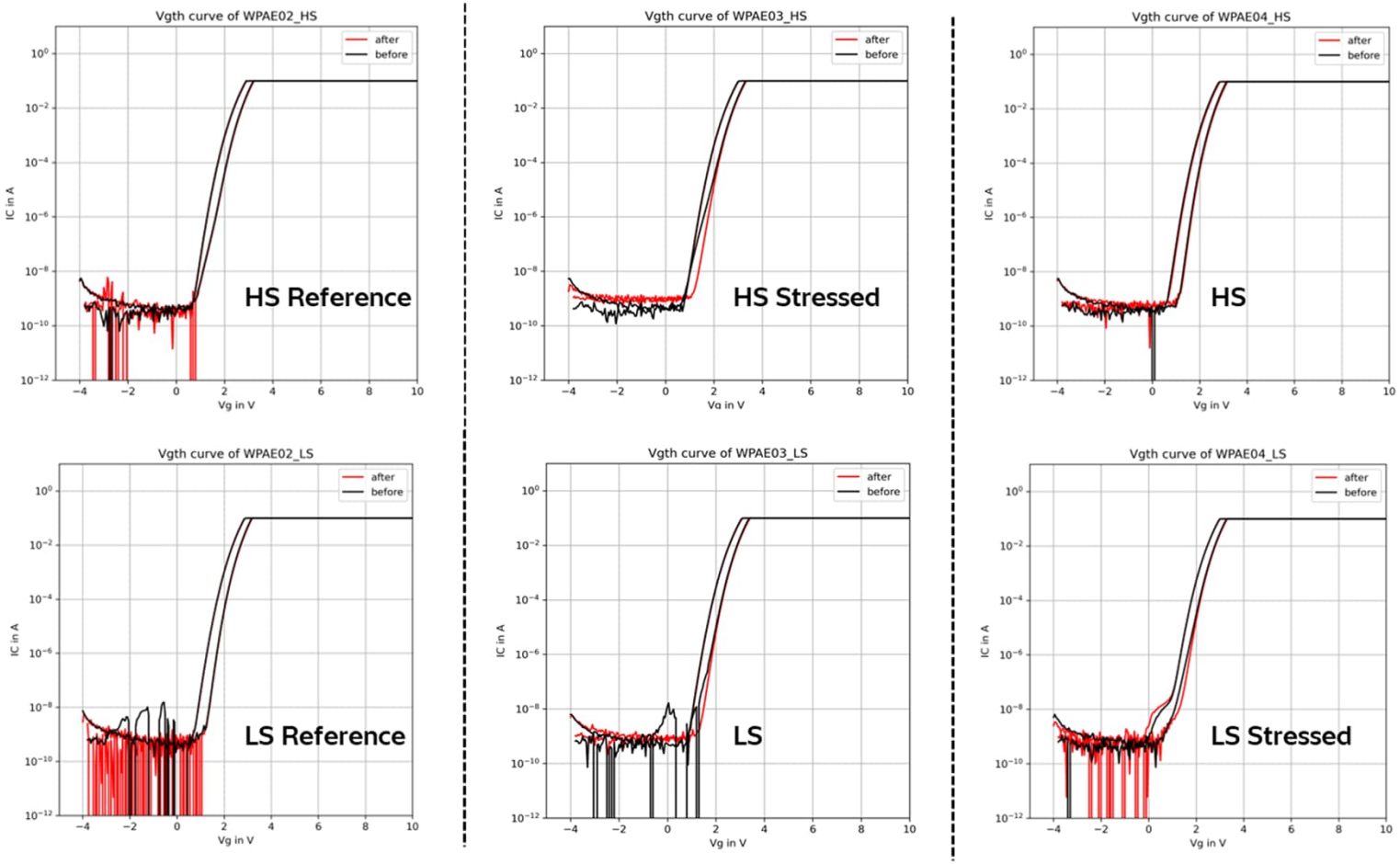
- In-situ monitoring of Temperature, Humidity, Voltage and Leakage Current





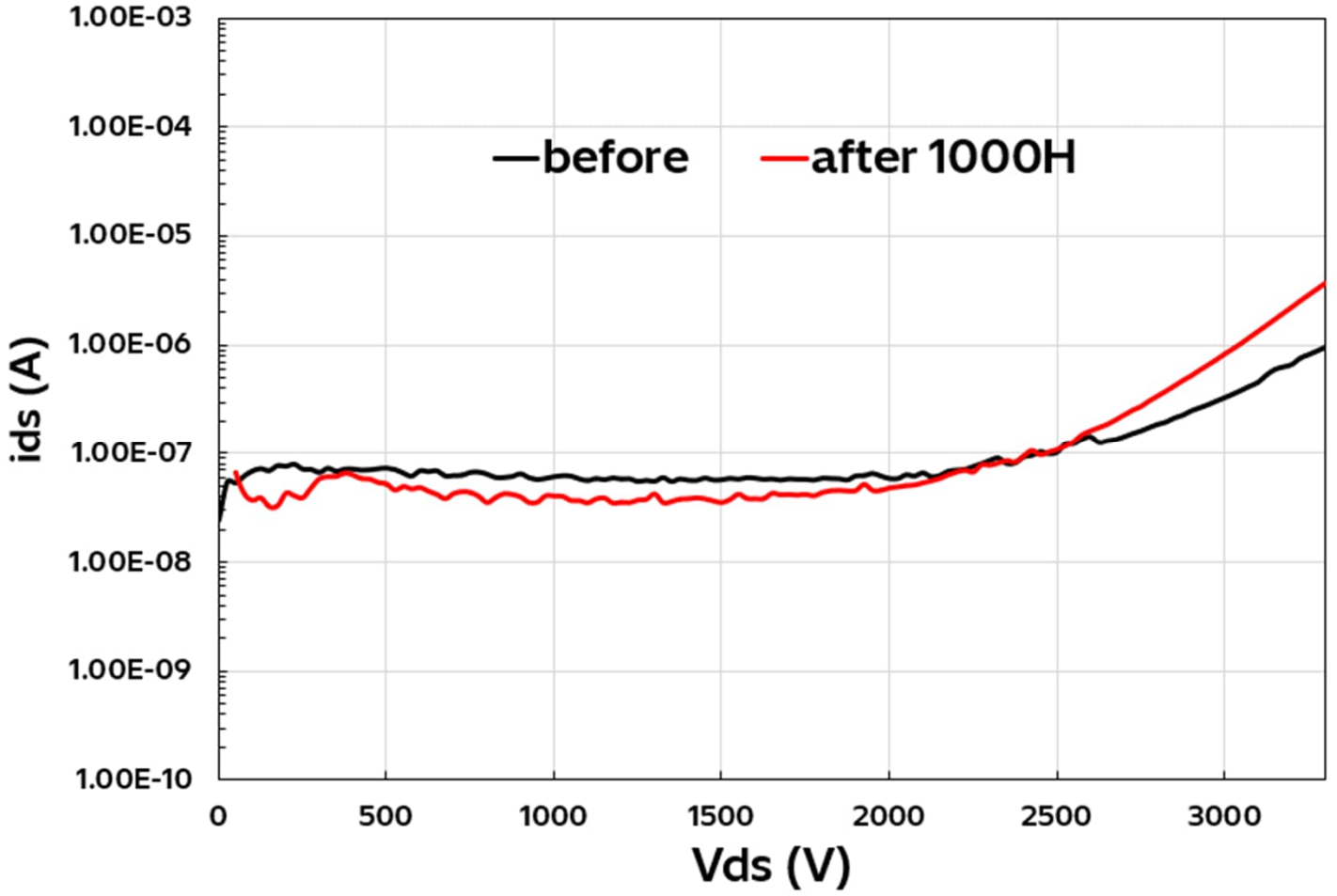
HV-H_3TRB according to ECPE Guideline

- Before-After Vth curves for modules that were tested vs. reference non stressed or not tested

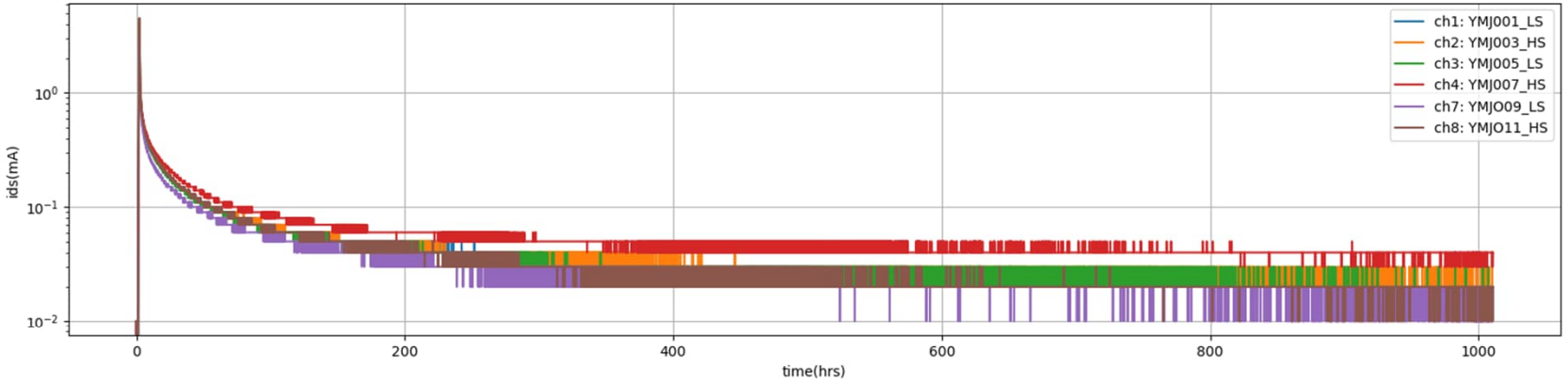


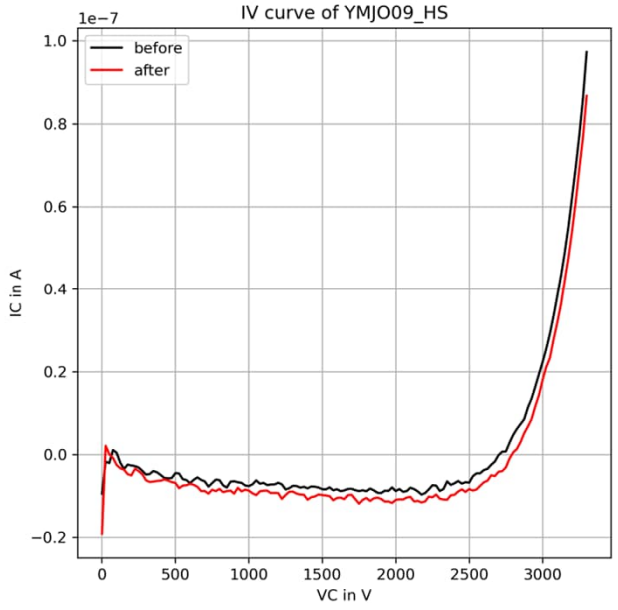
HV-H_3TRB according to ECPE Guideline

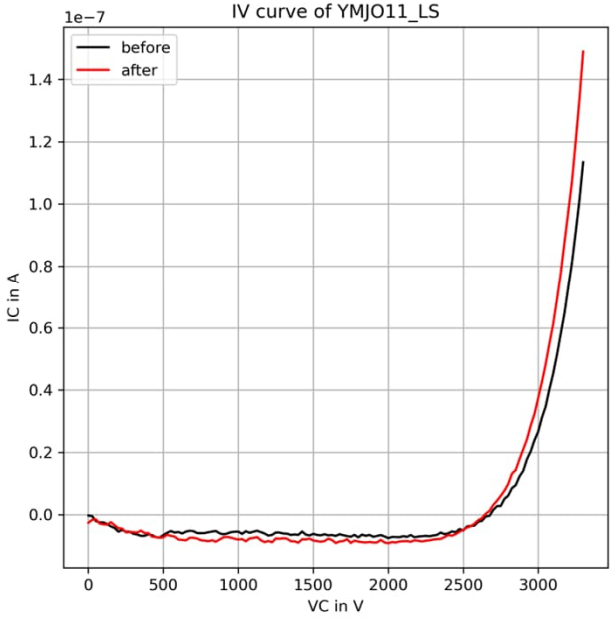
- Before-After IV curves for a typical module that underwent 1000h HV-H3TRB

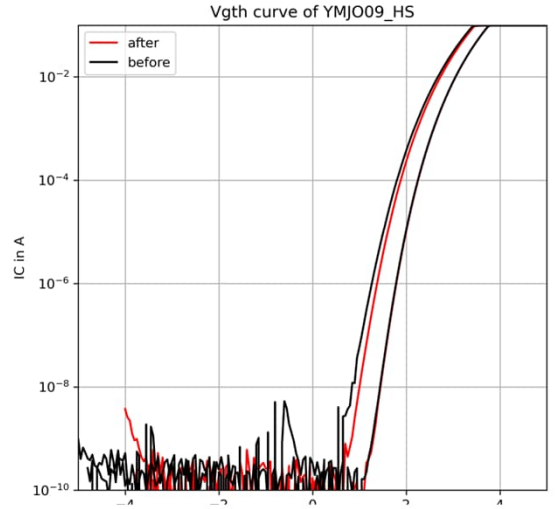


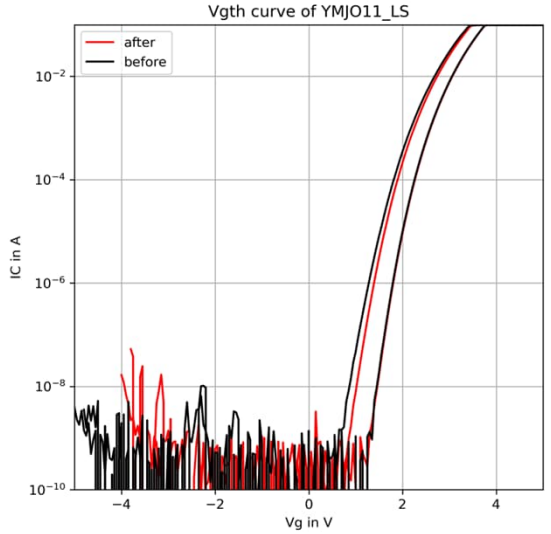
HTRB according to ECPE Guideline











Conclusion

- Hitachi Energy HV LinPak is a state-of-the-art module that can incorporate both Si IGBT and SiC MOSFET

- SiC switching characteristic allows the customer to increase switching frequency more than factor 20 when comparing to Si

- Design choices for housing, passivation materials and design of the chip termination allow successful pass of HTRB, HV-H3TRB, etc for both Si IGBT and SiC MOSFET

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