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Advances Through Innovation:
Transphorm Changes the Game with Gen-IV SuperGaN™ 650V GaN Platform

Yifeng Wu, Sr. VP of Engineering

transphorm

Highest Performance, Highest Reliability GaN

Outline

1. Overview—History and status of 600 V+ GaN products
2. Device configuration and Generation 4 SuperGaN™ design
3. Device characteristics
4. Application performance
5. Summary

Transphorm—A Leader in 600 V+ GaN Power Electronics

Start to Develop 600 V GaN (2005 – 2012)	600 - 650 V GaN Products (2017)	> 600 V GaN Product (2020)
EPC	~~EPC (450 V)~~	**600-650 V GaN Commercial**
Fujitsu	Fujitsu	✓ Transphorm
GaN Systems	✓ GaN Systems (TSMC)	✓ Infineon/Panasonic
Infineon	~~Infineon~~ (licensed Panasonic)	✓ TSMC (GaN Sys./Navitas)
International Rectifier	~~International Rectifier~~	✓ Texas Instruments
MicroGaN	~~MicroGaN~~	✓ Power Integrations
Panasonic	✓ Panasonic	**650 V GaN Automotive**
RFMD	~~RFMD~~	✓ Transphorm
Toshiba	~~Toshiba~~	**900 V GaN Commercial (JEDEC)**
Transphorm	✓ Transphorm/Fujitsu	✓ Transphorm

Transphorm Has Shipped 500,000 GaN Parts To The Market:

Enabled total conversion capacity in field: 200 MW

Markets

High-voltage GaN technology benefits numerous markets that require reliable higher efficiency, higher performance power conversion. The highest adoption rates are projected for the following application areas:

Increases clean power output in standardized server and telecom form factors.

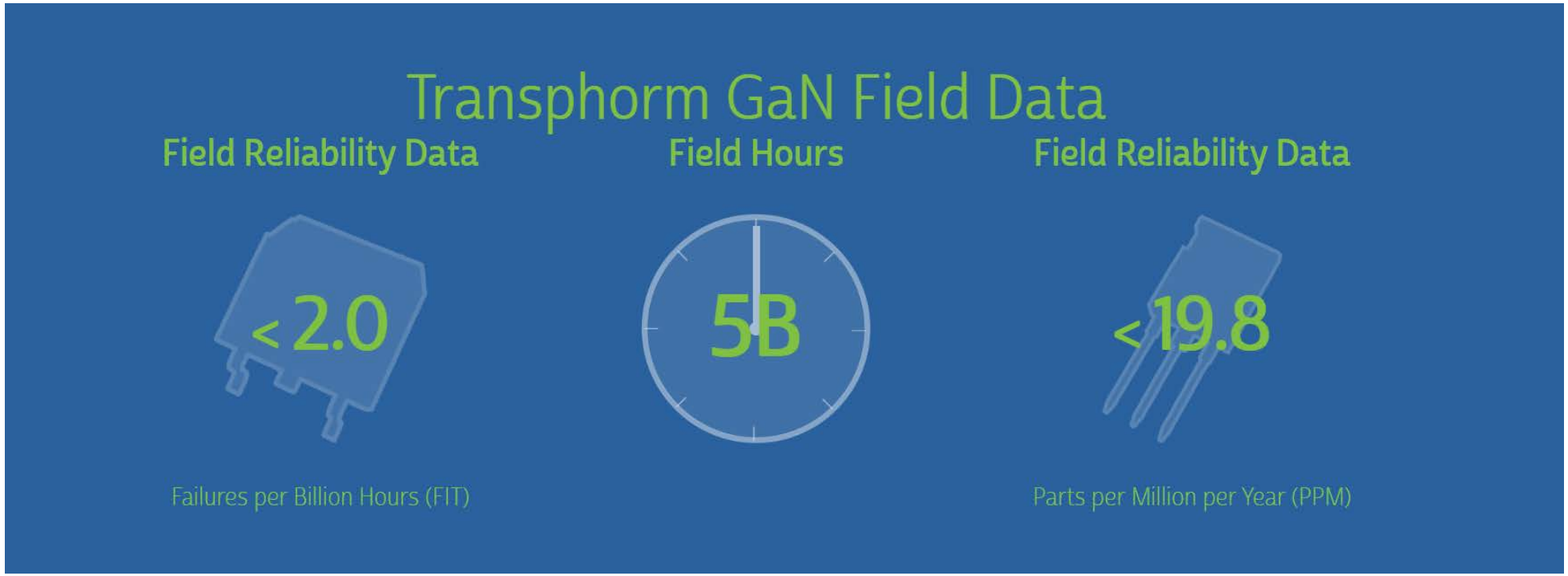
Improved efficiencies result in lower thermals, improved power density and lower system cost.

Reduces size and weight of systems that run industrial factories, charge battery powered forklifts, electric vehicles and keep critical data accessible..

Generates longer distance per charge with a lower overall system cost.

Field PPM Rates Showing Excellent Reliability

To Date: 4ppm Field Failure Rate

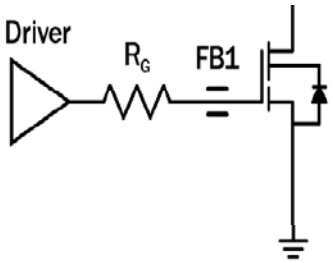


GaN 2-chip Normally Off Implementation

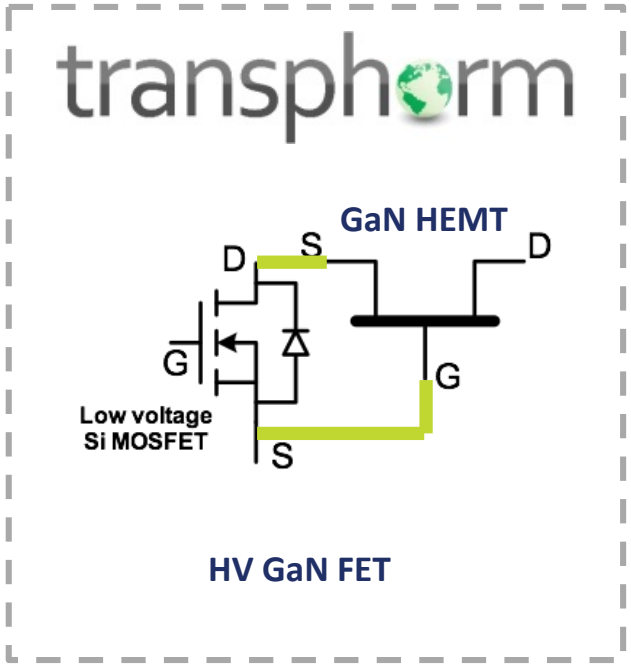
Packs High Performance With High Reliability

Standard Gate Driver Examples:

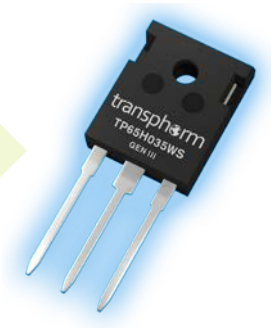
- Silicon Labs
- ON Semiconductor
- Texas Instruments



Simple to Drive GaN FET



HV GaN FET



Normally off Packaged Part

- ✓ Low R_{ON}
- ✓ Minimal miller plateau
- ✓ Fast switching
- ✓ Diode free bridge

Standard Gate Drivers

High Noise Immunity

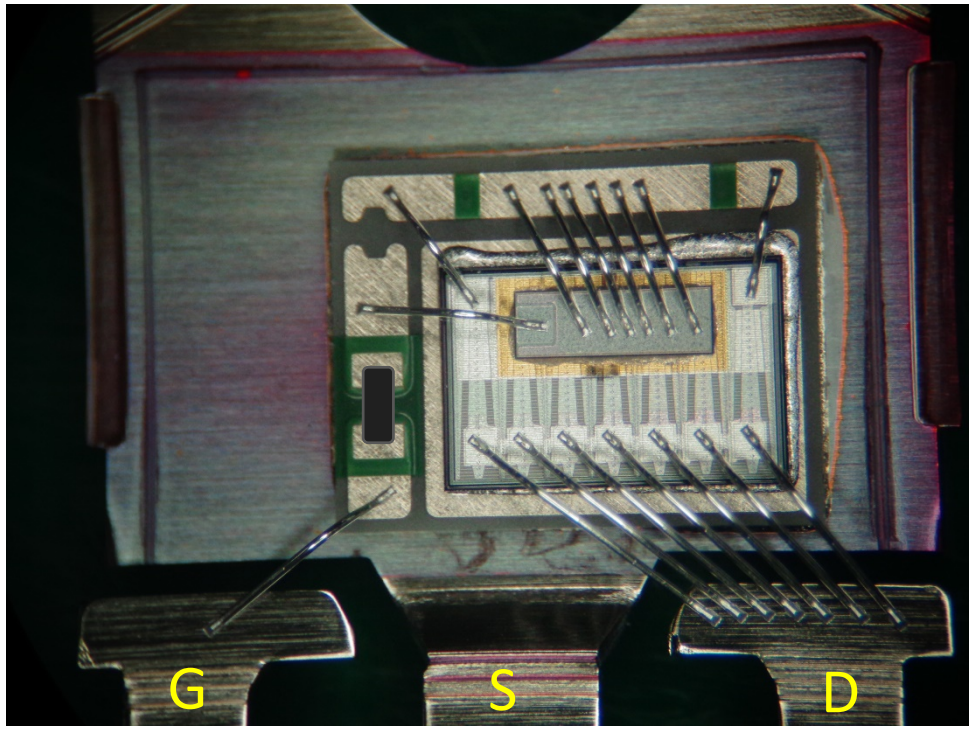
Robust Gate

High Gate Drive Margin

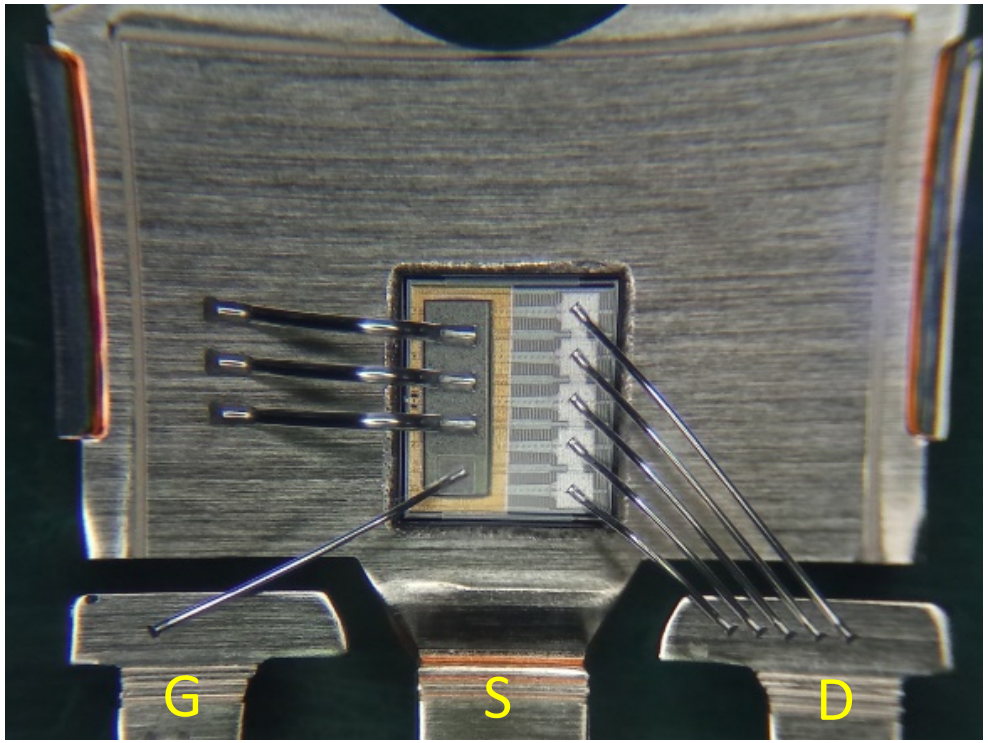
6

Innovative Design Enables Simplest 2-chip Normally-off GaN

Gen III



Gen IV



- Patented innovation transforms a complex 2-chip design into a simplistic “1-chip-like” package
- Multiple components/wires were removed from previous product
- Targeting remarkable cost reduction and significant performance improvement

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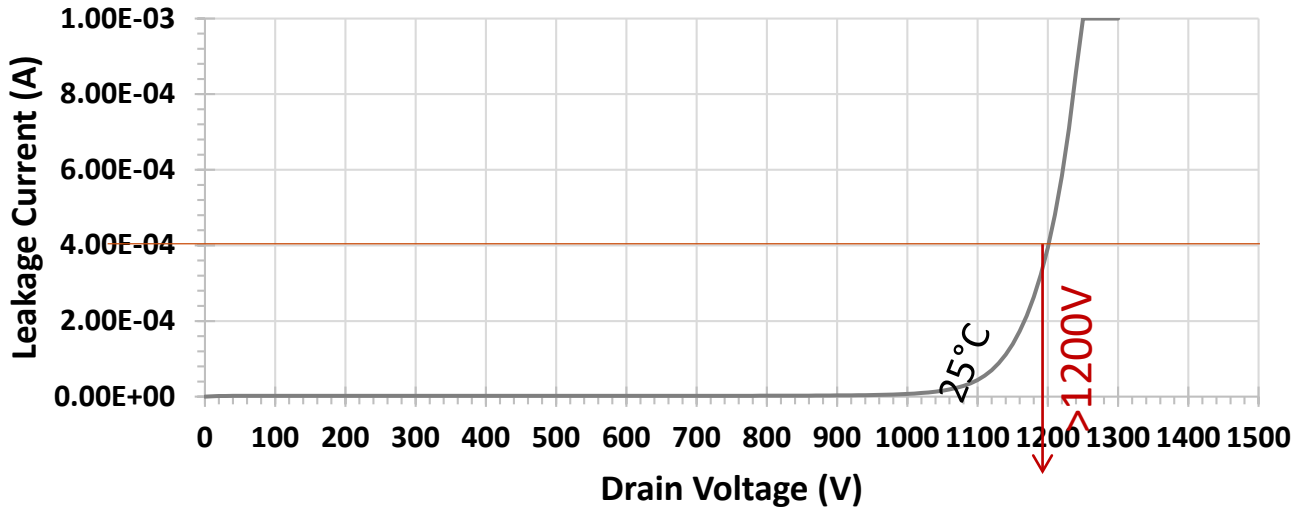
TPH Gen IV GaN Vs. Other GaN: I_{DSS} Comparison

TPH Gen IV (35mΩ):



Other GaN (70mΩ):

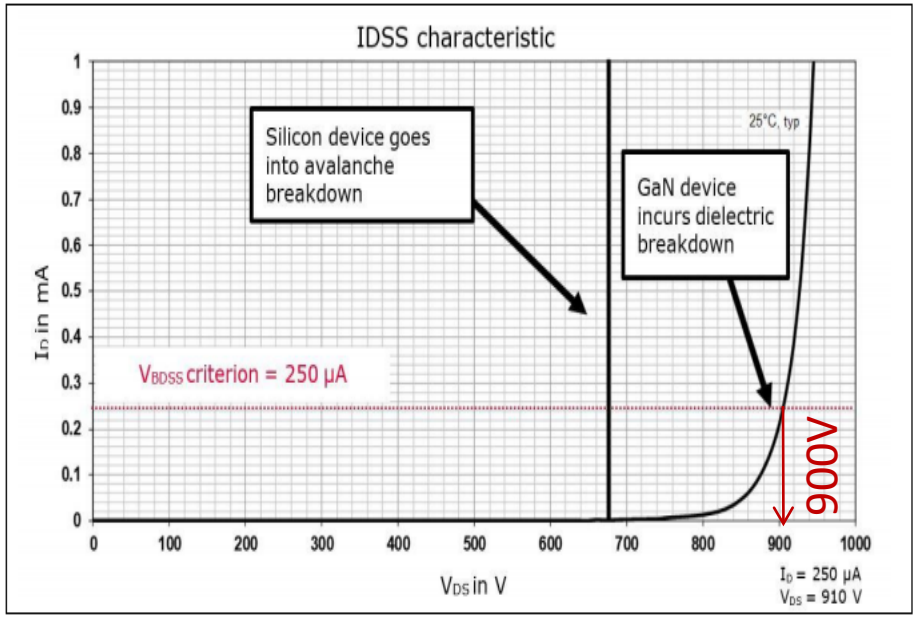
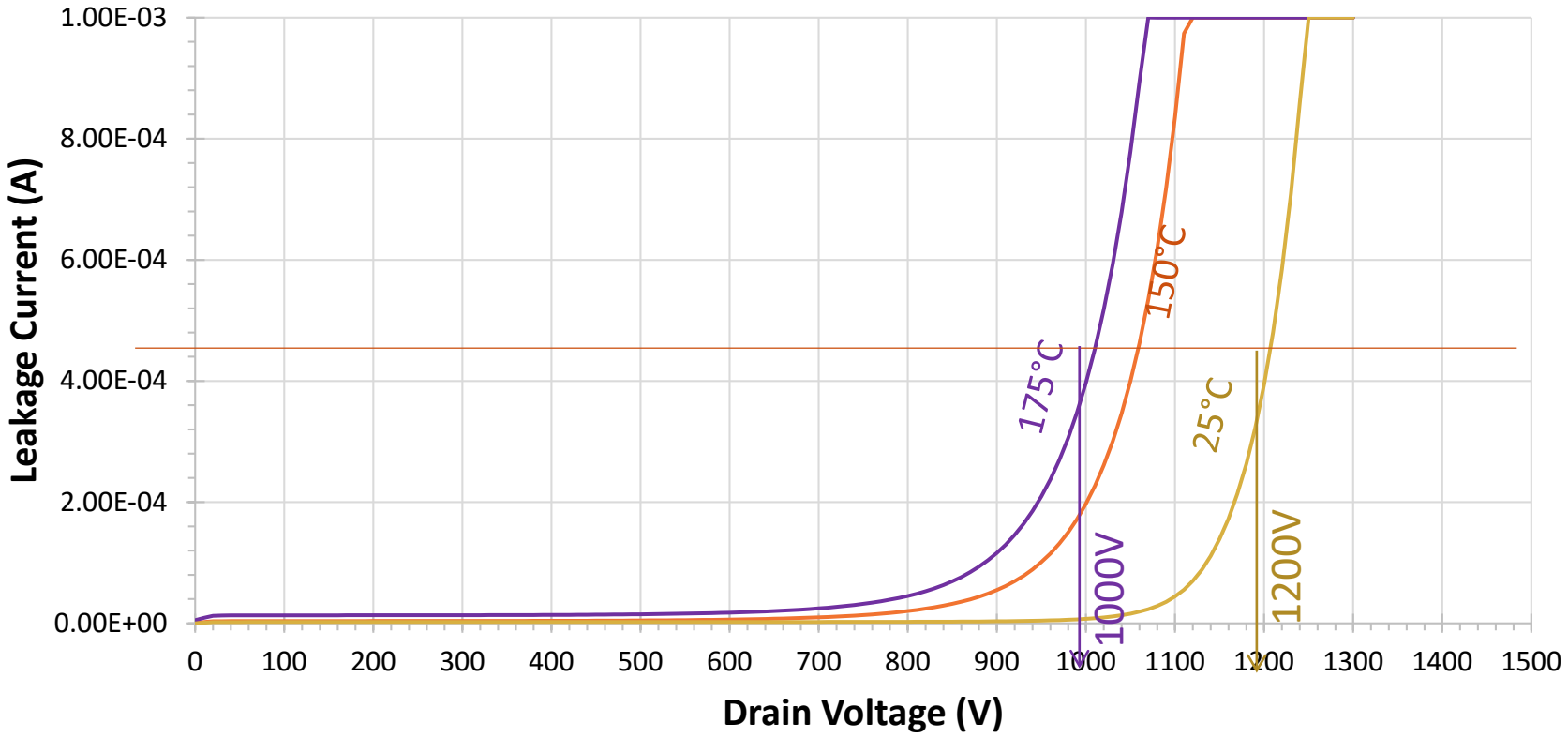


Figure 13 Overlay of drain current versus drain voltage traces for a 600 V-rated GaN HEMT and a 650V-rated silicon SJ MOSFET

- TPH Gen IV: 1200 V at 25°C
- 300 V higher than competition

Gen IV I_{DSS} At High Temperatures

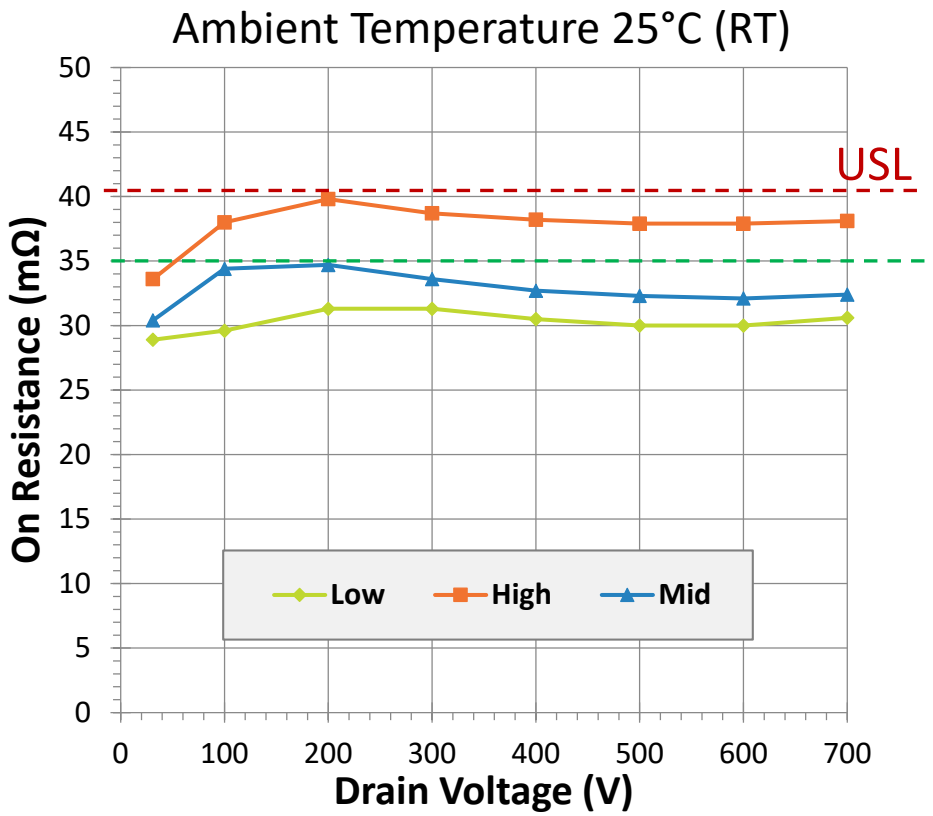


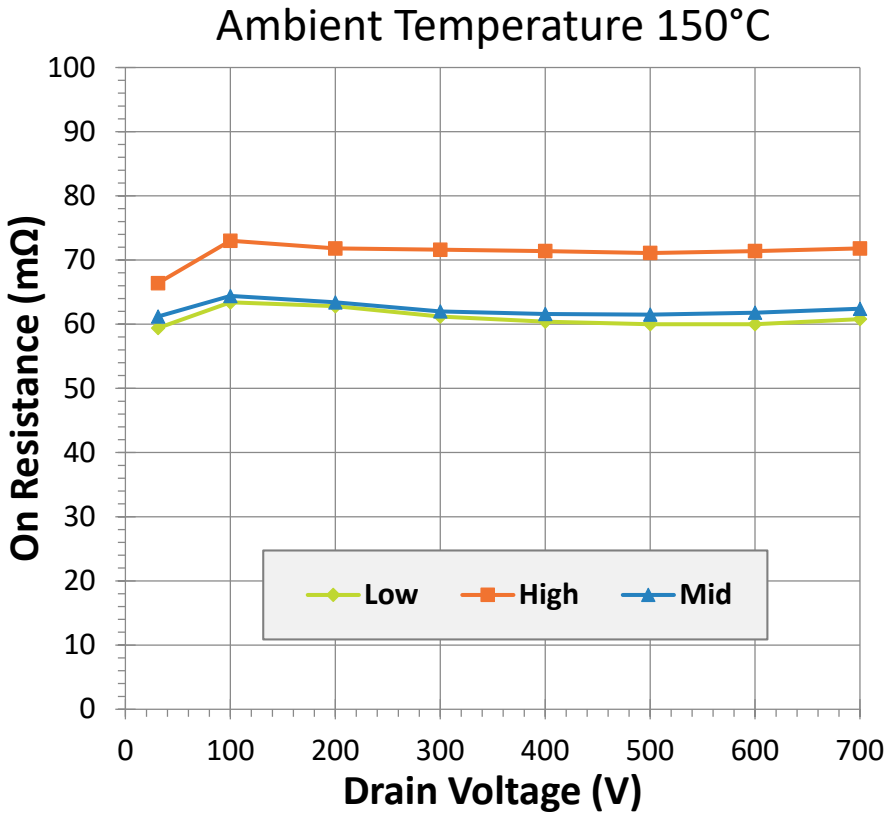
1000 V breakdown even at higher 175°C temperature

- Breakdown at 150°C: 1050 V
- Breakdown at 175°C: 1000 V

In Circuit Test - DyRon vs. Vd Very Stable at RT & 150°C

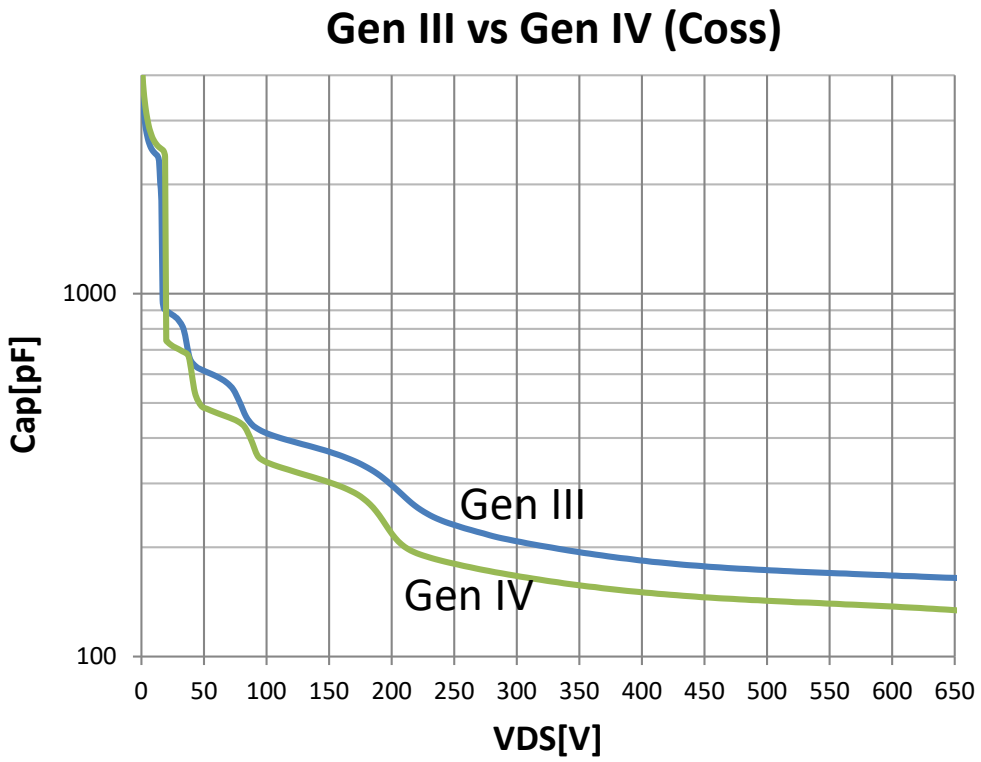
Switching to 700 V

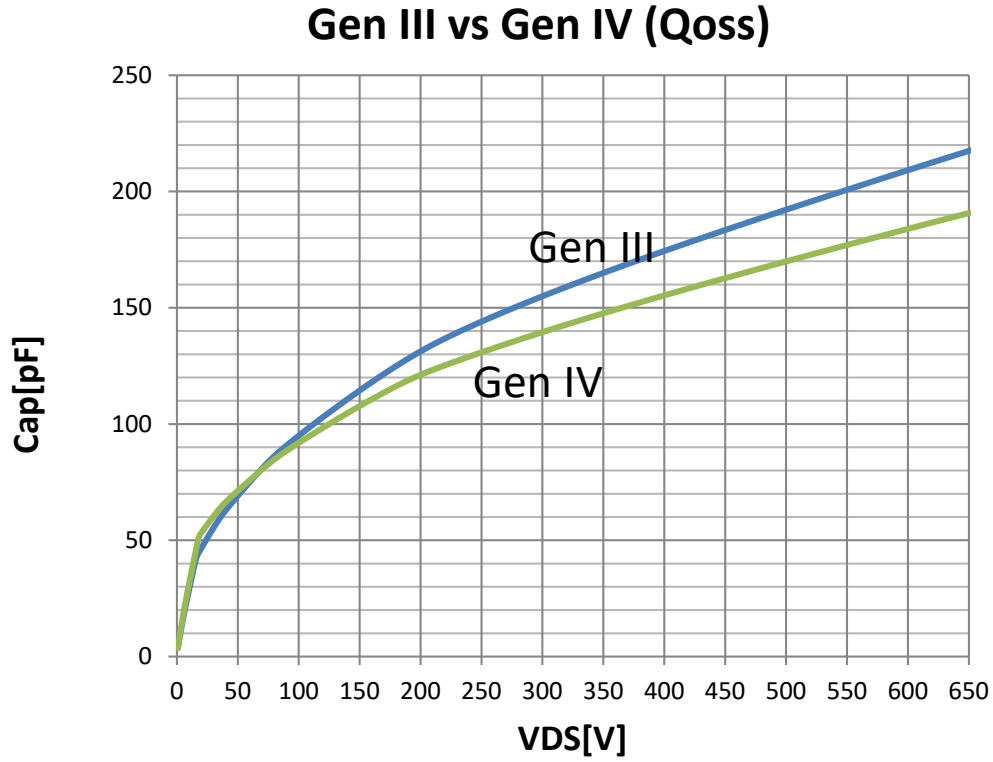




- Max/typical/low Ron devices tested
- Flat Dynamic $R_{DS(on)}$ to 700 V at 25°C & 150°C

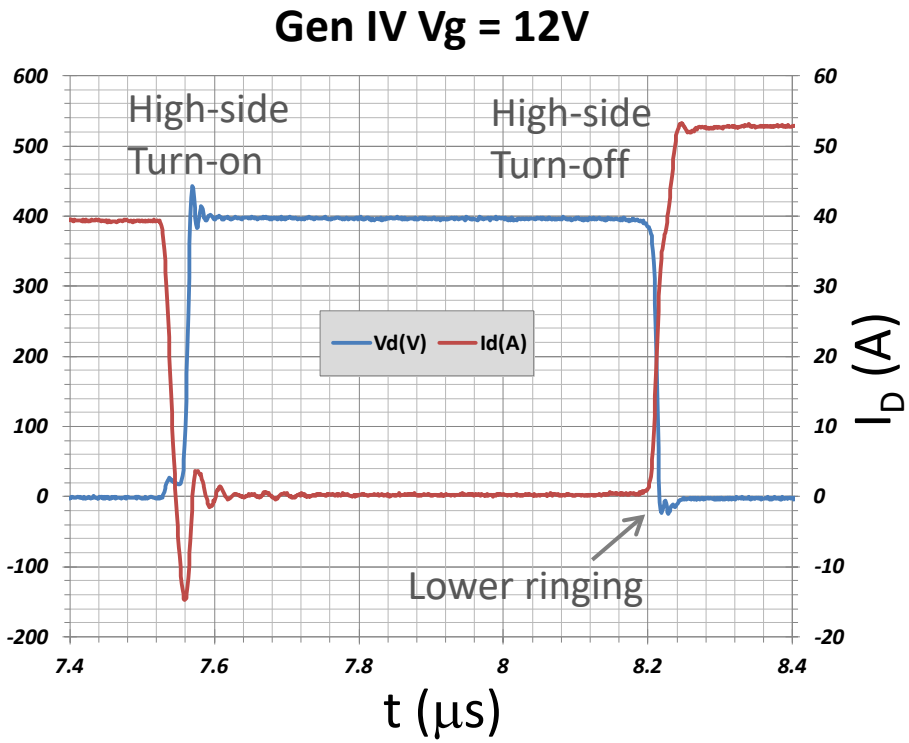
Dynamic Parameters- C_{oss} & Q_{oss} vs. Vd





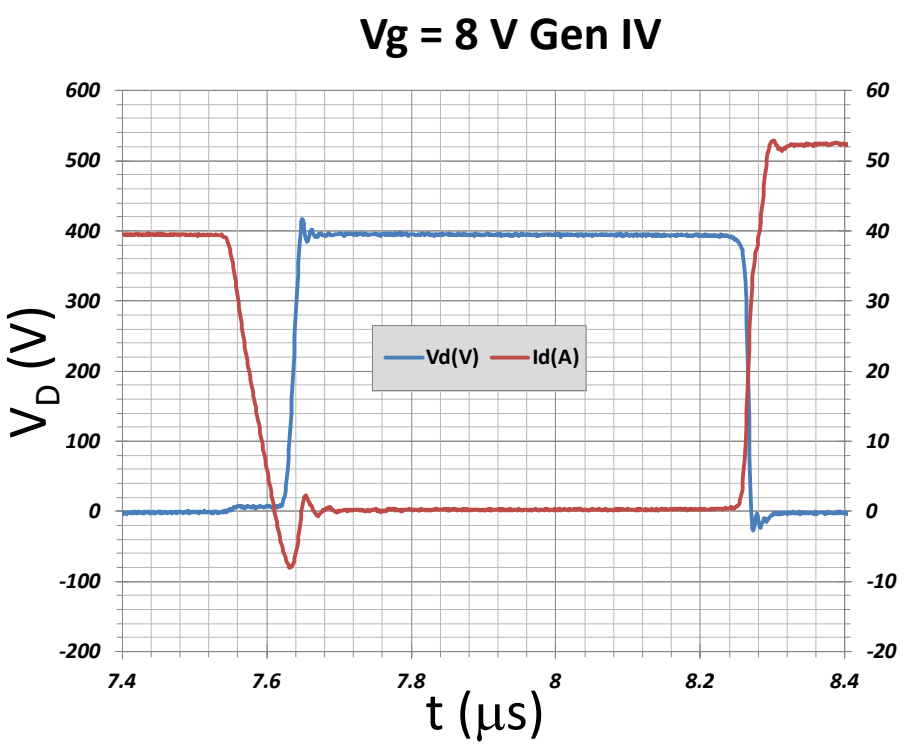
- Reduced C_{oss} & Q_{oss}

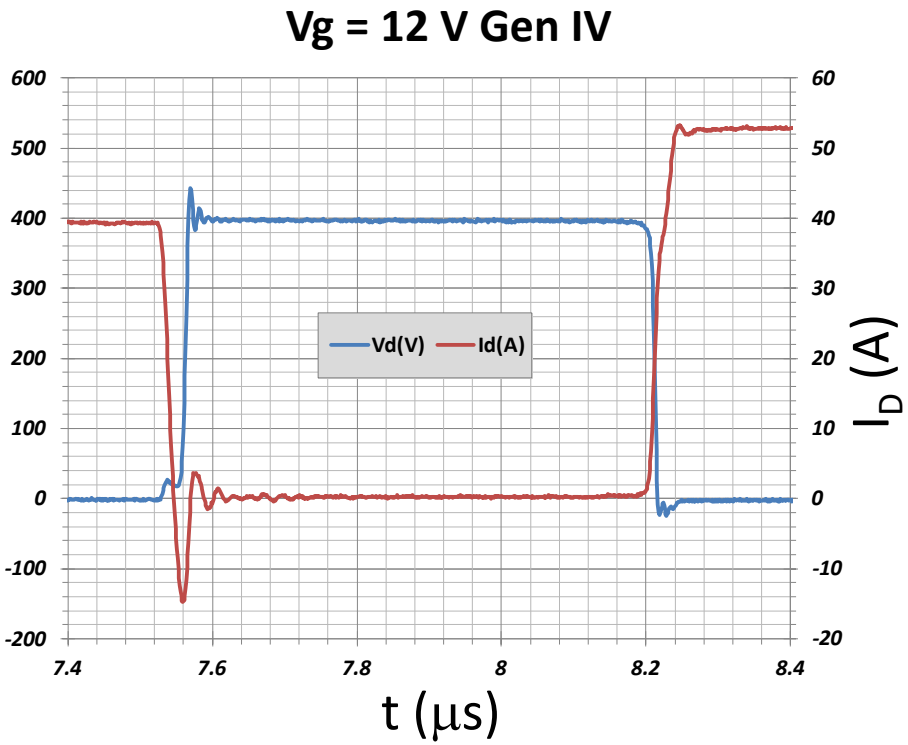
Verified Switching Performance: Gen IV



- Gen IV: Higher speed but much lower turn-off ringing
  =>Improved stability
- Turn-on spike can be controlled (next slide)

Switching Performance: Speed Controllability





- Switching speed controllable with Vg (or Rg)

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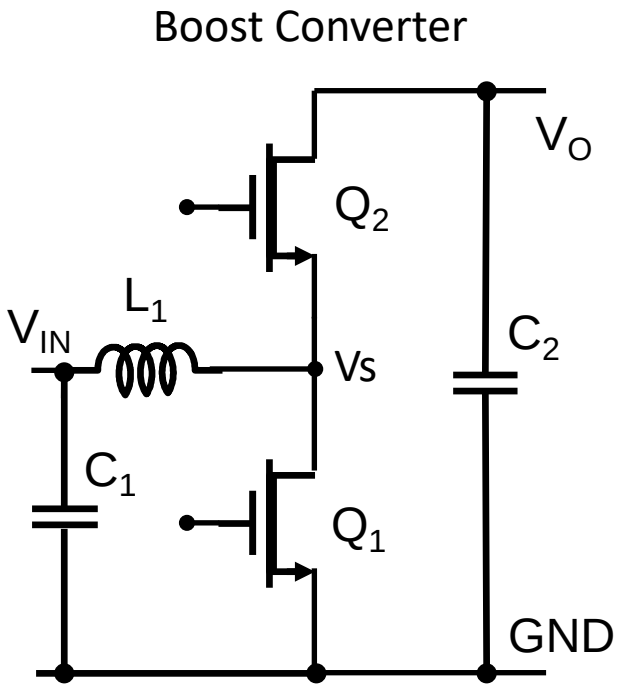
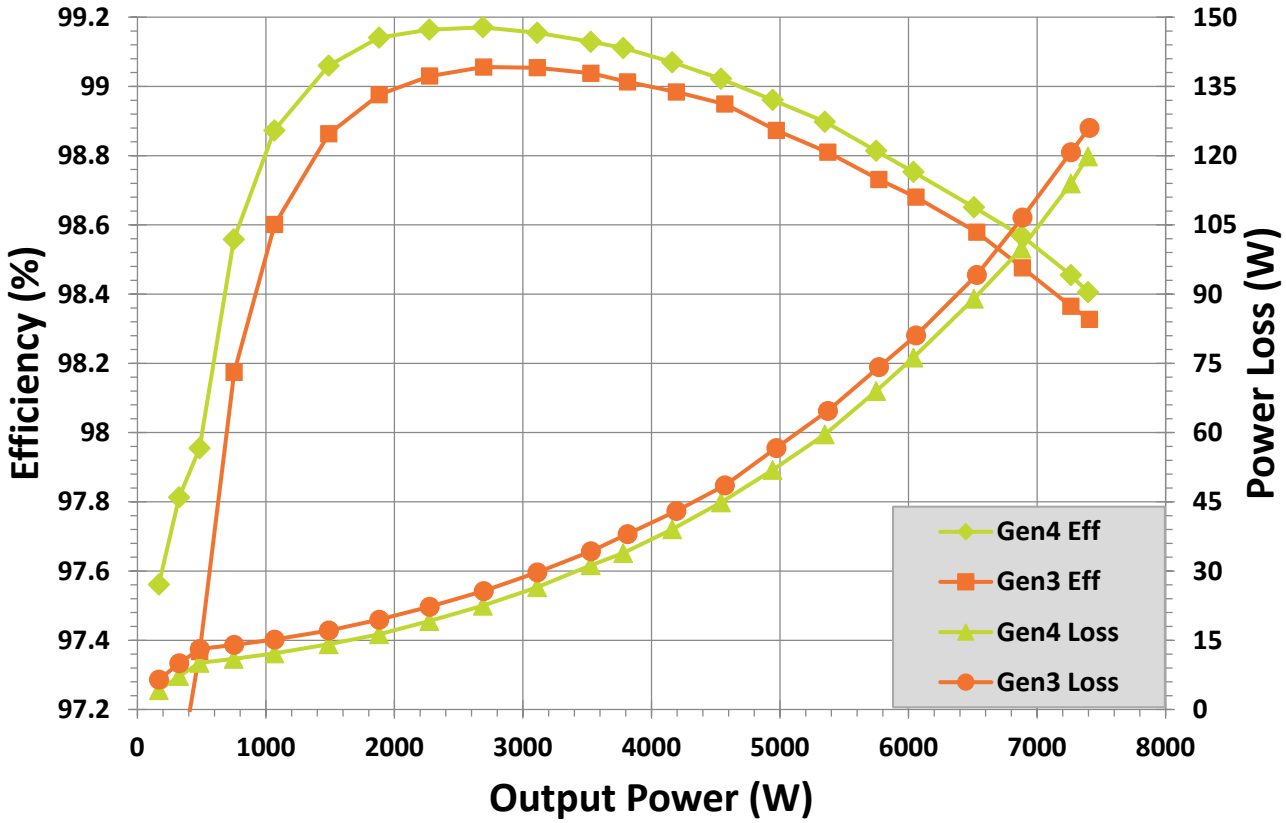
Performance Benefit, Gen IV vs. Gen III

Synchronous Boost Converter: 240 V:400 V @ 100 kHz



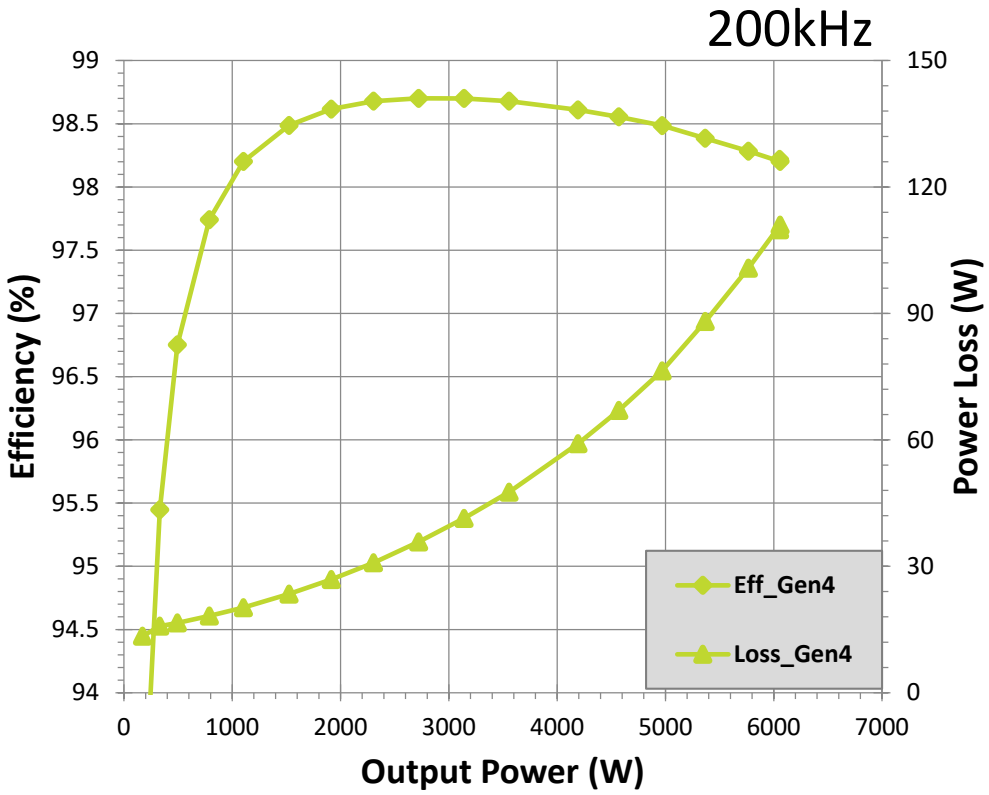


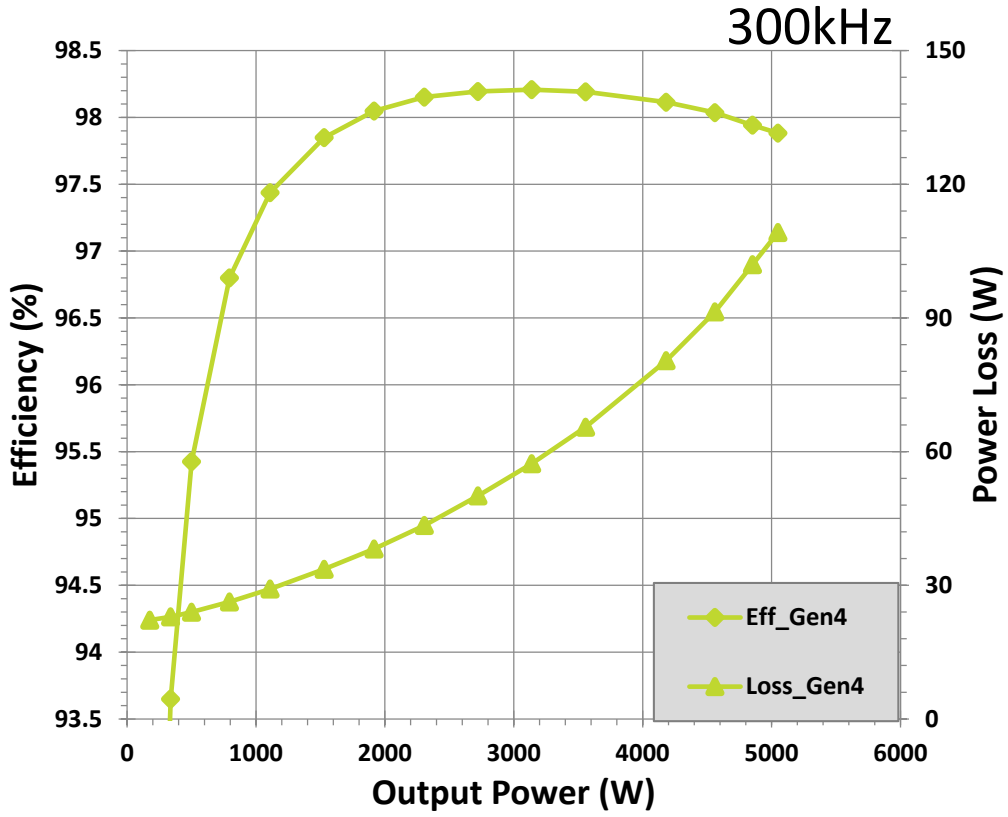
- Gen IV further improves efficiency:

✓ 0.2-0.4% improvement at low load & >0.1% at mid to high load.

Performance Benefit at 200 and 300 kHz

Synchronous Boost Converter: 240 V:400 V





- All test were in <u>hard-switching</u> (Expect higher Eff. in soft switching)

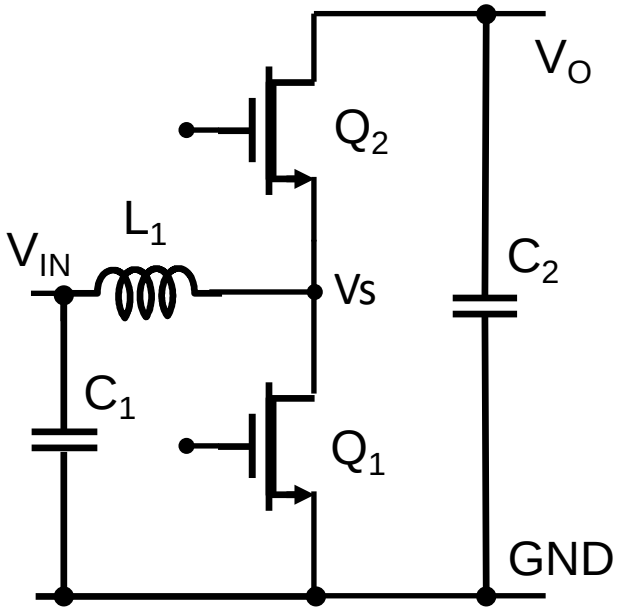
[200kHz] Peak efficiency: Gen IV 98.70% => Best-in-class

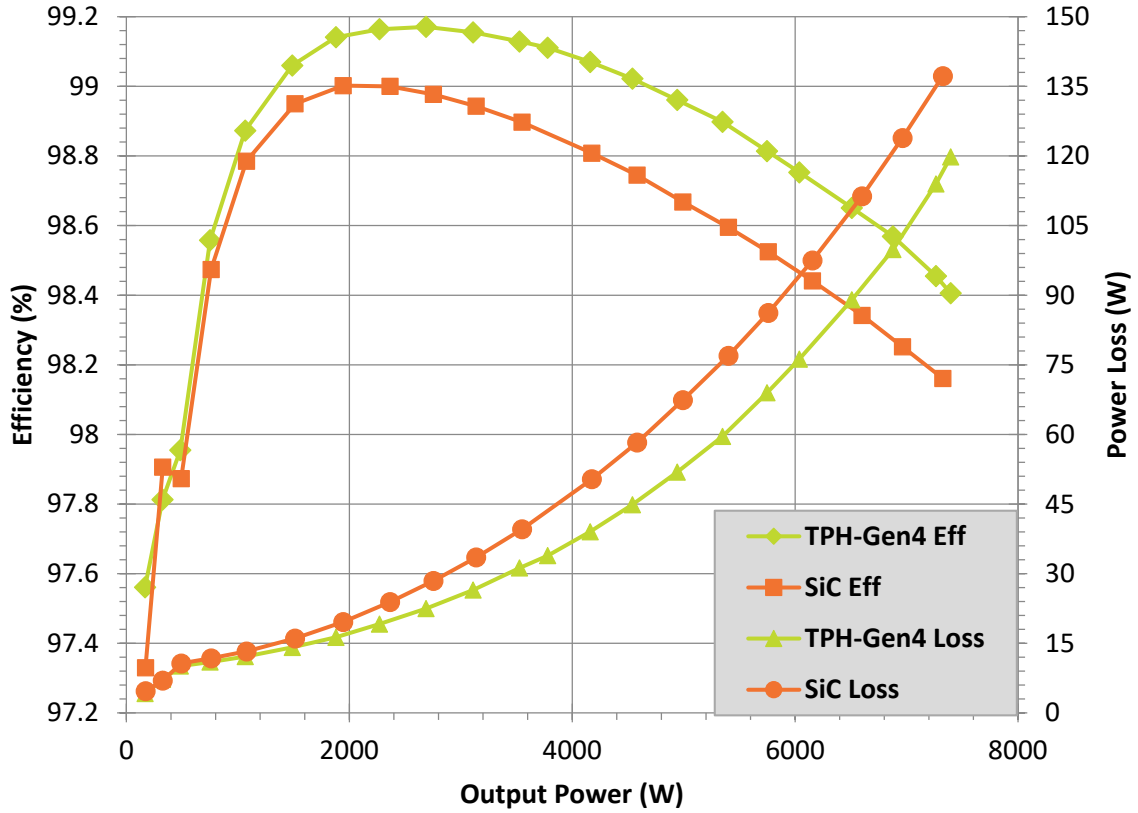
[300kHz] Peak efficiency: Gen IV 98.21% => Best-in-class

Performance Compared to SiC MOSFET (30mΩ)

Synchronous Boost Converter: 240 V:400 V @ 100 kHz

Half-bridge Boost Converter
[Gate drive] GaN: 0-12V, R_G=30
SiC: 0-18V, R_G=0

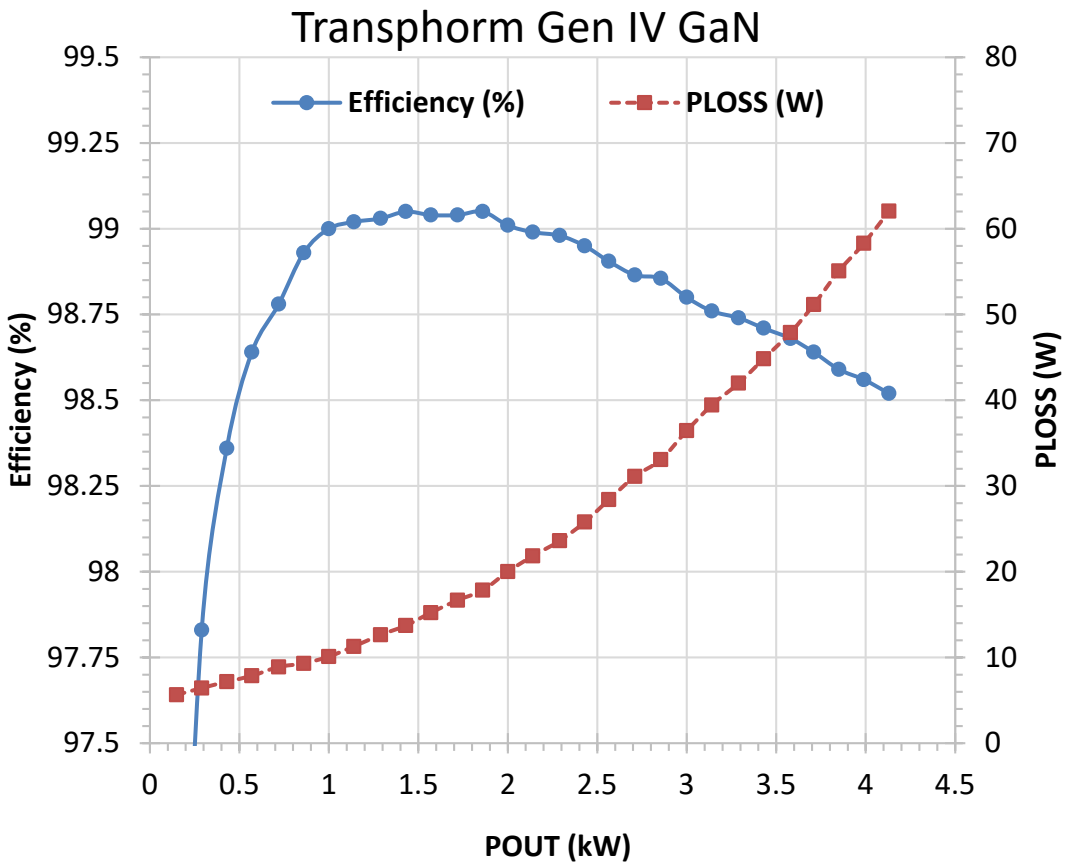


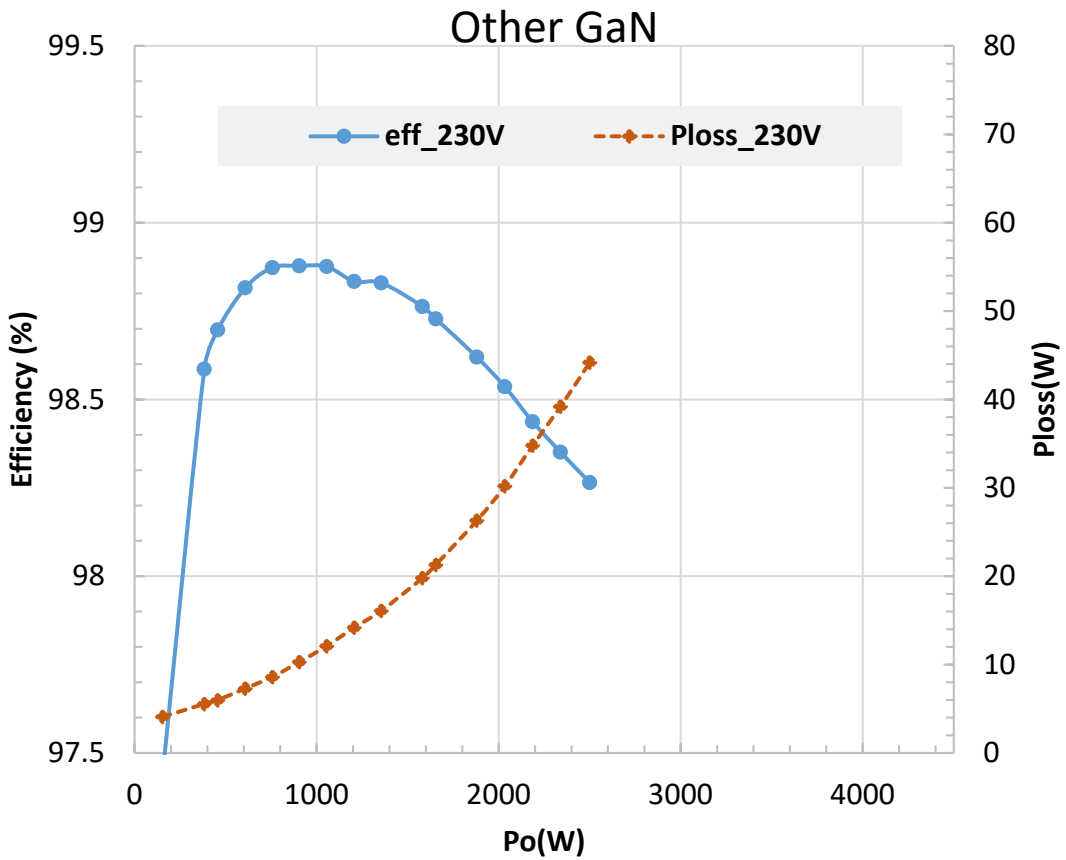


GaN: Efficiency improvement >0.2% from 3 kW-7.2 kW
✓The only GaN product to deliver 7.3 kW (100kHz)

Best-in-Class Totem-pole PFC Performance

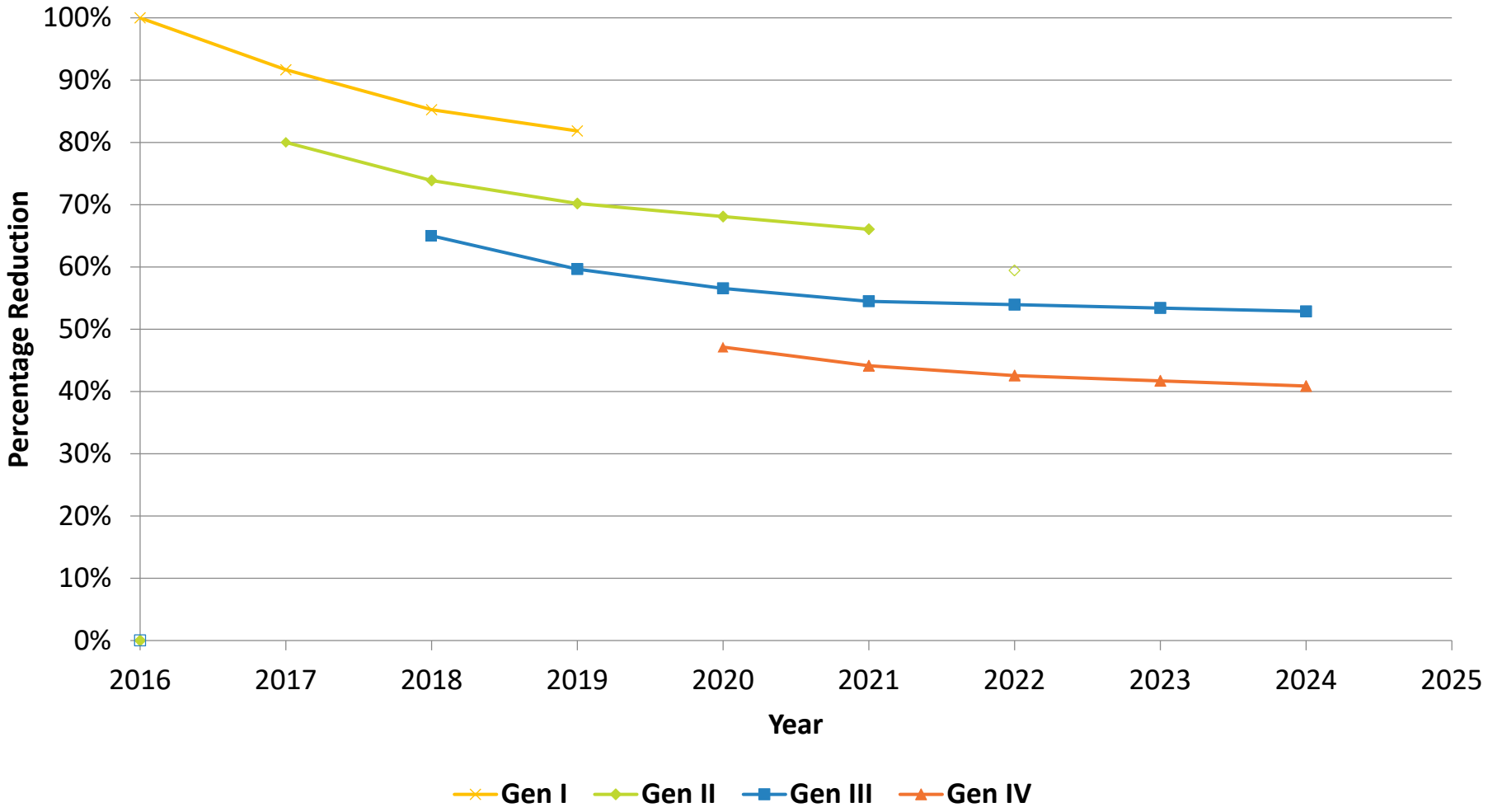
Highest Efficiency and Power Level By Discrete GaN: 230 Vrms:390 Vdc @ 65 kHz





- Same operation voltages & frequency in the same test setup.
- All auxiliary power & fan consumption included
- Peak efficiency: >99.0% vs. <98.9% (0.17% higher)
- Max power: 4.13kW vs. 2.50kW (65% higher)

Transphorm – Technology Price Reduction Y-O-Y



Summary

1. Transphorm has a proven success track record with 2-chip normally-off 600V+ GaN products based on a robust technology.
2. Continued innovation leads to Generation-4 devices transforming the 2-chip design into a 1-chip-like simplicity.
3. While Gen II/Gen III are matured and qualified as automotive grade (AEC Q101), Gen IV design is being introduced for commercial / industrial applications.
4. The simplicity and high-performance Gen IV product will accelerate GaN adoption in the power electronics market.

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