No Two Wide Bandgap Technologies are the Same: Switching Advantages of SuperGaN® FETs and Innovation

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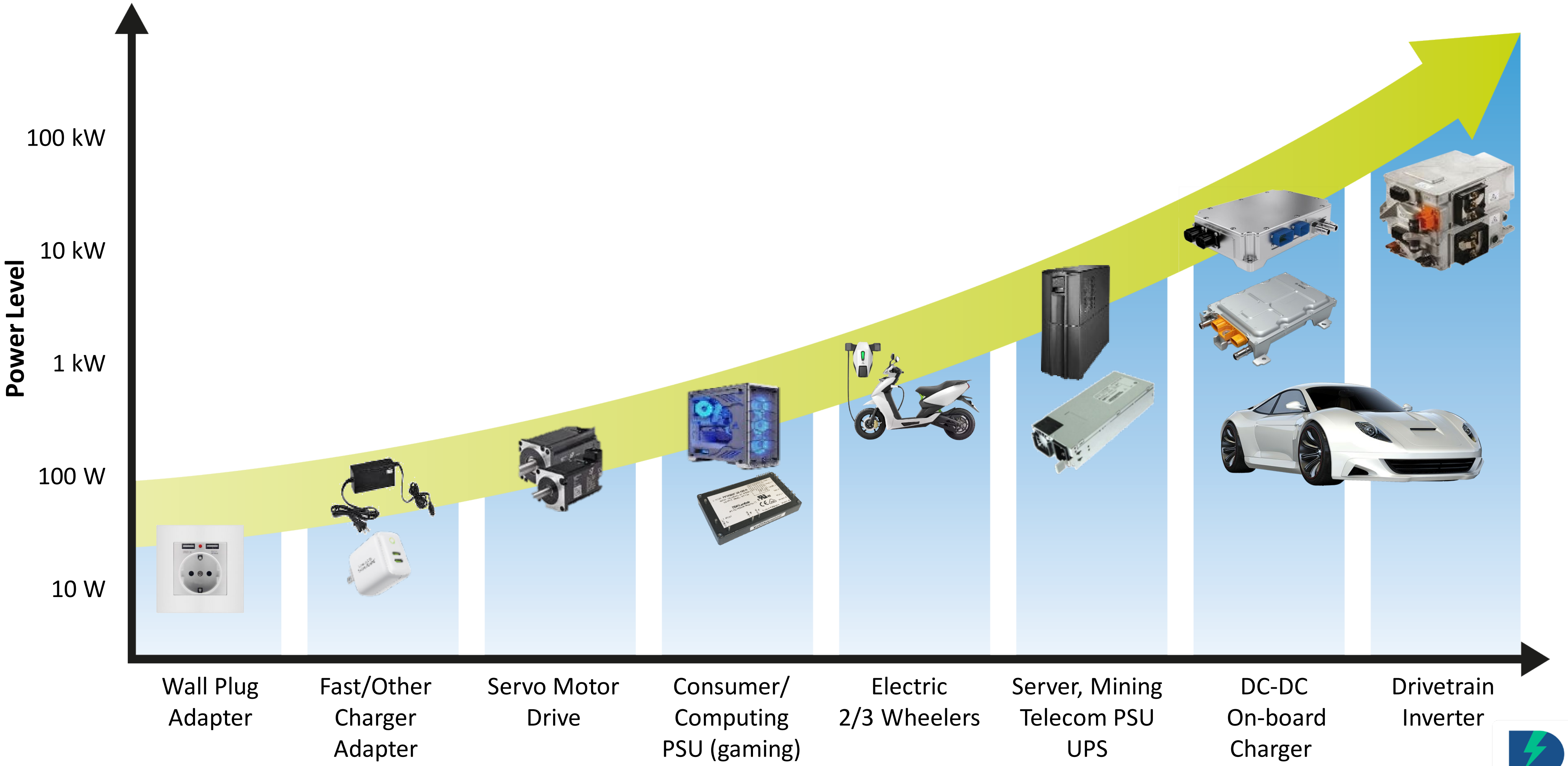
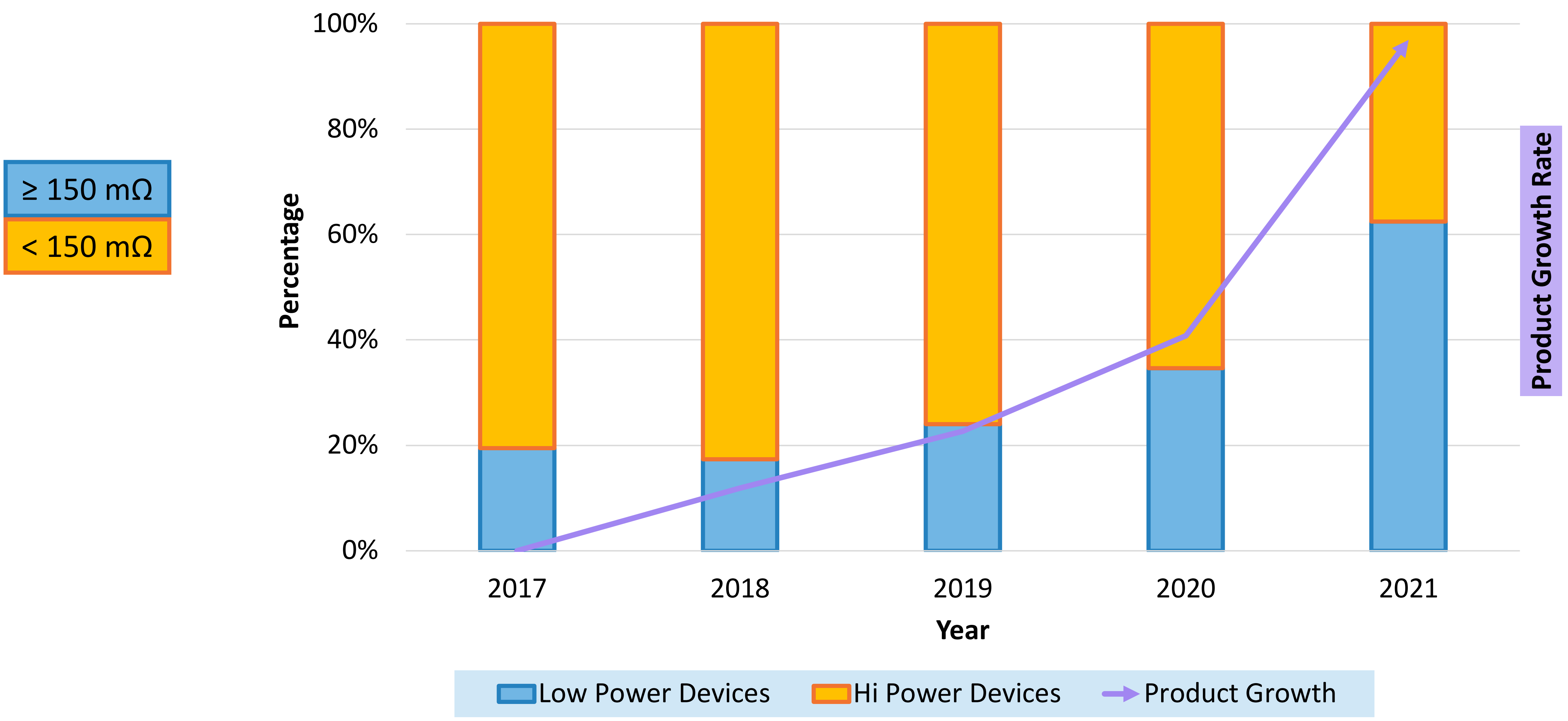
Agenda

- Broad market, application and power supplier
- <u>Current Technology Platform</u>
  - 650 V SuperGaN®
    - Comparison to previous Gen III technology
    - Comparison to the latest SiC technology
  - 900 V GaN FET Technology
- <u>Innovation</u>
  - 1200 V technology
  - Short Circuit Control Limiter (SCCL)
- Summary

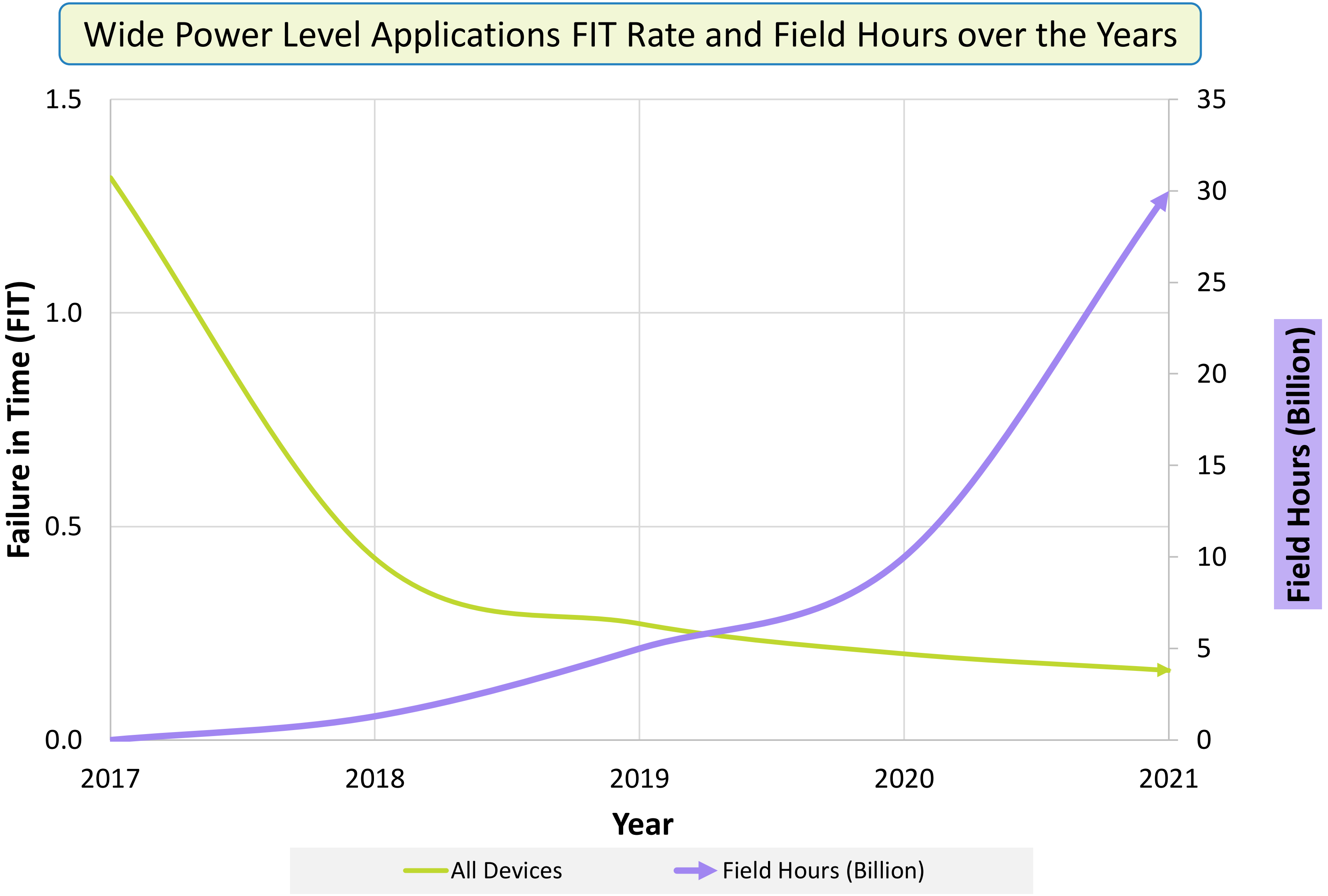
One Core Platform, Crossing the Power Spectrum



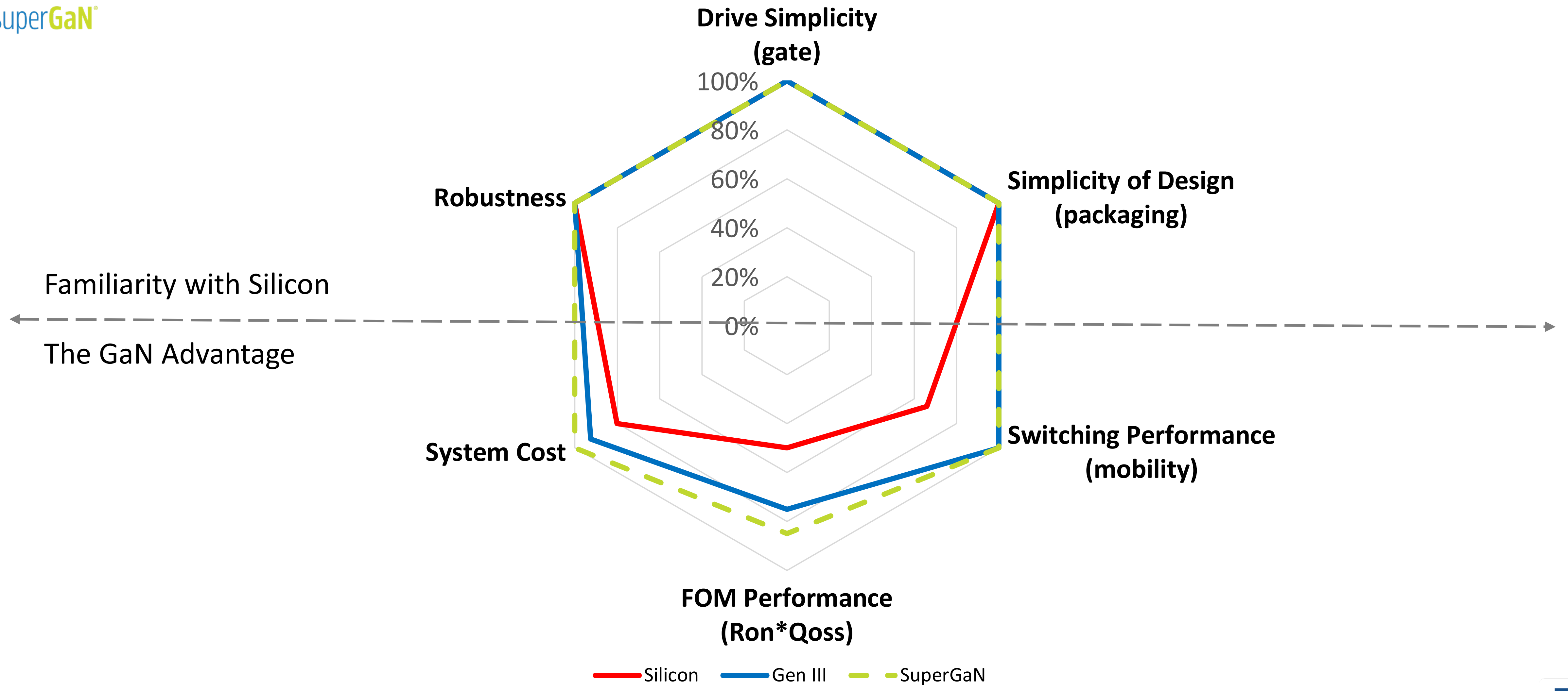
Product Mix and Growth From 45 W Through 4 kW



Field Reliability for Wide Market Adoption (45 W to 4 kW)

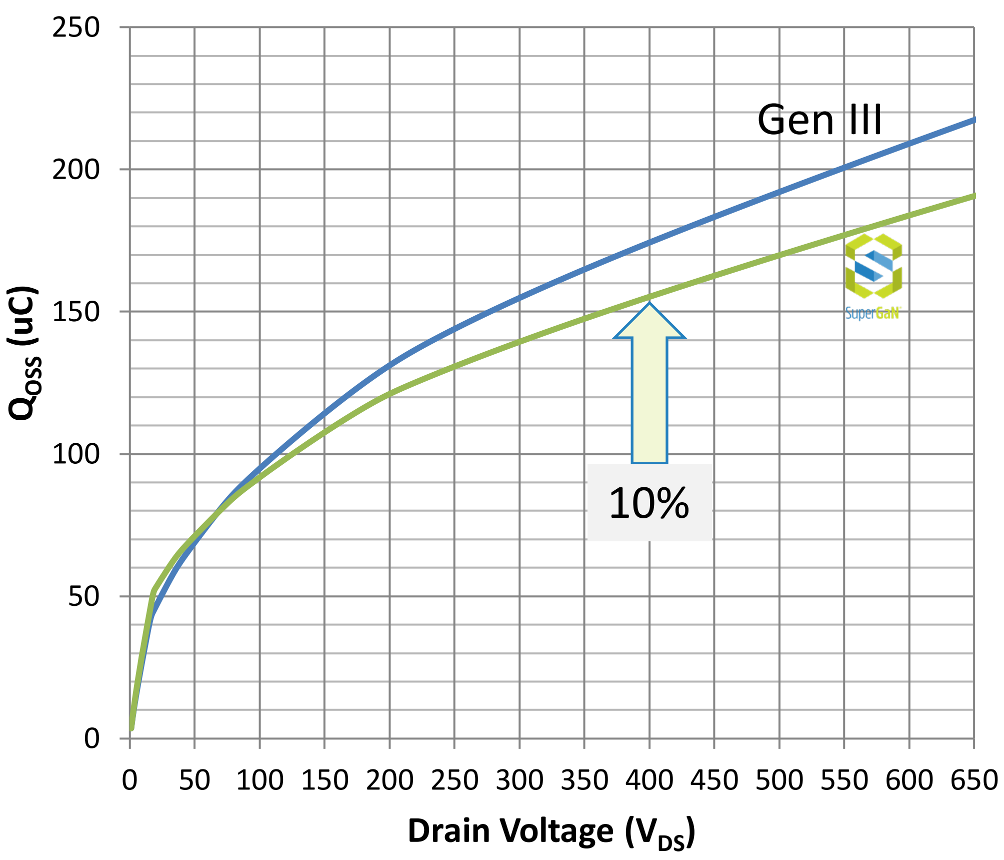


Gen IV vs, Gen IIII and Silicon Comparison

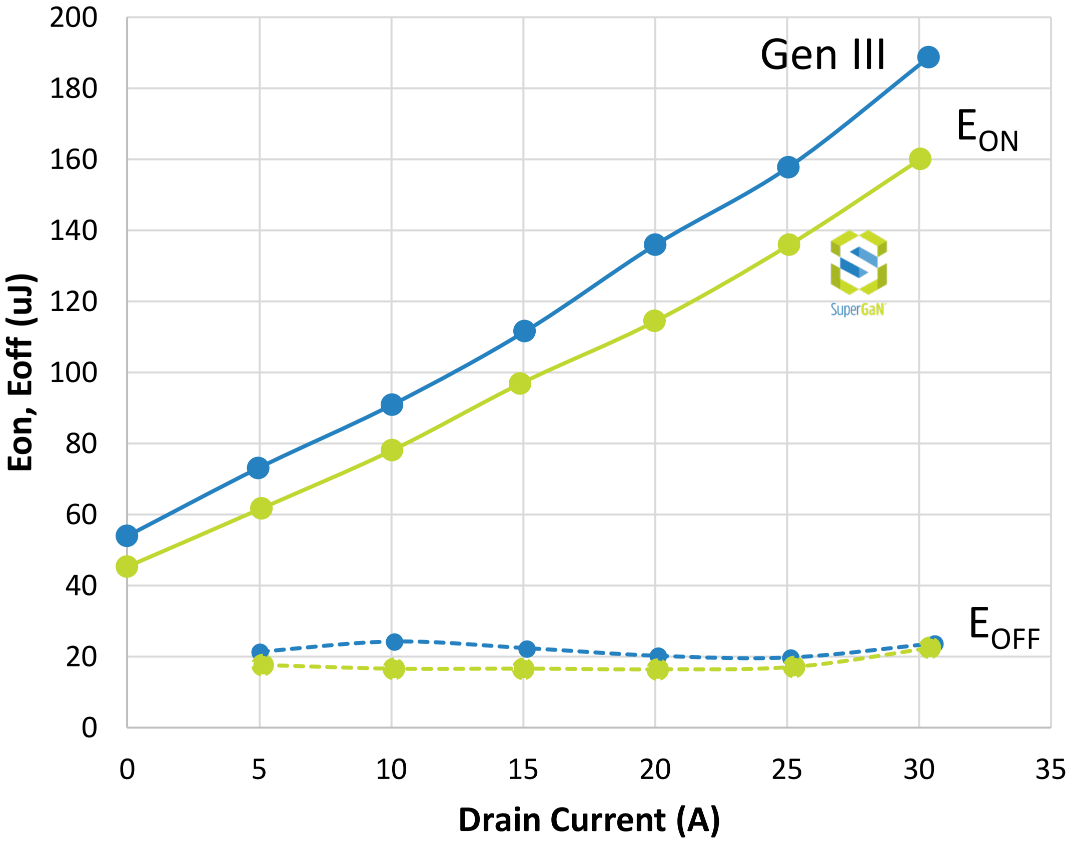


Gen IV vs. Gen III: Reduced Q_{OSS} by ~10%

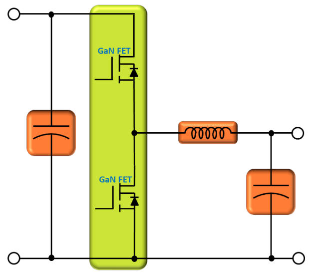
Gen III vs. SuperGaN (Q_{OSS})

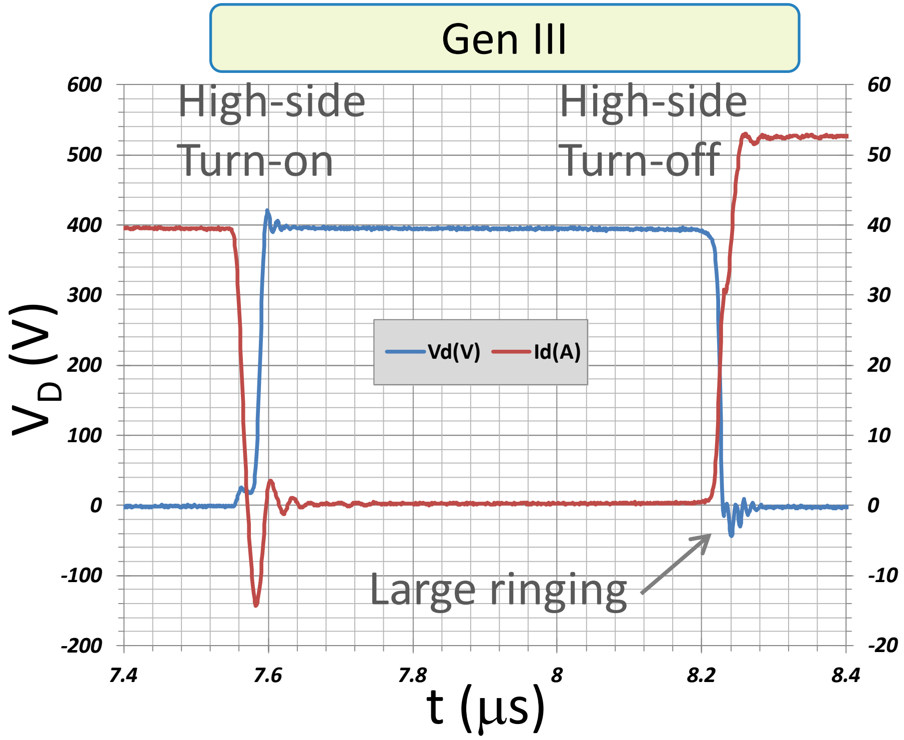


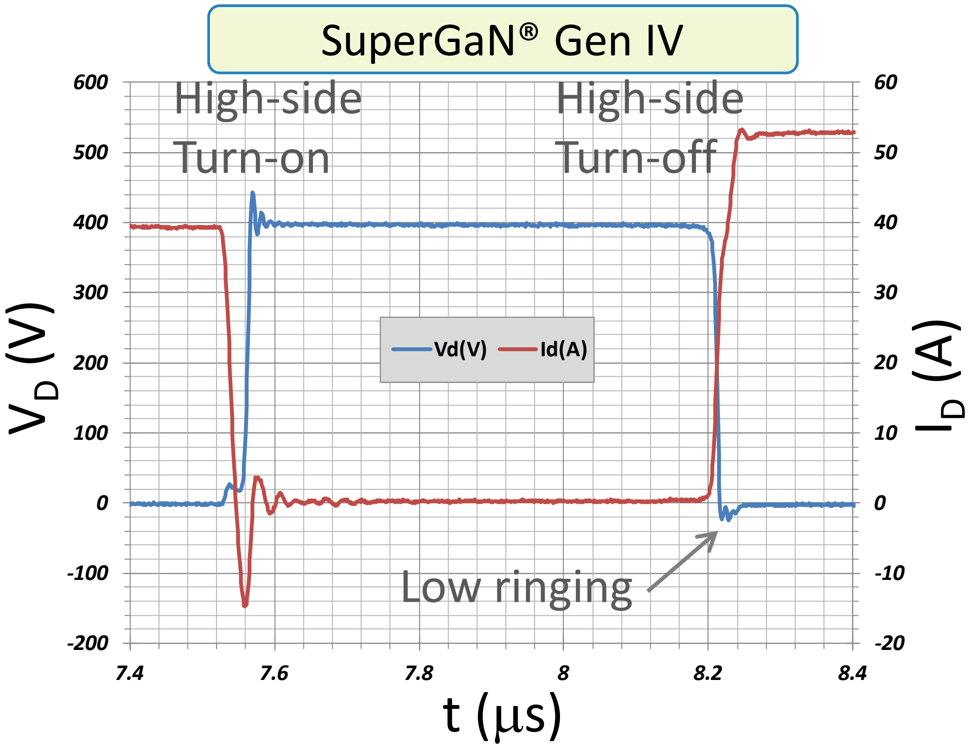
Gen III vs. SuperGaN (E_{ON} /E_{OFF})



Gen IV vs. Gen III: Faster Switching w/Reduced Oscillation

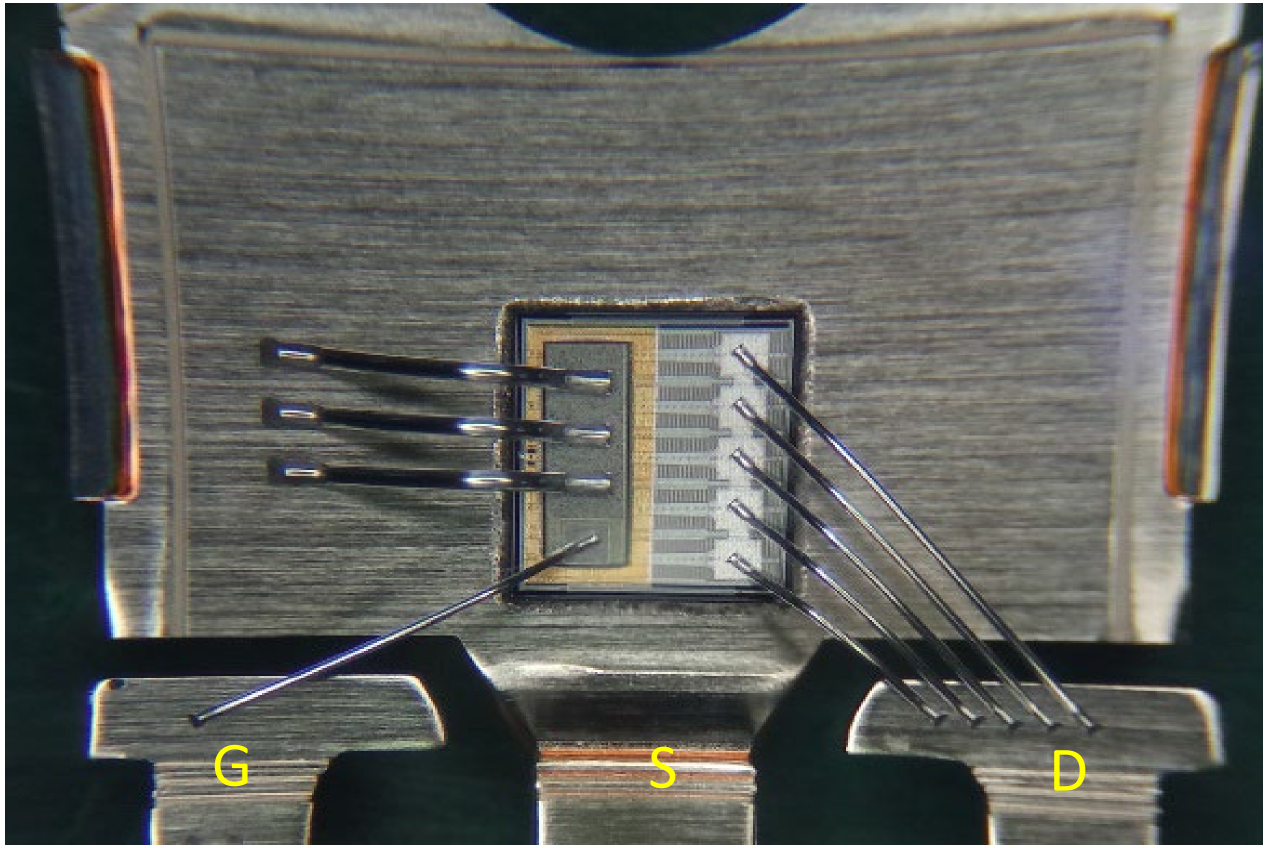






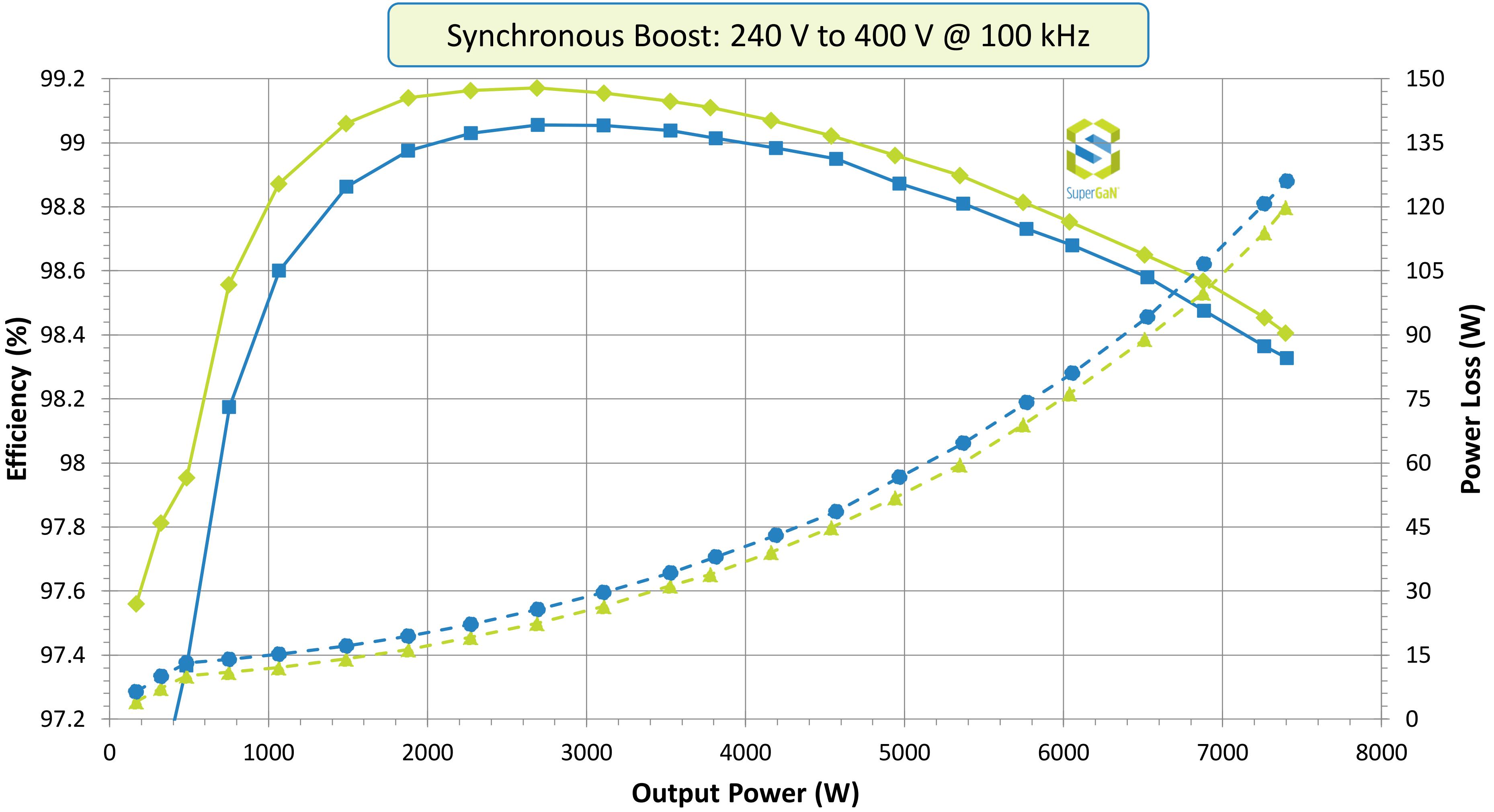
Turn-on: Gen IV is faster => higher spike, can be controlled by V_G or R_G
Turn-off: Gen IV has much lower turn-off ringing due to special design to avoid oscillation in FWD mode.

Gen IV: Simplified Packaging Innovation



- Most robust gate/best-in-class reliability
- “One chip like” assembly (< cost), less wires
- Patented innovation, higher performance

Gen IV: Reduction in Power Loss by ~15%

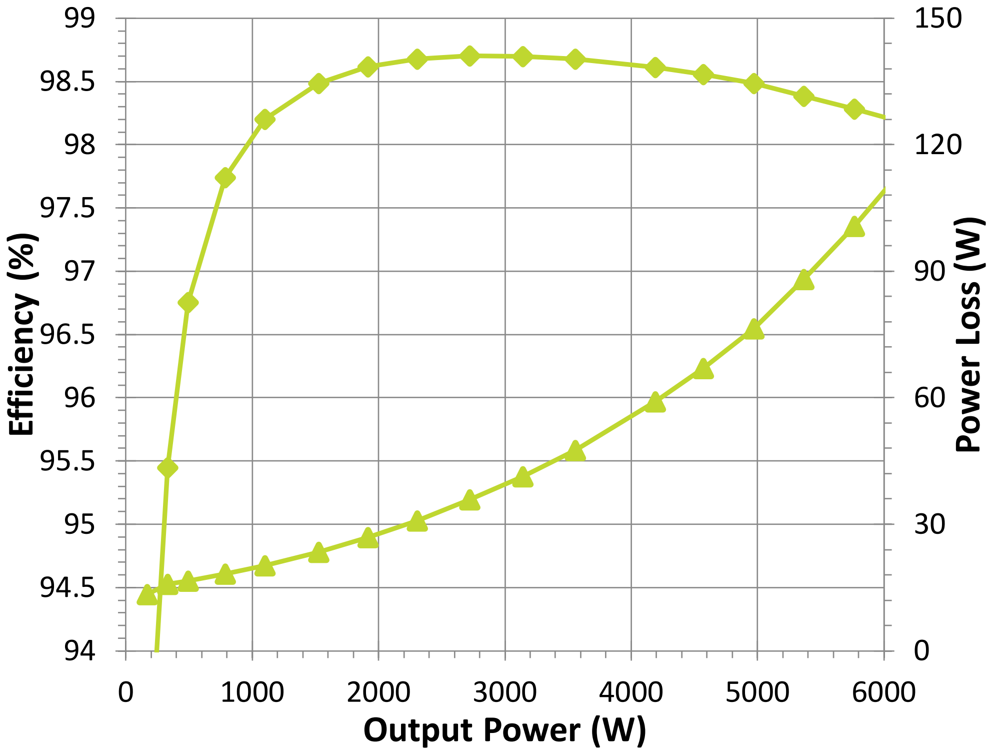


- Gen IV does not need a snubber
- Efficiency improvement ~0.15% at peak (Snubber: 0.1%, Gen IV: 0.05%)
- Efficiency increase: 0.2-0.5% at low power

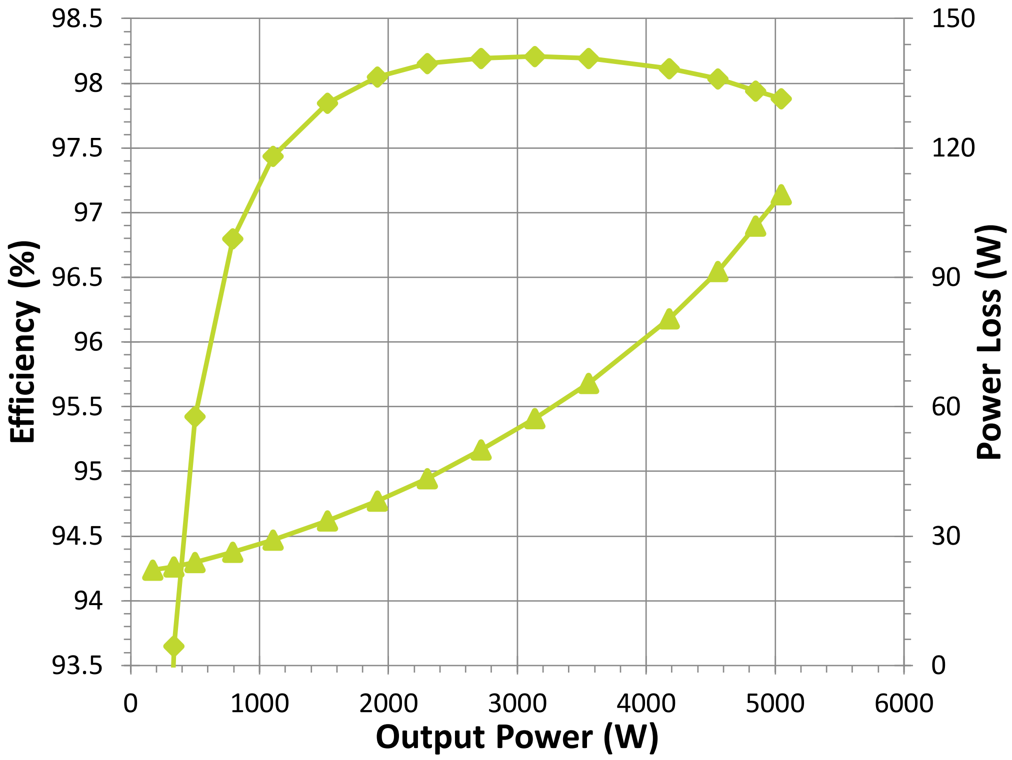
Gen IV: Continued Performance Benefit

Efficiency Higher than 98.6% at 200 kHz and 98.2% at 300 kHz

Synchronous Boost (200 kHz)

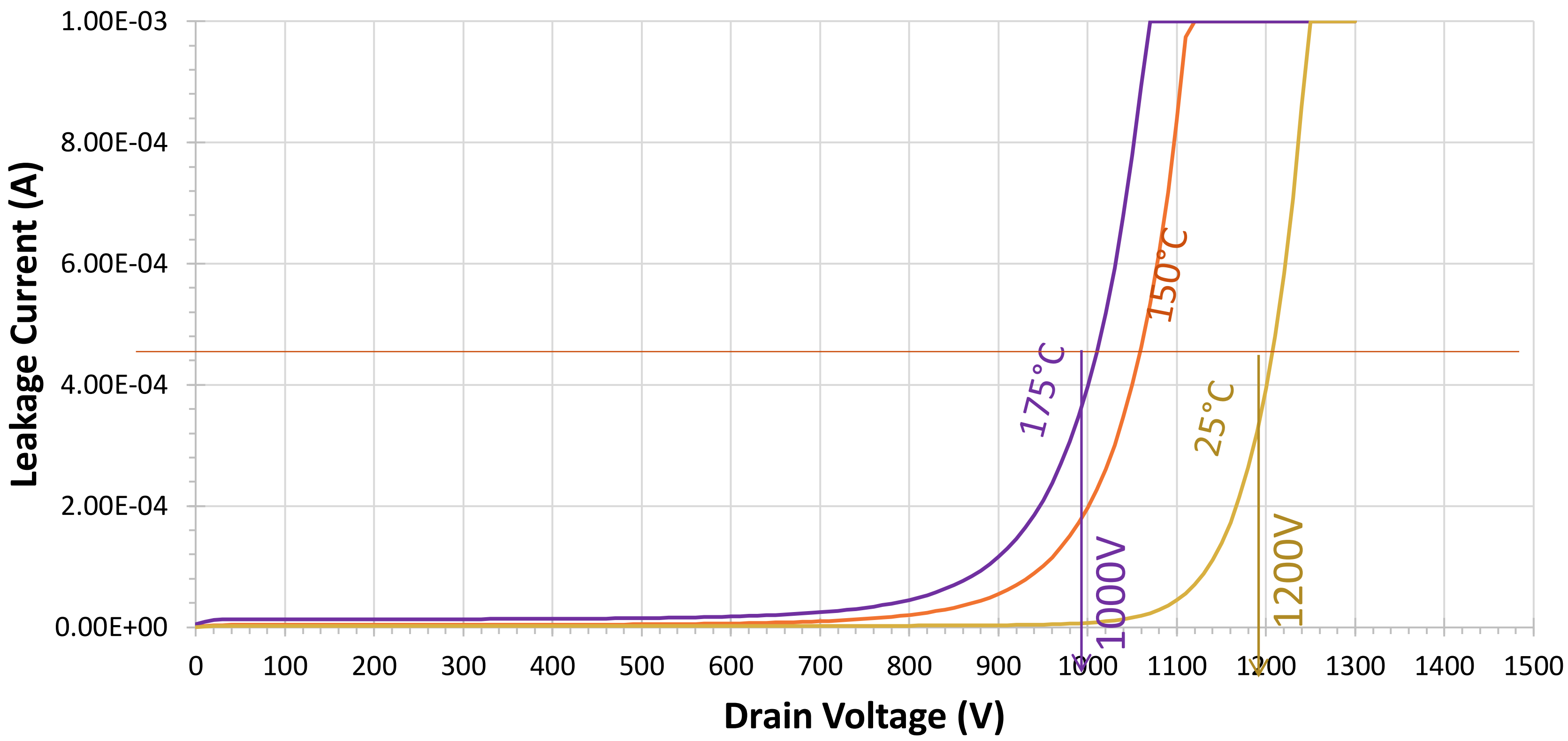


Synchronous Boost (300 kHz)



- All test were in hard-switching (Expect higher Eff. in soft switching)
- Peak efficiency (200 kHz): SuperGaN Gen IV 98.70% => Best-in-class
- Peak efficiency (300 kHz): SuperGaN Gen IV 98.21% => Best-in-class

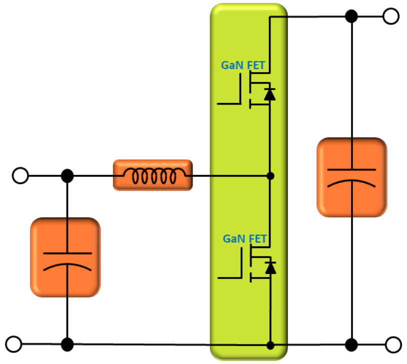
Gen IV: Maintains Ultralow Leakage with High BV



1000 V breakdown even at higher 175°C temperature

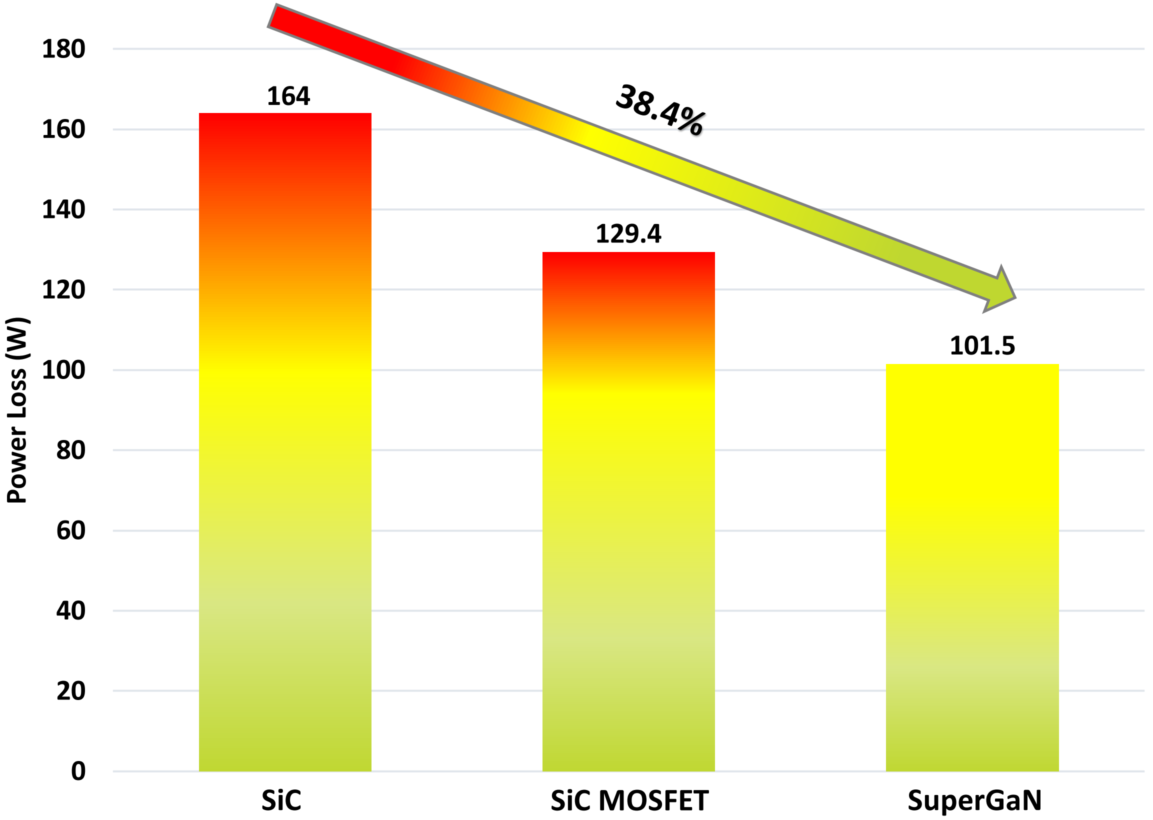
- Breakdown at 150ºC: 1050 V
- Breakdown at 175ºC: 1000 V

Gen IV: Offers Reduced Power Loss Over SiC



Half Bridge Synchronous Boost Converter (240 V : 400 V)			
Specifications	**GaN**	**SiC MOS**	**SiC FET**
Maximum power limit	12 kW[1]	11 kW[2]	9.2 kW[2]
On resistance @ 25°C	15 mΩ	20 mΩ	18 mΩ
Operating Frequency	70 kHz	70 kHz	70 kHz
Gate drive voltage	0 to 12 V	0 to 18 V	0 to 15 V
Gate drive resistor R_G	15 Ω	5 Ω	0/50 Ω
Driver consumption at 70kHz	288 mW	540 mW	N/A

[1] Gan FET junction temperature at 12 kW was 139°C
[2] SiC devices operating with a 165°C junction temperature

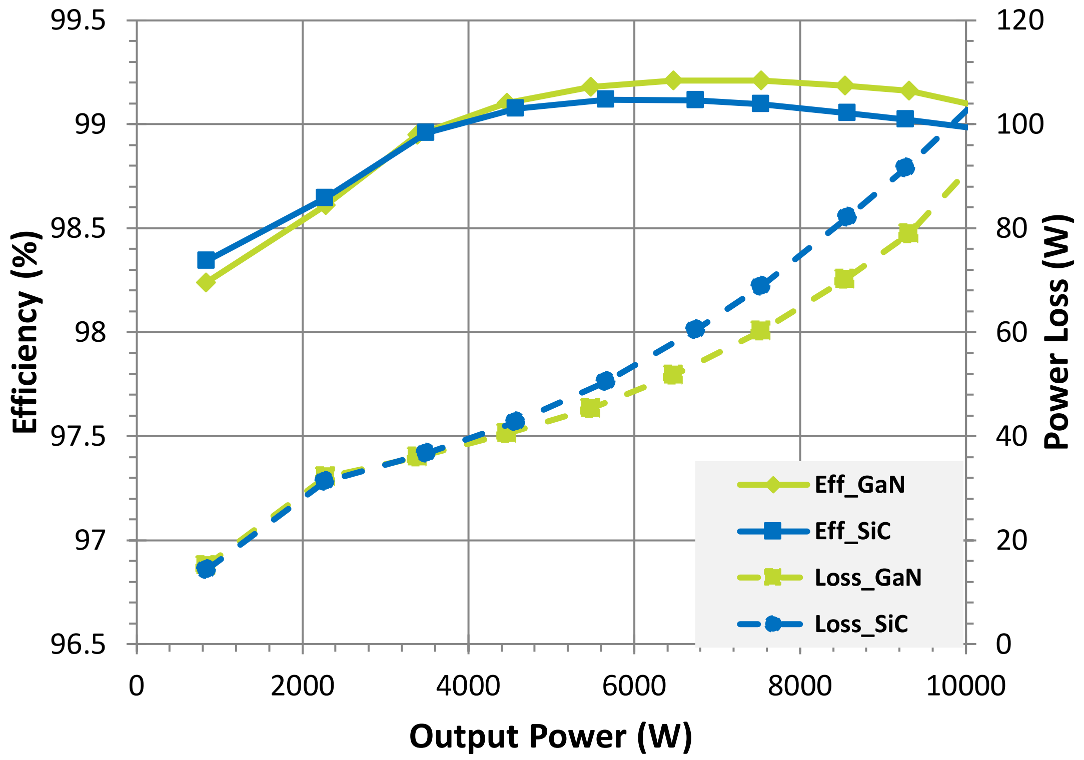


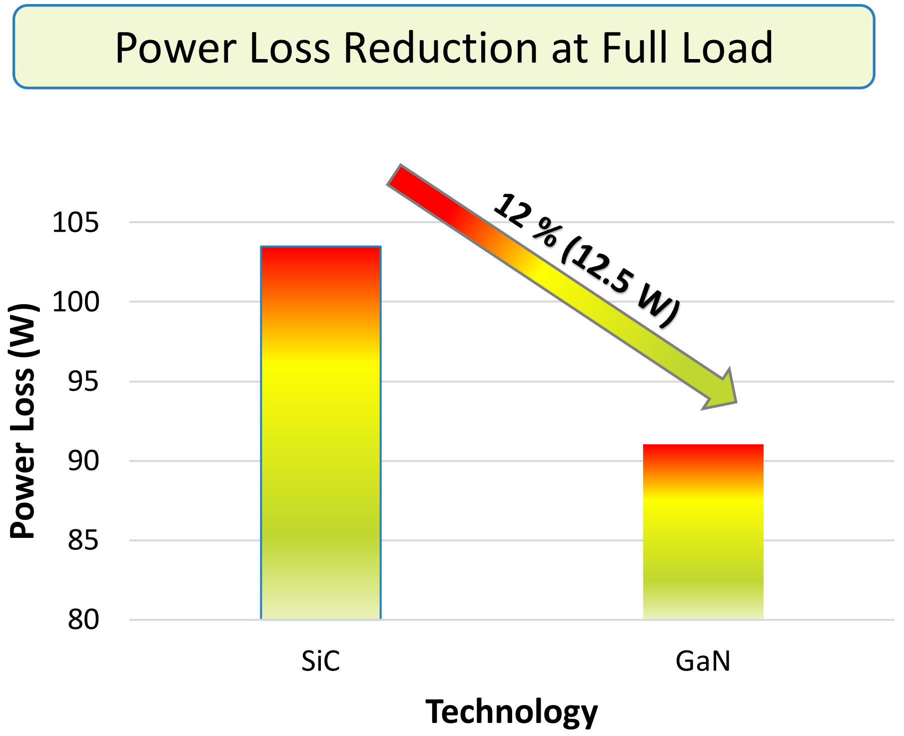
Device Power Loss Comparison (9.2 kW)
(Limited due to SiC FET device temperature)

Maximum Power Comparison
(SiC limited by device temperature)

Gen III: 900 V GaN FET: Continues to Outperform

Half Bridge Boost Converter: 560 V:808 V at 100kHz, Loss Reduction 12%

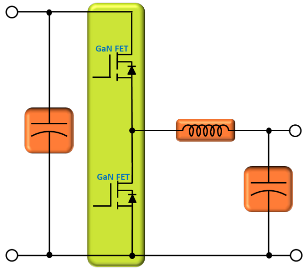




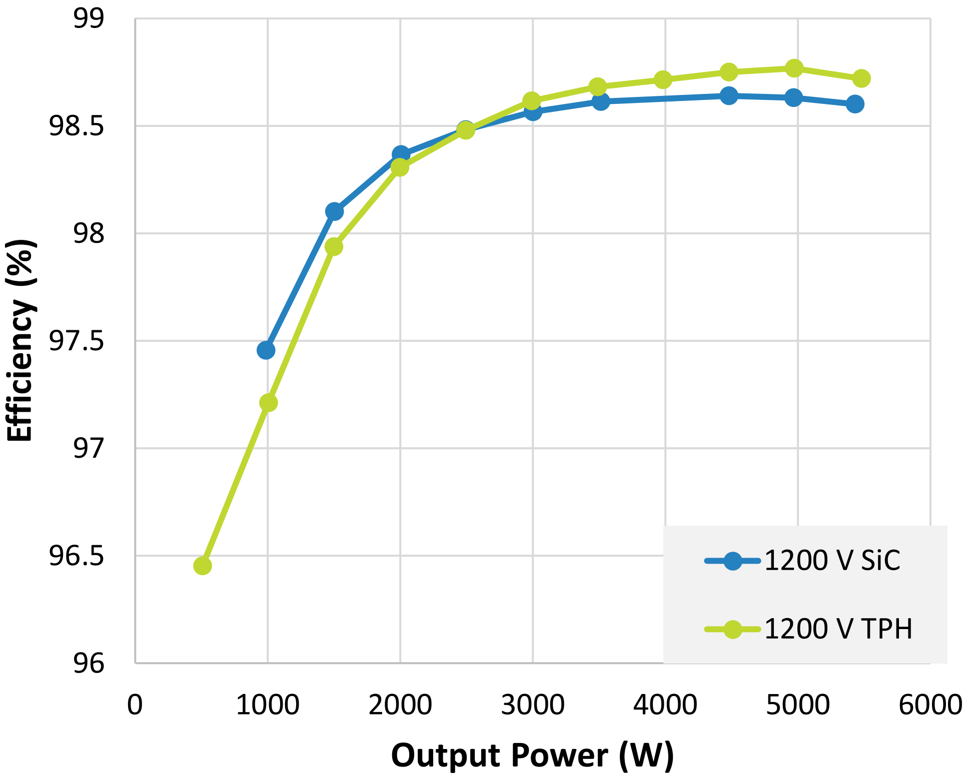
- GaN shows higher efficiency than SiC in 800 V converter and at a lower cost
- Commercially available SiC MOSFET with similar on resistance at 125°C

1200 V GaN FET Achieves > 98.7% Performance

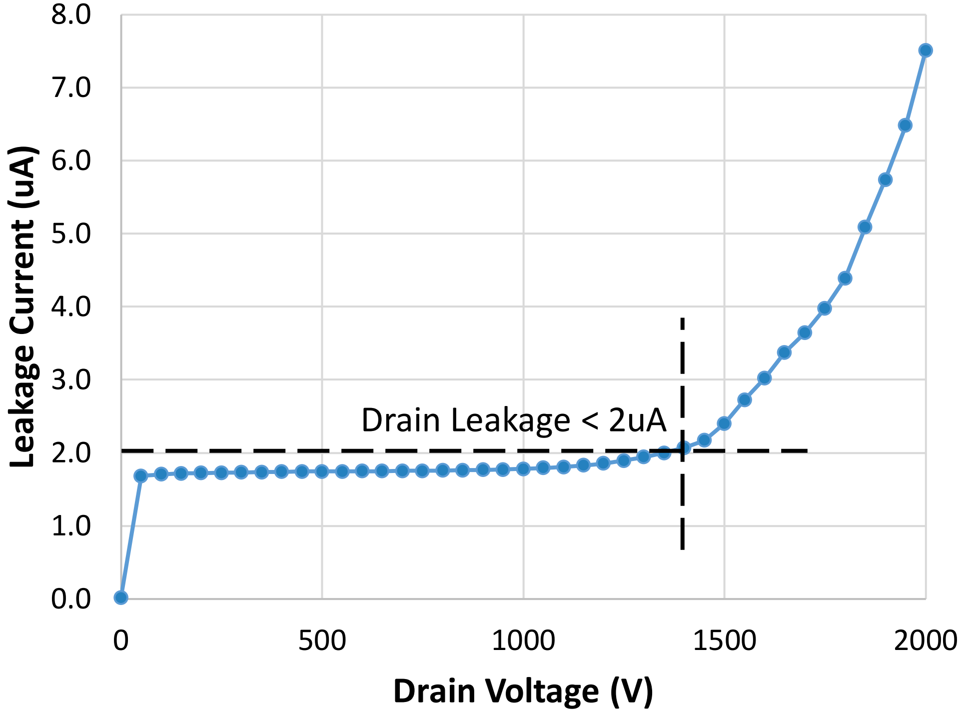
Demonstrated > 99% Efficiency at 50 kHz (Synchronous Boost)



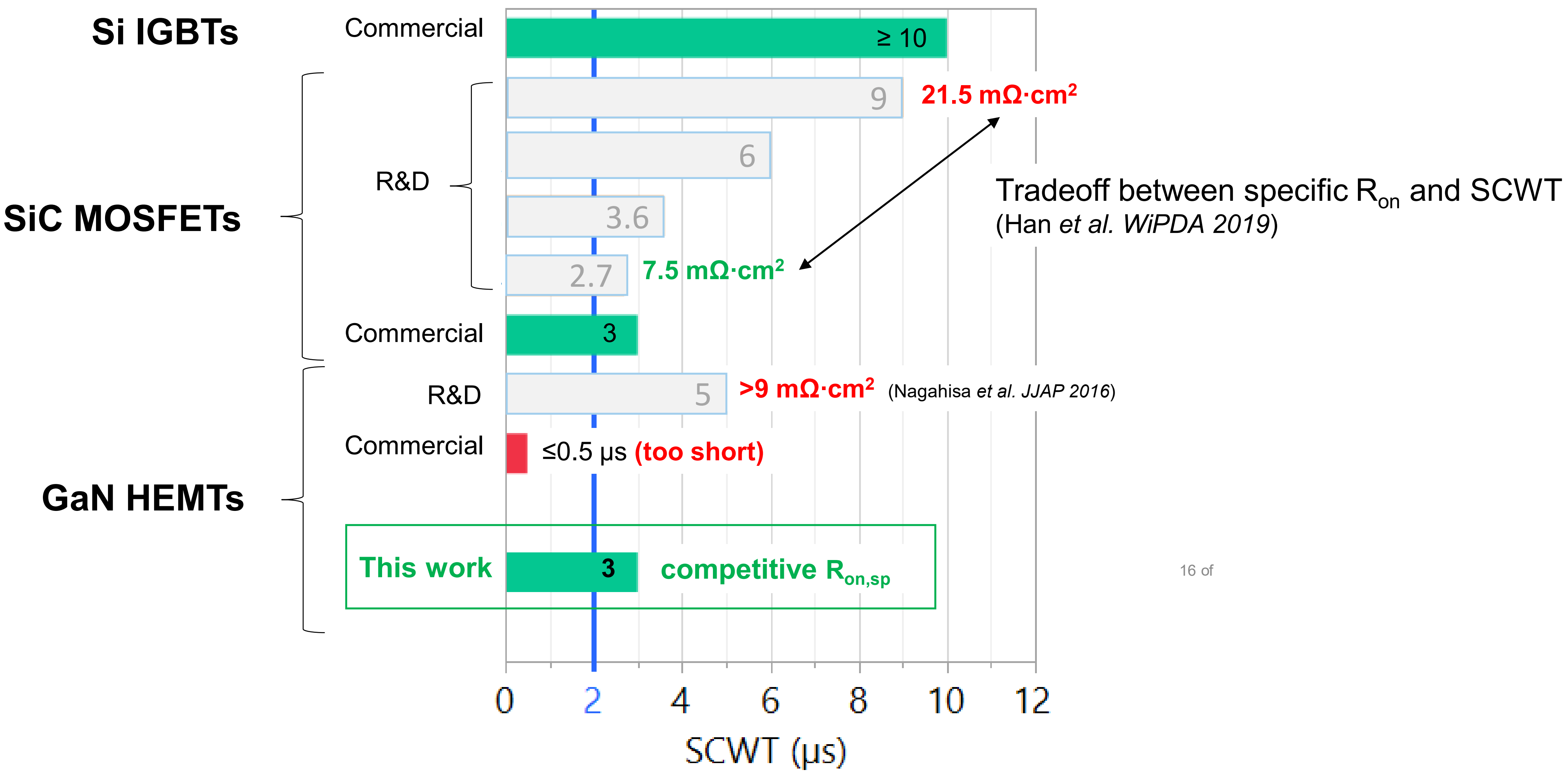
Sync Buck Converter: 900 V:450 V at 100 kHz



Ultralow Drain Leakage at 1400 V



Power Device: Technology Comparison



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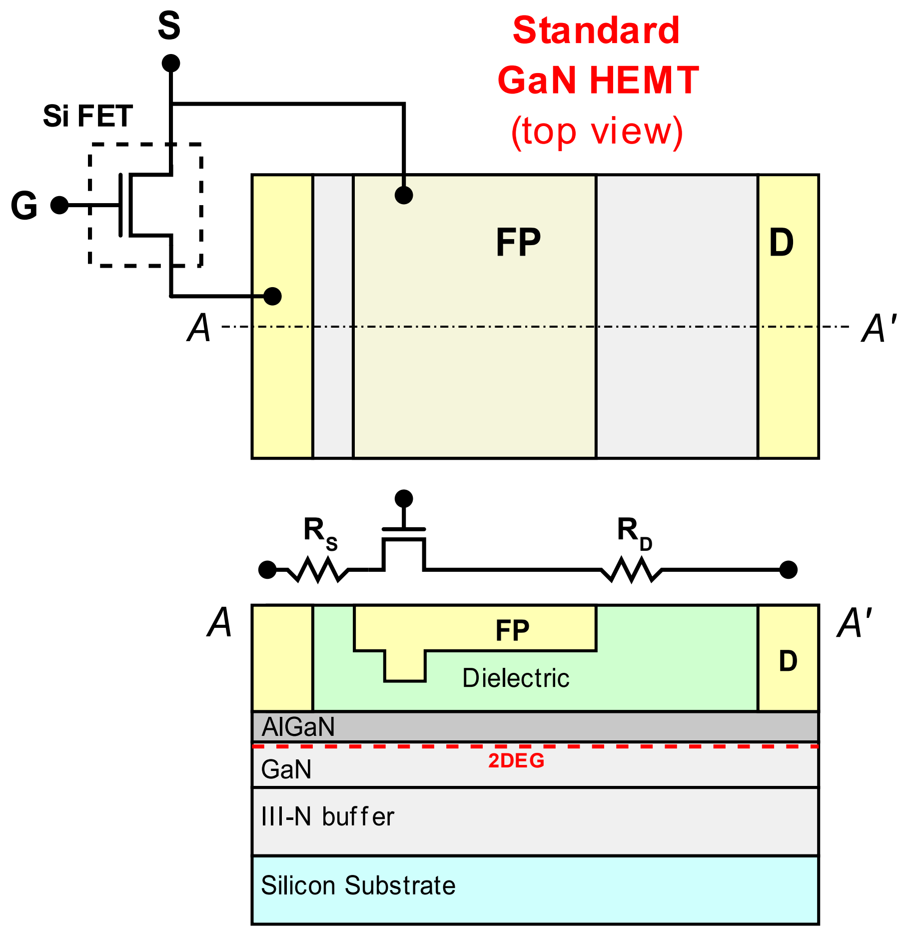
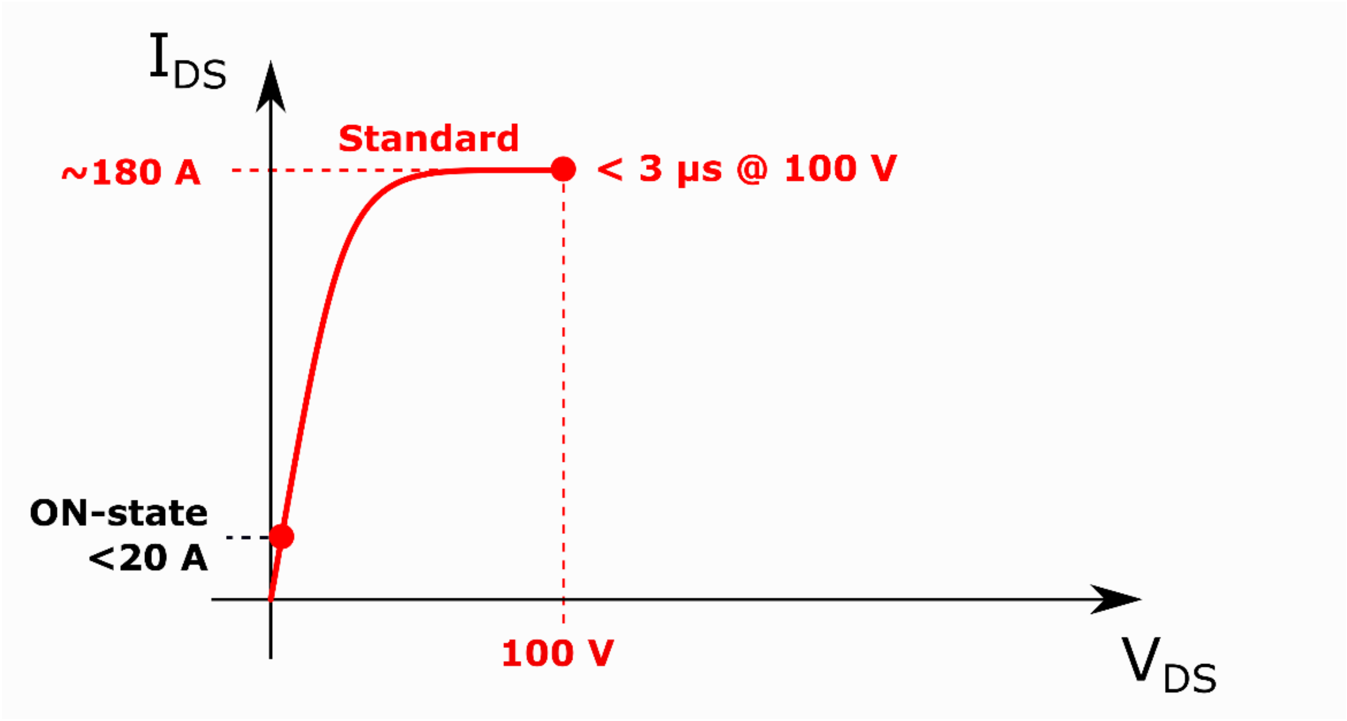
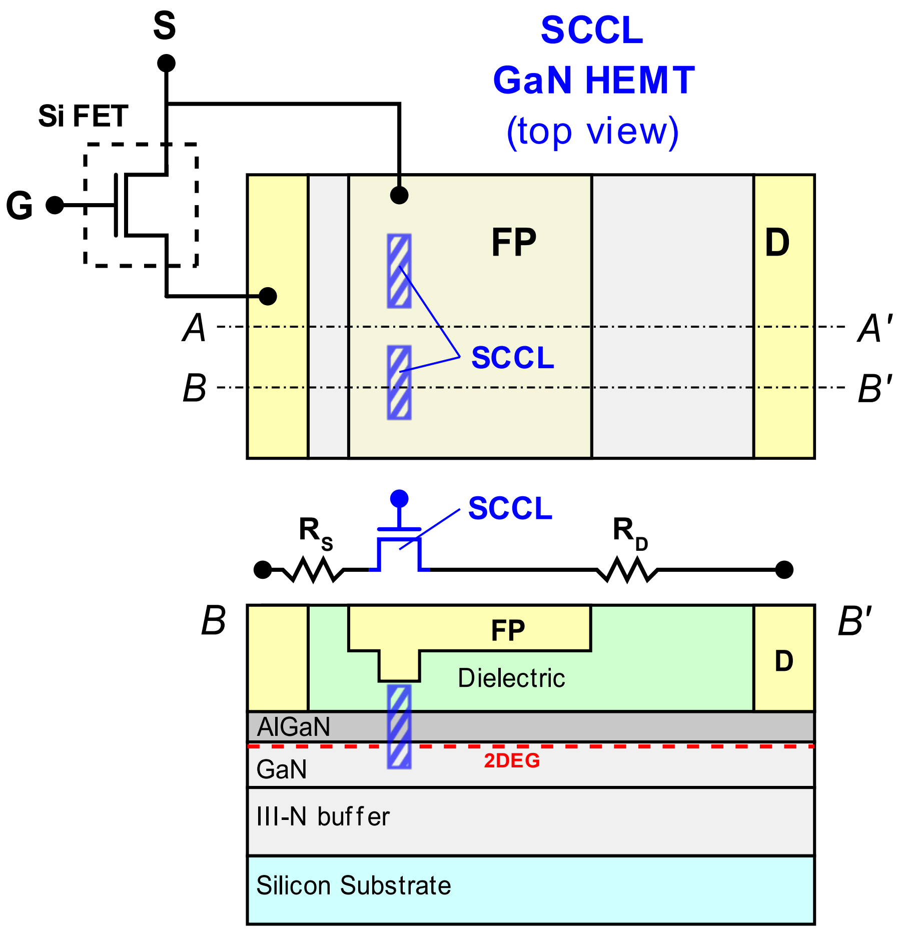
Standard GaN HEMTs



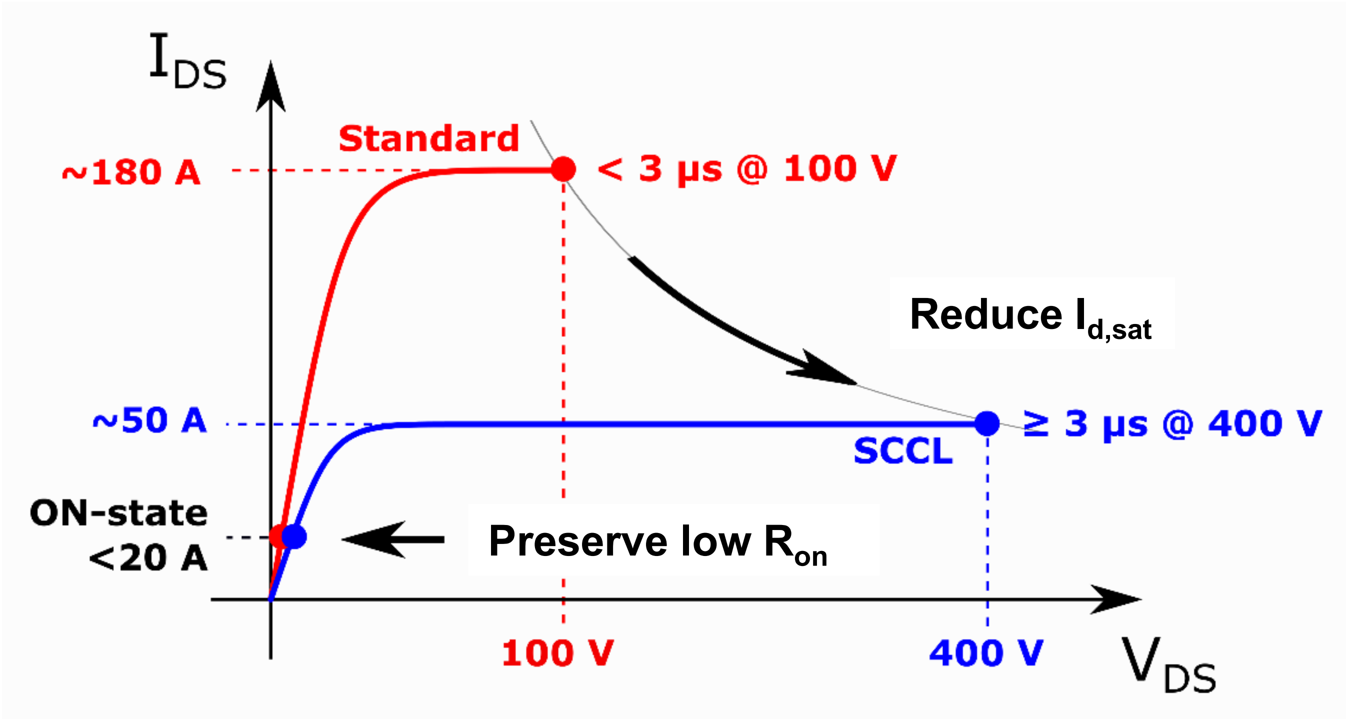


- Standard GaN HEMTs have high saturation current due to high performance 2DEG.
- Difficult to achieve short-circuit withstanding capability **(!)**

Short-Circuit Current Limiter (SCCL)

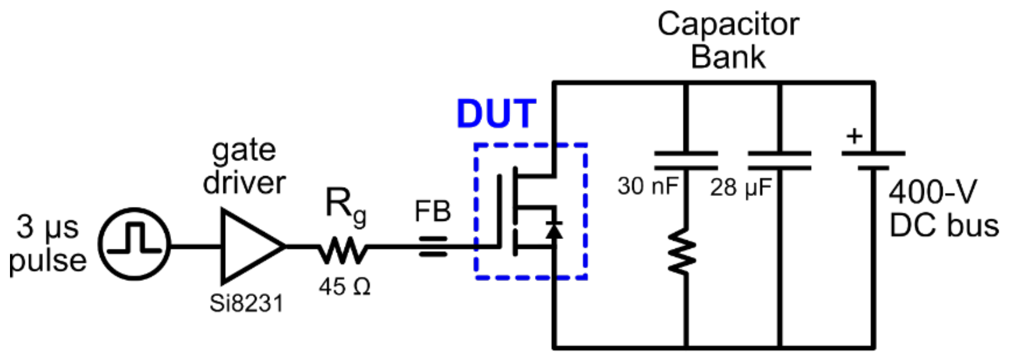


Y. Wu *et al.*, **U.S. Patents** 9443849, 8803246 & 9171910



- Reduces the saturation current to achieve long SCWT, while preserving low R_{on} ✓
- Easy to implement (no additional manufacturing costs) ✓
- Highly customizable (the limiter can be easily tailored to adjust SCWT for any gate driver) ✓

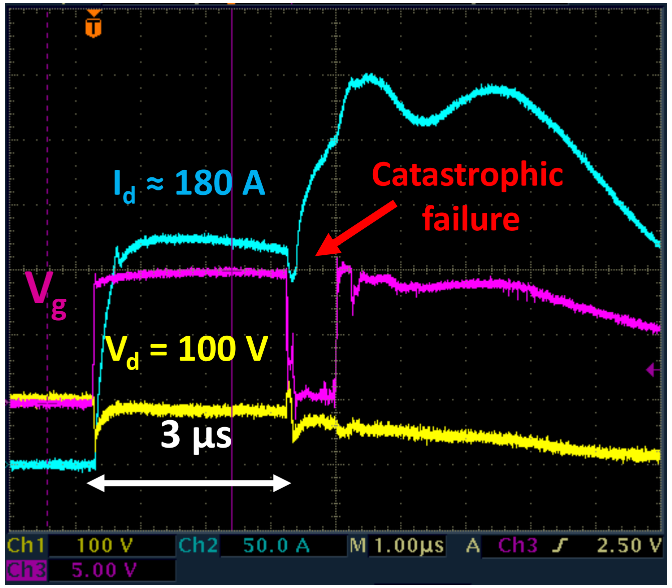
Short-Circuit Test



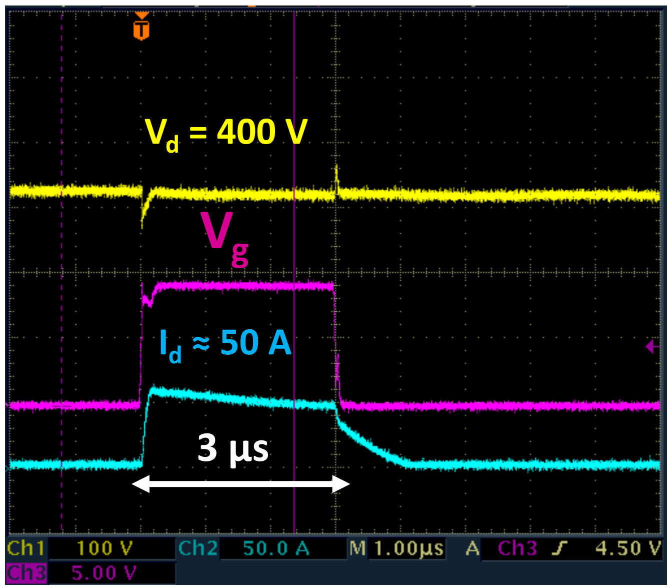
SCCL Technology:

- Short-Circuit capability improved more than 3x ✓
- **SCWT = 3 µs @ 400 V ✓**

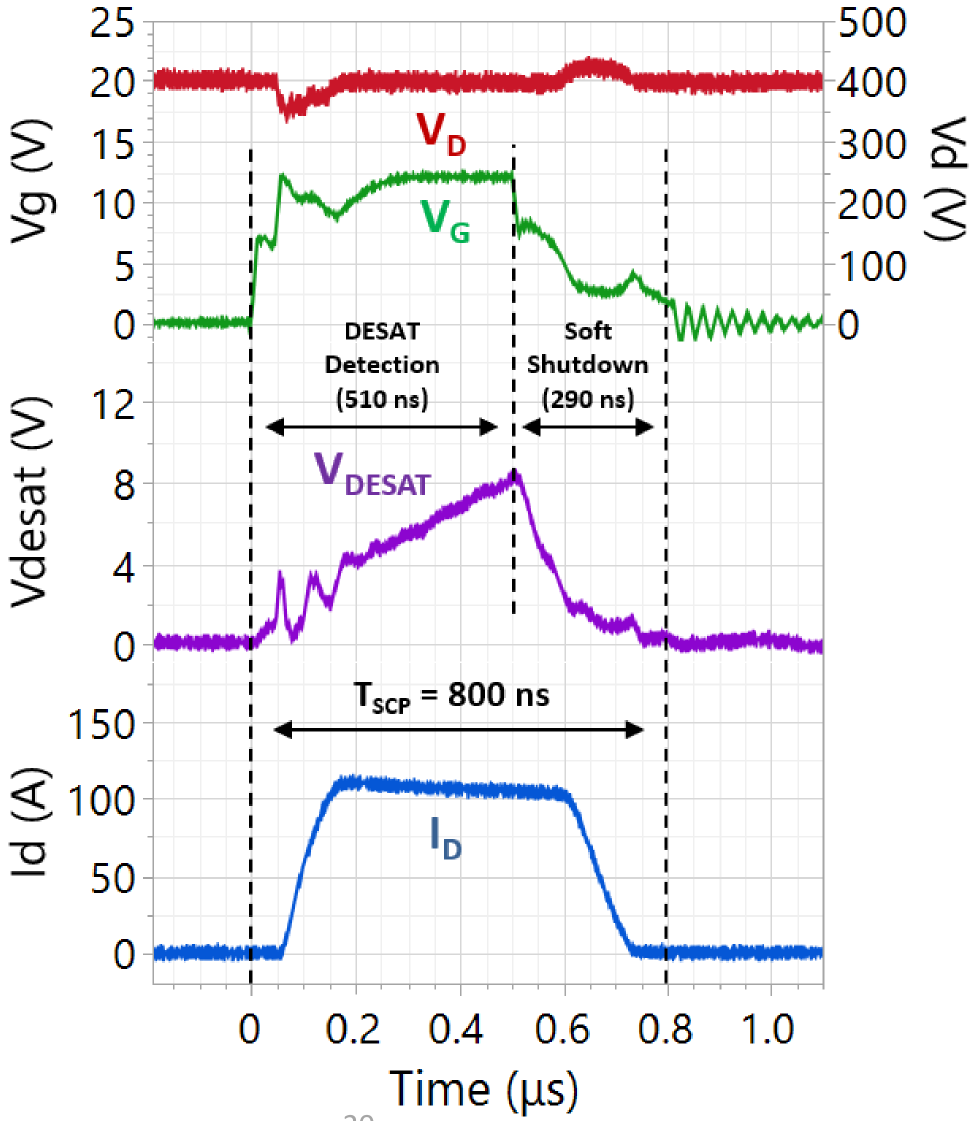
Standard (Fail ✗)



SCCL (Pass ✓)



Circuit DESAT Results



- The short-circuit is detected and shutdown in **800 ns**, a period sufficiently short to ensure the survival of the SCCL power device with ample margin. ✓
- The GaN power device with SCCL technology successfully survived the short-circuit event for all **100 repetitions** ✓

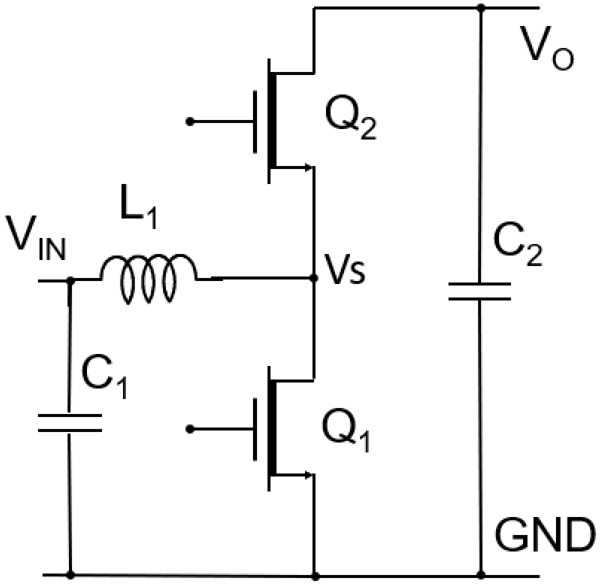
Parameter	Pre SC Test	Post SC Test	Conditions
Static Ron (mΩ)	47	46	I_d = 8 A
Dynamic Ron (mΩ)	55	54	I_d = 8 A
Threshold Voltage (V)	4.1	4.1	I_d = 1 mA
Gate Leakage (nA)	0.4	0.5	(V_g;V_d) = (20V;0V)
Drain Leakage (µA)	2.2	1.8	(V_g;V_d) = (0V;750V)

High Temperature Reverse Bias (HTRB)

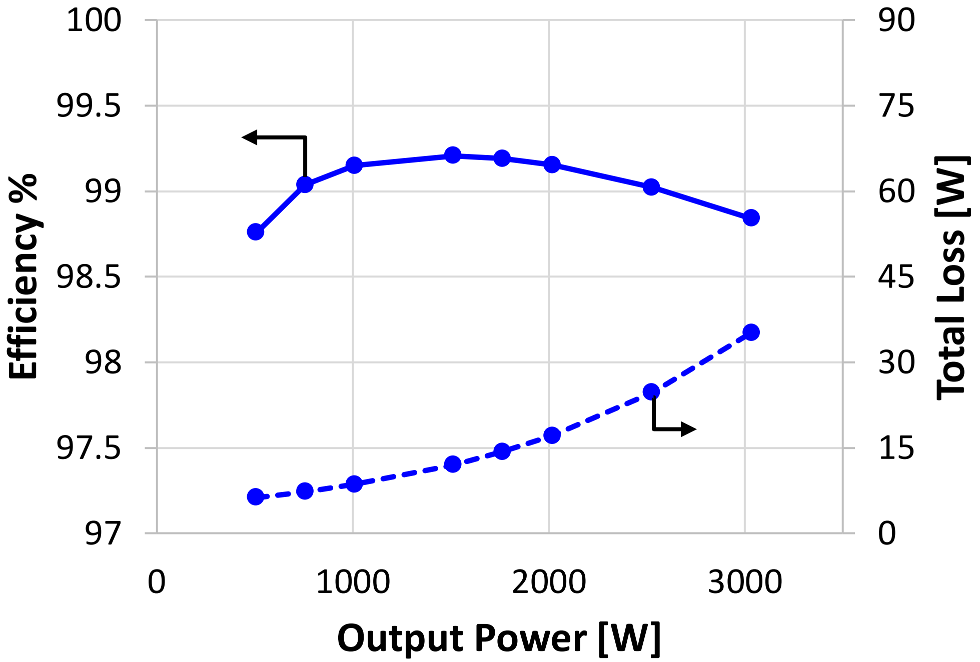
- 80 parts at 150C / 520 V – 1000 hours: Zero Failures

SCCL Technology (1.5 μs) Efficiency Test

Half-bridge **boost converter**
(240V:400V, 50 kHz)



Courtesy of P. Joshi and G. Bolante, Transphorm Inc.



The SCCL technology with 1.5 μs has peak efficiency greater than 99.2% ✓

Summary

- Transphorm's roadmap into the Future
  - 650 V, 900 V, 1200 V, SCCL and other verticals
- Innovation: Vertically Integrated with an Asset Light Strategy
- Creating strategic partnerships along the way
- Continuing as a broad-based market/application supplier
- Maintaining Best-in-Class quality and reliability
- Simplicity of drive and design ability

Thank you for your interest.

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Committee/Session
PSMA IS11

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