# High-Speed Gen3 Fast GeneSiC MOSFETs Deliver Best-In-Class Performance

*Dr. Ranbir Singh*
*EVP of SiC Business, Navitas Semiconductor*

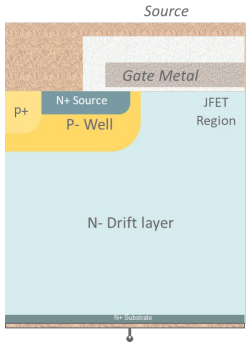
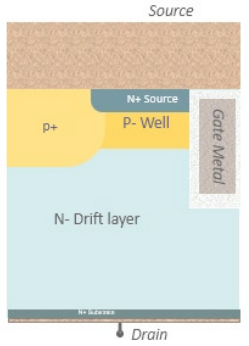
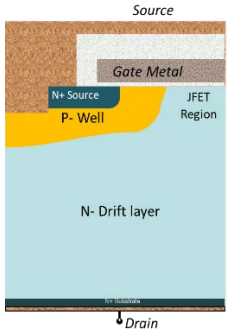
**Bodo's Wide Bandgap Event 2023**

December 13
Silicon Carbide / SiC

# No Compromise SiC MOSFET Technology

Navitas

***Trench-Assisted Planar Gate***

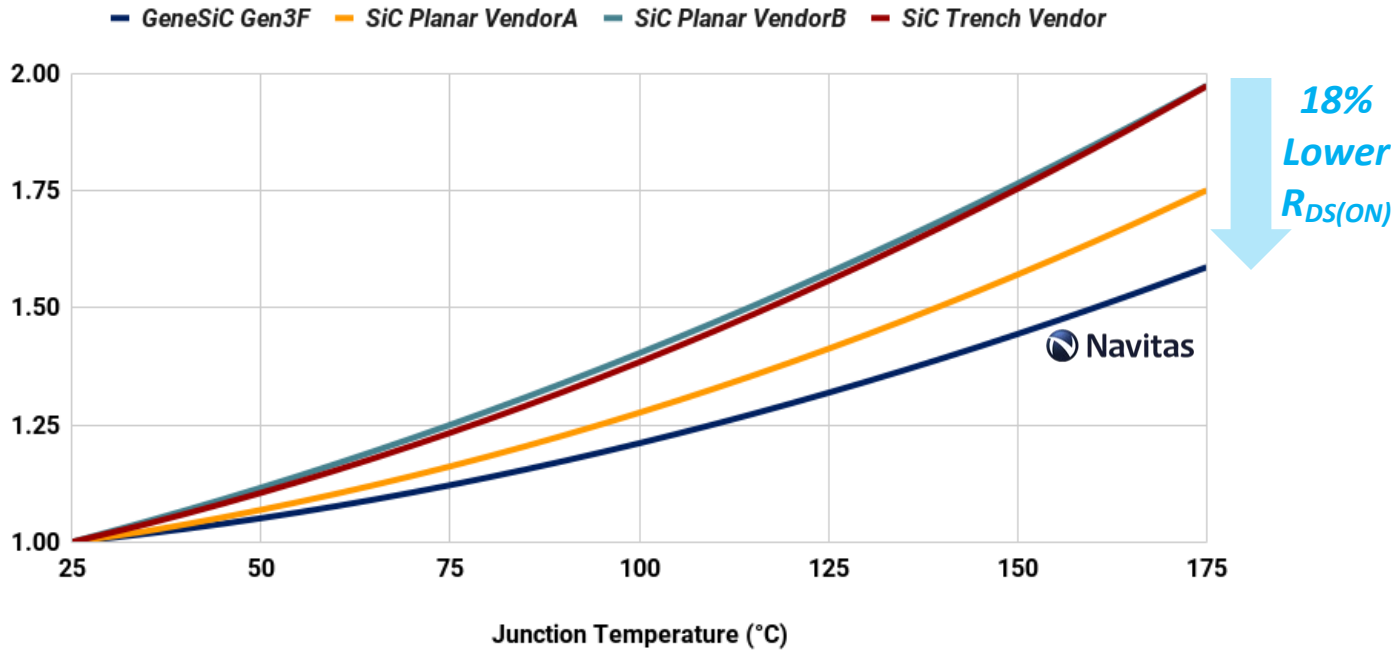
| | ***SiC Planar*** | ***SiC Trench*** | ***GeneSiC SiC MOSFET*** |
|---|---|---|---|
| |  |  |  |
| ***Manufacturability*** | ➢ High-yield & low-cost manufacturing | ➢ Complex manufacturing<br>➢ Low-yield & high-cost | ➢ High-yield & low-cost manufacturing |
| ***Performance*** | ➢ Higher $R_{DS(ON)}$ per chip area<br>➢ Slower switching FoM | ➢ Lower $R_{DS(ON)}$ per chip area<br>➢ Faster switching FoM<br>➢ Worst $R_{DS(ON)}$ vs. temperature | ➢ Lowest $R_{DS(ON)}$ per chip area<br>➢ Faster switching FoM<br>➢ Stable $R_{DS(ON)}$ vs. temperature |
| ***Reliability*** | ➢ Simpler device structure enables excellent reliability | ➢ Reliability concerns due to complex device structure | ➢ Simpler device structure enables excellent reliability |

***Trench-gate advantage is NOT true in SiC***

# Gen3 Fast SiC MOSFETs for Industry-Leading Performance Navitas

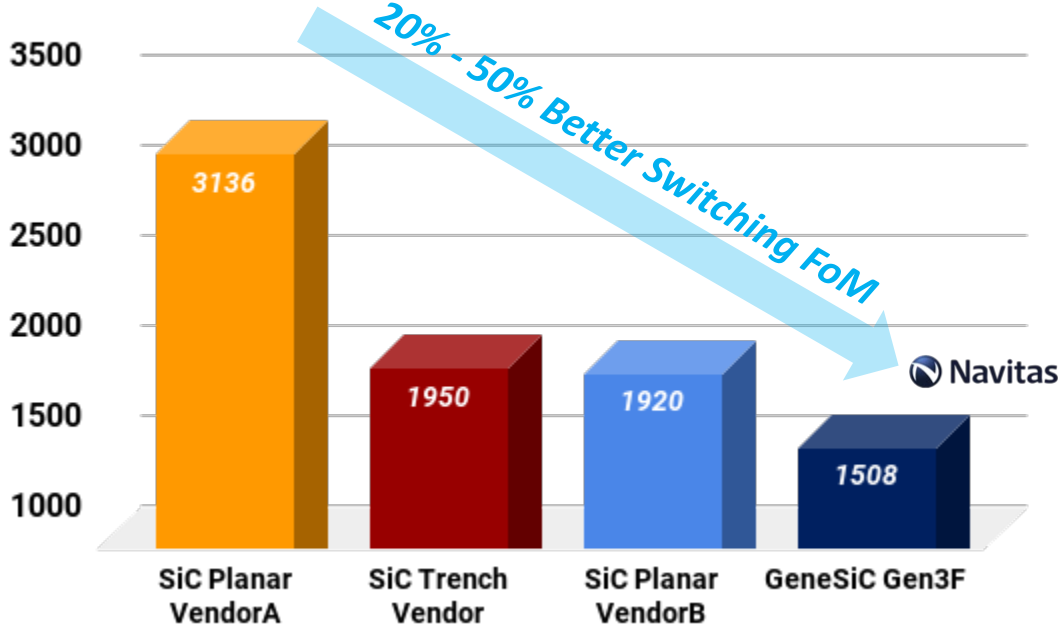
## Static Performance *(1200V)*

### $R_{DS(ON)}$ vs. $T_j$ (normalized)



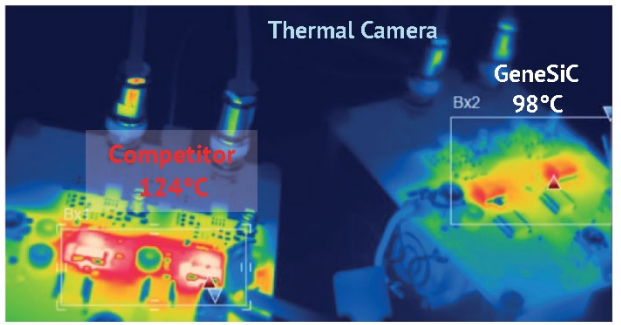

## Dynamic Performance *(1200V)*

### $R_{DS(ON)}$ x $E_{OSS}$ at 125°C (mΩ-µJ)




- ❑ *Gen3 Fast* offers 10% -18% lower $R_{DS(ON)}$ at hot temperature (175°C)
- ❑ 20% - 50% better $R_{ON}$ x $E_{OSS}$ switching figure-of-merit
- ❑ Enables lower losses and cooler operation
  - ✓ Better system efficiency and longer lifetime

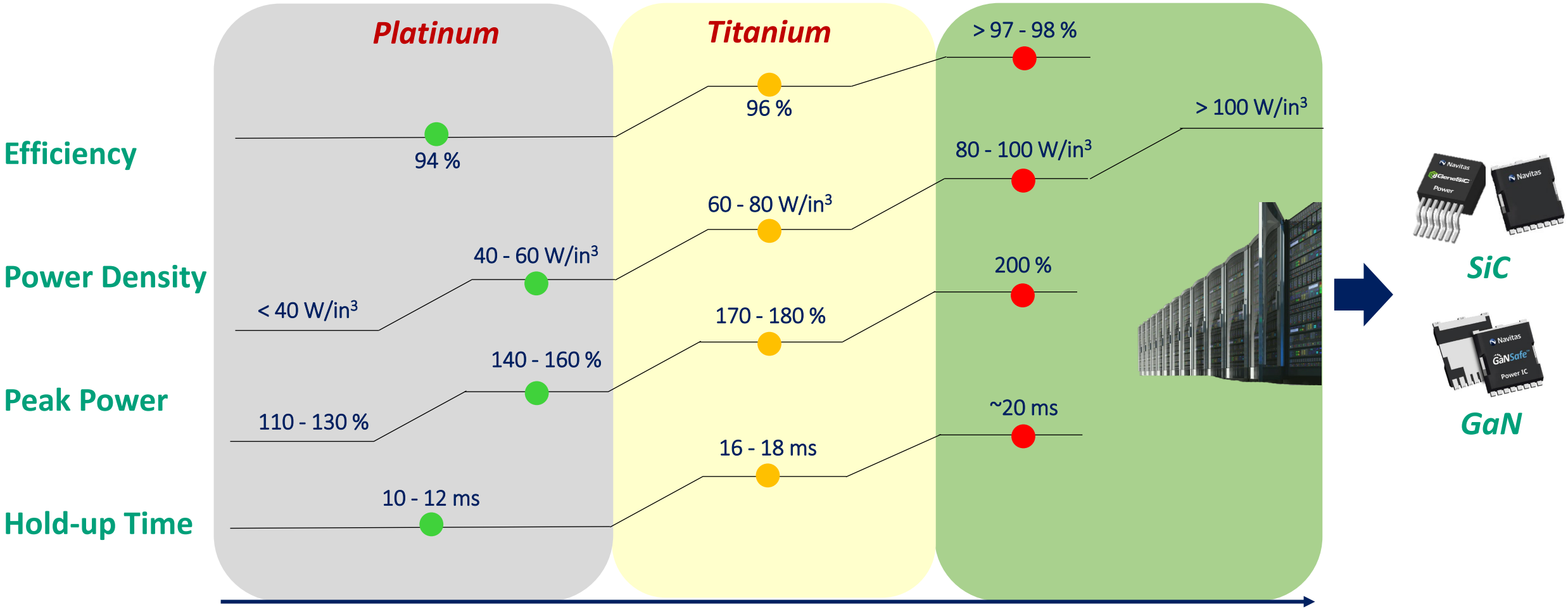
In-Circuit High-Speed Test



# Demanding Applications Require Advanced Technology

Navitas

## Data-Center PSU Trend Towards High Efficiency and High Power Density

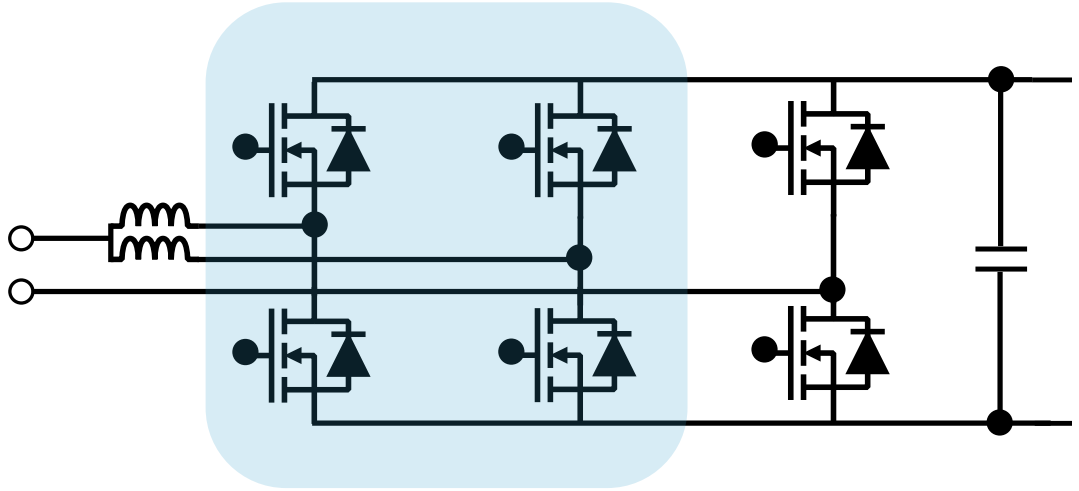



❑ SiC & GaN are key semiconductor technologies to meet server PSU development

# 650V SiC MOSFETs in CCM TP PFC of Data-Center PSU

Navitas

## Interleaved CCM Totem-Pole PFC *(> 2.7kW CRPS)*



*650V SiC MOSFETs*

GeneSiC™

| $R_{DS(ON)}$ @ $V_G$ = 18V , $T_j$ = 25°C | TO-LL | TO-263-7 |
|---|---|---|
| 650V 25mΩ | G3F25MT06L | G3F25MT06J |
| 650V 33mΩ | G3F33MT06L | G3F33MT06J |
| 650V 45mΩ | G3F45MT06L | G3F45MT06J |
| 650V 60mΩ | G3F60MT06L | G3F60MT06J |

### Key MOSFET parameters for CCM TP PFC

- ❑ Low RDS(ON) at all temperatures
- ❑ Low $E_{OSS}$ , $Q_{RR}$ , $Q_G$
- ❑ Low body diode $V_F$ and low $C_{OSS,tr}$
- ❑ High, stable $V_{GS(TH)}$ and high $C_{ISS}/C_{RSS}$

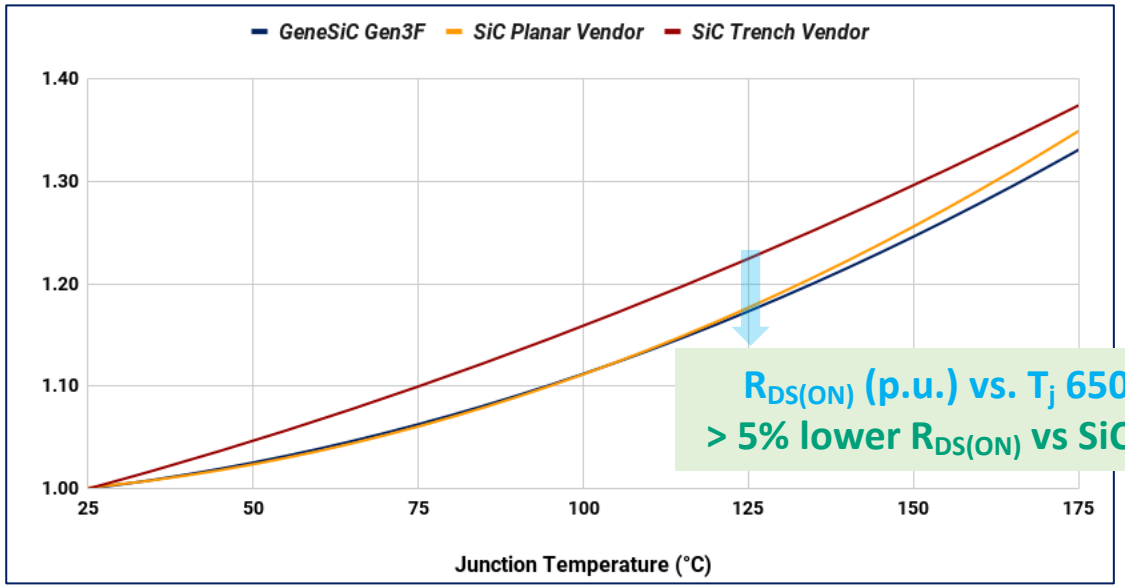
- ❑ TO-LL (Transistor Outline Lead-Less) package
- ❑ 30% savings in PCB area than TO-263-7 *(D2PAK-7L)*
- ❑ 2.30mm profile, 60% less volume than TO-263-7
- ❑ Low package inductance - 2nH
- ❑ Kelvin-source packages for lowest switching losses
- ❑ 100% avalanche (UIL) tested SiC MOSFETs

# Figure of Merits (FoM) for CCM Totem-Pole PFC

Navitas

- Lowest $R_{DS(ON)}$ at all temperatures
  - ✓ Lowest conduction losses

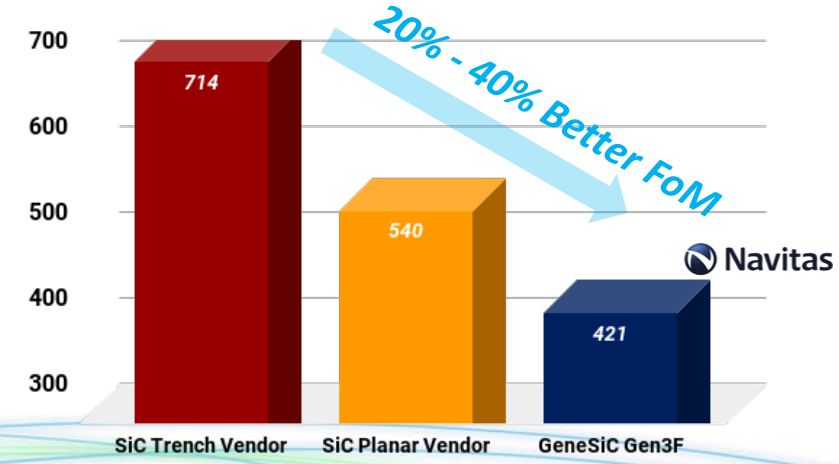
- Best-in-class $E_{OSS}$ , $Q_{RR}$ and $Q_G$
  - ✓ Lowest switching losses



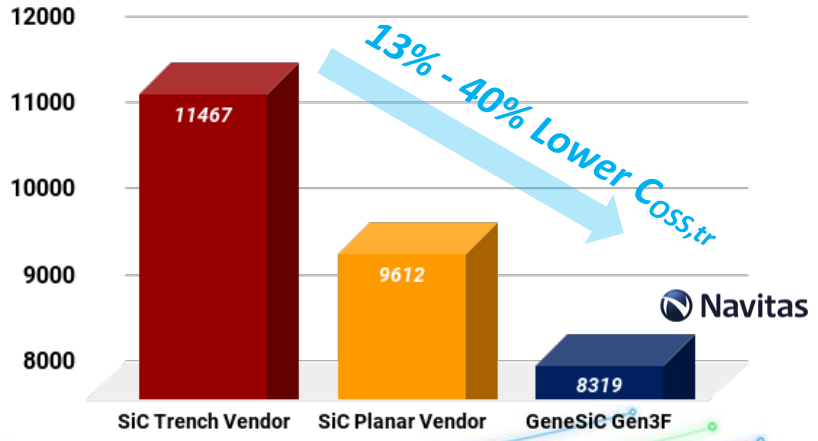

$R_{DS(ON)}$ (p.u.) vs. $T_j$ 650V SiC
> 5% lower $R_{DS(ON)}$ vs SiC trench

## Hard-Switching FoM *(650V)*

$R_{DS(ON)}$ x $E_{OSS}$ at 125°C (mΩ-µJ)




$R_{DS(ON)}$ x $C_{OSS,tr}$ at 125°C (mΩ-pF)



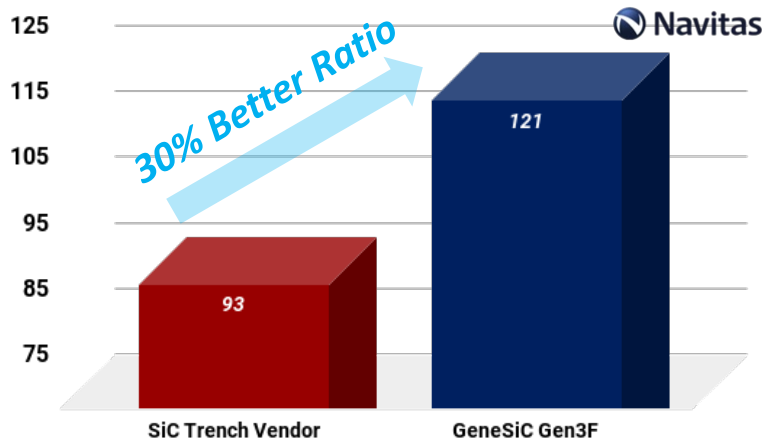

Low body diode $V_F$ and low $C_{OSS,tr}$ to enable low dead-time losses

# Optimized for Robust Fast-Switching Performance

Navitas

## Switching Robustness *(650V)*

### $C_{iss}$ / $C_{rss}$ Ratio




- Potential $V_{GS}$ overshoot can be estimated by "capacitance ratio"

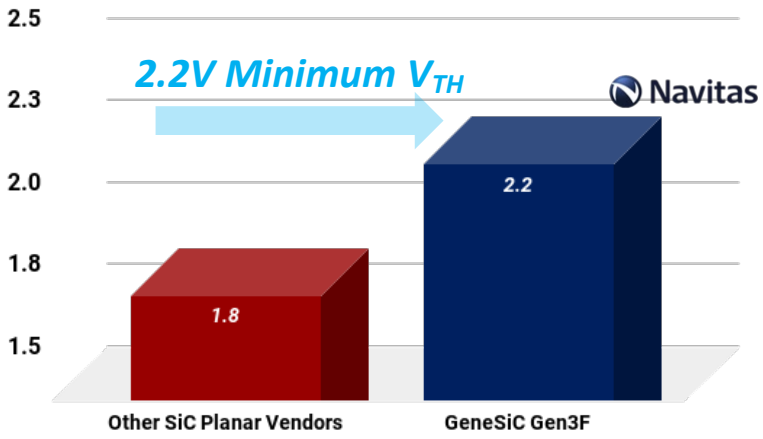
$$\frac{C_{GS}}{C_{GD}} = \frac{C_{iss}}{C_{rss}} - 1 \quad \Rightarrow \quad \Delta V_{GS} = \frac{C_{GD}}{C_{GS}} \Delta V_{DS}$$

- Higher $C_{iss}$ / $C_{rss}$ ratio (larger $C_{GS}$ in comparison to $C_{GD}$) is preferred
- "Gen3 Fast" MOSFETs optimized for "capacitance ratio"
  - ~30% better "capacitance ratio" as compared to SiC trench

- Although SiC trench MOSFETs offer higher $V_{TH}$ (~3.5V) they are more susceptible to overshoots, and poor $R_{DS(ON)}$ vs. $T_j$ and $R_{DS(ON)}$ * $E_{OSS}$ FOMs make them "less efficient"

- "Gen3 Fast" designed for robust fast-switching performance!
  - 2.2V minimum $V_{TH}$ vs. 1.8V minimum $V_{TH}$ specification from other planar SiC MOSFET vendors. Potential for "0V" turn-off with low-inductance package (TO-LL) and low-inductance PCB design

### Best-in-Class $V_{TH}$ *(Planar SiC)*

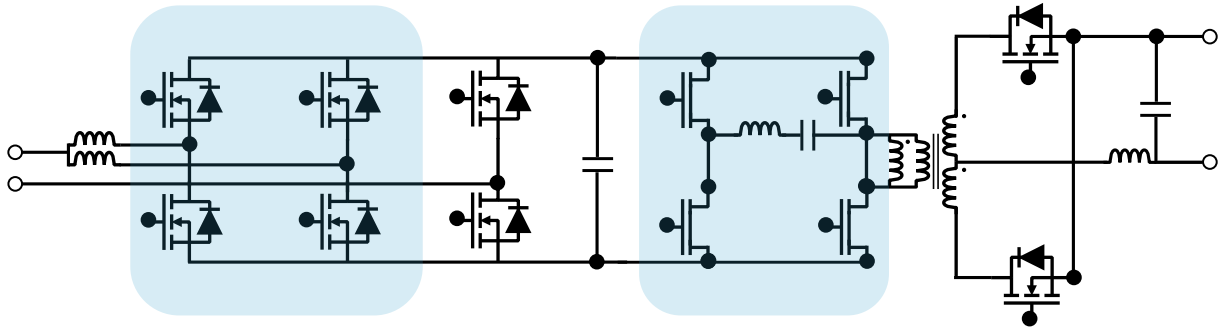


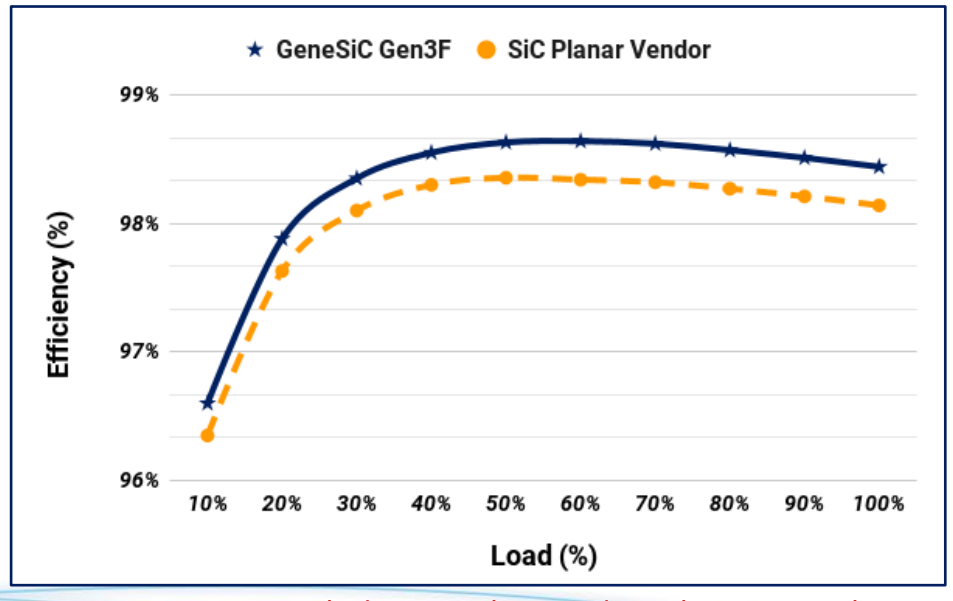
# NVTS 3.2kW Data-Center PSU in CRPS185 Form Factor

Navitas


## Platform Features

- ❑ Supports 2.7kW, 3kW and 3.2kW
- ❑ Up to 98 W/in$^3$ power density
- ❑ Titanium+ efficiency
  - ❑ 96.3 % @ 50 % load
  - ❑ > 96 % @20 % - 60 % load



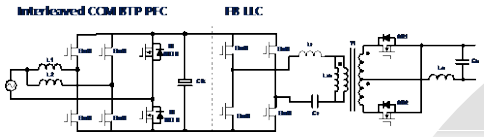




*230V AC input; including EMI loss and auxiliary power loss*

- ❑ **3.2kW interleaved CCM TP PFC**
- ❑ **Better than titanium efficiency (titanium requires 96%) measured using GeneSiC Gen3F 650V SiC MOSFETs *(45mΩ TO-LL)***
- ❑ **Excellent performance at high input current, high temperature conditions, as Gen3F's conduction loss is the lowest**

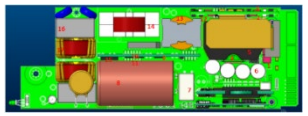
# Accelerating Time-to-Market : Unique System Design Centers

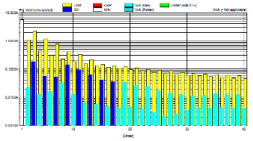
Navitas




**Power *Platform* Design**

*High Efficiency, High Density*





System design evaluation & feedback

Electrical, thermal, mechanical, EMI, BOM cost, manufacturing and yields

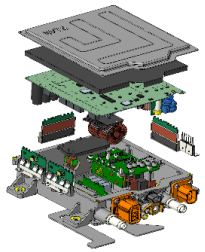

**Semi Design**

*Application-specific SiC / GaN*

**Customer Co-Dev.**

*Joint Labs*

*Joint Development*

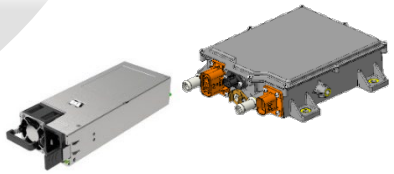


System know-how drives innovation

Close customer co-op for qualification, certifications, production readiness


**Mass Production**

*Fast time to market*



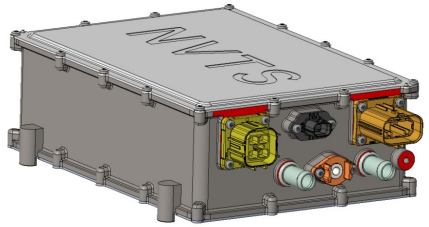
## SERVER PSU DESIGN CENTER


### 3.2kW CRPS Platform

***SiC in CCM TP PFC & GaN in FB LLC***

**98 W/in$^3$ with Titanium+ Efficiency**

## EV SYSTEM DESIGN CENTER



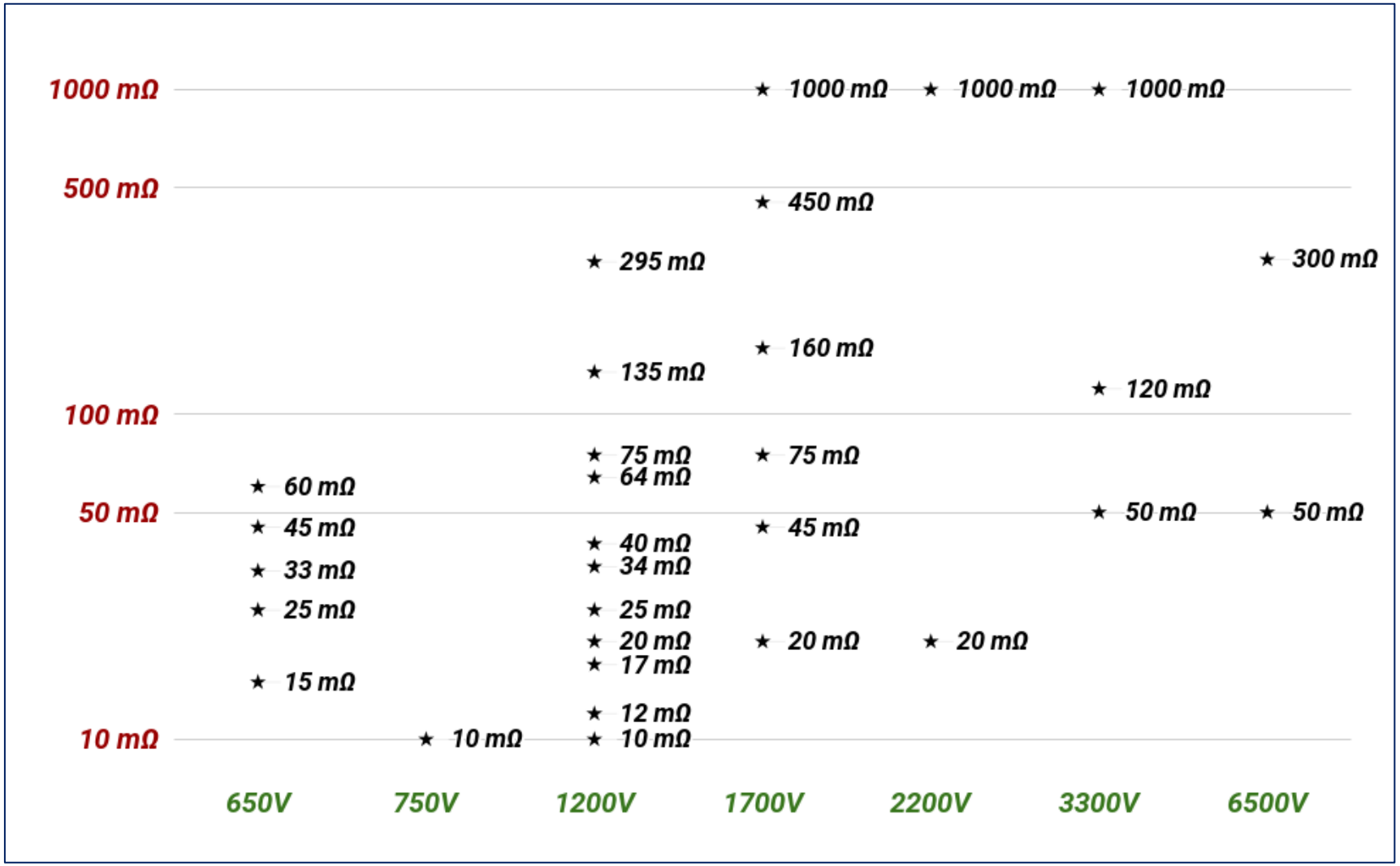

### 22kW OBC + 3kW DC-DC Combo

***Bi-Directional; SiC-based 1-φ & 3-φ* Compatibility**

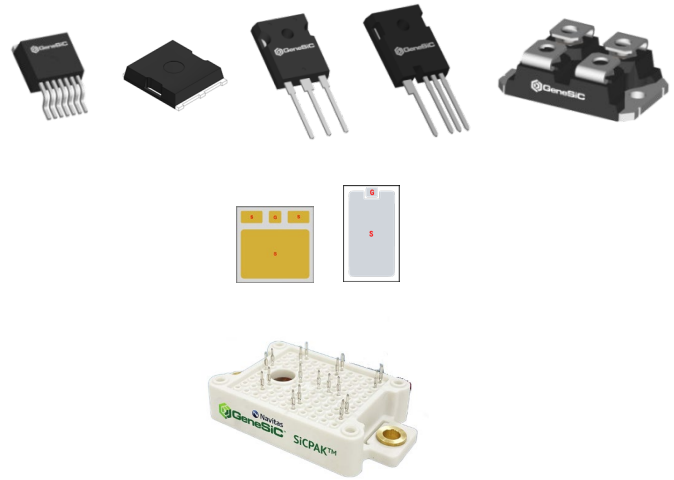
**CCM AC/DC (60 kHz) + CLLC DC/DC (120 kHz~250 kHz)**
**HV-LV DC/DC (65 kHz)**

**3.5 kW/L with Peak Efficiency > 95.5%**

# Broadest[1] SiC MOSFET Portfolio




- ✓ 60+ SiC MOSFET Products
  - ✓ Discrete
  - ✓ Bare Chips
  - ✓ Power Modules




*Note (1): based on GeneSiC voltage range of production released SiC MOSFETs compared to all publicly identified voltage ranges of other SiC suppliers.*