



# *Beyond Simply Replacing Silicon – System Level Impact of GaN Power ICs in Key Applications*



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*Senior Director Industrial & Consumer*



# Navitas

*Energy • Efficiency • Sustainability*



# *Beyond Simply Replacing Silicon – System Level Impact of GaN Power ICs in Key Applications*

- Navitas Semiconductor
- Performance implications of GaN power ICs
- Reliability implications of GaN power ICs
- Application example: High density mobile phone charger
- Application example: High performance motor drive
- Application example: High power SMPS
- Conclusion

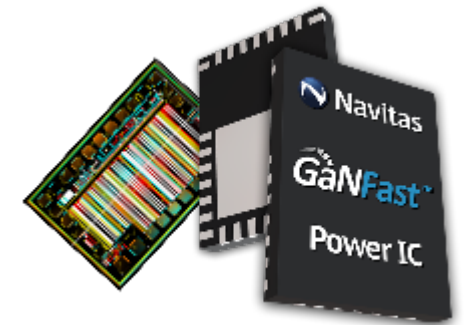


## *Pure-Play Next-Gen Power Semiconductors*

August 15th, 2022: Navitas Semiconductor, industry-leader in gallium nitride power ICs, acquired GeneSiC Semiconductor, silicon carbide pioneer and industry leader

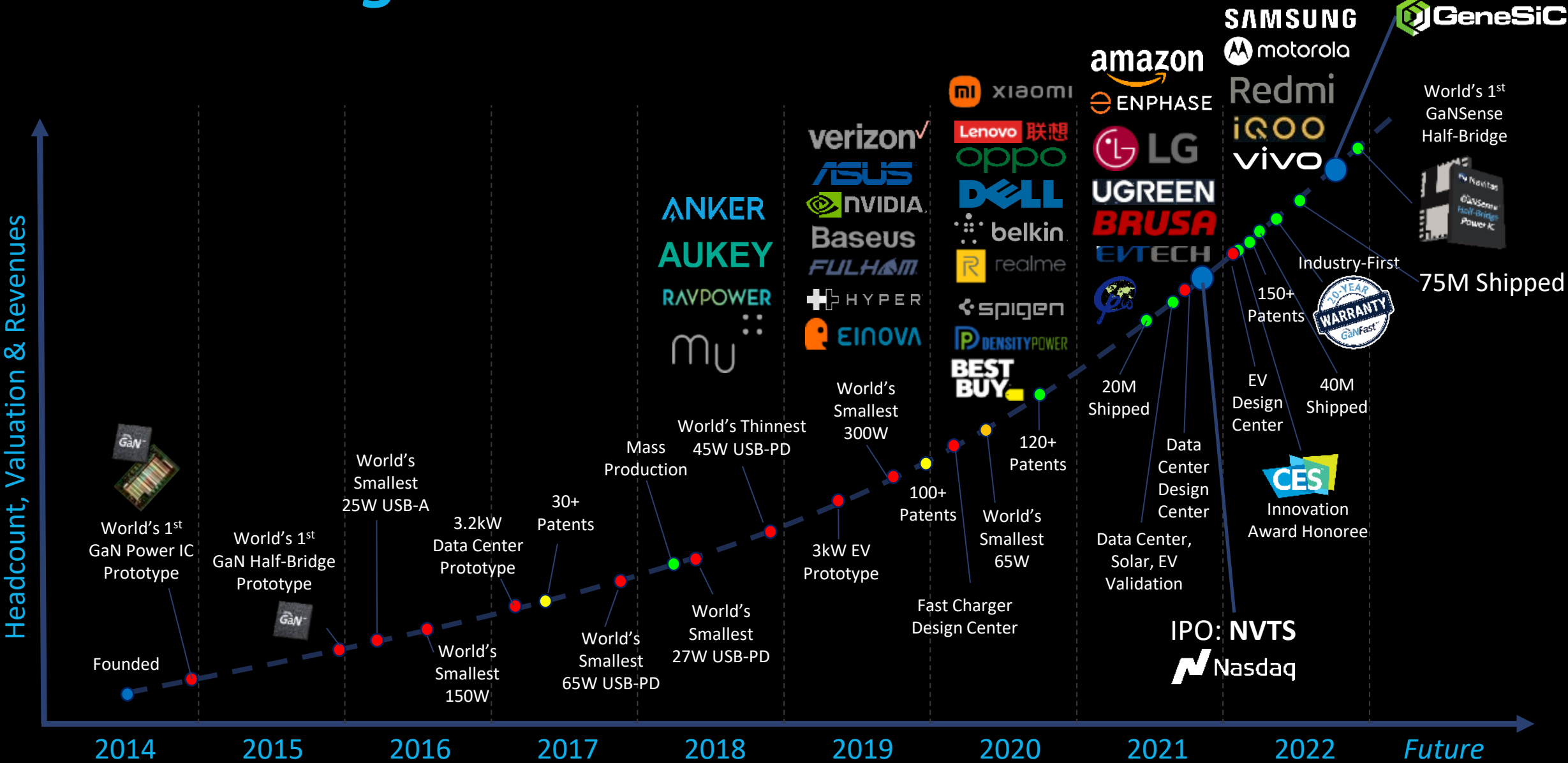
# Navitas Fundamentals<sup>(1)</sup>

- Industry's only pure-play next-gen power semi company, \$23B/yr market
  - Founded 2014, 220+ employees
  - Nasdaq: NVTX (IPO October 2021)
- Leading power GaN IC and power SiC technology, 185+ patents
  - >75M GaN, >9M SiC Shipped
  - 3x (GaN), 5x (SiC) capacity expansion starting in 2023
  - Major diversification in markets, regions
- Mission to Electrify Our World™
  - Industry leader in mobile fast, ultra-fast chargers
  - Market expansion on track / accelerated into data center, solar, EV



(1) See Navitas New York Investor Meeting September 13<sup>th</sup>, 2022, and Navitas' Q3'22 earnings November 9<sup>th</sup>, 2022, for details

# Accelerating Growth



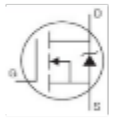
# Benefits of Integration – what is a GaN power IC?

**GaNFast™**

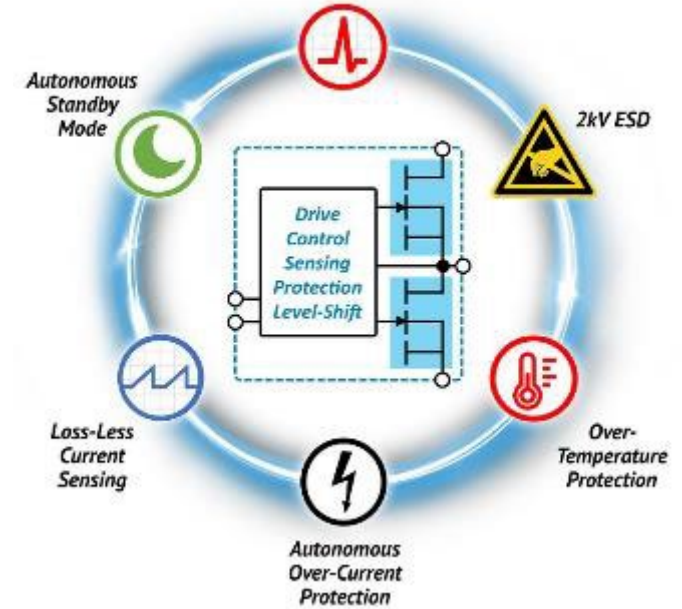
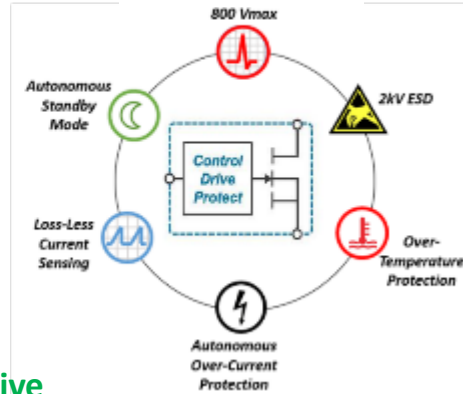
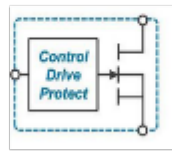
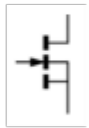
**GaNSense™**

**GaNSense Half-Bridge**

Silicon FET



Discrete GaN



- Old, slow
- High  $Q_g$
- High  $C_{oss}$
- $F_{sw} < 100$  kHz

- Exposed gate
- External gate drive
- $dV/dt$  sensitivity
- Layout sensitivity
- ESD sensitivity
- Unknown reliability
- Unknown robustness

- ✓ Internal Gate
- ✓ Integrated Gate Drive
- ✓  $dV/dt$  Immunity
- ✓ Layout Insensitive
- ✓ 2 kV ESD rating
- ✓ Proven Reliability
- ✓ Proven Robustness

- GaNFast plus:**
- ✓ Autonomous Standby
  - ✓ Autonomous Protection
  - ✓ Loss-less Current Sensing
  - ✓ High Precision
  - ✓ High Efficiency

- GaNSense plus:**
- ✓ Highest integration
    - ✓ integrated HS and LS FETs
    - ✓ Integrated level-shift isolation
    - ✓ integrated boot-strap
    - ✓ Shoot-through protection
    - ✓ Enlarged cooling pads
  - ✓ Fastest switching
  - ✓ Highest efficiency



# GaN Integration Drives Speed, Efficiency, Stability Navitas

## Discrete GaN Half-Bridge



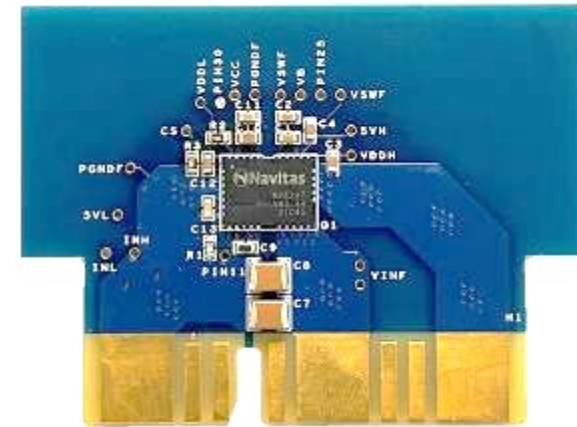
- 33 components
- 250 mm<sup>2</sup> footprint
- External HB driver HVIC
- External HV bootstrap
- 2x HV bypass diodes
- 2x external gate drives
- Exposed gates

61% fewer components

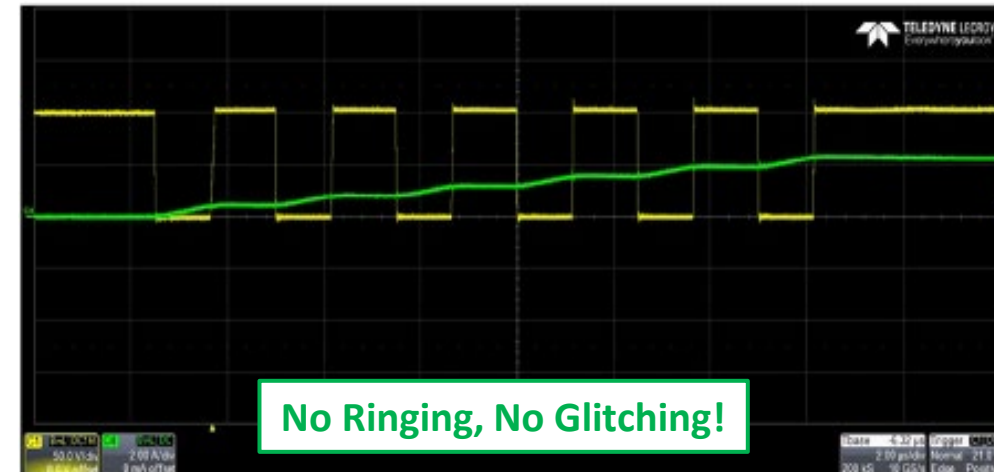
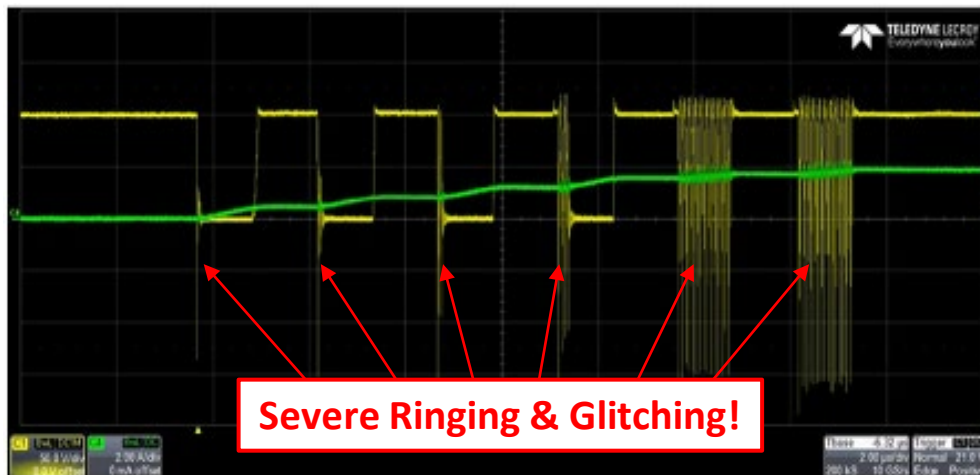
64% smaller footprint

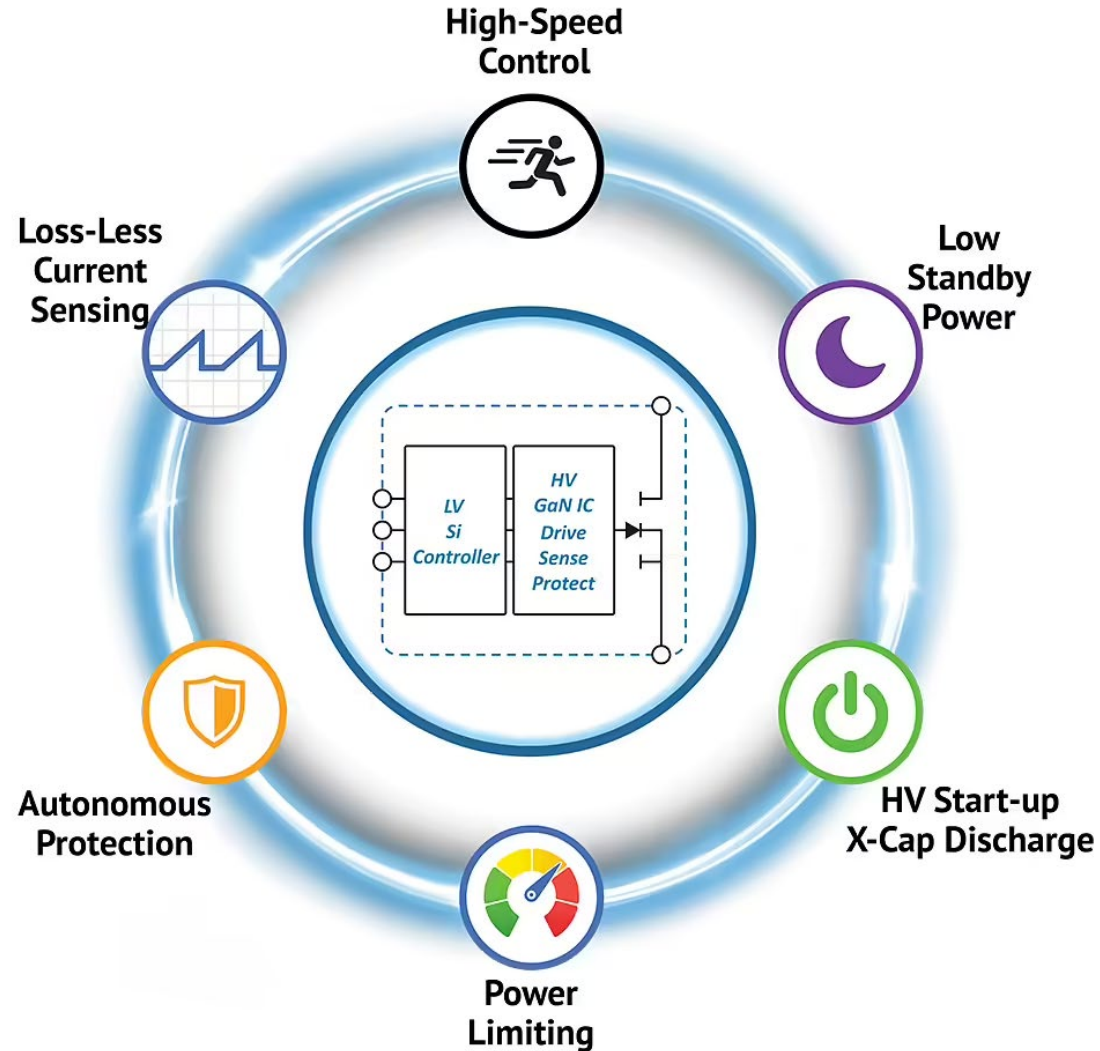
Complete integration

## GaNSense Half-Bridge IC



- ✓ 13 components
- ✓ 90 mm<sup>2</sup> footprint
- ✓ Level shifters
- ✓ Bootstrap
- ✓ Gate drivers
- ✓ No exposed gates

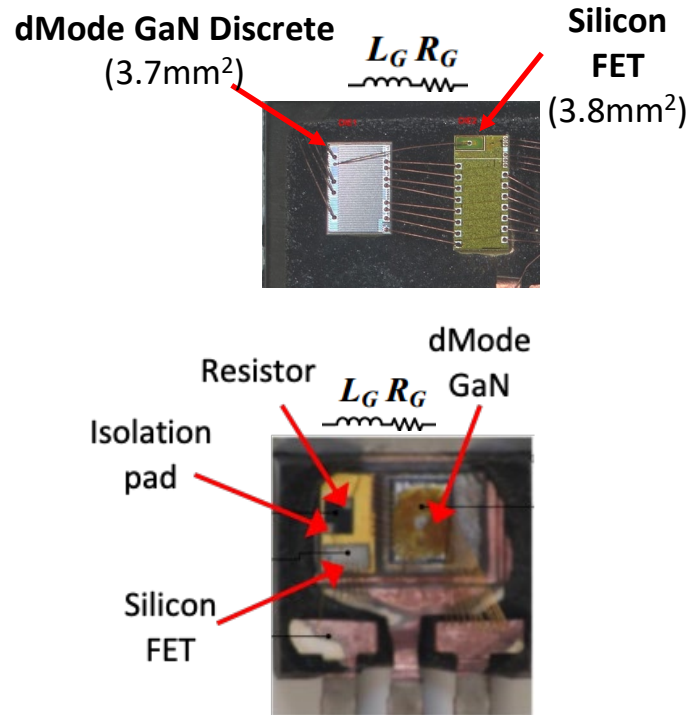






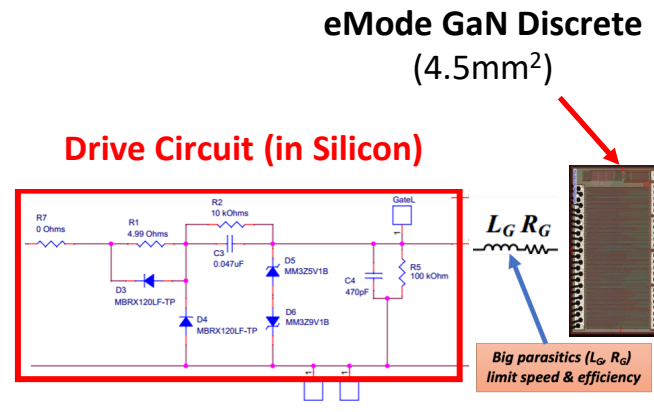
# Navitas GaN IC: Smaller, Faster, Robust

## Discrete dMode GaN



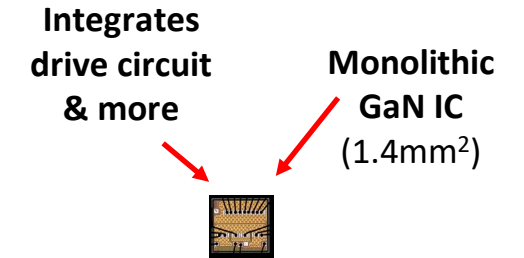
- Extra Si FET + other
  - Cost & complexity
  - Adds parasitics & delay
  - Limits speed & efficiency

## Discrete eMode GaN



- Extra Si driver circuit

## Navitas eMode GaN IC



- No extra circuits
- No parasitics & delay
- Drive & power matched in GaN
- Integrated features, functions
- Highest speed & efficiency
- Highest robustness and reliability
- Simple customer design
- 50-80% smaller chip

(1) 'dMode' = depletion mode = 'normally on' transistor, causes short circuit unless additional transistor added.

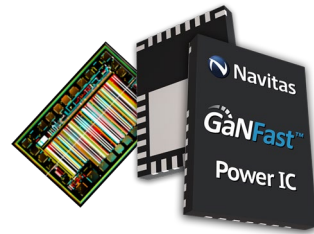
(2) 'eMode' = enhancement mode = 'normally off' transistor.

# Leader in Sustainability: 150,000+ tons CO<sub>2</sub> Saved! <sup>(1)</sup>



February '22 First GaN sustainability report based on global standards.

Every **GaNFast™ IC**  
saves  
**4 kg CO<sub>2</sub>**



**4x-10x** lower component CO<sub>2</sub> footprint than silicon

**28% lower** lifetime CO<sub>2</sub> footprint for chargers / adapters

**Accelerates** transition from ICE to EV by **3 years**, saving **20%/yr** of road-sector emissions by 2050

GaN + SiC save up to **6 Gton / year** by 2050



May '22 World's first semiconductor company CarbonNeutral® certified



August '22 First 100,000 tons CO<sub>2</sub> saved



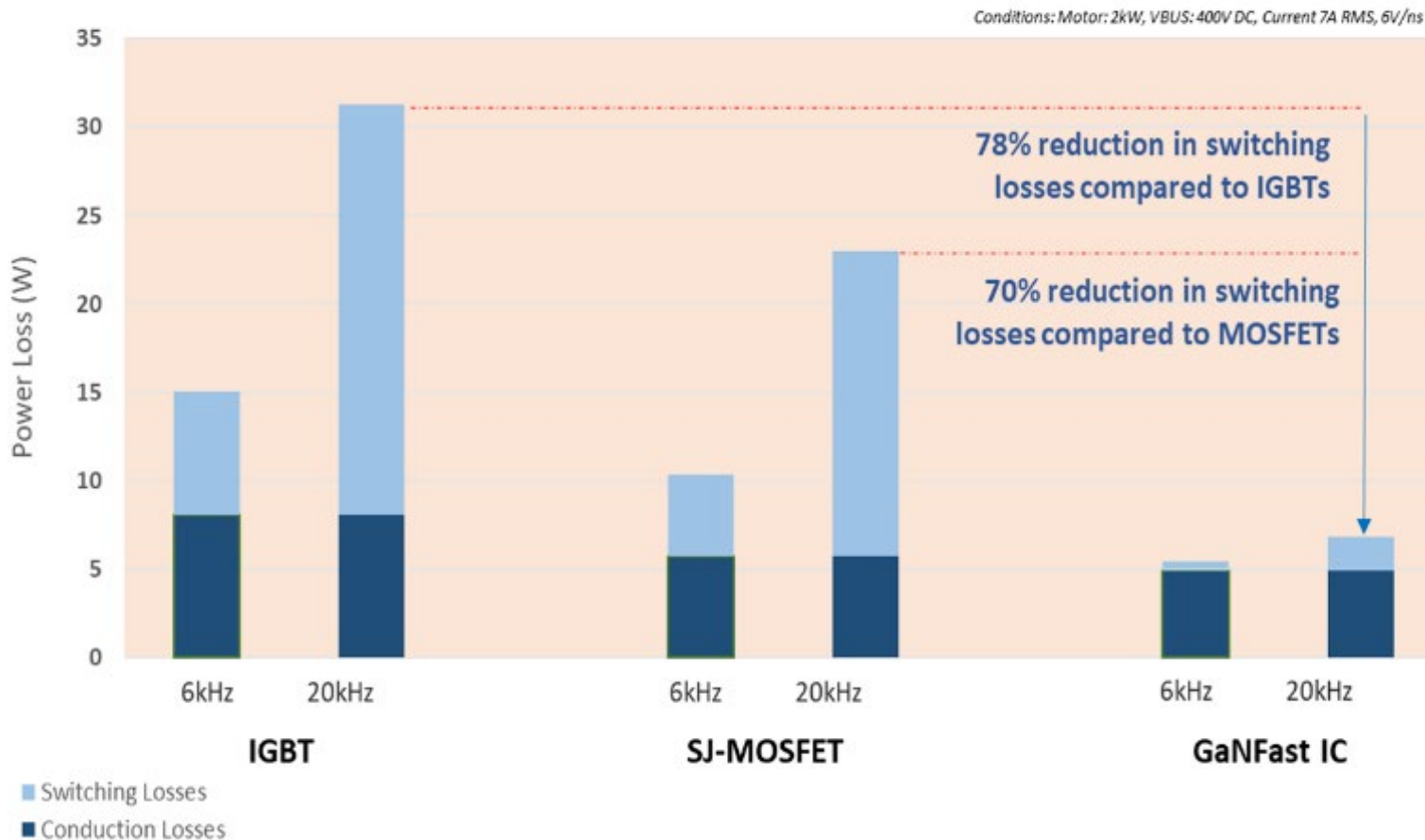
October '22 Recognized for industry-leading sustainability reporting

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- Conclusion

# Motor Drive: 70%+ Reduction in Loss vs. Silicon

Power Loss Comparison between IGBT, SJ-MOSFET, and GaNFast IC in Motor Drives



Application case:

- Bus voltage 400 V
- Current 7 A RMS
- Motor power 2 kW
- Switching 6 V/ns
- GaN and MOSFET same conduction losses

Using GaN FETs, the inverter efficiency increases by 2.5% (96%→98,5%) and total losses are halved (15 W→6-8 W)

→ Significant reduction in cost, weight and size of thermal management (heatsink, fans, etc.)

→ Benefit even larger at higher switching frequency

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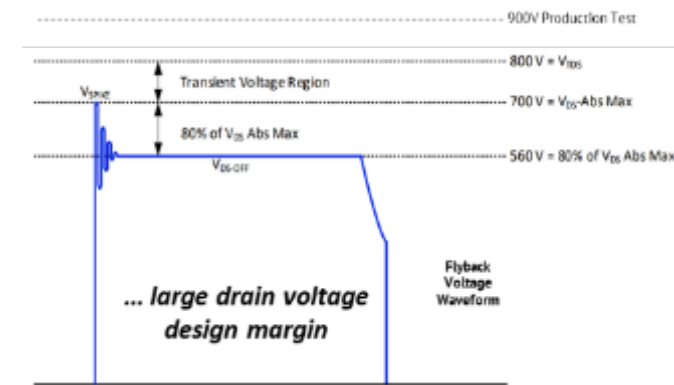
- **Design** for Reliability

- Integrated drive, sensing and protection
- Component reliability, and **system** reliability



- **Testing** for Reliability:

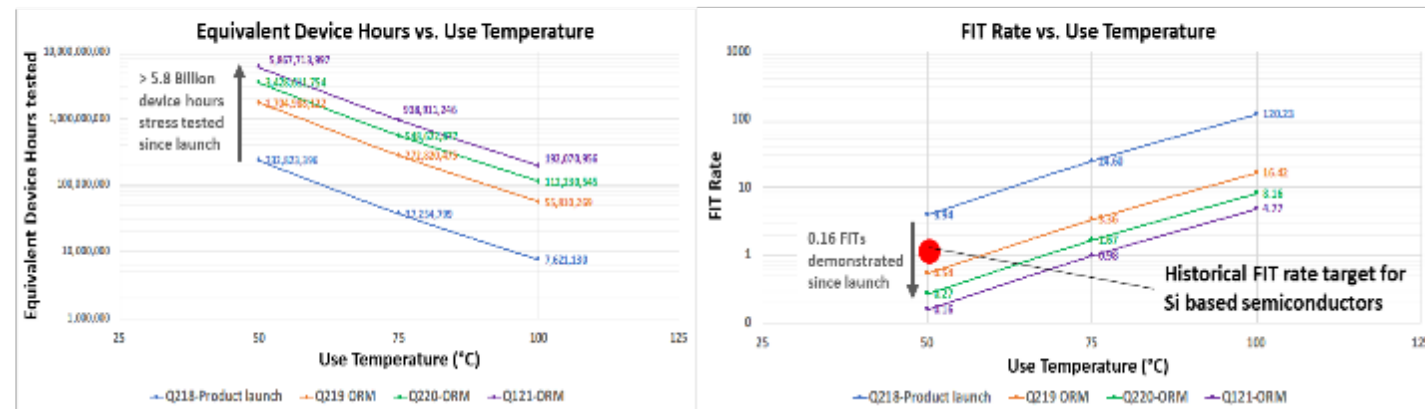
- Proprietary production test methods
- GaN ICs tested 400% (multi-temp, high-frequency)



- **Characterization** for Reliability

- Exhaustive, proactive, and unique Navitas reliability program
- 5.8 B equivalent device hours tested<sup>(1)</sup>
- Proprietary, highly-accelerated Op-Life, plus JEDEC, plus ELFR monitoring
- Founder member of JEDEC JC70.1

Reliability Statistics  
Calculated for High Line condition using HTOL (ZVS) results



(1) As of September 2022  
© Navitas Semiconductor 2023

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# 100% Tier 1 Mobile OEMs Adopting Navitas

## Tier 1 OEMs

## Aftermarket Examples

**240+**

GaN Chargers  
Mass Production<sup>(1)</sup>

**250+**

GaN Chargers  
In Development<sup>(1)</sup>

**100%**

Mobile OEMs Designing With Navitas  
GaN ICs

**75M+**

GaN ICs Shipped<sup>(2)</sup>

(1) as of Q4'22 report (2) as of March '23  
© Navitas Semiconductor 2023



# Now Ultra-Fast Chargers

- New, fast-growth market: \$1B opportunity by 2025<sup>(1)</sup>
- Full charge in <10 mins (200W)
- Increased GaN content per charger
- World's highest power density 120W, 150W, 200W

## Key value drivers:

- **Lowest losses → High power density**
- **No big penalty for high switching frequency → Smaller components**



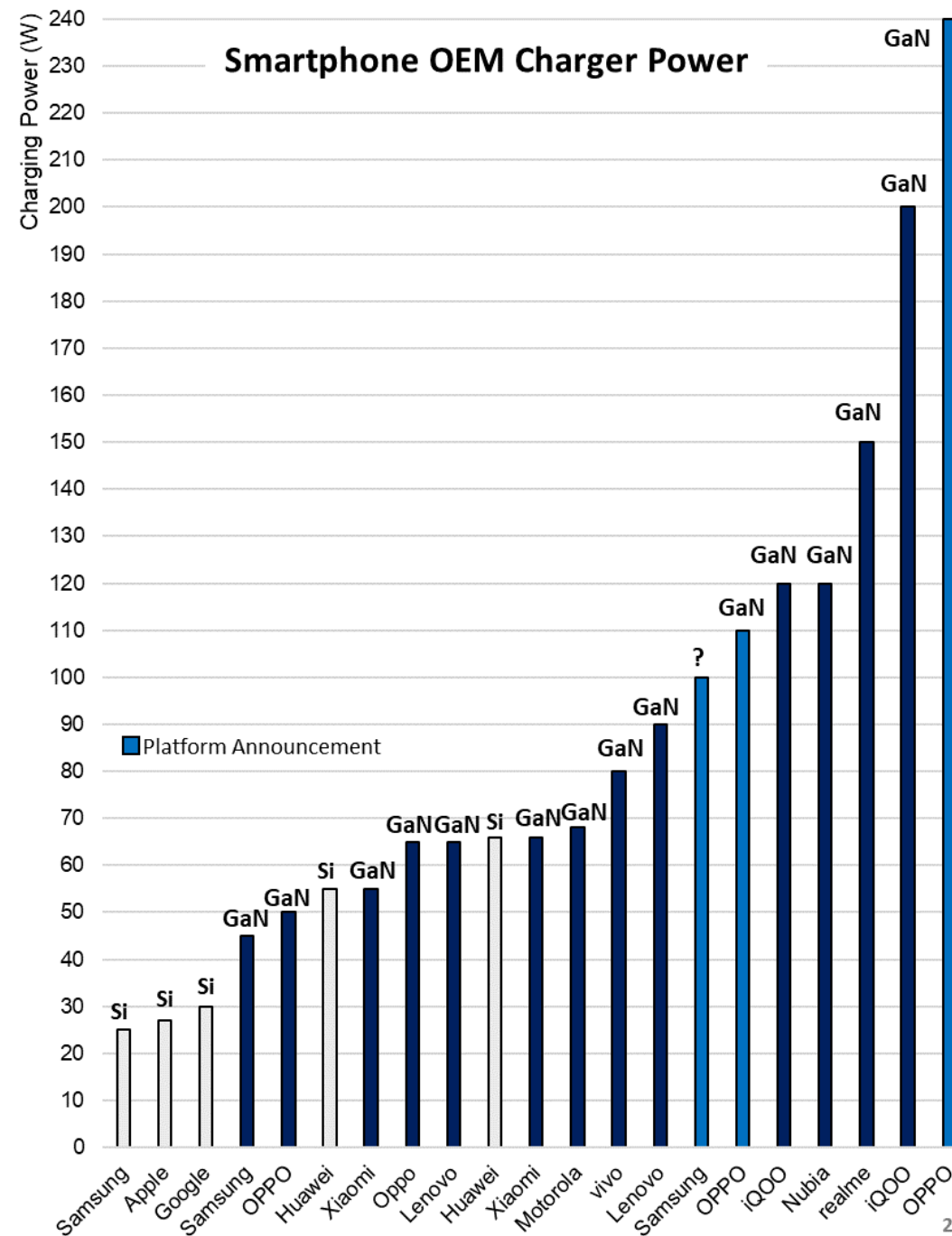
RedMi (Xiaomi) F1 Mercedes 120W



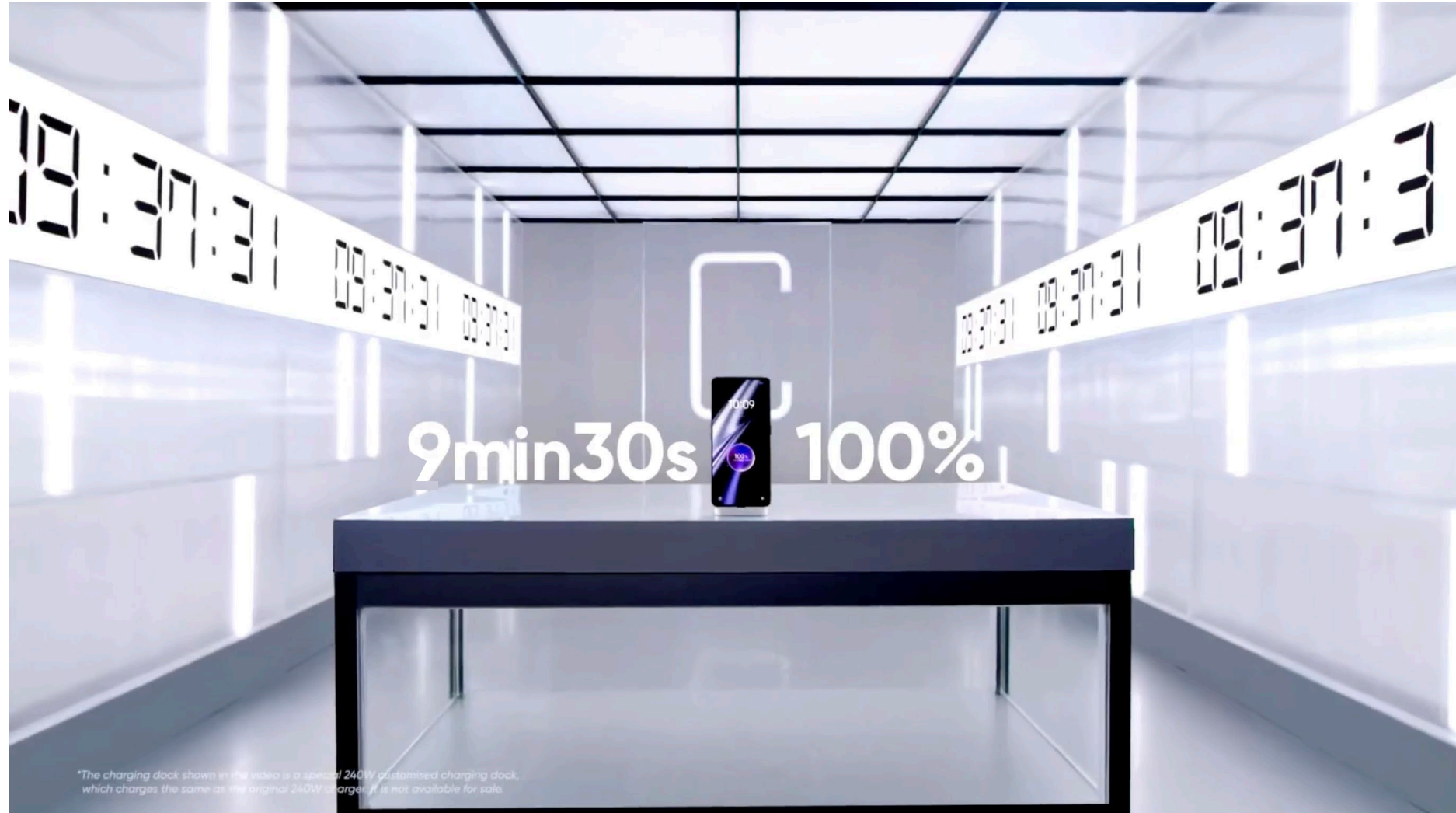
Realme (OPPO) GT Neo 3 150W



iQOO (vivo) 10 Pro, 200W

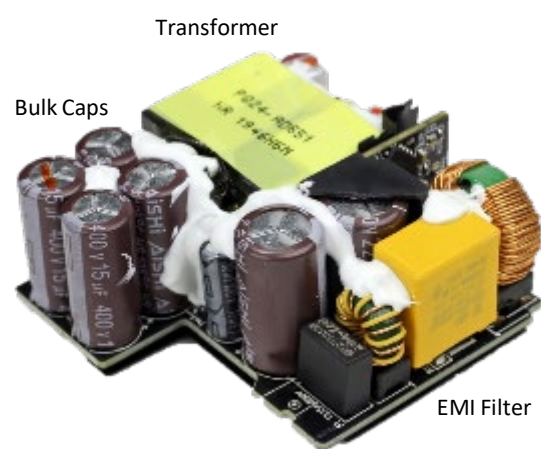


# Powering the World's Fastest-Charging Smartphone

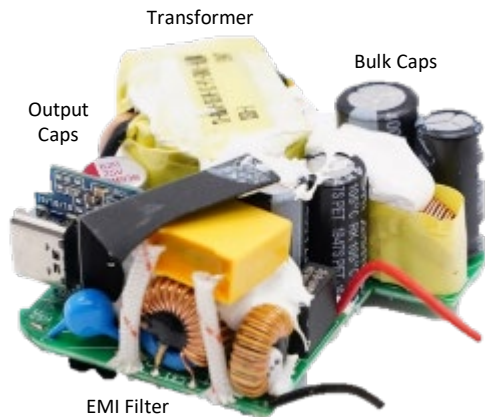


# High Speed Shrinks Passive Components

Typically, slow-speed designs have ~70% of volume used by transformer, capacitors, EMI filter, etc.

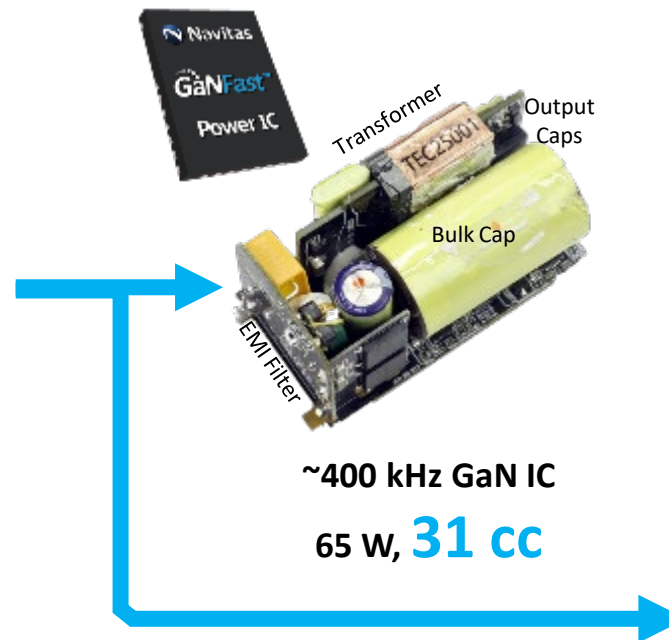


~65 kHz Silicon  
65 W 43 cc



~75 kHz GaN Discrete / MCM  
65 W, 46 cc

High-speed GaN IC designs **shrink** 'passive' components by ~50%<sup>(1)</sup>



~400 kHz GaN IC  
65 W, **31 cc**

Half-Bridge IC delivers ~2x the power, or ~2x faster charging in the **same size**<sup>(1)</sup>



~750 kHz peak Half-Bridge GaN IC  
**120 W, 44 cc**

**~2x faster charging!**

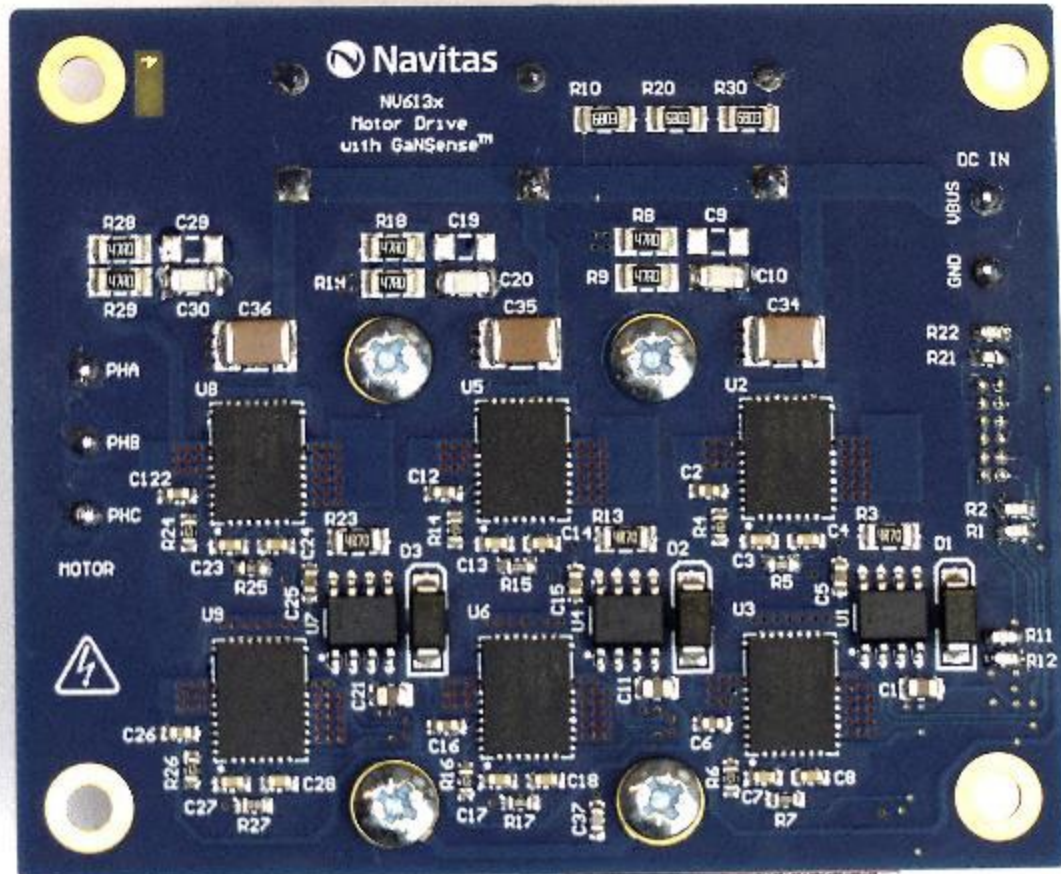


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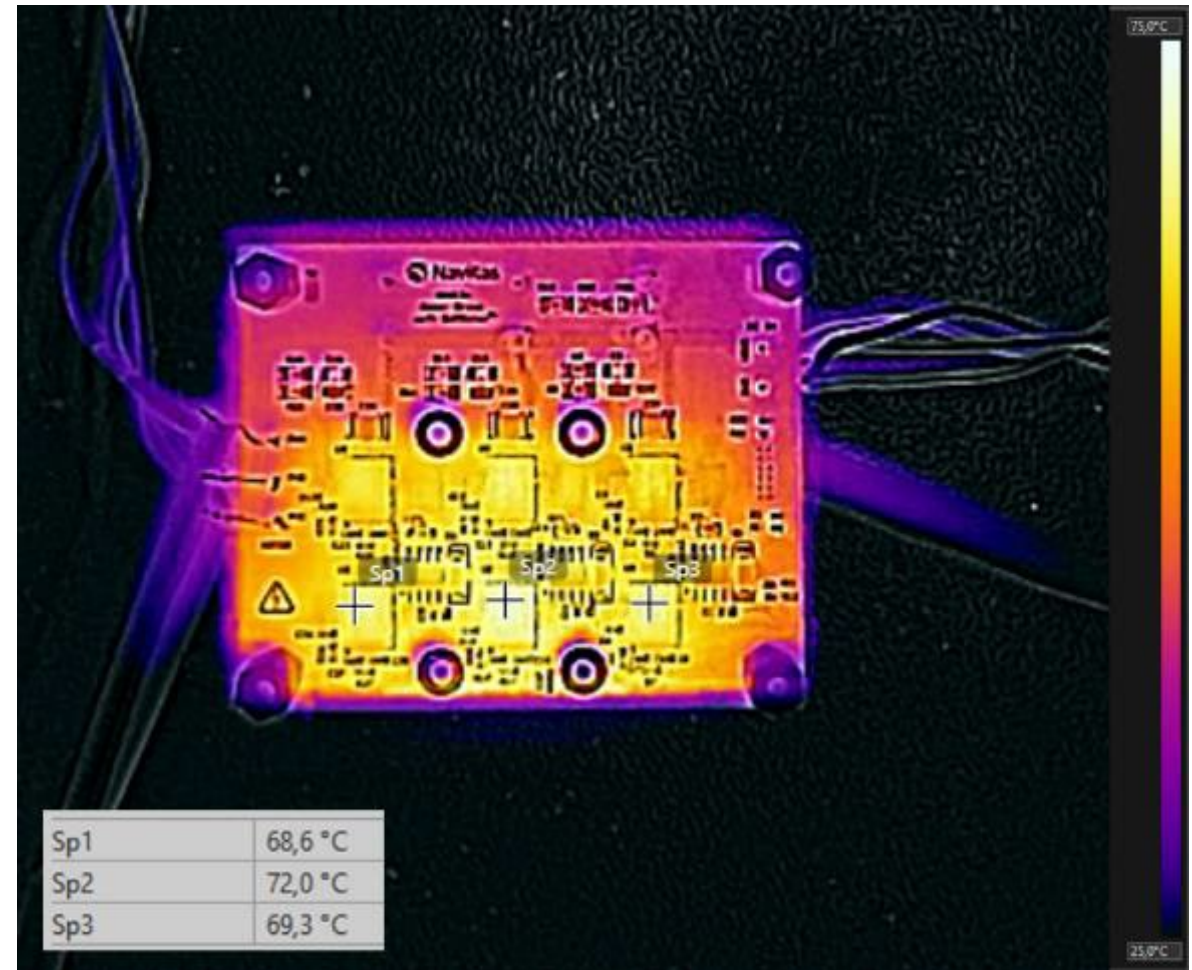
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# Reference design high power 6-in-1 inverter

## Efficiency >99% at 500 W, using NV6138



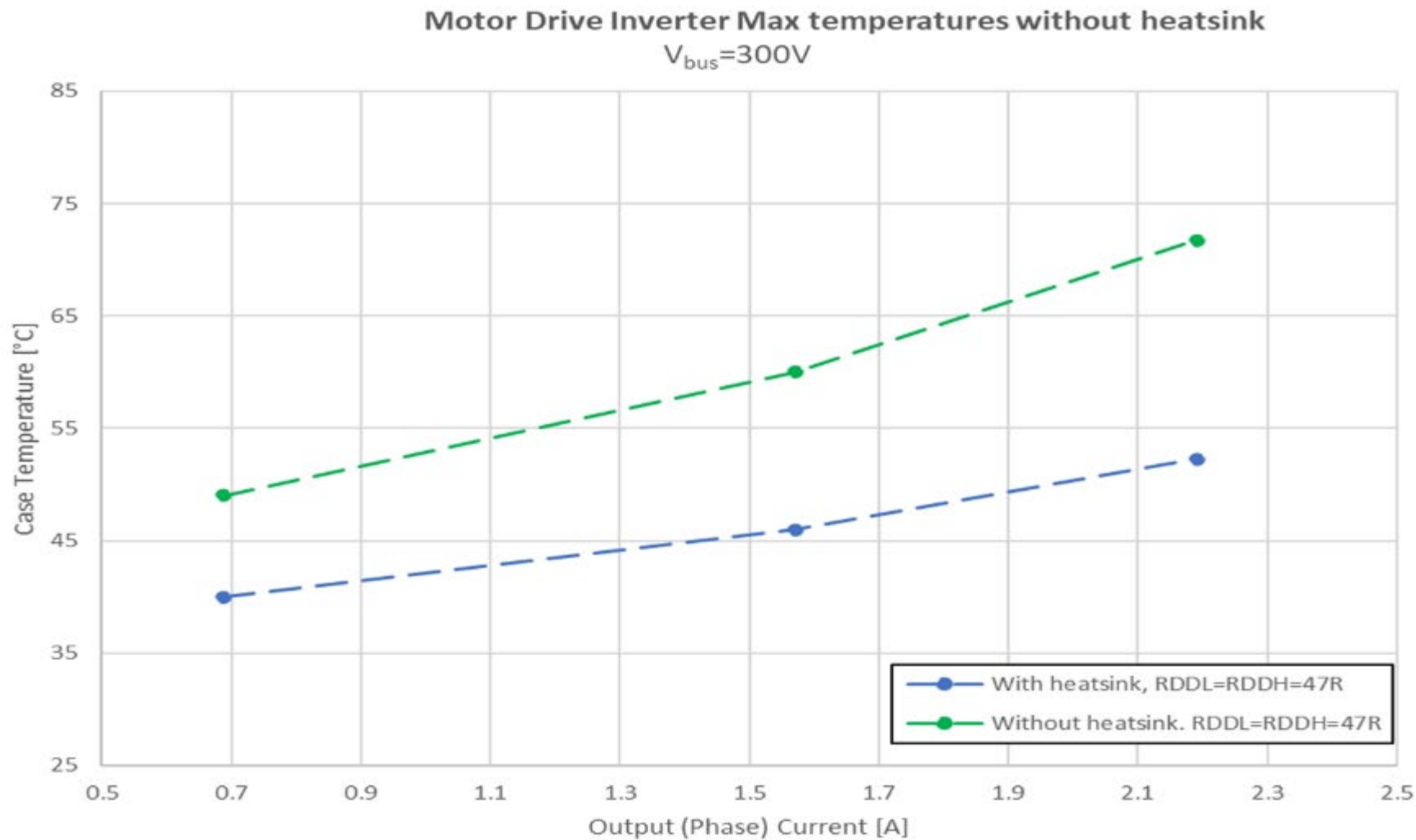
Board size 74 x 62 mm



Thermal scan @ 500 W, 20 kHz ( $R_{THCA} \sim 20$  K/W),  $T_{amb} = 25^\circ\text{C}$   
**No heatsink used**

# Reference design 1kW motor inverter

## Max temperatures with / without heatsink





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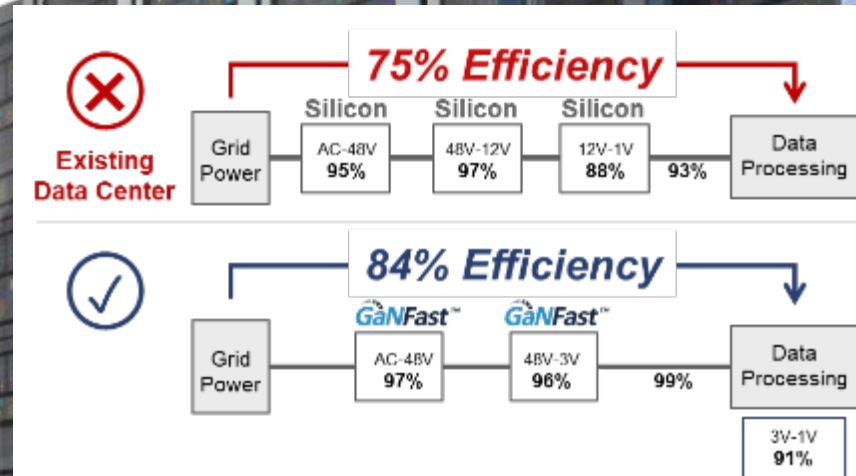
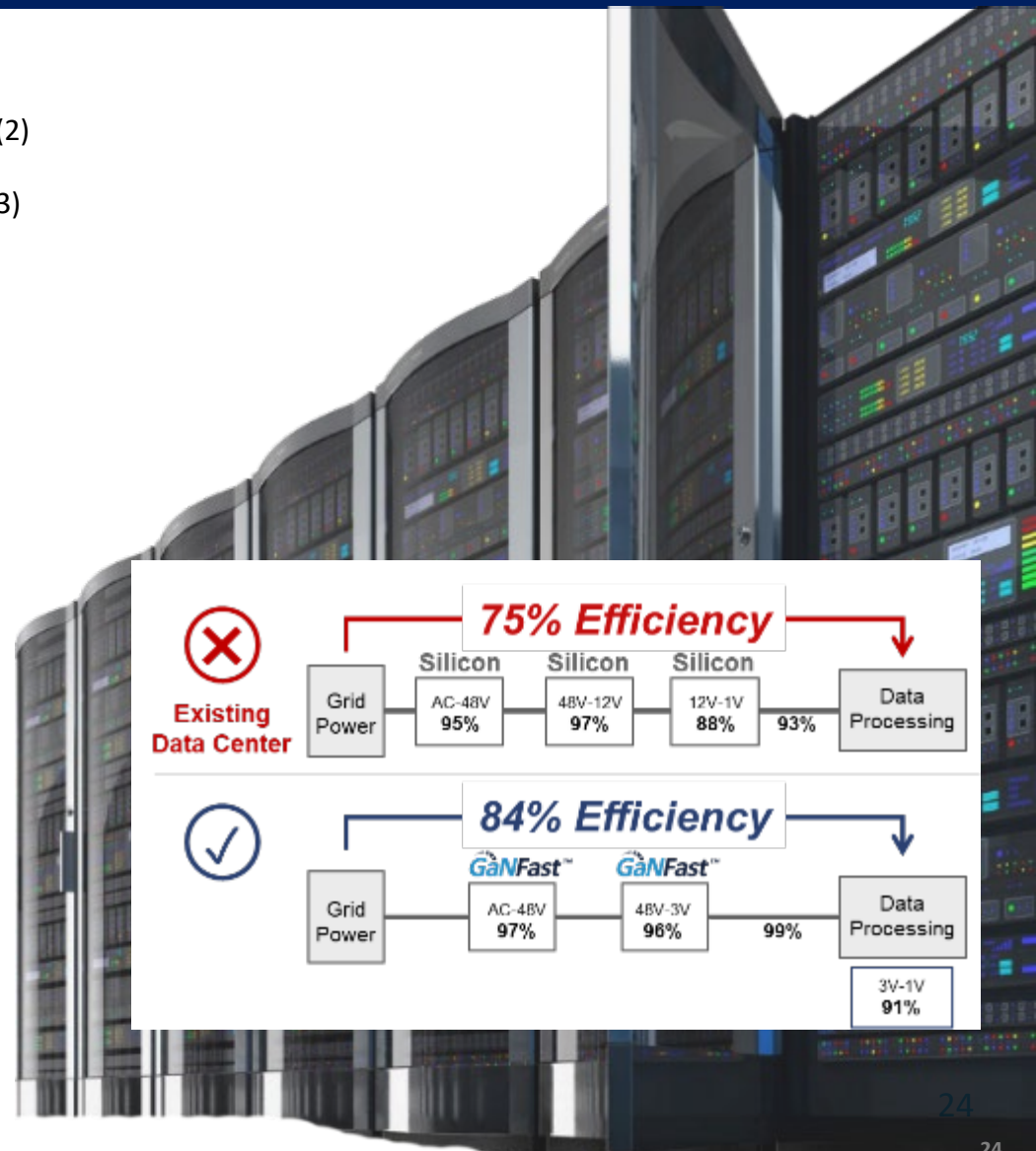
# GaNFast Exceeds “Titanium” with >2x Power Density

- Euro ‘Titanium plus’ standard from January 1<sup>st</sup>, 2023<sup>(1)</sup>
- System Design Center: 4 platforms: 1.3 kW, 1.6 kW, 2.7 kW, 3.2 kW CRPS<sup>(2)</sup>
- GaN can reduce electricity use by up to 10%, save >15 TWh or \$1.9B/yr <sup>(3)</sup>

| Slow Silicon AC-DC 3,200W  | GaNFast AC-DC 2,700W  |
|--|---|
|  <p>47 kHz<br/>325 x 107 x 41 mm<br/>2.2 W/cc</p> |  <p>300-500 kHz<br/>185 x 73.5 x 39 mm<br/>5.1 W/cc</p> |
|  | <ul style="list-style-type: none"> <li>• &gt;2x higher power density</li> <li>• &gt;30% reduction in energy loss</li> </ul>               |

*“GaN is a breakthrough new technology that is enabling dramatic reductions in size, energy savings and power density”*  
*“Navitas is an excellent partner with industry-leading GaN ICs”*

Robin Cheng, VP R&D

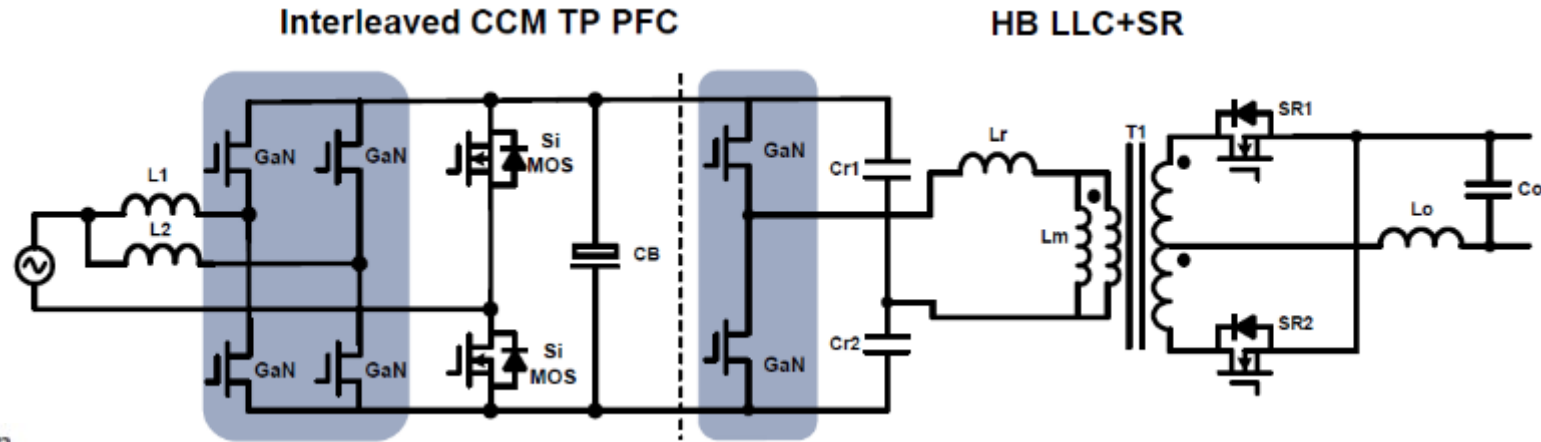


(1) European Union ‘Directive 2009/125/EC, 2019 Annex’, power supplies must be >96% efficiency peak.  
 (2) CRPS = Common Redundant Power Supply standard, defined by Intel for standardized mechanical form-factors, targets hyper-converged compute, storage and networking eqpt.  
 (3) Navitas est. based on a) Navitas server/datacom forecast & AAAS data, b) \$0.12/kWhr, c) Si vs. GaN \$/W and d) data-center loading profile. Estimated based on known existing Si-based solutions to deliver >500A next-generation data processors to Navitas targets for new GaN-based AC/DC and DC/DC for these same next-generation data processors

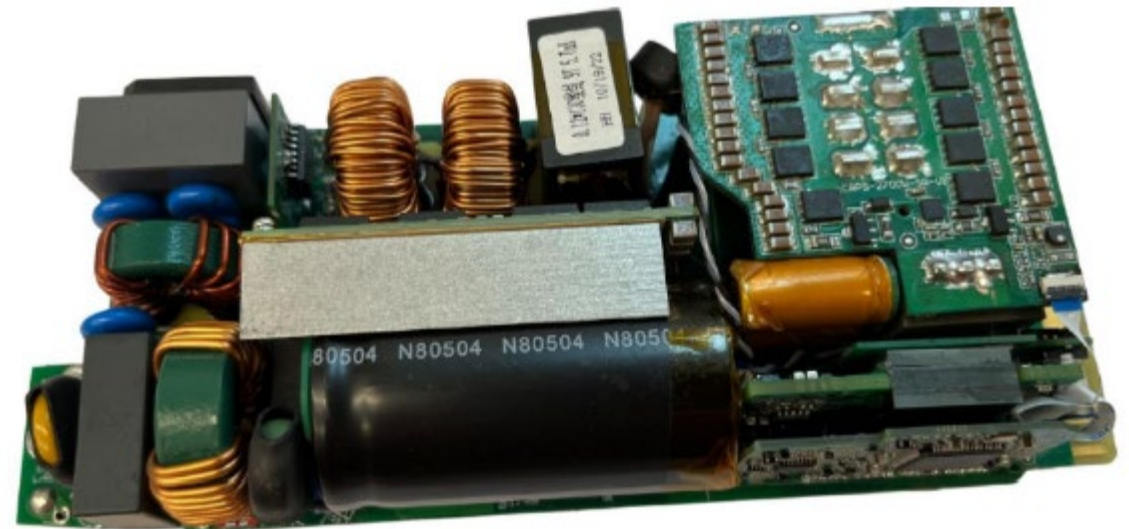
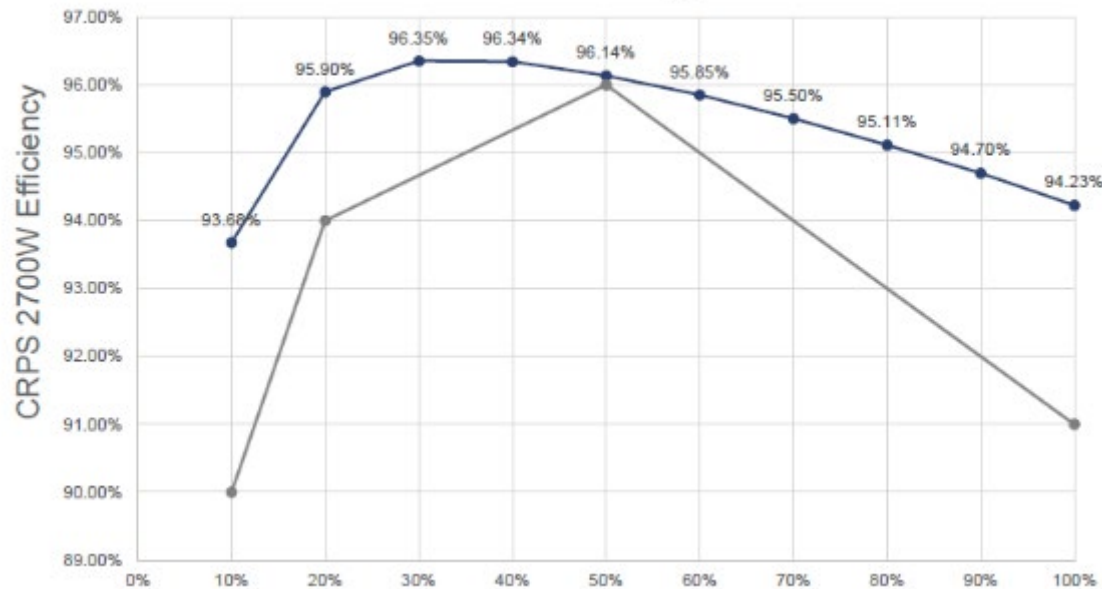


# GaNFast™ Server power supply 2.7kW Titanium+

- Output power 2.7kW
- Peak efficiency 96.34%
- Power density 5.1W/cc



Vin=230VAC@25C exclude fan

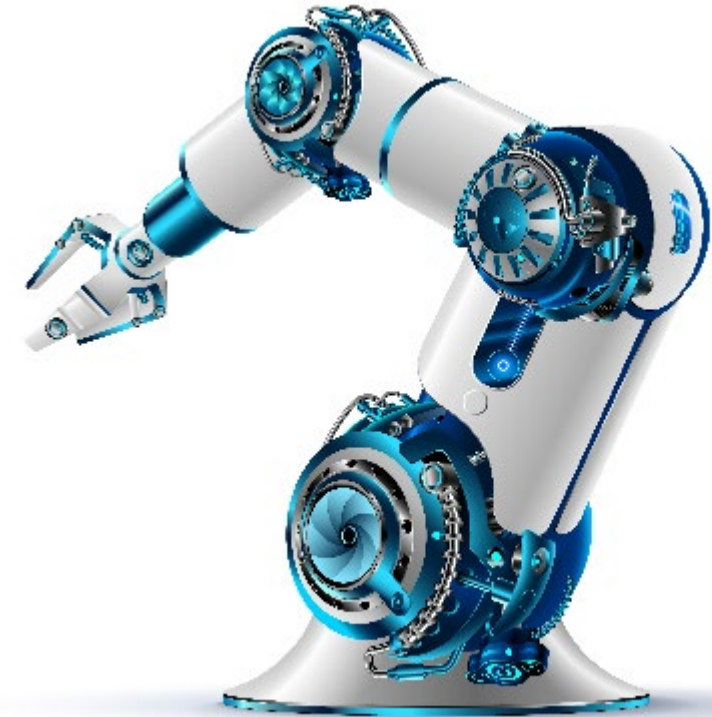


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# Conclusion – The time is now

- Through GaNFast / GaNSense integration, GaN power ICs are ready now
  - Reliable and repeatable performance of e-mode GaN power transistors
  - Smallest form factor and lowest losses
  - Easy to use digital power stage
- Massive performance improvement over silicon alternatives
- Immediate availability
  - 16 week leadtime
  - 3x capacity increase
  - Re-using older silicon fabs with little additional expense and waste



***GaN power ICs enable the next level of performance, reliability and robustness in power electronics applications***

*Thank you!*



**Navitas**

*Energy • Efficiency • Sustainability*

Contact: [alfred.hesener@navitassemi.com](mailto:alfred.hesener@navitassemi.com)

