



/Autonomous  
/Sensing  
/Communication  
/Battery  
/Navigation  
/Mirrorless  
/Ecology

# TRANSFORMING THE WORLD

WITH SMALLER, LOWER  
COST, MORE EFFICIENT  
POWER ELECTRONICS

## GaN Technologies For Electric Vehicles

NOVEMBER 2019



## Market leader for GaN power transistors

- GaN-on-Silicon transistors for power conversion
- Industry's broadest & highest-performing products
  - 100V & 650V devices; industry-best performance
  - Applications from 25W to 225,000W

## Global reach with decades of experience in GaN

- Parts shipping to >2000 customers since 2014
- World-class fabless manufacturing and advanced packaging
- HQ in Ottawa, Canada
- Sales/App. Eng. in Germany, Japan, China, Taiwan, Korea, USA



Power Supply with Silicon



Power Supply with GaN

### CUSTOMERS ACHIEVE IMPROVED SYSTEMS

- |                     |                        |
|---------------------|------------------------|
| • Efficiency        | <i>4x lower losses</i> |
| • Size              | <i>4x smaller</i>      |
| • Weight            | <i>4x lighter</i>      |
| • Lower system cost | <i>10% to 20%</i>      |

# GaN's Major Market Segments

## CONSUMER



Large, heavy, and Ecodesign directive for higher efficiency

## DATA CENTERS



Inefficient and approaching 5% of global power usage

## RENEWABLE ENERGY



Storage needed for Distributed Energy (ESS)

## INDUSTRIAL



Inefficient and 30% of worldwide electricity usage

## ELECTRIC VEHICLES



Government reduced CO2 & high MPG regulations



## Computer charger

4x smaller  
3x lighter  
40 W/in<sup>3</sup>

**Solar ESS**  
2x smaller  
3x lighter  
Eliminated fan



## AC/DC Converter

2x smaller  
3x more power  
6x density increase

## Data Center server power supply

50% higher power density  
20% lower  $P_{loss}$



# Market Leaders have bought into GaN



## BMW i Ventures

BMW i Ventures Leads Strategic  
Investment in GaN Systems



Delta becomes Strategic Investor  
in GaN Systems



ROHM and GaN Systems Join Forces  
for GaN Power Semiconductors



## ON Semiconductor

ON Semiconductor Expands GaN  
Ecosystem with GaN driver ICs

# Market leaders confirm the value of GaN



**#1 Worldwide in Energy Storage**



**#2 Worldwide in Automotive**



**#4 Worldwide in Data Center Servers**

## Advantage with GaN Systems



- GaN Systems' technology gives us improved design freedom
  - Higher Efficiencies: **4% round-trip efficiency increase**
  - Normalized Efficiencies: **at low and high power**
  - Reduction in Material Cost: **8% BoM cost savings**
  - Reduction in Size: **30% smaller**
- GaN provides an improved value-stack at a competitive cost position
  - Extending the value of the battery usable capacity by improving directional efficiencies
  - Allow us to design more integrated solutions

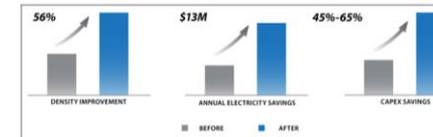


	Si	GaN
Power Conversion Unit of DC/DC Converter		
# of SubAssy	<b>5</b>	<b>1</b>
Volume		



## Improved data center power efficiency

- Supermicro high-density, high-efficiency cost effective solutions save space, money and reduce our imprint on the environment.



Density improvement, annual electricity savings and CAPEX savings per refresh cycle for a new Data Center of a Fortune 100 company

- GaN-based power supplies provide the leap in efficiency and power density.





## Electric Vehicle market drivers

- CO<sub>2</sub> emissions
- Renewable energy



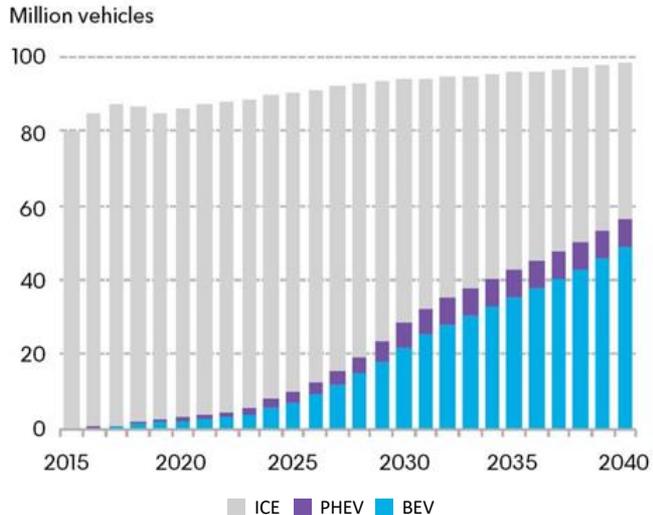
## Autonomous Vehicle market drivers

- Safety
- Convenience
- Productivity
- Accessibility
- Social Integration
- Resource Utilization

## EV Sales

- 2M+ vehicles in 2018
- 10M vehicles in 2025
- 28M vehicles in 2030

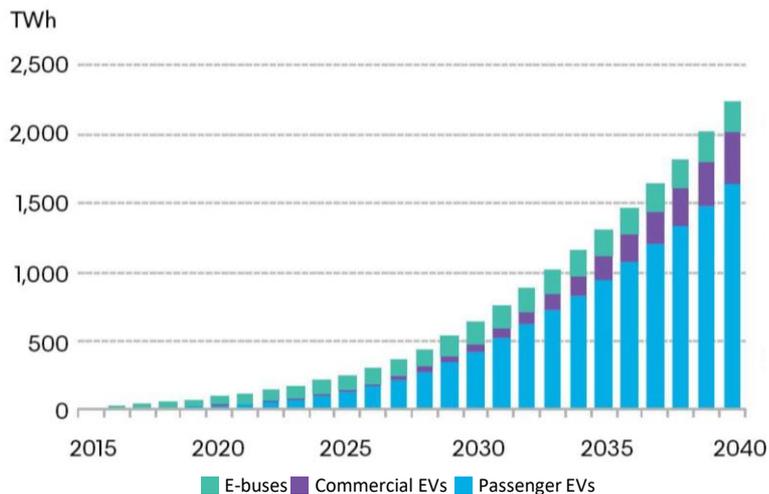
Global long-term passenger vehicle sales by drivetrain



## EV Electricity Demand

- 60 TWh in 2018
- 2,333 TWh in 2040
- EVs add 7% to WW electricity usage

Yearly electricity consumption



# Aggressive EV performance targets

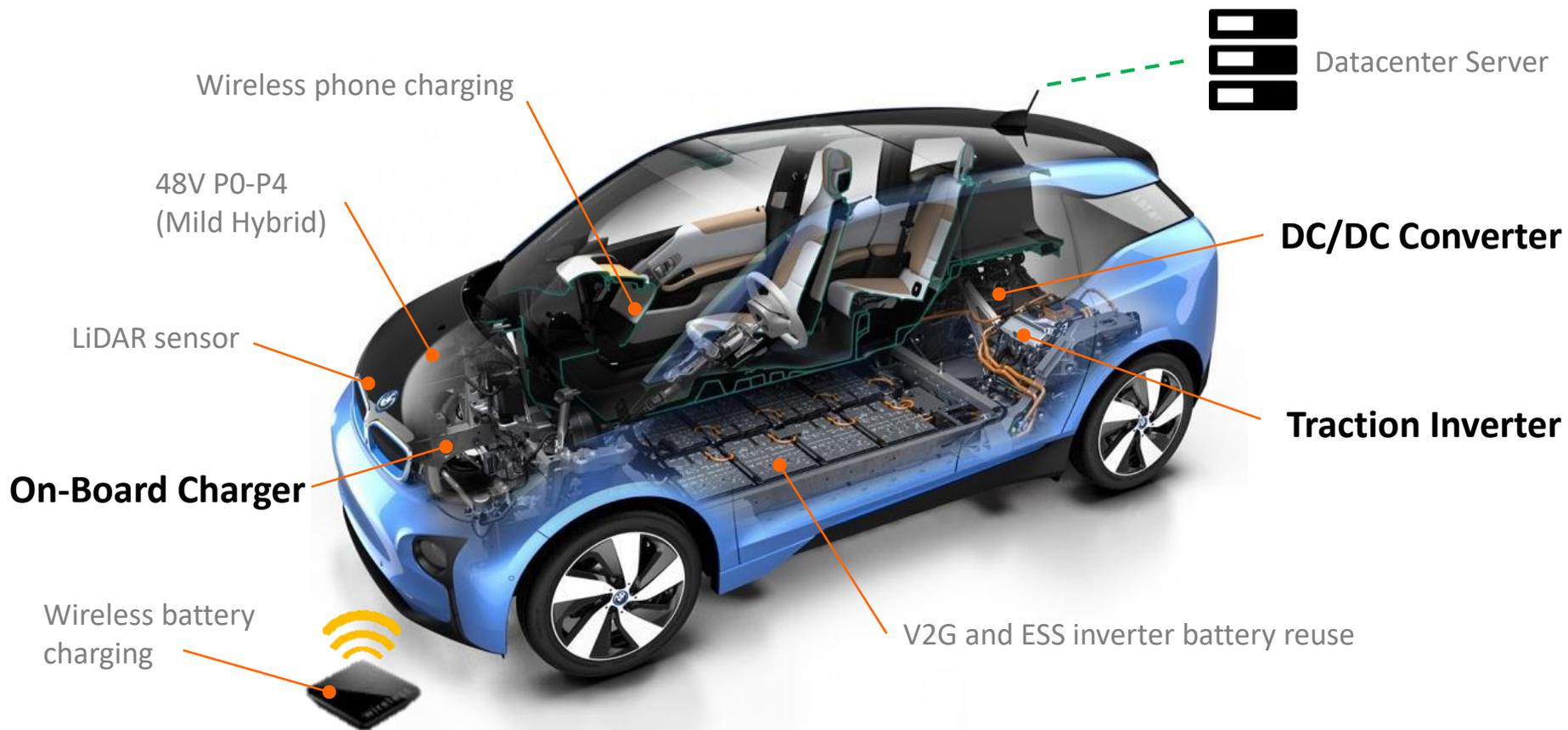
On-Board Charger	2020	2025	Change
Cost, \$/kW	50	35	30% cost reduction
Specific power, kW/kg	3	4	33% weight reduction
Power density, kW/L	3.5	4.6	24% volume reduction
Efficiency	97%	98%	33% loss reduction

DC/DC Converter	2020	2025	Change
Cost, \$/kW	<50	30	40% cost reduction
Specific power, kW/kg	>1.2	4	70% weight reduction
Power density, kW/L	>3.0	4.6	50% volume reduction
Efficiency	>94%	98%	60% loss reduction

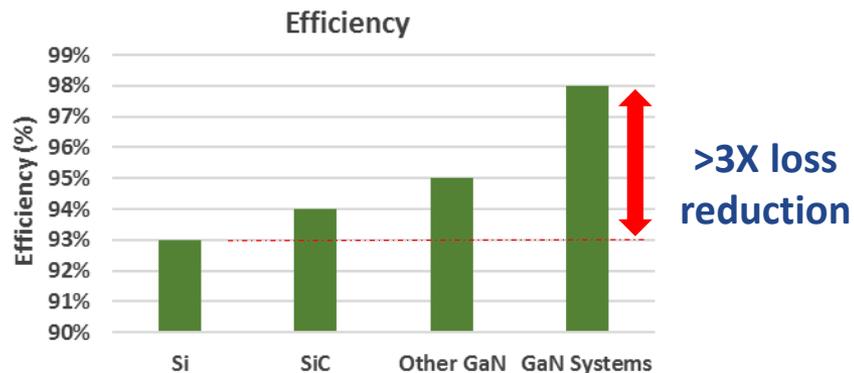
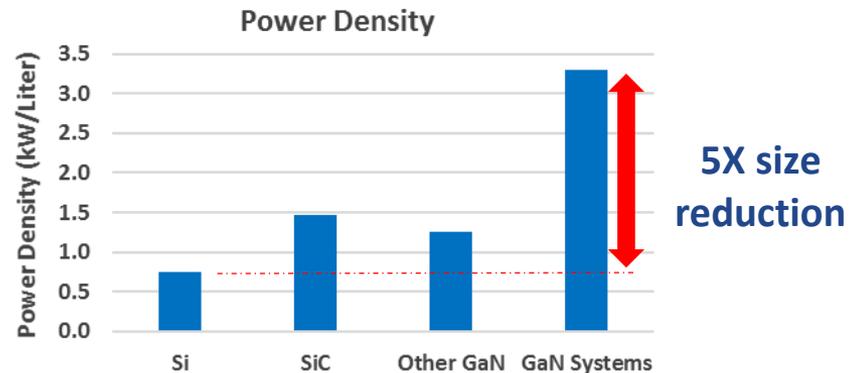
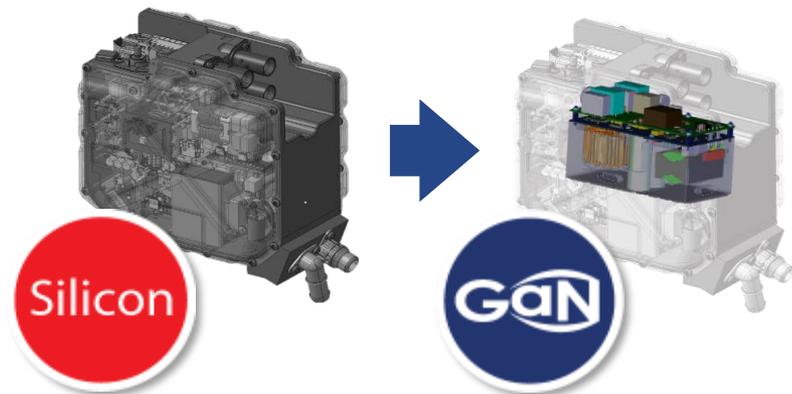
Traction Inverter	2020	2025	Change
Cost, \$/kW	8	6	25% cost reduction
Power density, kW/L	4.0	33	88% volume reduction



- Industry association for EV
- Analysis on each key electronic system of the price/performance needed:
  - For Consumers
  - For Automobile makers
  - Expressed as targets for the Tier 1's



## On-Board Charger (OBC)



## DC/DC Converter

Silicon



1 kW/L

93% Efficient  
Water-cooled

GaN



2 kW/L

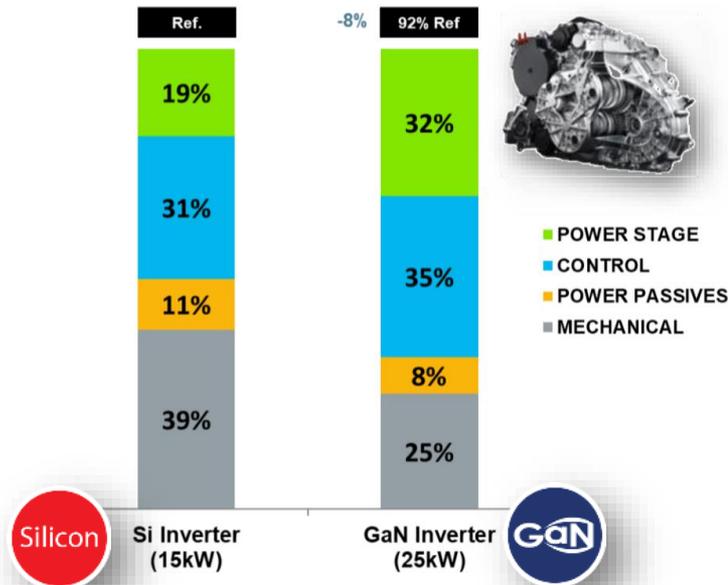
98% Efficient  
Air-cooled  
Lower Cost

100% better Power Density

## Inverter

### INVERTER BOM COST BY TECHNOLOGY

(2021-2022)

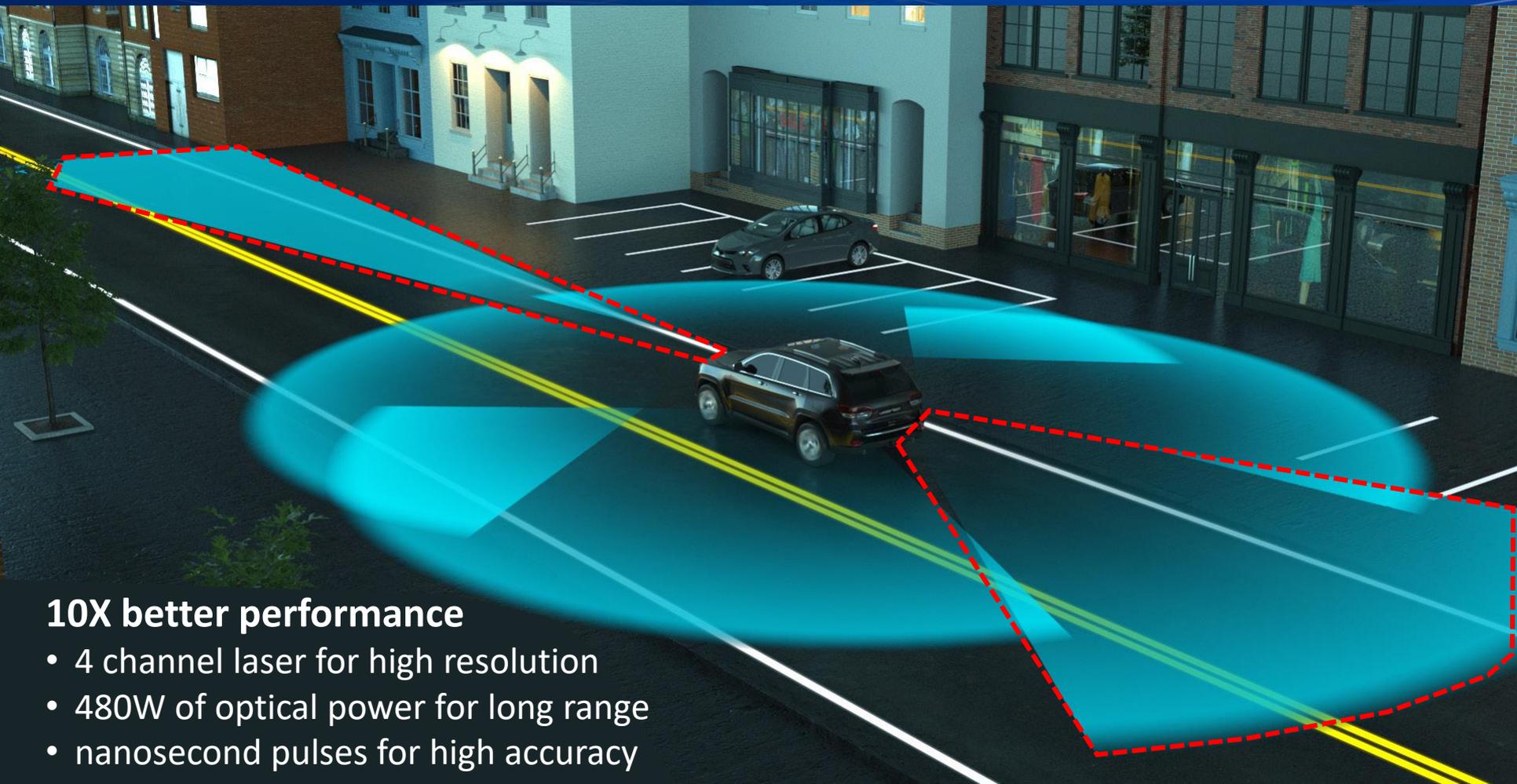


Silicon

GaN

8% Cost Reduction

# GaN enables long range, high resolution LIDAR



## 10X better performance

- 4 channel laser for high resolution
- 480W of optical power for long range
- nanosecond pulses for high accuracy

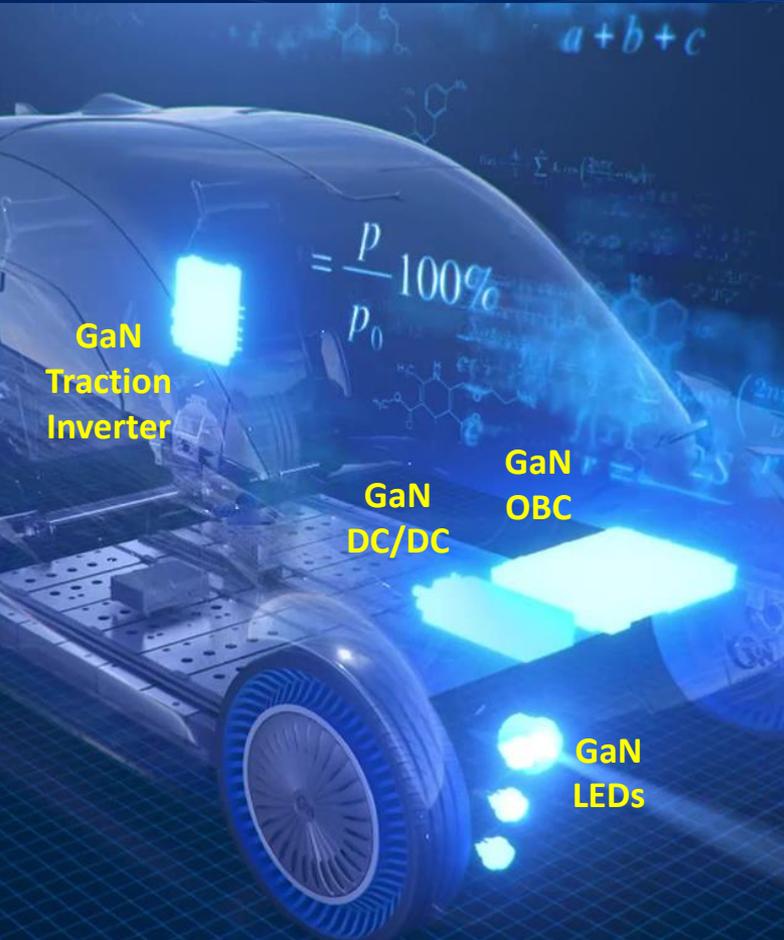
# In-cabin Wireless Charging with GaN

## Advantages with high frequency wireless charging

- Multiple phones
- High power, fast charging
- Randomly positioned, stacked
- Foreign objects don't interfere



# All GaN Vehicle at the Tokyo Motor Show



## Broadest line of Products

650 V GaN

 <b>GS66502B</b> 7.5 A, 200 mΩ 6.6 x 5.0 mm	 <b>GS66504B</b> 15 A, 100 mΩ 6.6 x 5.0 mm	 <b>GS66506T</b> 22 A, 67 mΩ 5.6 x 4.5 mm	 <b>GS66508T</b> 30 A, 50 mΩ 7.0 x 4.5 mm
 <b>GS66508B</b> 30 A, 50 mΩ 8.4 x 7.0 mm	 <b>GS66516T</b> 60 A, 25 mΩ 9.0 x 7.6 mm	 <b>GS66516B</b> 60 A, 25 mΩ 11.0 x 9.0 mm	
 <b>GS-065-080-1-D2</b> 80 A, 18 mΩ 6.6 x 5.6 mm	 <b>GS-065-150-1-D2</b> 150 A, 10 mΩ 12.7 x 5.6 mm		
 <b>GS-065-004-1-L</b> 3.5 A, 500 mΩ 5.0 x 6.0 mm	 <b>GS-065-008-1-L</b> 8 A, 225 mΩ 5.0 x 6.0 mm	 <b>GS-065-011-1-L</b> 11 A, 150 mΩ 5.0 x 6.0 mm	

100 V GaN

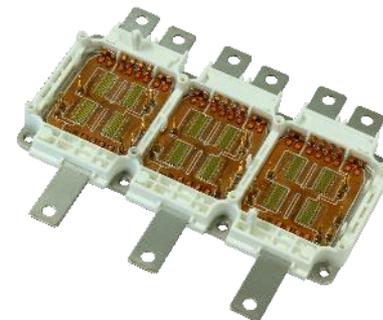
 <b>GS61004B</b> 45 A, 15 mΩ 4.6 x 4.4 mm	 <b>GS61008P</b> 90 A, 7 mΩ 7.6 x 4.6 mm	 <b>GS61008T</b> 90 A, 7 mΩ 7.0 x 4.0 mm
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← Packaged devices used in  
**On-Board Charger  
DC/DC Converter**

**NEW**

← Die used in power module for  
**Traction Inverter**

← Packaged devices used in  
**48V Mild Hybrid Inverter**



75 kW Traction Inverter module with GaN Systems 150 A devices

# GaN Systems Today

## #1 in GaN

- Highest current; broadest voltages
- Best electrical performance
- Best die & best package
- Most widely used by customers

## Shipping since 2014

- Parts shipping to >2000 customers
- Worldwide distribution & direct sales

## Customer Successes

- AC Adapters
- Wireless Power and Charging
- Datacenter Server and Rack Power
- Solar Inverter and ESS
- Motor Drives
- Automotive OBC & Traction Inverter



### CONSUMER



### DATACENTER



### INDUSTRIAL



### TRANSPORTATION

