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Smart GaN / SiC Power Devices Developers

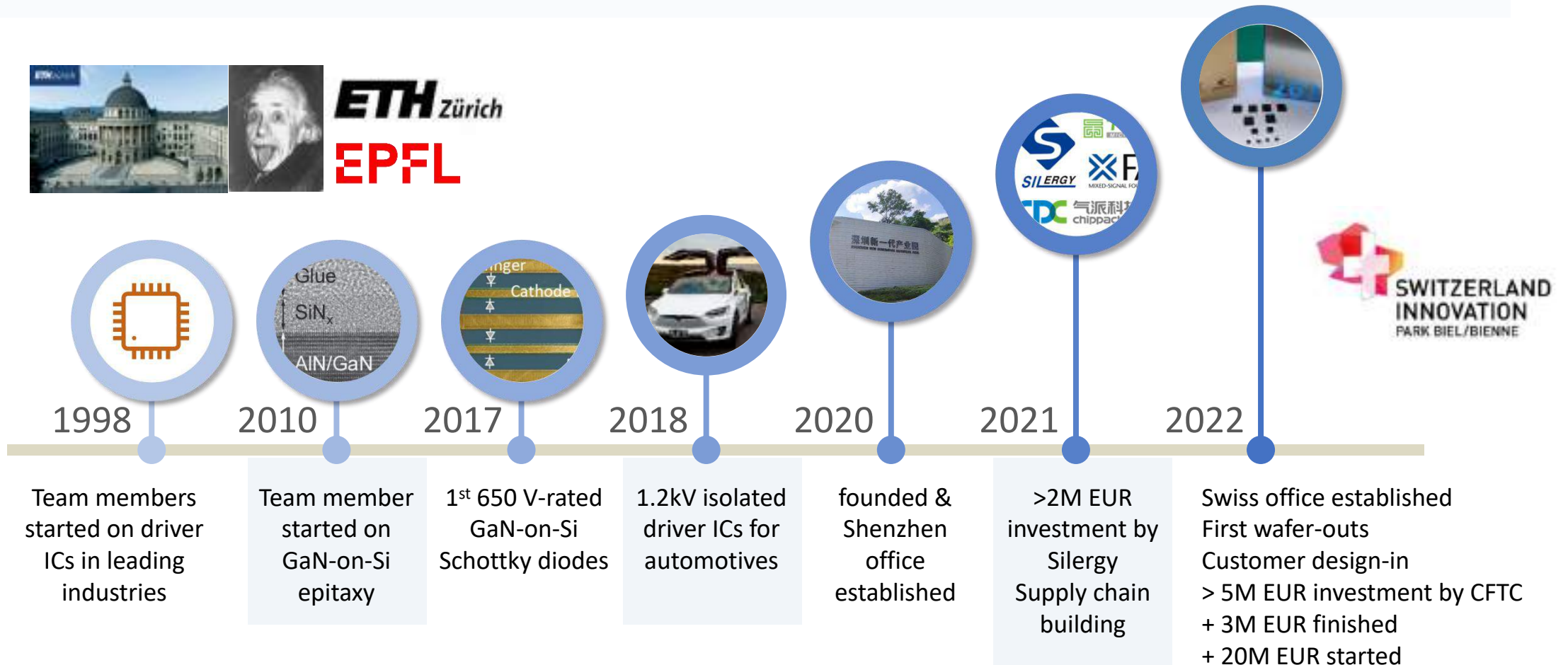


**Focus on Smart and Integrated GaN Power Solution**

# NovaWave's History



- Founded on Dec. 25<sup>th</sup>, 2020 by a team of experts from ETH and EPFL, Switzerland.
- Excellent industrial & academic backgrounds in power electronics.
- International vision with offices in Switzerland, China and APEC



# What do we do?

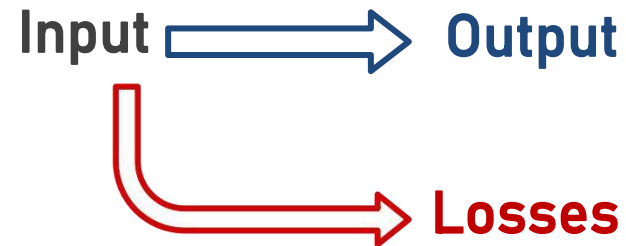
Power Transistor



Power Transistor



Power Transistor



~10-20% losses: > 2000 TWh  
(230 nuclear power plants)

The goal is to reduce losses and achieve more compact and cost-effective solutions

# GaN: A game changer in green energy and energy efficiency



Solar energy

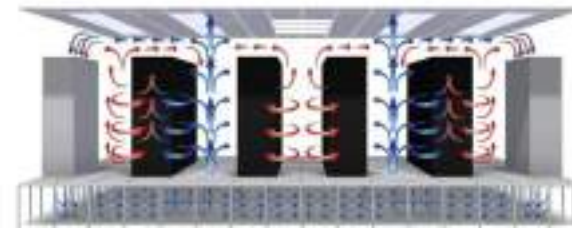


Electric vehicles

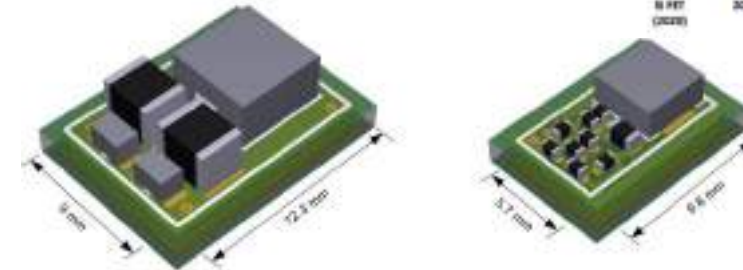
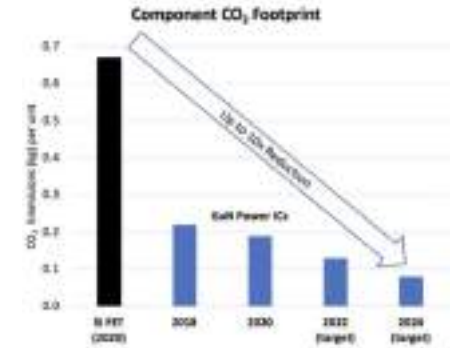


New mobility

Lower AC waste



Less impacting manufacturing



Less material required

**New technologies for energy production and sustainable mobility**

**Energy saving and more efficient manufacturing**

**GaN is a game changer in tackling CO2 emissions and enabling the green transition**

# Strong and growing team



Growing team of 9 people in Biel, Switzerland



6 Ph.D. from ETH, EPFL, Neuchatel University, Padova University

2 Masters from ETH and UNIGE



More than 300% team growth in 2022 with a total of 35 people



Strong expertise in several domains including design, reliability and qualification, marketing, and finance



**Driver IC Scientist**

- ETH, Ph.D in gate driver IC design
- Director of ASIC department in Power Integrations, Switzerland. Expert of isolated driver IC design and drivers for power devices
- Over 20 years experience in power devices driver IC design



**Senior GaN Engineer**

- EPFL, Ph.D. in Electrical Engineer
- Grand Prix de Stage de Recherche, Ecole Polytechnique, Paris, 2016
- Expert of Modeling of GaAs\GaMnAs
- Published over 15 scientific papers



**Driver IC Scientist**

- 20 years of experience in power management and power driver chip design.
- Technical director in ST Microelectronics, Infineon, Freescale, etc.
- Excellent experience in EMC and automotive safety design.



**GaN Power Device Expert**

- World-class GaN power devices and process expert.
- Recipient of the "The Charitat Award" at IEEE ISPSD twice in a row and of the Swiss Nanotechnology Doctoral Award
- Over 30 papers in top GaN conferences and journals



## Smart-GaN<sup>®</sup> SiP

Integrated driver and GaN packaging,  
multiple protections  
**650V, 50 - 260mΩ Rdson**



## Smart-Driver<sup>®</sup> IC

GaN / SiC / MOSFET / IGBT Driver IC  
**High-speed Driver IC**



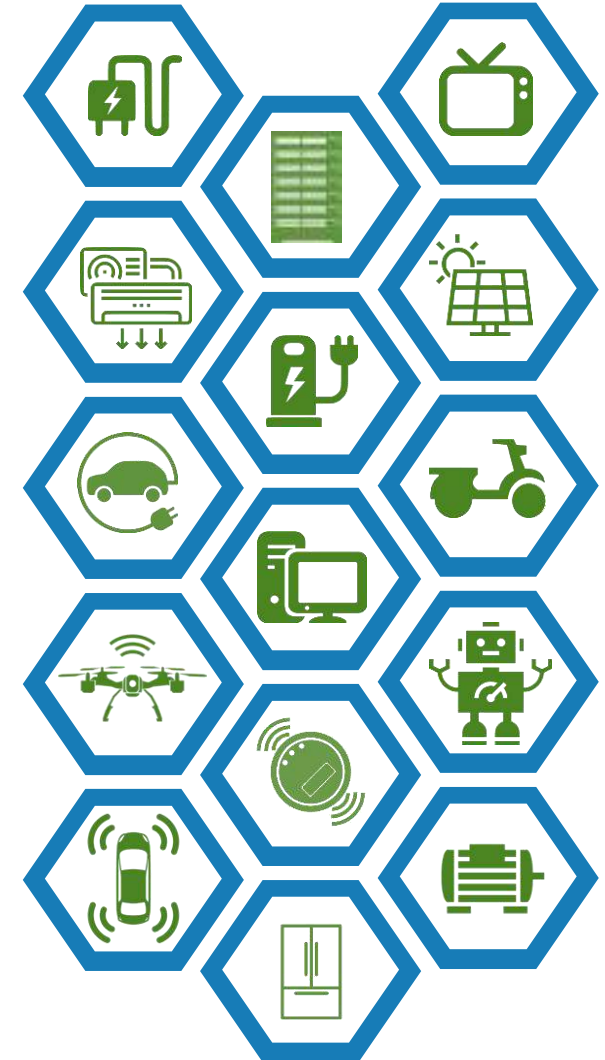
## Flash-SBD<sup>®</sup> IC

world's first GaN-on-Si SBD  
**1A - 15A**



## GaN bare die

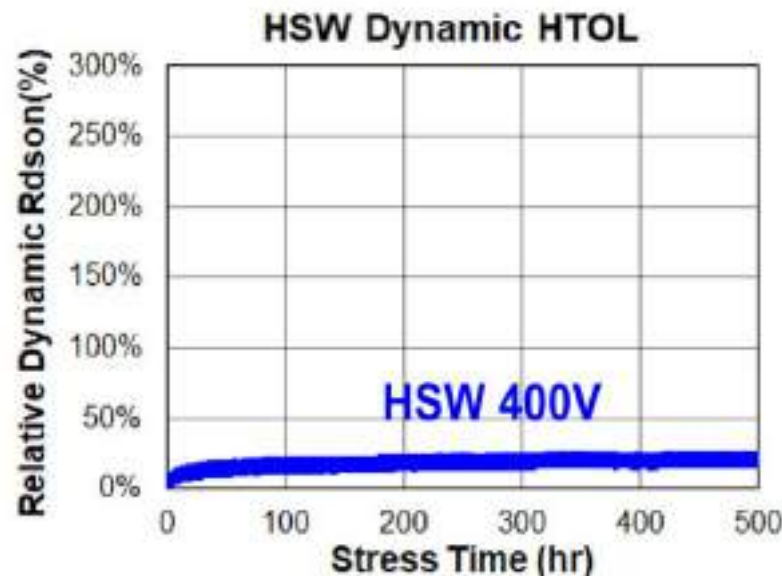
E-mode, D-mode, GaN HEMTs bare die  
**650V, 50 - 500mΩ Rdson**



# NovaWave GaN Devices: High Reliability



Tests	Stress conditions	Duration	Results	Pass or fail
HTRB	Vd = 520 V, 150 °C	1000 hrs	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass
HTGB	Vg = 6 V, 150 °C	1000 hrs	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass
TC	-65 to 150 °C	1000 cycles	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass
HTS	150 °C	1000 hrs	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass
PCT	121 °C, 100% RH, atm	96 hrs	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass
THB	100% RH, 85 °C, Vd = 100 V	1000 hrs	0 fail/77ea (per lot), 0 fail/231ea (3 lots)	Pass



500 hour dynamic HTOL test

- 400V hard switch
- Tj = 125 °C
- Vgs = 6 V, Ids = 2 A, f = 100 kHz



## Function

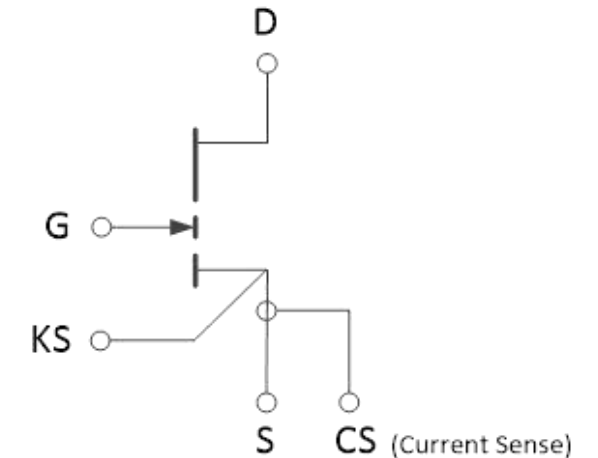
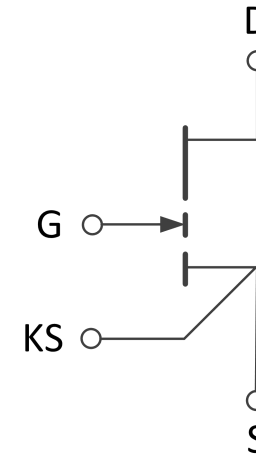
- 650V E-mode normally-off Smart-GaN® SiP
  - R<sub>dson</sub> 70/120/160mΩ (Existing samples)
  - Support customization R<sub>dson</sub> Design
- Dynamic R<sub>dson</sub> full voltage range ≤25%
- High precision non-destructive current detection output
- Complete reliability test and dynamic HTOL test
- Special substrate design with stronger heat dissipation
- Ultra low gate capacitance
- Zero reverse recovery charge
- Supports Wafer Sale, suitable for controller sealing

## Application

- Controller sealing scheme
- Power switch module
- PD fast charging, power adapter
- Portable energy storage
- Communication, server power supply

## Advantages

- Low dynamic resistance
- high reliability
- Superior heat dissipation performance compared to similar products
- Support customized design for customers



## Application difficulty # 1

- External LDO chip is required to adjust the driving voltage
  - Increase BOM cost and PCB area
- NovaWave Smart-GaN®
- Integrated LDO

## Application difficulty # 2

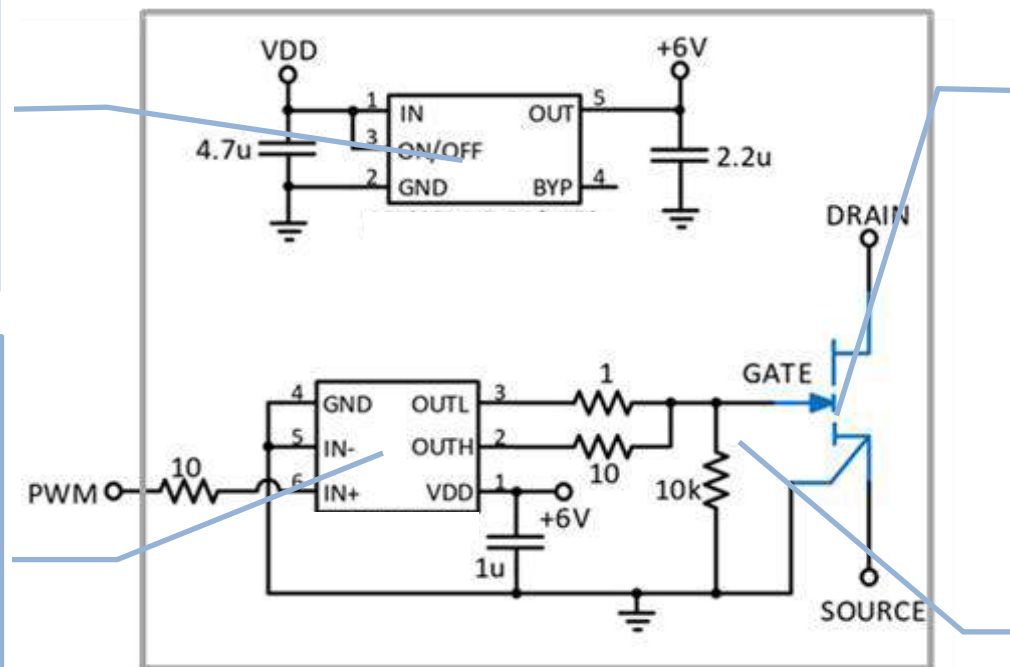
External drive IC and drive resistor increase BOM cost and PCB area

- Parasitic inductance in the drive circuit causes gate overvoltage and damages GaN devices
- No negative pressure shutdown, quick switching can easily cause misdirection and damage to GaN devices

## NovaWave Smart-GaN®

- Integrated Driver IC
- Very low gate drive parasitic inductance
- Integrated negative pressure shut-off function

## 传统Driver + GaN 分立方案



## Application difficulty # 3

- The Problem of High Dynamic Resistance in GaN Devices
- Reliability issues of GaN devices

## NovaWave Smart-GaN®

- Industry leading low dynamic resistance GaN device design
- Superior heat dissipation performance compared to similar products
- Complete reliability verification

## Application difficulty # 4

No short circuit protection, unable to quickly turn off when a short circuit occurs

- No overtemperature protection, unable to quickly shut off when overtemperature occurs
- EMI issues

## NovaWave Smart-GaN®

- Integrated GaN current detection
- Fast overcurrent and short circuit protection
- Integrated over temperature protection
- Integrated fault indication function
- dv/dt adjustable, optimized EMI



## NovaWave Smart-GaN®

- High reliability GaN devices
- Drive Integration
- Multiple protection

# NovaWave: Characteristics & advantages of GaN driver IC



Driver IC characteristics	NovaWave	competitor 1 (NV)	competitor 2 (Inno/GS Discrete drive+GaN)	NovaWave Advantage
driver mode	current mode	voltage source	voltage source	Current driven: Supports higher switching speeds. No gate oscillation problem.
dv/dt Adjustment	drive current	Drive resistor	Drive resistor	Drive current regulation: No delay conduction problem, supports higher switching speed and lower switching loss. Supports wide range dv/dt adjustment.
Negative pressure shutdown	YES	no negative pressure	no negative pressure	Negative pressure shutdown: Supports fast shutdown of high current GaN devices in industrial applications. Reduce switch losses without any risk of misleading communication. Two stage negative pressure drive further reduces the conduction loss during current reversal.
Programmable driving voltage	YES	NO	NO	Adapt to different specifications of GaN devices
Programmable driving current	YES	NO	NO	Adapt to different specifications of GaN devices without the need for driving resistors.
Non destructive current testing	YES	YES	NO	No need for external current detection circuit, reducing power consumption and BOM cost
Over current/short circuit Protection	Over current/short circuit two-stage protection	Over current protection	NO	Quickly turn off components in short circuit state to ensure system safety
Over Temperature Protection	YES	YES	NO	Quickly turn off components during overtemperature to ensure system safety
Fault signal indication	YES	NO	NO	Provide fault indication signals, simplify system design, and ensure system safety
Built in wide voltage input LDO (24V)	YES	YES	NO	No need for external LDO, reducing BOM cost and PCB area
low power mode	YES	YES	NO	Meet the requirements of light load power consumption such as fast charging and PC power supply
PWM direct power supply	YES	NO	NO	Supports PWM direct power supply without external power supply, and supports industrial grade packaging form

## Function

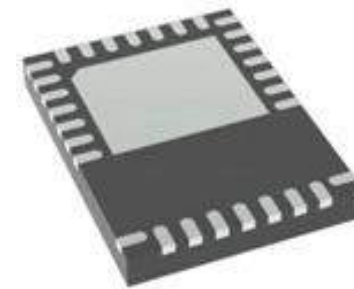
- 650V intelligent GaN power switch
  - 120 mΩ /160mΩ conduction resistance, industry leading low dynamic resistance
  - Suitable for 45W – 240W power supply design
- Built-in intelligent GaN driver IC
  - 3.3V/5V PWM signal direct drive
  - High reliability gate drive design
  - Current signal output
  - Overcurrent and short circuit protection
  - Over temperature protection
  - Error signal indication
  - Dv/dt regulation, EMI optimization
  - Ultra low gate capacitance, zero reverse recovery charge
  - Supports 1MHz high switching frequency
  - QFN packaging: low parasitic inductance, high heat dissipation performance

## Application

- PD fast charging, power adapter
- PC, TV power supply
- Communication power supply
- Photovoltaic inverter
- Portable energy storage
- Universal switching power supply

## Advantages

- Cost advantage
  - No need for external LDO
  - No need for external drive IC
  - Saving 7-10 peripheral components
  - Save over 50% of area
- High reliability
  - Minimal parasitic inductance, no risk of explosion
  - Higher switching speed, reduced power consumption and temperature rise
  - Built in multiple protections for high reliability
  - Low parasitic inductance, high heat dissipation performance TOLL packaging



## Function

- 650V Smart GaN power SiP
  - 70 m Ω conduction resistance, industry leading low dynamic resistance
  - 20 A continuous conduction current
  - Suitable for 300W-2000W power design
- Built-in Smart-GaN Driver IC
  - 3.3V/5V PWM signal direct drive
  - High reliability gate drive design
  - Current signal output
  - Overcurrent and short circuit protection
  - Over temperature protection
  - Error signal indication
  - Dv/dt regulation, EMI optimization
- Ultra low gate capacitance, zero reverse recovery charge
  - Supports 1MHz high switching frequency
- Toll packaging: low parasitic inductance, high heat

## Application

- PC, TV power supply
- Communication, server power supply
- Photovoltaic inverter
- Portable energy storage
- Universal switching power supply
- OBC, DCDC

## Advantages

- Cost advantage
  - No need for external LDO
  - No need for external drive IC
  - Saving 7-10 peripheral components
  - Save over 50% of area
- High reliability
  - Minimal parasitic inductance, no risk of explosion
  - Higher switching speed, reduced power consumption and temperature rise
  - Built in multiple protections for high reliability
  - Low parasitic inductance, high heat dissipation performance TOLL packaging



## Function

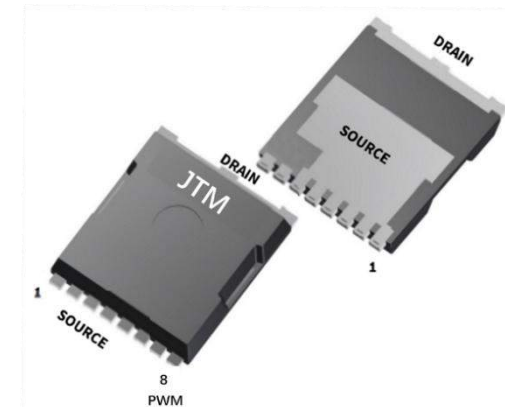
- 650V Smart-GaN Power SiP
  - 70mΩ / 120mΩ conduction resistance
  - Dynamic resistance full voltage range  $\leq 25\%$
  - Suitable for 300W-2000W power supply design
- Built-in driver IC
  - 3.3V/5V PWM signal direct drive
  - High reliability gate drive design
  - EMI optimization design
- Ultra low gate capacitance, zero reverse recovery charge
  - Supports 1MHz high switching frequency
- TOLL packaging
  - Low parasitic inductance
  - Excellent heat dissipation capability

## Application

- PC, TV power supply
- Communication, server power supply
- Photovoltaic inverter, portable energy storage
- Universal switching power supply
- OBC, DCDC

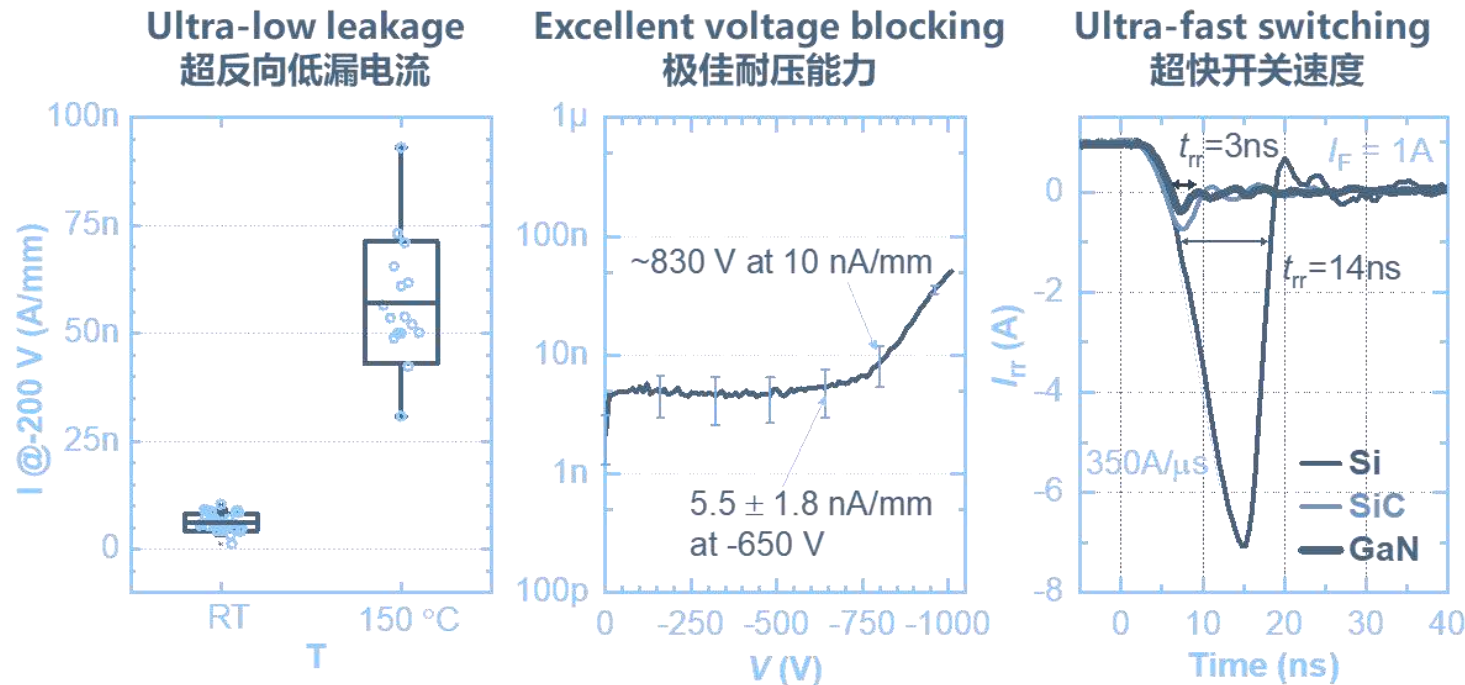
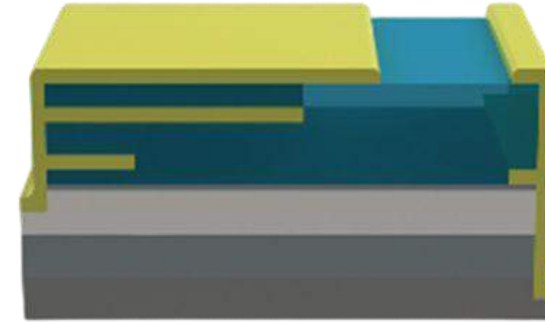
## Advantages

- Cost Advantage
  - No need for external LDO
  - No need for external drive IC
  - Saving 7-10 peripheral components
  - Save over 50% of area
- High Reliability
  - Minimal parasitic inductance, no risk of explosion
  - Higher switching speed, reduced power consumption and temperature rise
  - Built in multiple protections for high reliability
  - Low parasitic inductance, high heat dissipation performance TOLL packaging



## World's First 650V GaN-on-Si SBD

- A groundbreaking new structure
- Solved the commercialization bottleneck of reverse leakage in GaN-on-Si SBD

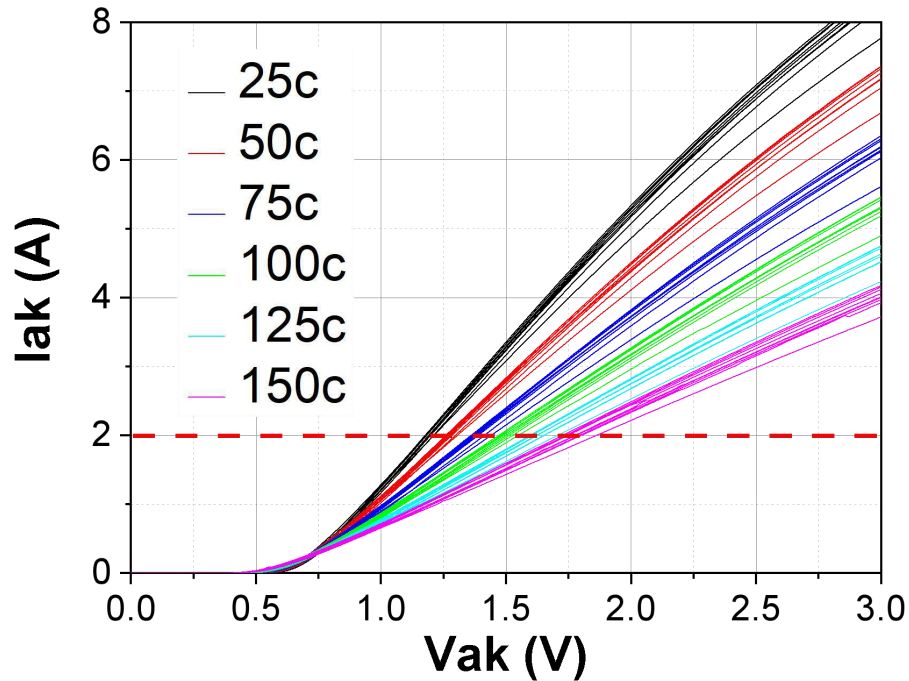


# NovaWave GaN-on-Si SBD Test Result

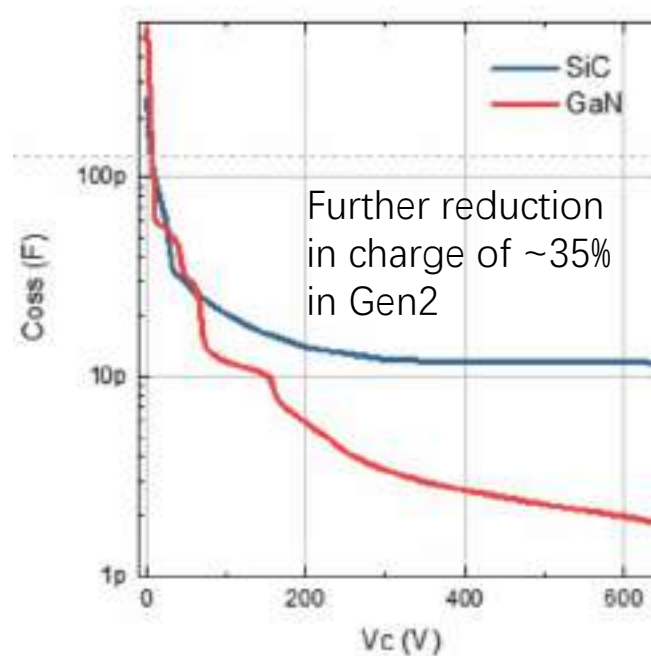


	Spec	Technology	Vf@RT	Vf@150C	Ir@RT	Ir@150C	Cr@600V
NovaWave S series	650 V / 2 A	GaN-on-Si	1.20 V	1.75 V	1.0 uA	10 uA	2 pF
W*	650 V / 2 A	SiC	1.50 V	1.80 V	3.5 uA	7.5 uA	8.5 pF

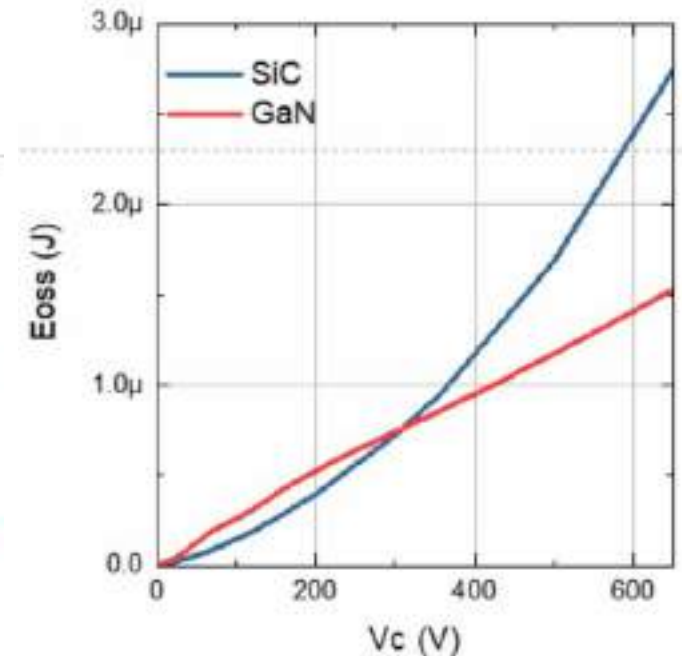
Small Vf:  
1.20 V @ RT & 1.75 V @ 150 C



Small Capacitance  
Compared to CoolSiC



Small switching loss  
Compared to CoolSiC





## Features

- Industry's first 650V GaN SBD
- Supports switching frequencies > 1MHz
- Zero reverse recovery charge
- Extremely low off state leakage current
- Switch loss lower than SiC SBD
- Multiple packaging forms: TO220, DFN8x8

## Applications

- ac adapter
- TV, Home Appliances
- Communication, server power supply
- Photovoltaic inverter
- Household energy storage

## Parameters (4A SBD)

Parameters	Value	Unit
VDC	650	V
I <sub>f</sub>	4	A
V <sub>f</sub> @ 4 A	1.25	V
I <sub>leak</sub> @650V	1	uA



# NovaWave Product Catalog



	Part Number	Family	V <sub>DS</sub> (V)	R <sub>DS,ON</sub> (typ.) (mΩ)	Package	Sample
<b>Smart-GaN® SiP</b>	JT6507P	Smart-GaN®	650	70	TOLL	3Q23
	JT6512P	Smart-GaN®	650	120	TOLL, QFN6x8	3Q23
	JT6516P	Smart-GaN®	650	160	QFN6x8	3Q23
<b>GaN Bare die</b>	JT6507W	GaN bare die	650	70	Wafer	4Q23
	JT6512W	GaN bare die	650	120	Wafer	4Q23
	JT6516W	GaN bare die	650	160	Wafer	4Q23

	Part Number	Family	V <sub>DS</sub> (V)	IF (A)	Package	Sample
<b>GaN SBD</b>	JT6502R	GaN SBD	650	2	QFN	4Q23
	JT6504R	GaN SBD	650	4	TO220	4Q23
	JT6508R	GaN SBD	650	8	TO220	4Q23

	Part Number	Family	Channel	UVLO (V)	V <sub>DD</sub> (max) (V)	Source Current (A)	Sink Current (A)	Package	Sample
<b>Driver IC</b>	JT0505M0S-T1	Smart-Driver®	1	4.5	28	5	7	SOT23-6	Now
	JT0505M0S-T2	Smart-Driver®	1	4.5	28	5	7	SOT23-5	Now
	JT0505M0D-C1	Smart-Driver®	2	4.5	28	5	7	SOP8	Now
	JT0505G0D-C1	Smart-Driver®	2	10	28	5	7	SOP8	Now

01

## Electric Vehicle



- ▶ OBC&DC/DC
- ▶ In car charging
- ▶ Wireless charging
- ▶ inverter
- ▶ Charging station

02

## Consumer Electronics



- ▶ 65W – 240W PD fast charging adapter
- ▶ Portable energy storage
- ▶ PC, Notebook
- ▶ Household appliances

03

## Industrial Power Supply



- ▶ Data Center
- ▶ Base station power supply
- ▶ Industrial power supply
- ▶ Medical power supply

04

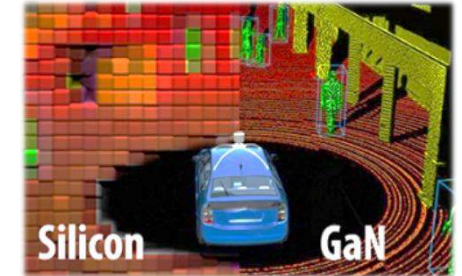
## Green energy



- ▶ Photovoltaic inverter
- ▶ Household energy storage

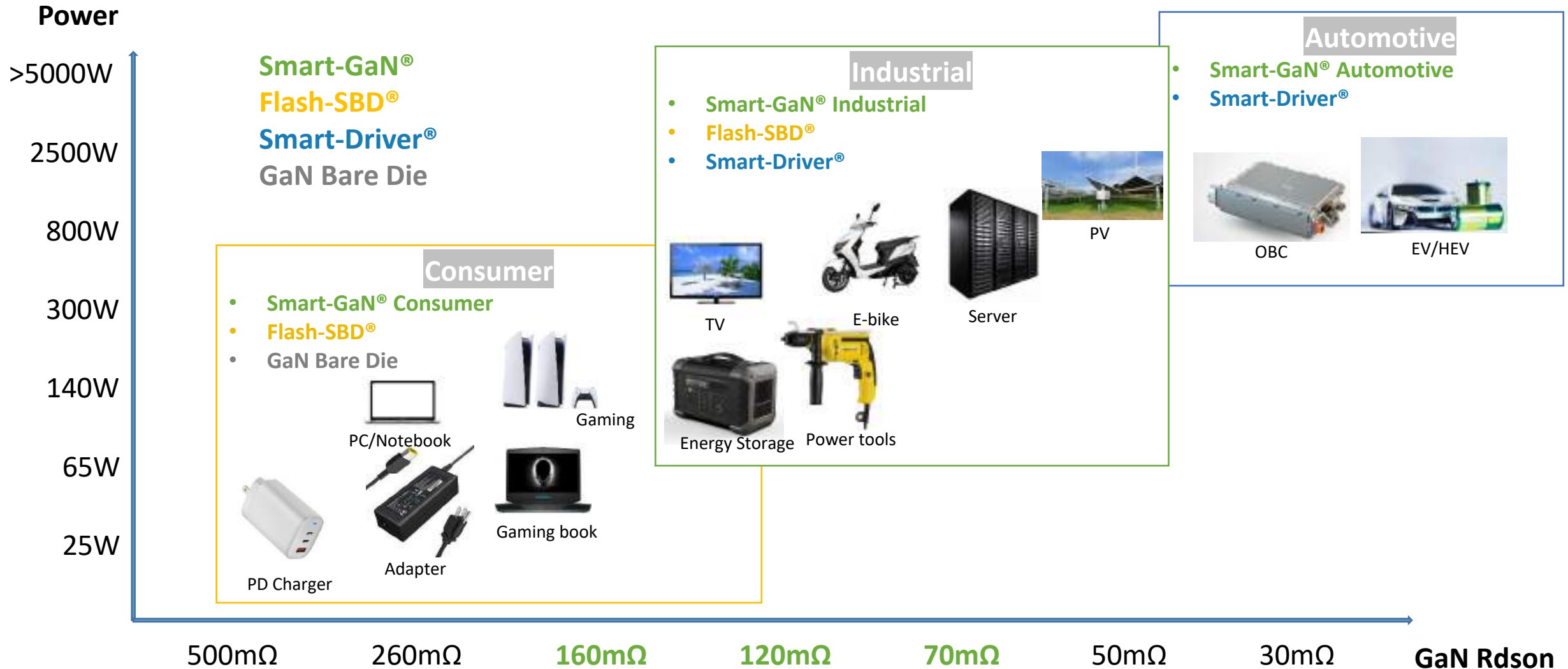
05

## Lidar

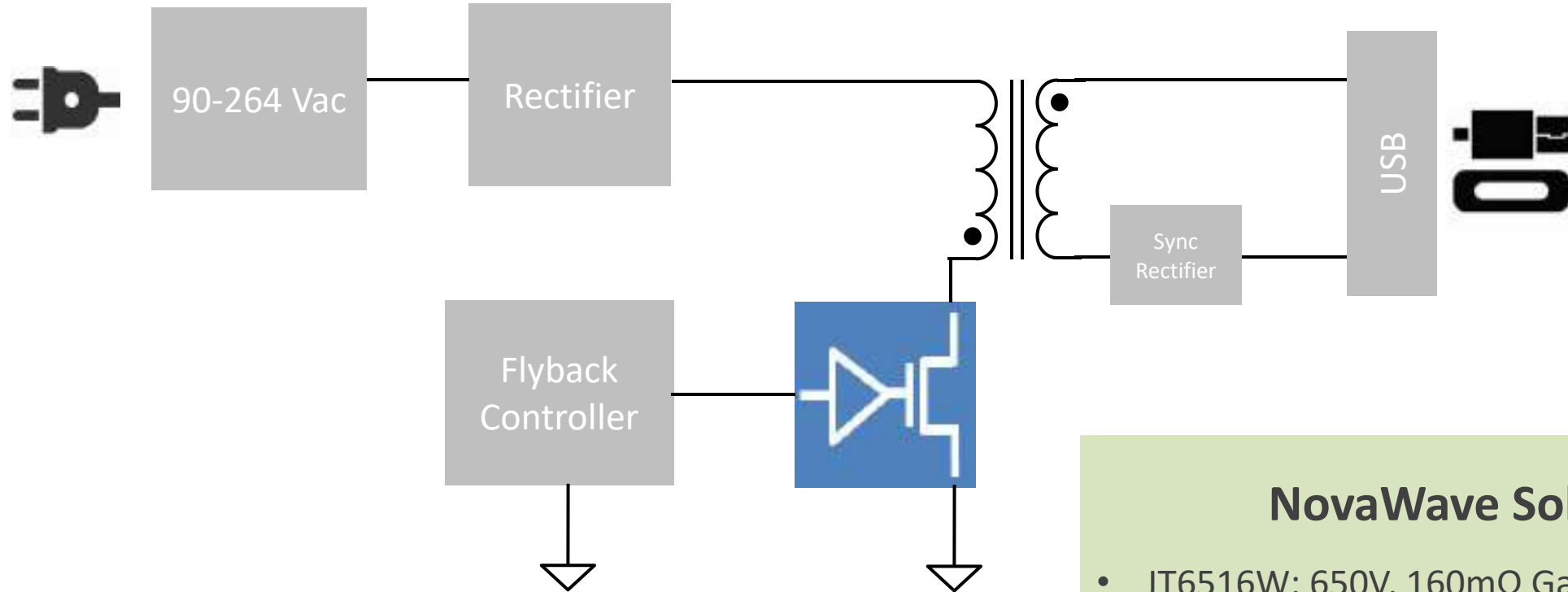


- ▶ Smart cars
- ▶ AGV
- ▶ industrial robot
- ▶ Household robots

# Application scenarios of NovaWave product

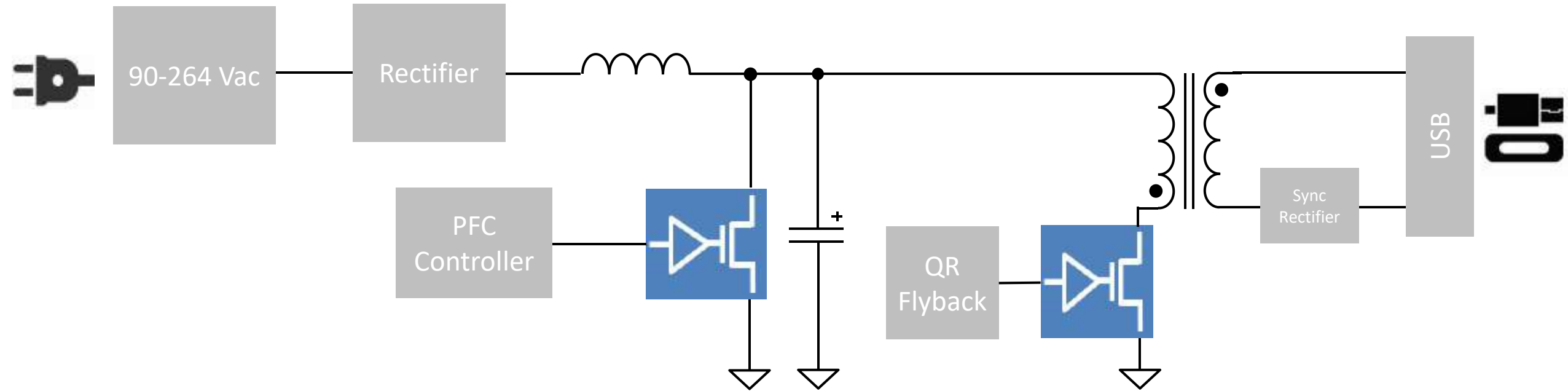


# PD Fast charging (30W – 65W) – QR Flyback



**NovaWave Solutions**

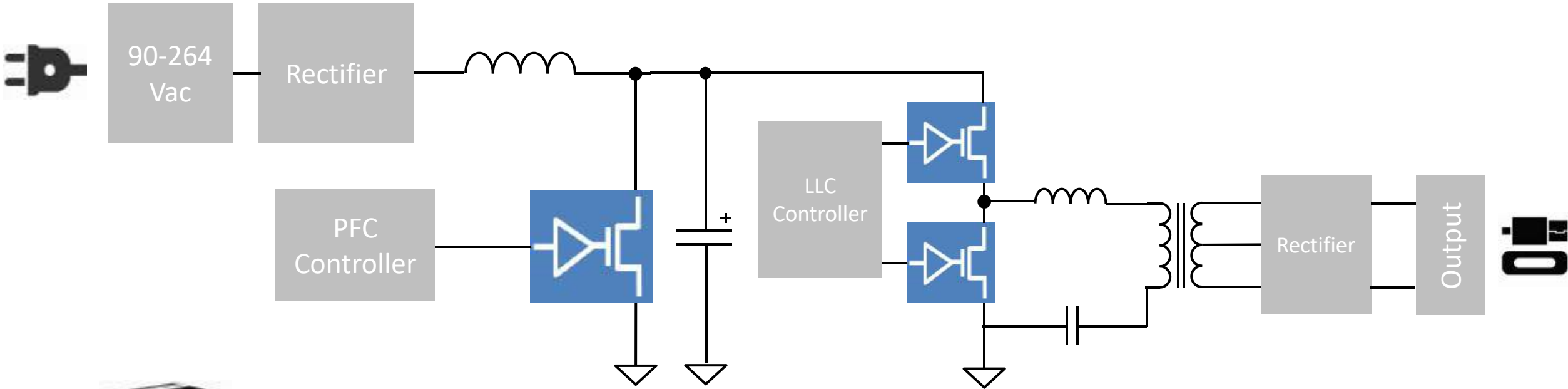
- JT6516W: 650V, 160mΩ GaN HEMT bare die
- JT6516P: 650V, 160mΩ Smart-GaN<sup>®</sup> SiP



## NovaWave Solutions

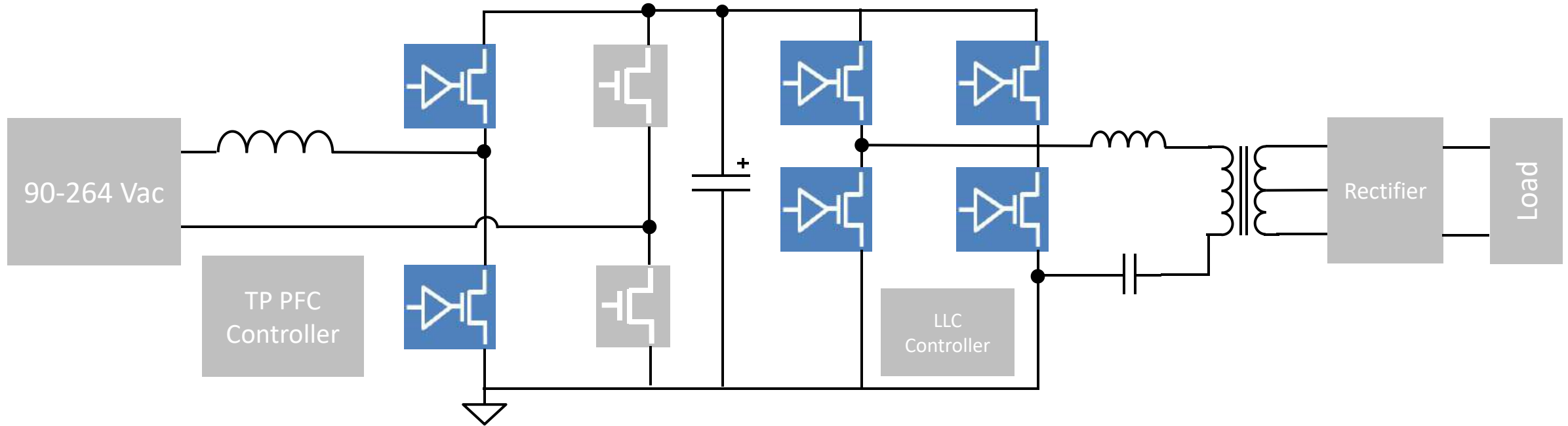
- JT6512W: 650V, 120mΩ GaN HEMT bare die
- JT6516W: 650V, 160mΩ GaN HEMT bare die
- JT6512P: 650V, 120mΩ Smart-GaN® SiP
- JT6516P: 650V, 160mΩ Smart-GaN® SiP

# PC Power supply adapter (140-500W) – PFC+LLC



**NovaWave Solutions**

- JT6512P: 650V, 120mΩ Smart-GaN<sup>®</sup> SiP
- JT6507P: 650V, 70mΩ Smart-GaN<sup>®</sup> SiP

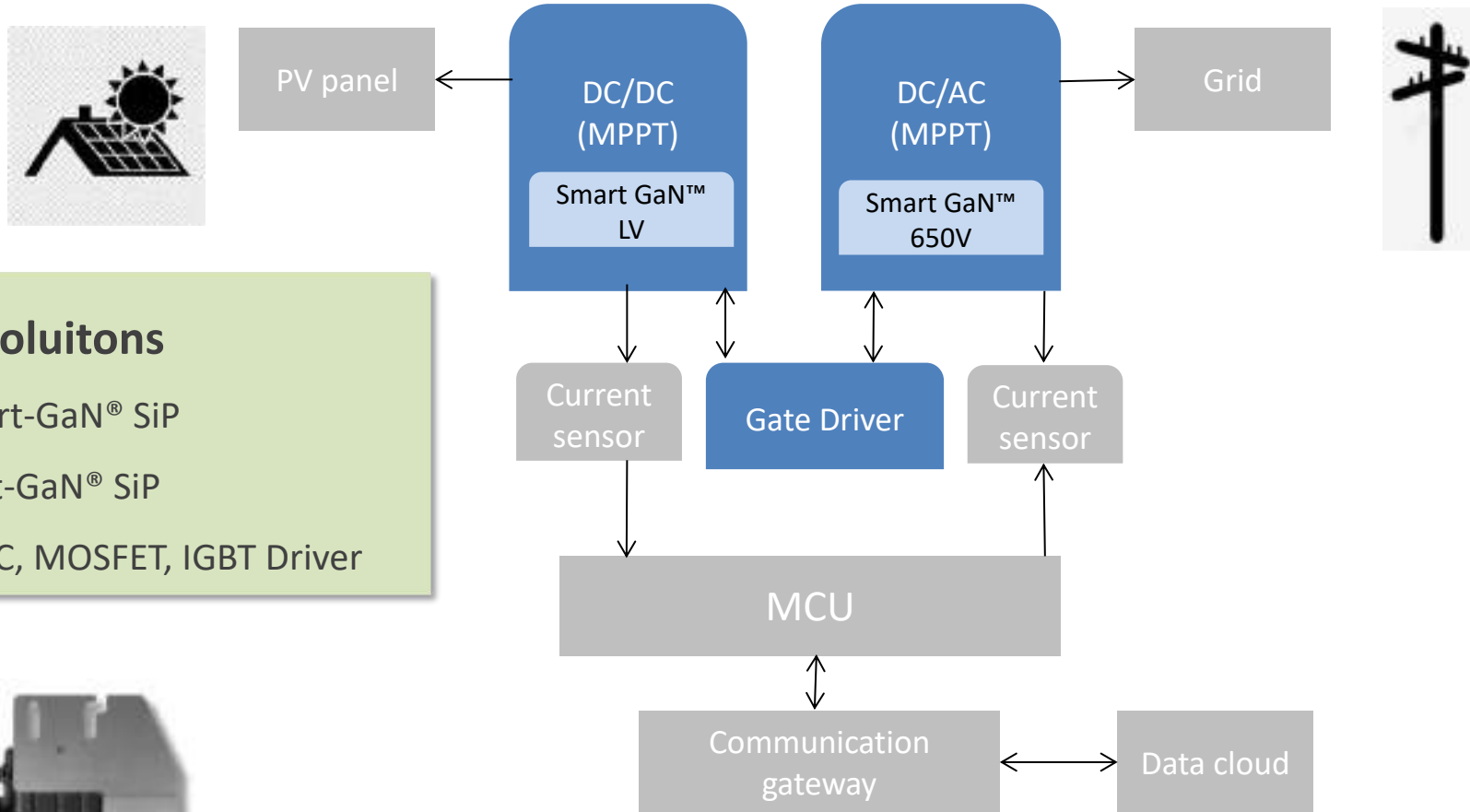


## NovaWave Solutions

- JT6512P: 650V, 120mΩ Smart-GaN<sup>®</sup> SiP
- JT6507P: 650V, 70mΩ Smart-GaN<sup>®</sup> SiP



# Micro inverter Microinverter

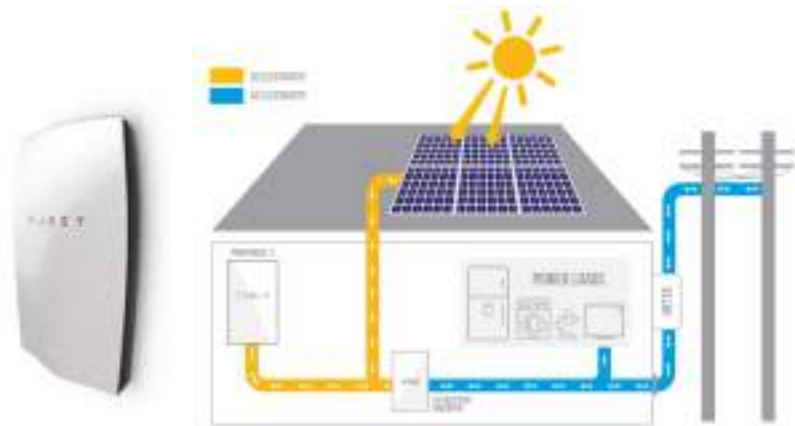
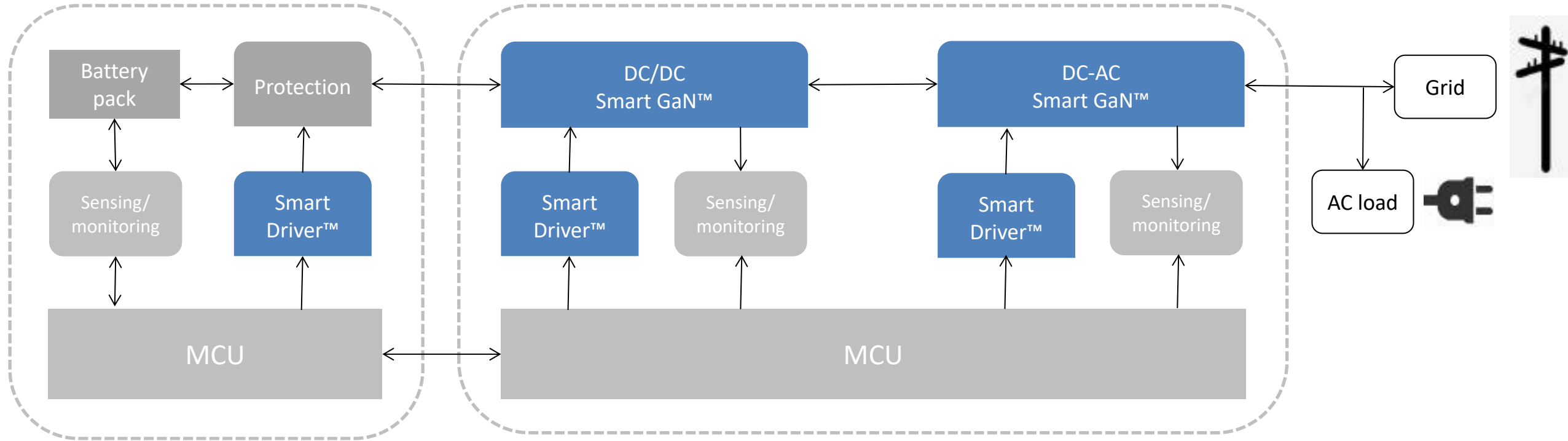


## NovaWave Solutions

- JT6512P: 650V, 120mΩ Smart-GaN® SiP
- JT6507P: 650V, 70mΩ Smart-GaN® SiP
- JT0505: High speed GaN, SiC, MOSFET, IGBT Driver



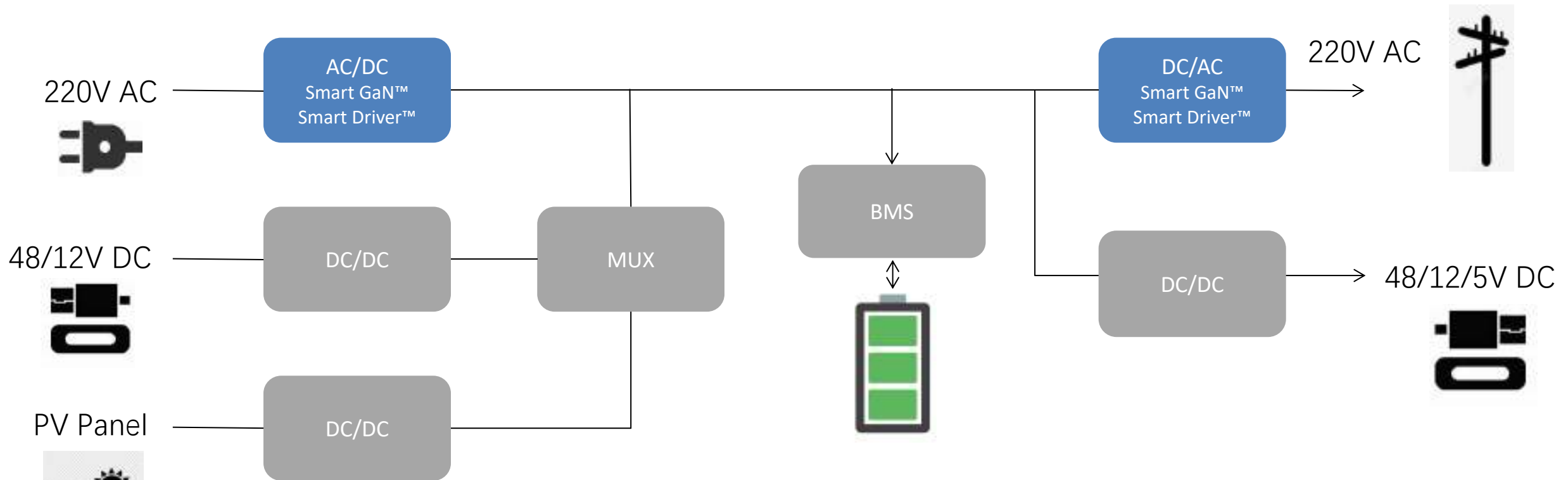
# Household energy storage



## NovaWave Solutions

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# Portable energy storage

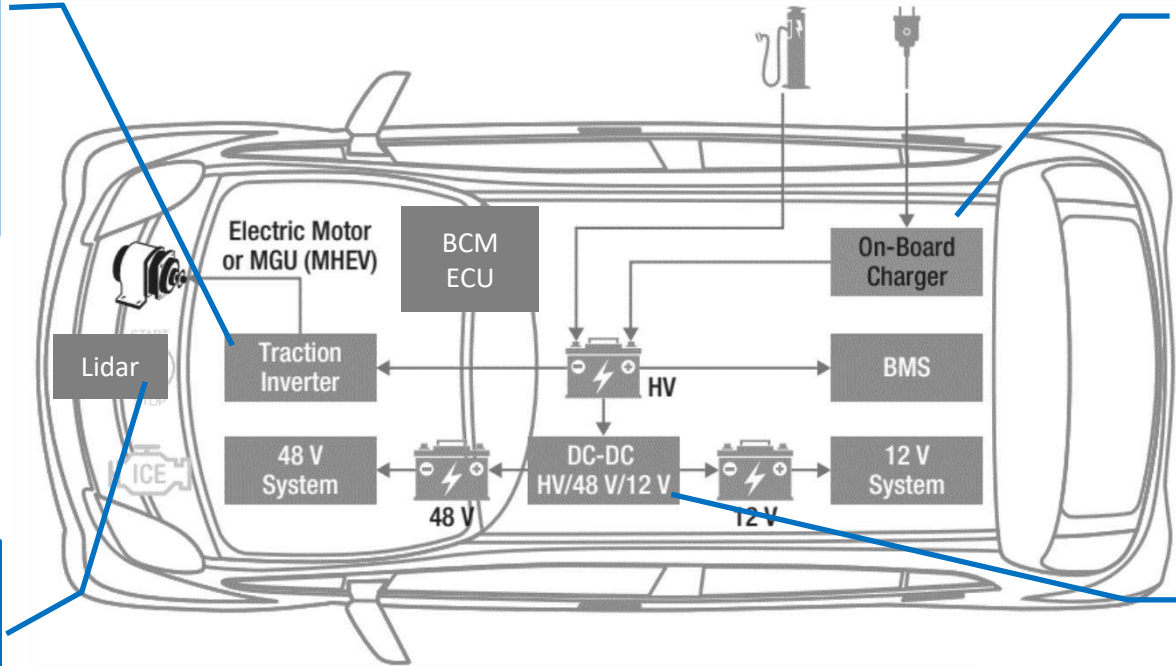


## NovaWave Solutions

- JT6512P: 650V, 120mΩ Smart-GaN® SiP
- JT6507P: 650V, 70mΩ Smart-GaN® SiP
- JT0505: High speed GaN, SiC, MOSFET, IGBT Driver

# Automotive Grade planning

- Isolated SiC, IGBT driver
- HV Smart-GaN<sup>®</sup> SiP



- Isolated SiC, IGBT driver
- HV Smart-GaN<sup>®</sup> SiP

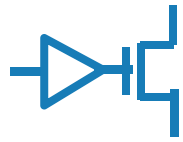
- LV Smart-GaN<sup>®</sup> SiP

- LV Smart-GaN<sup>®</sup> SiP

## NovaWave Solutions

- JT6512P: 650V, 120mΩ Smart-GaN<sup>®</sup> SiP
- JT6507P: 650V, 70mΩ Smart-GaN<sup>®</sup> SiP
- JT0505: High speed GaN, SiC, MOSFET, IGBT Driver

# Broad product portfolio



## 1. Smart GaN SiP

SiP with integrated driver and protections  
650V / 50 - 450 mΩ R<sub>dson</sub>



## 2. Si Driver ICs

Drivers for GaN HEMTs, IGBTs, Si and SiC MOSFETs  
Low-side single and dual channel / Half bridge  
junction isolation / Galvanic isolation



## 3. GaN-on-Si SBDs

The first 650 V GaN-on-Si SBDs  
650V / 1A - 10A SBD



## 4. GaN bare dies

E/D-mode GaN HEMTs for integration with controllers  
650V / 50 - 450mΩ R<sub>dson</sub>



# Why NovaWave?

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## Strong Experience

We combine strong expertise in GaN Power Devices, Driver ICs, and power modules, including for industrial and automotive applications (more than 20kk chips for automotive shipped)

## Broad Portfolio

Large product portfolio with both E-mode and D-mode for a wide range of applications and customers

## Novel Technologies

Unique GaN-on-Si SBDs technology as a promising low-cost replacement to SiC SBDs.

## Loyal Customers

Several key customers believed in us and have become our investors and more customers are joining our venture

# Our competitive advantage



## Competitors

## Advantages

Smart-GaN®  
Automotive-grade



- Low dynamic resistance
- QST substrate, 1200V device, higher reliability
- TOLL package, stronger heat dissipation
- Integrated drive and protection functions
- dv/dt adjustable, reduce EMI



Smart-GaN®  
Industrial-grade



- Low dynamic resistance
- QST substrate, 1200V device, higher reliability
- TOLL package, stronger heat dissipation
- Integrated drive and protection functions
- dv/dt adjustable, reduce EMI



Smart-GaN®  
High-end consumer-grade



- Low dynamic resistance
- Multiple OEM resources, supply guarantee
- In-depth cooperation with customers and joint development



Smart-Driver®



- SOI process, stronger anti-interference and driving ability
- UVLO adapts to SiC/GaN/MOS driver



Flash-SBD



- More cost-effective than silicon carbide SBD of the same level