

# **High Voltage Traction Inverter Application Presentation**



## **Traction Inverter trends**









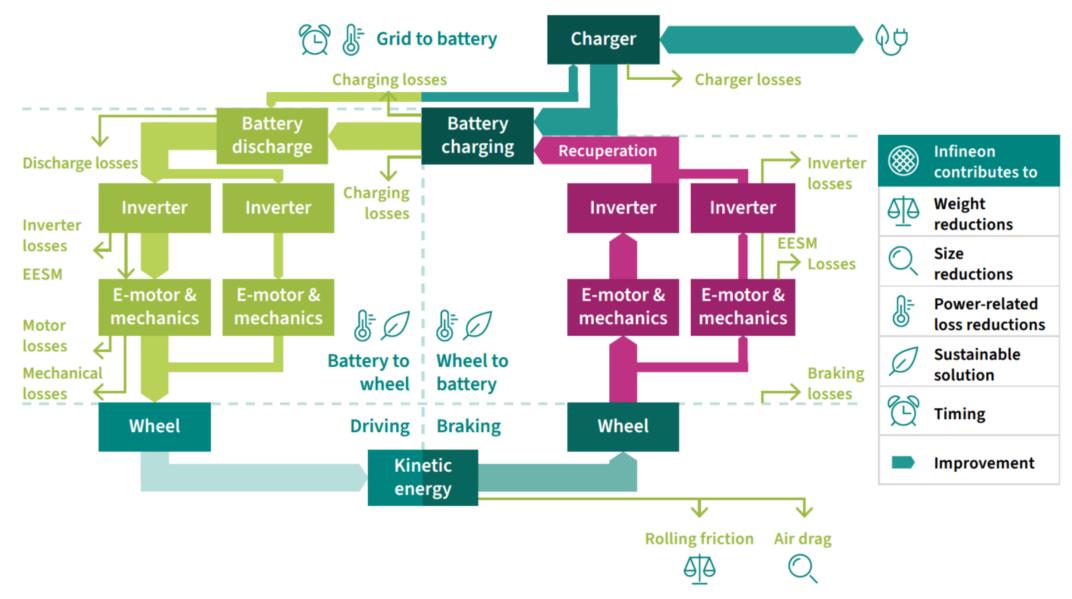






# Semiconductors contribute to improved energy efficiency, but also to size and weight reduction, to improve the vehicle dynamics





## Vision: How to get there







Smart Charging Right timing and performance



Energy Management
Energy handling
predictive driving



Semiconductor Efficiency Reduce power losses



Rolling resistance and air drag
Reduce size and weight



Connected
Environment
V2x and Infrastructure

10 kwh
100 km

Higher energy utilization of renewable energies



**10% smaller battery** 10% more vehicles



Less dependability in supply e.g. on rare earths



Less weight for less PM2.5 & better driving performance



Vehicle to x (V2x): new business models



# Xiaomi SU7 Max: Infineon contributes > 60 different components, incl. 2x HybridPACK™ Drive G2 CoolSiC™ 1200 V power modules



#### Infineon provides system solutions with > 60 different components for more than 10 applications

- MCUs, PMICs: AURIX™ TC3, TRAVEO™ T2G, and PSoC™ for zone controller, ADAS, xEV drivetrain, and suspension
- > 2x HybridPACK™ Drive G2 CoolSiC™ 1200 V power modules or bare dies and gate drivers for traction inverter in Xiaomi SU7 Max
- > PROFET™ for E/E architecture
- > MOSFETs, system basis chips, others







# Through technology excellence and long term supply security Infineon and Stellantis collaborate on 1Billion EURO business





## **Advantage of Infineon SiC**

For EV traction inverter, **more efficiency and right performance** are key. While IGBT is ideal for cost-optimized drive-train, SiC demonstrates higher efficiency under WLTP partial load scenario.

Infineon offers the **best scalability in market** between IGBT and SiC, allowing customers to freely choose the technology for their needs, **reduce platform migration effort while achieve fast time to market**.



#### **Collaboration with Stellantis**

Infineon and Stellantis have agreed on MoU of multi-year delivery of silicon carbide chips. The potential sourcing volume and capacity reservation have a value of more than €1 billion.

Infineon's 2<sup>nd</sup> generation CoolSiC chips are chosen by Stellantis, owing to its unmatched performance, reliability and quality leadership. Stellantis will hence build highly efficiency electrical vehicles with longer range and less power consumption, eventually support the company's pursuit to standardize, simplify and modernize platforms.

# Suzhou Inovance selects 2nd generation HybridPACK Drive CoolSiC with optimized gate-driver in its 4-in-1 e-axle





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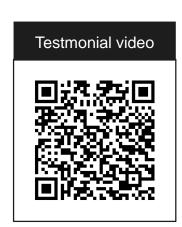
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#### Collaboration with Suzhou Inovance automotive

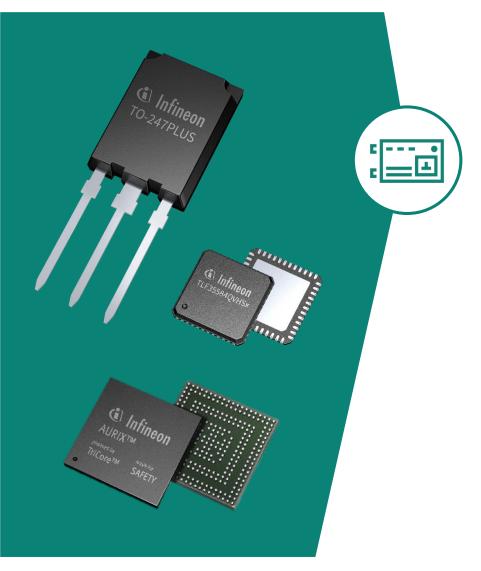
Inovance has chosen Infineon for its complete system solution due to superior performance, high scalability and quality leadership, this includes 2<sup>nd</sup> generation of HybridPACK drive in SiC, SiC optimized gate-driver as well as AURIX microcontroller.

our 'One Inverter, One Infineon' approach helps Inovance to reduced design-in effort and achieve faster time to market.



# infineon

## **Enpower uses discrete IGBT & AURIX MCU in Traction inverter**



#### **Advantage of Infineon Discrete IGBT (TO247-PLUS)**

Infineon's industry-leading discrete IGBTs are compatible with Empower's latest generation inverter in terms of packaging. Together with the high current density, ultra-low saturation voltage drop and superior parallel performance, Discrete products has increased power density by more than 20%.

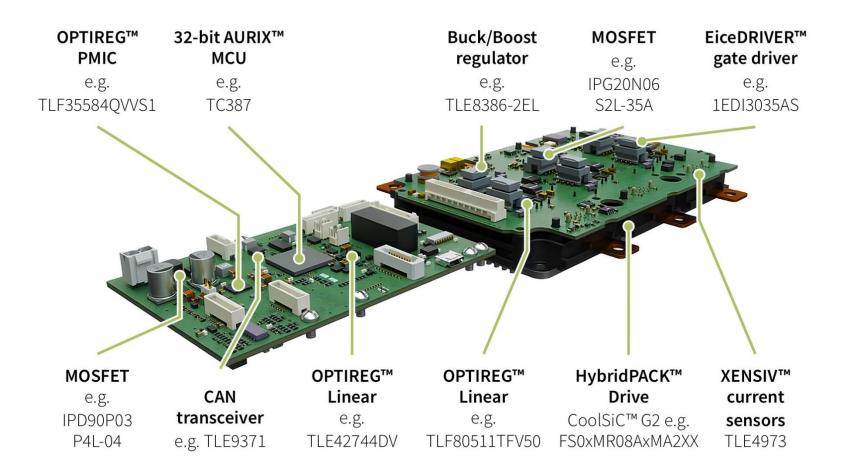
Aside from power components, Infineon's market leading Microcontroller AURIX (TC38x) and power supply PMIC (TLF35584) offer Empower one-stop-shop experience, enabling fast time to market.





## One Inverter: One Infineon





#### One inverter, one Infineon

System solution for easy, fast design

#### Fast time to market

Reference design <=300 KW inverter</li>

#### Freedom of choice

- IGBT& SiC in 750/1200 V scale up to your preferred power class
- HybridPACK™ Drive CoolSiC™ G2 continuous operation at 175°C
- EiceDRIVER™ gate driver G3 optimized for CoolSiC™

#### **Space optimization**

 Integration of coreless current sensor (without magnetic concentrator)

# Infineon offers all components for Traction Inverters The one-stop shop for competitive application solutions





## **Functional Safety**

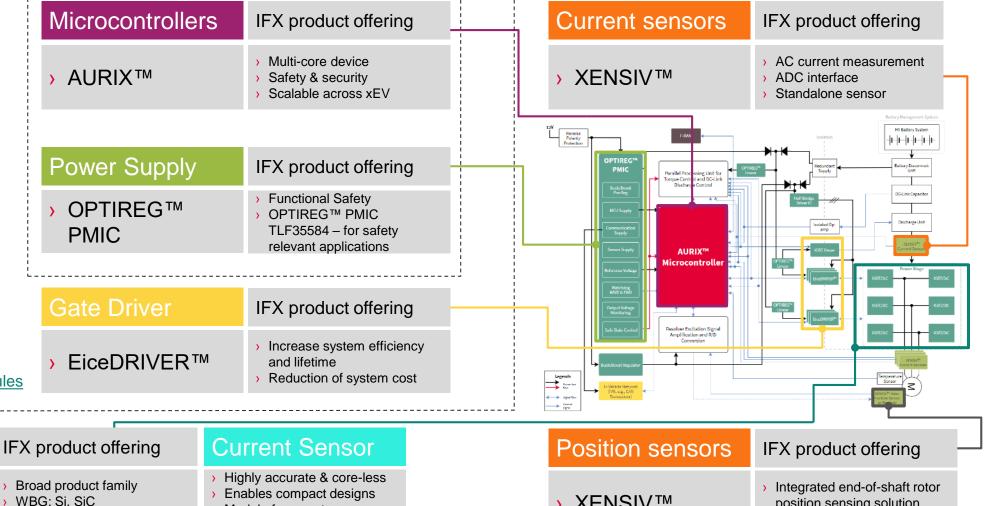
- Complementing and interoperable chip set
- ISO26262 compliance
- Harmonized Documentation

#### **Traction Inverter**

- Overview
- **Products**
- **Documents**
- **Videos**
- Training
- Support

#### **Products**

- Microcontroller
- **Driver Stage**
- **PMIC**
- **CAN Transceiver**
- Memory
- IGBT Modules / SiC Modules
- **Position Sensor**



### **Power Switches**

Modules, Discretes, **Bare Dies** 

- High volume experience
- Module from partner Swoboda in development

XENSIV™

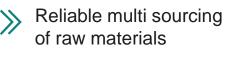
- position sensing solution
- More compact design

Infineon's wide bandgap strategy



# Undisputed power systems leadership mastering all three key materials





World-scale fabs



Application understanding

Packaging know-how and hybridization competence

#### Leadership in Power Systems across all materials and technologies

#### Silicon

Diode - MOSFET - IGBT - Driver - Controller



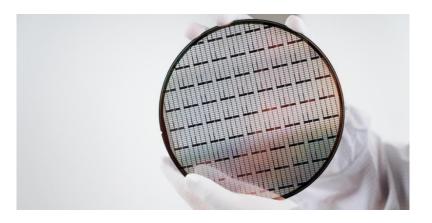
#### Silicon carbide

Diode - MOSFET



#### **Gallium nitride**

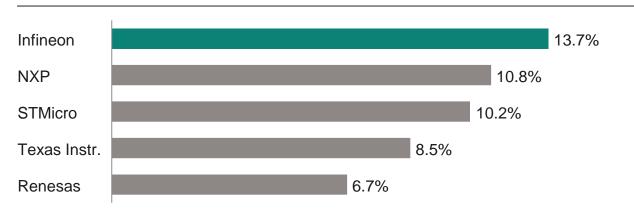
HEMT – Driver



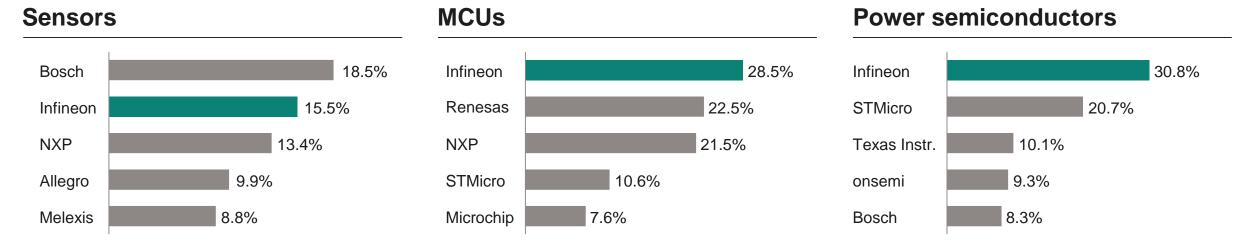
# Infineon's top market position is built on system competence based on an industry-leading product portfolio



## Automotive semiconductors (2023 total market: \$69,200n; +16.5% y-y)



- Infineon grew by 26% y-y, gaining 1.0%-pts of market share to 13.7%, the highest level ever
- Infineon outgrew the market in all regions
- In MCUs, Infineon grew by 44% y-y (about twice as fast as the market), becoming the new #1
- Continuing #1 position in power semiconductors based on industry's broadest product portfolio
- Undisputed #1 in automotive NOR Flash memory ICs

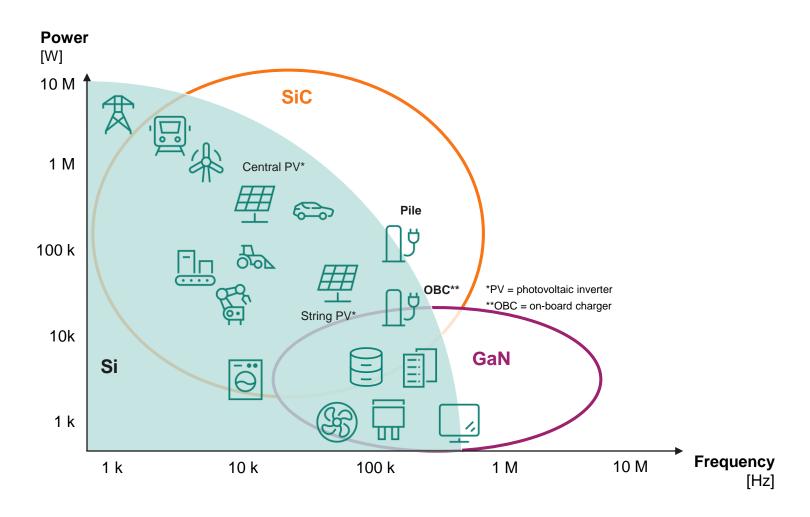


TechInsights: Automotive Semiconductor Vendor Market Shares. March 2024. Sensors: S&P Global: Automotive Semiconductor Market Share Database. April 2024.

# Leveraging full potential based on the power ratings and switching frequency required by the application



## **Comparison of technologies**



#### Si

- Si remains the mainstream technology
- Targeting 25 V 6.5 kV
- Suitable from low to high power

#### SiC

- SiC complements Si in many applications and enables new solutions
- Targeting 650 V 3.3 kV
- High power high switching frequency

#### GaN

- GaN enables new horizons in power supply applications and audio fidelity
- Targeting 80 V 600 V
- Medium power highest switching frequency

# Transition to WBG will vastly differ by application with Si expected to remain technology of choice for many of them



**Key automotive applications** 2020 2030 **Technologies** xEV traction SiC inverter with advantage in **high power** switching performance and power density DCDC HV-HV On-board charger **GaN** DCDC HV-LV superior switching performance results in higher efficiency and lower system cost Si LED lighting Power DC motor control **Smart Power Switching** distribution is 3-4 times **cheaper than WBG**, will remain competitive in many applications where top

■ Si ■ SiC ■ GaN

performance and form factor are secondary

# With a world-scale fab complementing existing strengths, Infineon will be the industry's most competitive provider of SiC technology





#### SiC raw material supply + Cold Split technology



- More than 6 qualified SiC wafer and boule suppliers
- Increased productivity through Cold Split



#### **Superior trench technology**



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- 30% more chips per wafer than planar
- Unmatched reliability with zero field returns



#### Packaging portfolio

- Best-in-class in-house packaging solutions
- New .XT technology for highest power density

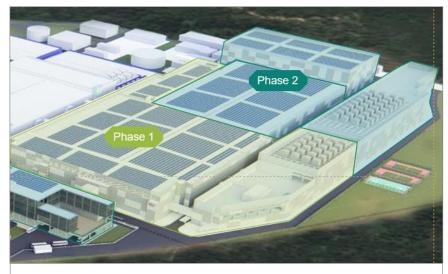


#### Deep system understanding



- Decades of experience
- Broadest portfolio: off-the-shelf plus customized solutions





World-scale 200-millimeter fab with industry-leading cost position

# Smart phase-over and ramp-up of 200mm volume production to enable next level of innovation for customer value with SiC



Villach



## Pilot projects on track



- Qualification on selected high-volume technologies nearly finished
- SiC multi-sourcing strategy for raw materials in place
- Wafer yield equal or better to 150mm

## Smart 200mm phase-over



- Volume production in Villach and Kulim
- Cleanroom and tools already available
- Full transition to 200mm
   within 3 years after
   qualification planned

#### **Timeline**



- Product roll-out based on
   200mm starting Q1/2025
- Major new chip developments on 200mm

# Expansion of Kulim 3 backed by strong long-term customer commitments



#### **Automotive**



## Industrial (incl. PV and ESS)





Design-wins: ~ €5bn



## Related customer pre-payments: ~ €1bn

- Phase 2 of Kulim module 3 expansion is backed by numerous customer commitments
- Significant design-wins in automotive and renewable applications
- About €1bn of customer pre-payments contribute to our free cash flow in FY24 and FY25

# First Si/SiC fusion module concept (Si<sup>2</sup>C) significantly exceeding performance expectations without adding system complexity





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Infineon solution offers compelling cost-performance ratio without adding system complexity for customers



## World-scale capacity, unmatched portfolio breadth and our worldwide customer base lead to accelerated growth in SiC



#### Leading SiC technology and production efficiency

- Unrivaled productivity with worldscale fab and most diversified supplier network
- Superior trench technology and highest reliability
- Extensive packaging portfolio and complete system competence



#### Most scalable SiC auto portfolio

1,200 V



#### Continued strong SiC design-win momentum





















































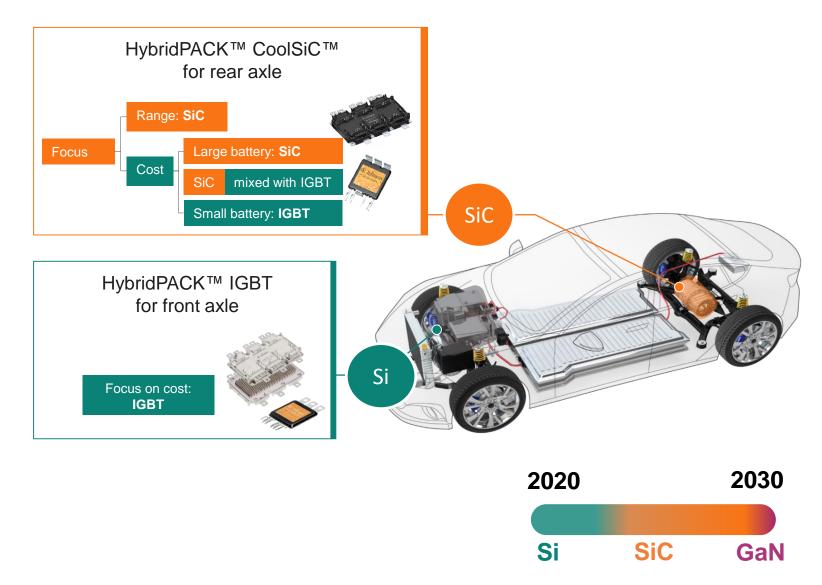




# SiC will be main material for traction inverter, complemented by Si-IGBTs wherever focus on cost is key

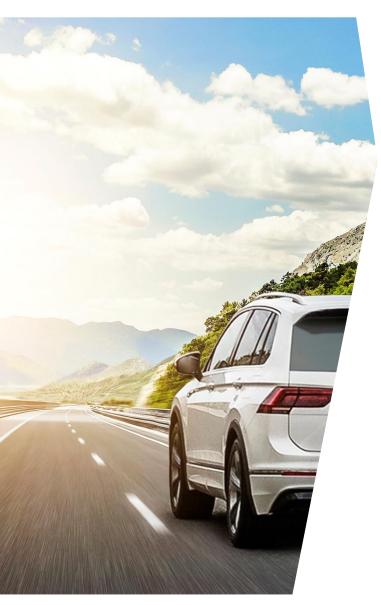


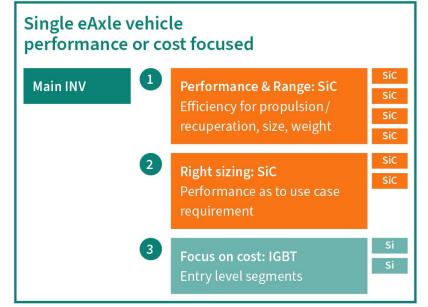




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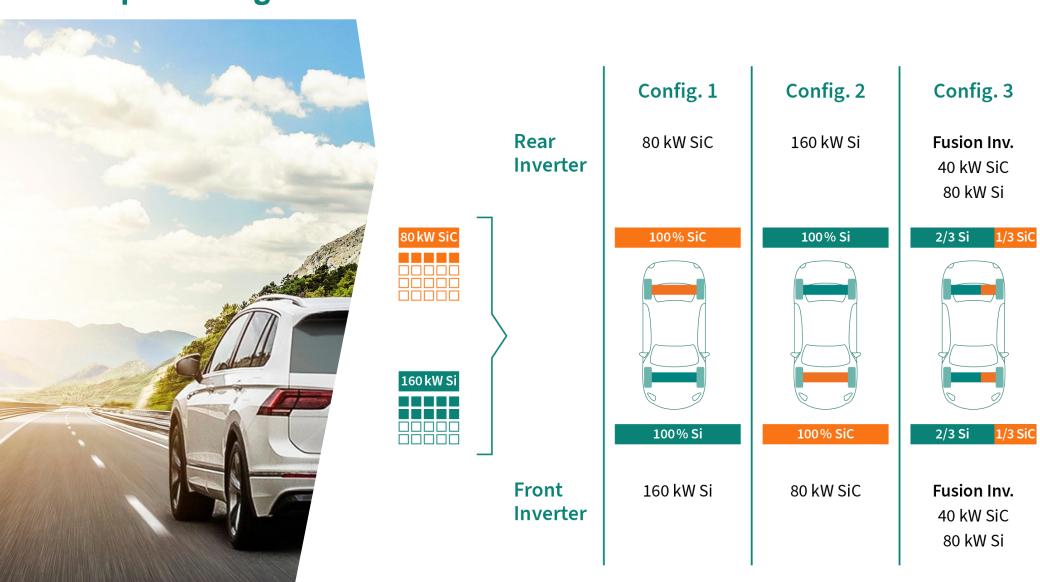


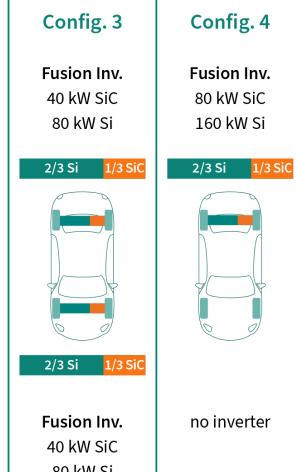




## Si/SiC FUSION: Example configuration of Front / Rear wheel drive

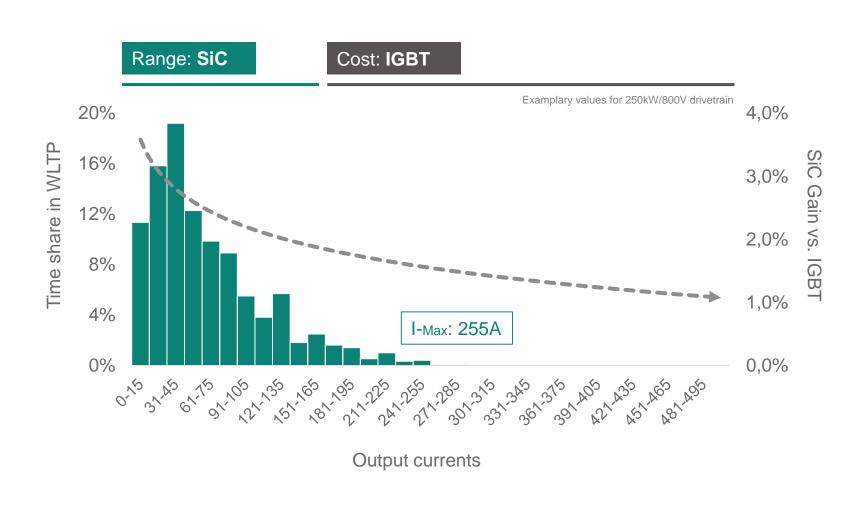






## SiC benefit





Partial load dominates
WLTP use cases, where
SiC enables higher
efficiency for EV inverter

Lower efficiency penalty under full load & relevance of full load on range are key to **select IGBT** 

# Combine SiC & IGBT to optimize between efficiency and peak power competence

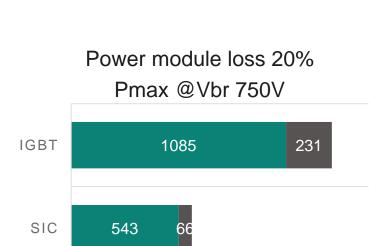
Examplary values for 250 kW/400 V drivetrain

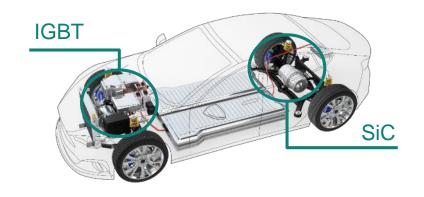
# Scaling vehicle peak performance by adding a IGBT based 2<sup>nd</sup> axle is a common solution to balance efficiency and cost



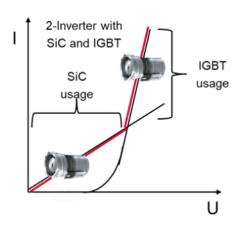
## 2<sup>nd</sup> axel approach

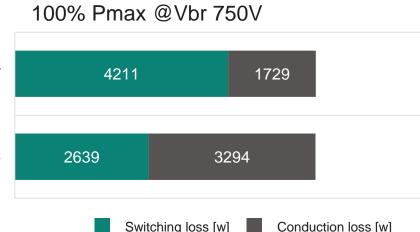
- SiC for higher efficiency
- Si for cost effective peak power











## **Design considerations**

- Primary axle always engaged and sufficiently dimensioned to cover >90% of WLTP drive cycle
- 2<sup>nd</sup> axle provides additional torque to provide 4 wheel drive capability and maximum performance

## Most scalable power portfolio





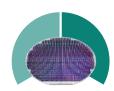














SiC **GEN1** 





1200 V

Si IGBT













EasyPACK™ HybridPACK™ Drive

HybridPACK™ DSC

HybridPACK™ SSC/LFM

Bare die

Discrete (e.g. TO247, IDPAK)

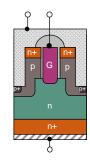
# Infineon's fine tuned SiC Trench technology out-performs Planar demonstrating more protection vs. traditional Trench



### **SiC Planar**

- ✓ Low complexity process
- Good shielding of oxide possible

## **SIC TRENCH**



- Low channel resistance
- ✓ Shrink potential higher than in planar DMOS

### **Infineon TRENCH**



- Low channel resistance
- Shrink potential higher than in planar DMOS
- Oxide corners shielded by folded double trench
- Long experience in trench know-how

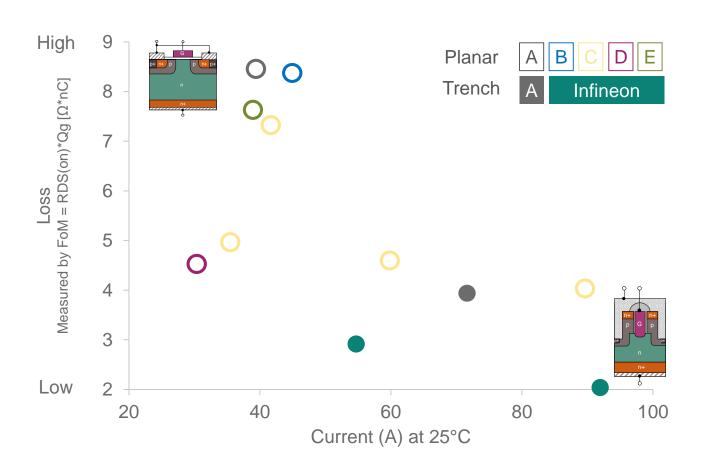
 Sophisticated process knowhow needed

- X Very low channel mobility
- x Limited shrink options

x Protection of oxide corners needed

# Trench out-performs Planar it is THE technology to go for



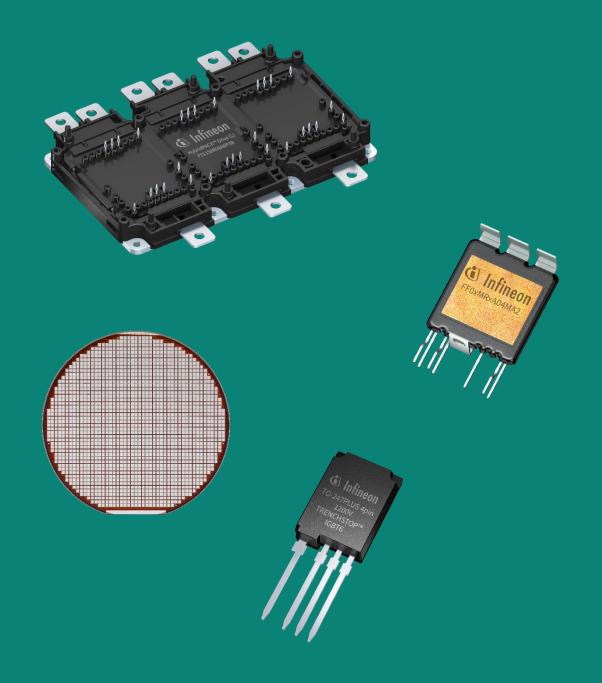


# TRENCH is the future! All semi vendors have announced trench roadmap in 2023+

# Infineon TRENCH out-performs PLANAR, enabling highest switching capability in the market

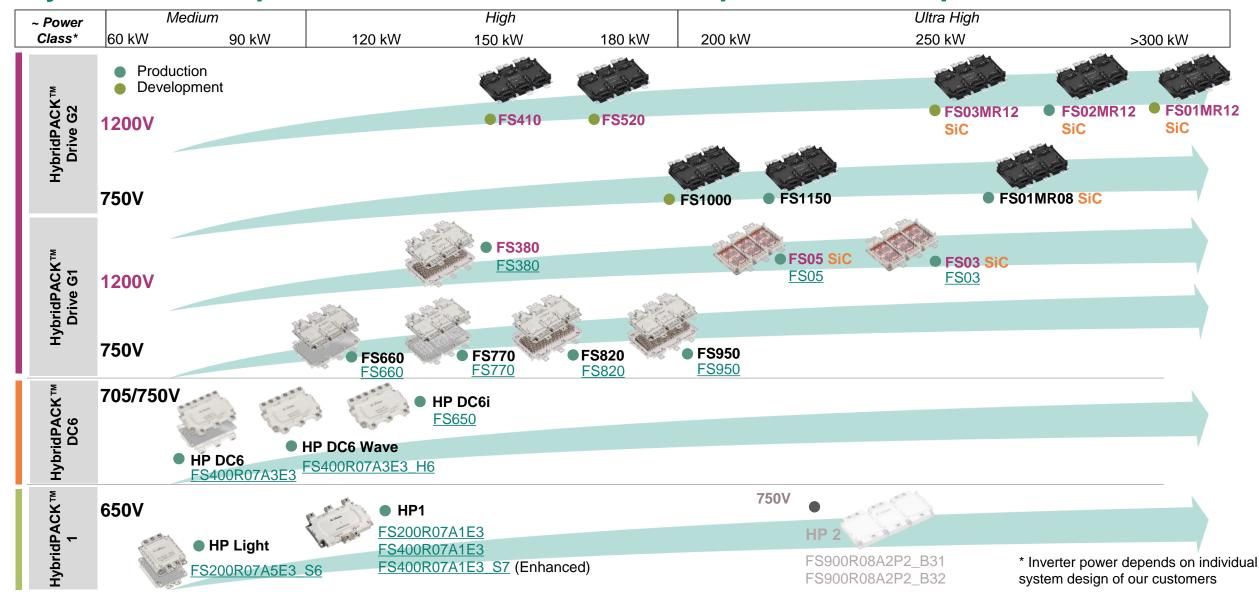
Source: System-Plus Consulting: "SiC Transistor Comparison 2020". November 2020

# **Power switches**





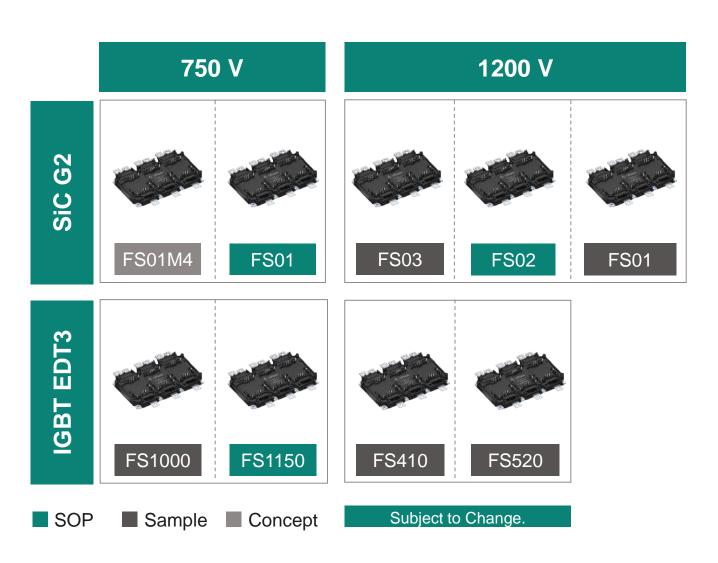
## HybridPACK™ product families cover the full performance spectrum



# HybridPACK™ G2 power your inverter with most scalable portfolio cross Si & SiC







# HybridPACK™ Drive G2 leading device FS02 1200V SiC in OEM car models since 2023



## **Features**

- B6-module family in 1200 V / 750 V
- up to 620A DC current
- Mechanically compatible with all HybridPACK<sup>TM</sup> Drive variants
- Sintered, performance ceramic, direct cooling
- Supports continuous operating at 175°C,
   peak operating at 200°C

Seamless connected with EiceDRIVER & XENSIV current sensor





- Million sold package, well acknowledged among automotive OEMs
- Best market scalability cross IGBT & SiC, enable easy, fast & scalable inverter design
- Enable fast time to market through system solution

QS available

# Infineon automotive discrete IGBT solutions address the key value drivers of traction inverter systems



# Customers chose discrete IGBT for





## **Scalability**

Up- & downscale by flexible number of parallel units



## System cost

By lower piece price, standard packages



#### Flexible inverter form factor

Free-of-choice assembly of small package units



## **Quality Leadership**

Infineon Quality seen as market leader

Dependable track record and high robustness in harsh automotive environment



## Proven technology

Decades of experience in semiconductor development & production

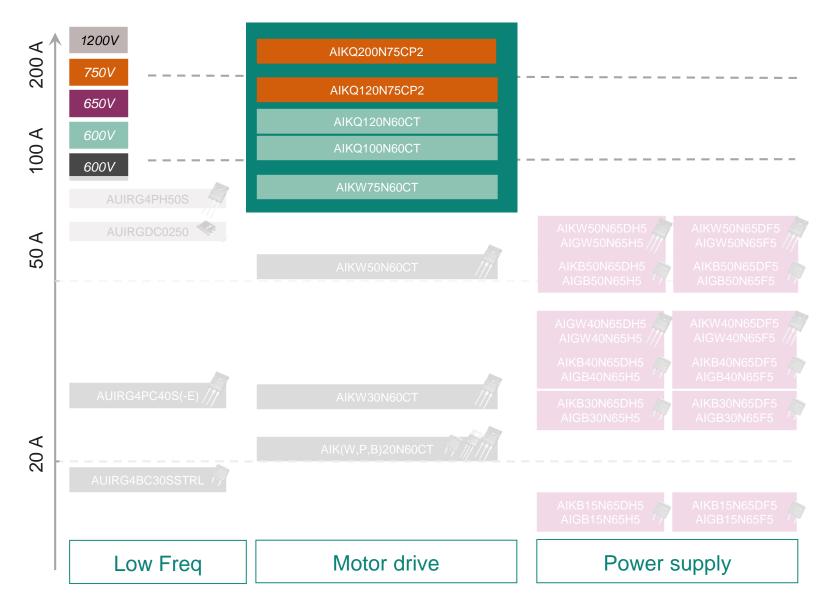


## Technical leadership

Market innovator with extensive local technical support









# Infineon's Automotive 750V EDT2 in TO-247PLUS product portfolio





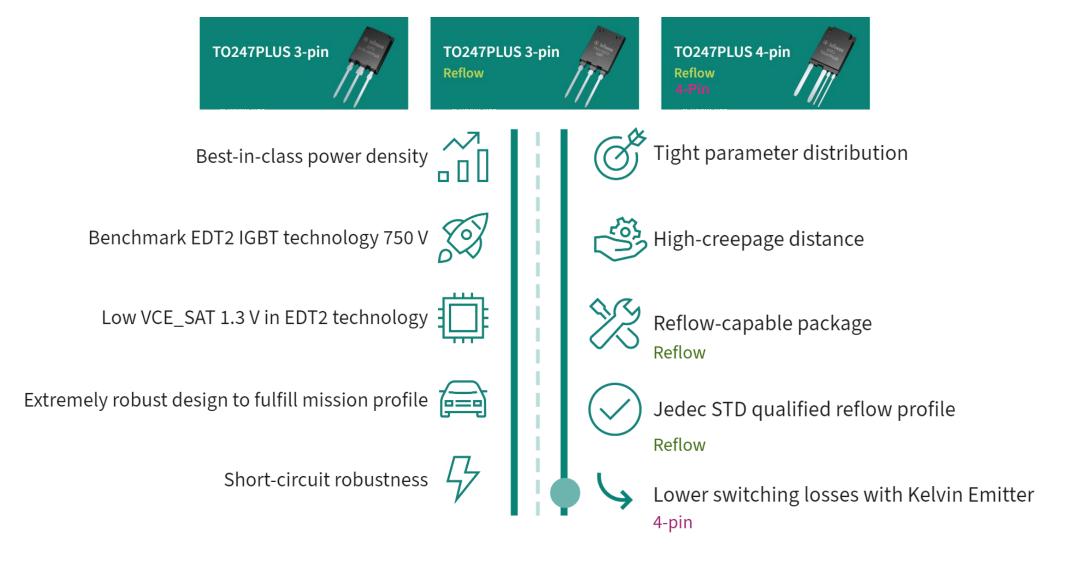






# **Key Benefits of Infineon's 750V EDT2 in TO-247PLUS** product portfolio







### **EDT3** technology enables higher current density

#### **Chip Set Solution**

New IGBT technology based on superior cell concept

Improved diode complementing IGBT

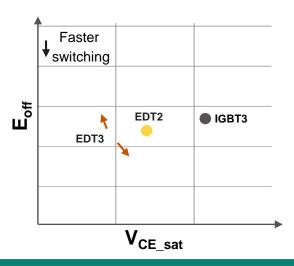




#### 1200 V

- >>15% higher output current density vs. previous generation due to reduced losses
- Drop in replacement for existing power module design

Earnile avail



#### 750 V

- Lower losses due to faster switching & lower VCEsat
- Better Si utilization: extended junction temperature range up to 185°C
- > Up to 25% higher output power
- > Higher current with same module size: enable addressing higher performance vehicles

## **IPOSIM ATV – Power Modules Key Features**



### Live since August 2020



DC-AC topology for HybridPACK<sup>TM</sup> modules more are coming for next product generations...

New control algorithms including Discontinuous PWM and new parameter of load type selection

Fast but accurate online power loss and temperature simulation powered by PLECS engine

Easy to use with defined user interface and clear simulation flow

Separation for device selection and application data settings, quick to share and archive with deep-link

Advanced functions: sophisticated load cycle, multi-selection of up to 5 products, extended scope functions

## **ATV IPOSIM Updates 2022**



- NEW Adaptions on GUI:
  - Updated data base for parameter filtering @150°C
  - Package name preselection/filtering
  - Gate Driver recommendation for simulated device

- LINK: IPOSIM
- Deep-LINK: Simulation Product Comparison
- Deep-LINK: Simulation Product Comparison Load Cycle

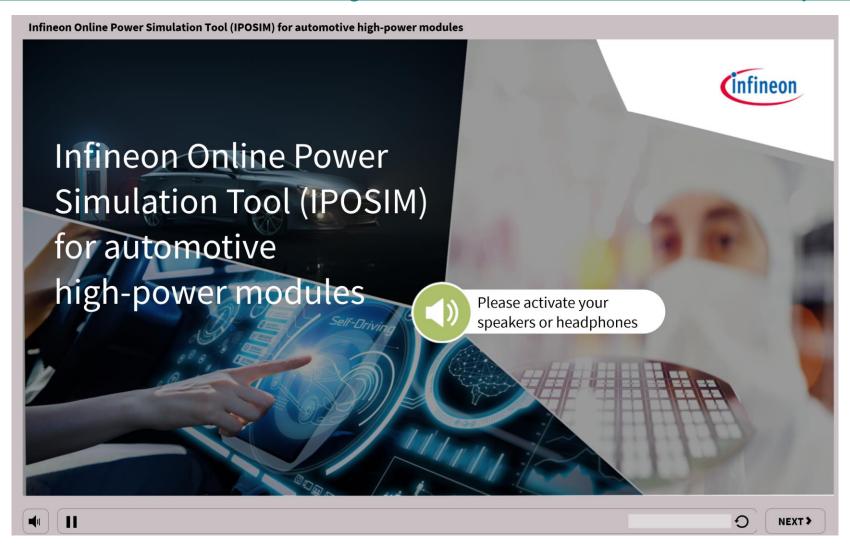
NEW	E <sub>on</sub> + E <sub>off,150°C</sub> [mWs]	R <sub>thJH</sub> [K/W]	T <sub>vjmax</sub> [°C]	V <sub>F,150°C</sub> [V]	E <sub>rec,150°C</sub> [mWs]	R <sub>thJH</sub> [K/W]	T <sub>vjmax</sub> [°C]
	8.05	0.46	150	1.59	1.35	0.46	150
(	19.1	0.34	150	1.15	8.51	0.53	150



## IPOSIM ATV – Power Modules Infineon Power Simulation Tool Video



https://www.infineon.com/cms/media/eLearning/Automotive/IPOSIM-for-automotive/story.html



# **Sensors**Current / position sensors





### **Customer value – Current sensor family TLE4972/TLE4973**





- One package with integrated current rail (PG-TISON-6) for up to 132A
- Two packages with external current rail for up to 2kA
- Fully scalable with complete HPD G2 family to address various power classes





 Low total error over temperature and lifetime allow for reliable performance over time







- Highly accurate over temperature and lifetime due to high linearity, stray-field robustness and lack of hysteresis
- in-system, end-of-line calibration (±15%)
- Low phase shift at fundamental frequency (<2° @1kHz)</li>





- Enables high ASIL on system level
- Integrated and programmable solution for overcurrent protection
- Diagnosis mode for AOUT and OCD pins implemented

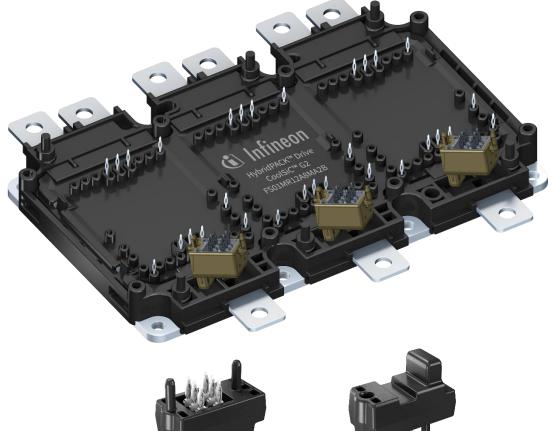




- No need for magnetic concentrator nor a shield
- Based on differential sensing concept

### Swoboda current sensor module scalable for complete HybridPACK™ Drive G2 portfolio



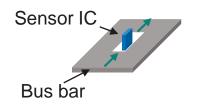


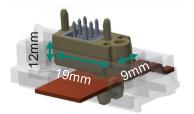




**QS** available

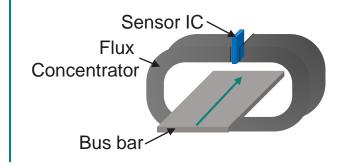
#### **Core-less**

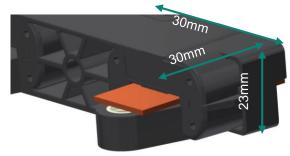




Based on TLE4973 **core-less** technology Scalable for **complete** HybridPACK™ Drive G2 portfolio

#### **Core-based**



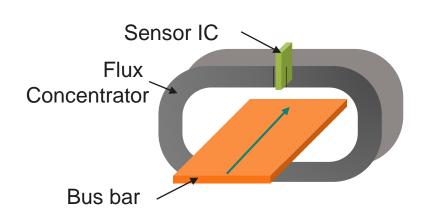


## **Space optimization Swoboda current sensor**









#### **Easy platform migration**

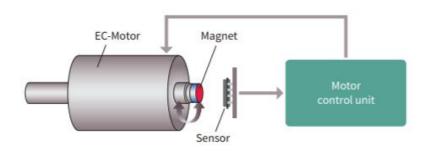
- Scalability cross whole HybridPACK™ Drive G2 portfolio
- Easy migration for preferred power segments

#### **Less cost & complexity**

- Eliminate long tab
- No magnetic concentrator
- Reduce assembly time

### Electric main drive – solution based on magnetic sensors Magnetic angle sensor resolver replacement reduces system cost





TLE5309D End of Shaft (EoS)



TLE5309D integrated End of Shaft (iEoS)

## SYSTEM COST REDUCTION – No carrier Gen. & Demod. circuit

DIVERSE ANALOG ANGLE SENSOR (AMR & GMR)

#### FUNCTIONAL SAFETY-ASIL-D Ready

HIGH ACCURACY & HIGH SPEED

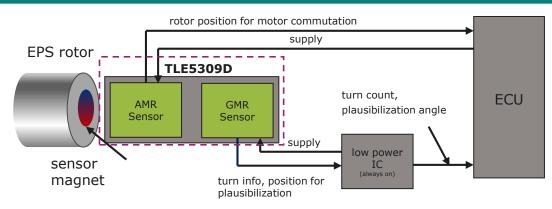
#### REDUCED CONSTRUCTION SPACE -with iEoS

TDSO Pkg. Grade 1 today ,Grade 0 in 2023

TLE5309D together with Infineon integrated end of shaft (iEoS) system solution saves cost on system level and provides stray field immunity

### TLE5309D - rotor position sensor with analog outputs

#### Target Application



Diagnostic functions in combination with iAMR and iGMR diversity supports **ASIL-D** applications

#### **Tools & Support**

- Documents
  - TLE5x09A16 D-DataSheet-v02 00-EN.pdf
  - Infineon-TLE5x09A16(D)-Eval Kit-UserManual-v01 00-EN.pdf
- > Evalulation-Kit
  - TLE5309 EVAL KIT

**Product Highlights** 

- Analog output of sine and cosine
- Up to 30,000rpm, ~9µs delay time
- Combination of AMR and GMR sensor
  - AMR for high accuracy (180° angle)
  - GMR for 360° range
  - Supports functional safety ASIL C (D) Intrinsic diversity

#### **Status And Derivatives**

> Products in volume production





(PG-TDSO-16)

- TLE5309D E1211: 3.3 V, dual die, AMR (bottom) and GMR (top), with TCO\*
- > TLE5309D E2211: 5.0 V, dual die, AMR (bottom) and GMR (top), with TCO\*
- > TLE5309D E5201: Dual die, 5.0V AMR (bottom), 3.3V GMR (top), w/o TCO\*

For more information see: https://www.infineon.com/sensors and check MyInfineon

<sup>\*</sup>Temperature Compensation Offset

# **EiceDRIVER**<sup>TM</sup> **Gate driver**



## Born for SiC EiceDRIVER™ GEN 3 Teaser Slide for the New further optimized products





#### **Born for SiC**

 Best fit for Infineon SiC, available technologies in the market (e.g. OVLO to protect higher gate oxide abs. ~23 V)

#### **Efficient & Robust**

- Enhanced ADC accuracy for temperature measurement
- Dedicated soft-off pin & Super fast DESAT incl. BIST to protect power device

#### FuSa up to ASIL-D (on system level)

- Dedicated safety input (SI1/SI2)
   increases interoperability with
   Infineon PMIC
- More safety features such as
   VEE2 monitoring implemented

#### **Cost optimized**

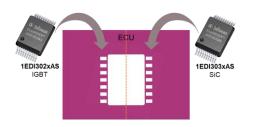
- Separated TON/TOFF pin allows removal of diode
- Reduces external safety logic circuit

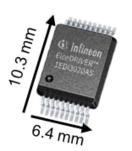
### EiceDRIVER™ 1EDI302xAS / 1EDI303xAS (3<sup>rd</sup> GEN) Leanest ISO-26262 compliant gate driver on the market



Infineon's <u>lean and powerful</u> gate drivers tailor made for SiC or IGBT power devices used in several HV Applications (Traction Inverter, HV-AUX, EESM¹)

- Plug & play, no programming needed, diagnosis via PWM
- Leanest ISO-26262 ASIL-B(D) compliant driver on the market
- > Pin compatible variants for SiC and IGBT







### Existing product variants Released in Q1/2021, parts are in mass production

Product variant	IGBT/SiC	ADC/ASC
1EDI3020AS	IGBT	ADC for temp
1EDI3021AS	IGBT	ASC
1EDI3023AS	IGBT	ADC for DC-Link measurement
1EDI30 <b>3</b> 0AS	SiC	ADC for temp
1EDI30 <b>3</b> 1AS	SiC	ASC
1EDI30 <b>3</b> 3AS	SiC	ADC for DC-Link measurement

#### NEW further optimized products are on its way! Samples available under NDA

NEW Product variant	IGBT/SiC			
1EDI3025AS	IGBT			
1EDI3026AS	IGBT			
1EDI3035AS	SiC			
1EDI3036AS	SiC			

<sup>1</sup>EESM = Externally Excited Synchronous Motor

## Evaluation Boards / Kit available to kick off the design activities with IFX gate driver

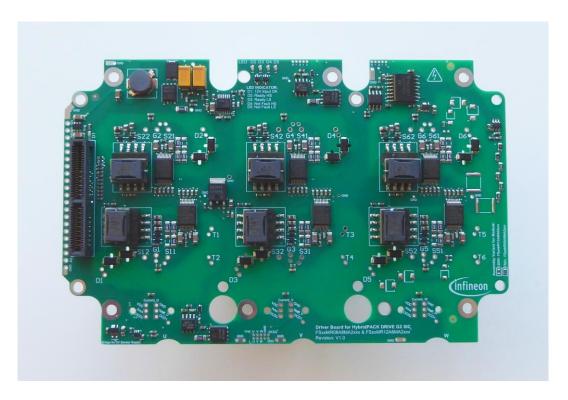


#### 3<sup>rd</sup> Generation Gate Driver

#### 3 Phase Gate Driver Board



Board Name	Remark
1EDI30XXAS EVALBOARD	No device mounted
1EDI302XAS EVALBOARD	1EDI3020AS/1EDI3021AS mounted
1EDI303XAS EVALBOARD	1EDI3030AS/1EDI3031AS mounted

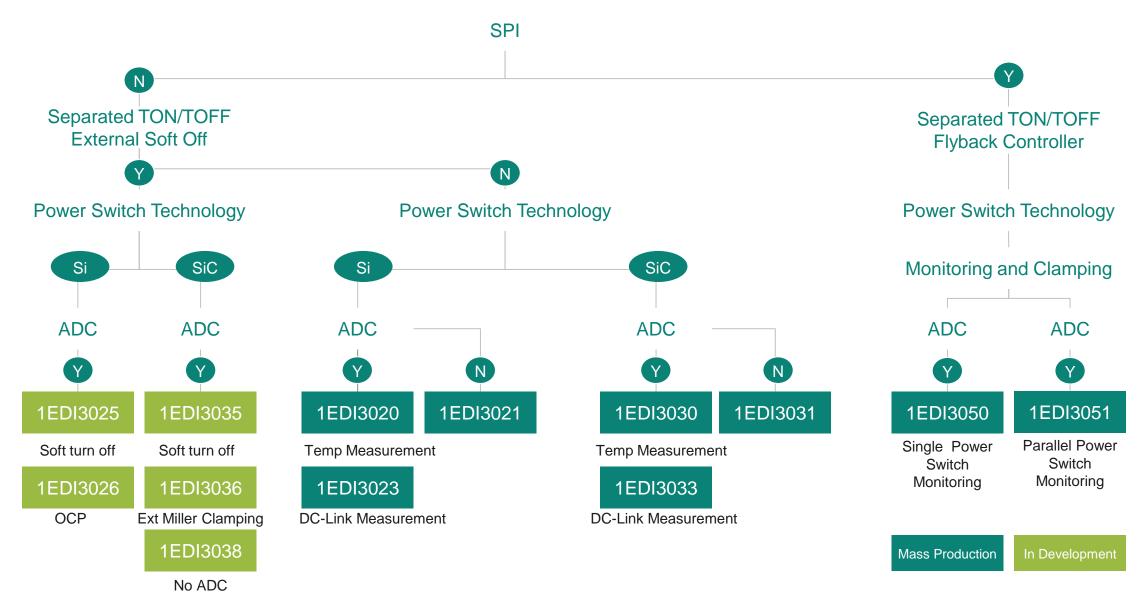


Various half bridge gate driver boards are available!

3 phase gate driver board is also available for system evaluation!

#### Selection Tree 3<sup>rd</sup> Generation EiceDRIVER™





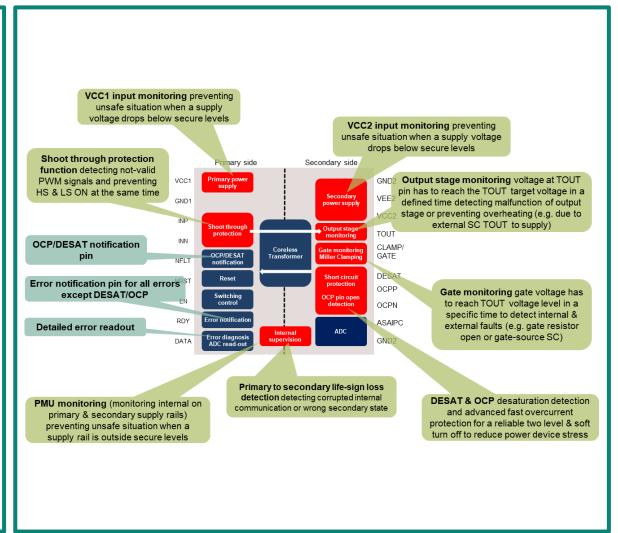
## **EiceDRIVER™ 3<sup>rd</sup> Generation ISO-26262 compliant gate drivers for ASIL-D traction inverters**



#### **Decomposition half bridge overview**

#### Each error on device level leading to a FSR violation on system level (wrong torque) is covered by the device itself through with ASIL-B. Additionally each error on device level is covered by: Complementary ASIL-B driver via DESAT (for all critical errors leading to short circuit events in the half bridge) External phase current plausibility check over the MCU TLSR-1: PWM integri IGBT/SiC destruction Host Microcontroller PWM HS AURIX™ Phase PWM LS current ISO 26262 ault notification Lo w-side FLSR-1: PWM integri TLSR-2: prevention of IGBT/SiC destruction

#### Safety features reaching ASIL-D on system



# **AURIX**<sup>TM</sup> **Microcontroller**



## **AURIX™ TC3x** is the-state-of-the art solution for Inverters The Inverter of the future is enabled by **AURIX™ TC4x**



	— AURIX™ solution —	— тсзх —	— тс4х —	
	Observer/virtual Sensor by AI	Standard, e.g., Kalman filter	Parallel Processing Unit (PPU),  → Virtual Sensing and Model predictive control	
spu	Enhanced Integration		Hypervisor & Virtual Machine  → SW-Sharing on one Core	
Market trends	Platform		→ Model-based development  Up to 6 cores at 400 MHz	
& Mark	Embedded real time performance	Up to 6 cores at 300 MHz GTM, 5V ADCs, and furthermore	TC3x + (e)GTM, low latency bus,	
nverter 8	Sensor Evaluation	AURIX™ Resolver ADC SW-concept → The market-standard	CDSP* unloads main core and improves accuracy  Enhanced Resolver SW-concept + virtual sensing via PPU	
	Security	Evita Full through HSM	CSRM + CSS to protect with future Post- Quantum Cryptography ISO/SAE 21434 certified	
	Functional Safety	ISO26262 certified FuSa concept, more than a safety island	TC4x-enhanced FuSa + FFI in combination with Hypervisor	
WHY	HOW	WHAT		

## AURIX™ TC3x device overview at glance Most common Inverter-devices are TC37x and TC38x families



9xA Series 6/4*x300MHz - 16 MB 9x Series 6/4 x 300MHz - 16 MB Ex Series 4/2 x 300MHz - 12 MB	Compute			•	LRR end EMS in Control	TC397XA	TC399X	
8x Series 4/2 x 300MHz - 10MB		Advanced E EMS,Trans	_	vortor BMS		TC387Q	TC389Q	
<b>7 Series</b> 3/2 x 300MHz - 6MB		High-end bo	ody control	,		ТС377ТХ		
<b>7x Series</b> 3/2 x 300MHz - 6MB					TC375T	TC377T		
<b>6x Series</b> 2/2 x 300MHz - 4MB			TC364D	TC366D	TC365D	TC367D		
<b>5xA Series</b> 3/2 x 300MHz - 4MB		Front radar		TC356TA		TC357TA		
<b>3xA Series</b> 2/1 x 300MHz - 2 MB	Corner radar		TC336DA 2/1		TC337DA 2/1			
<b>3x Series</b> 1/1 x 300MHz* - 2 MB	TC332L	TC333L	TC334L	TC336L		TC337L		g, EPS,Airbag, DBC, DCDC
<b>2x Series</b> 1/1x200MHz** - 1 MB	TC322L	TC323L	TC324L			TC327L	<ul><li>4WD,e</li><li>Host co</li></ul>	Clutch ontrol, Telematics
Flash Package	TQFP 80	TQFP 100	T/LQFP 144	BGA 180	LQFP 176	LFBGA 292	LFBGA 516	

<sup>\*</sup> Number of cores /lockstep

#### **MCU Scalability**

- > Up to 6 cores + 4 lock-steps, 300 MHz
- > Up to 16 MB P-Flash
- A/B swap for FOTA
- Software & Pin-compatibility



#### Safety/Security Concept

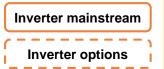
- > ISO26262 ASIL-D compliance
- > EVITA Full hardware security support on all devices



#### **Connectivity Highlights**

- > Ethernet: up to 2x 1GBit/s
- ) CAN FD: up to 20 ch
- > LIN: up to 24 ch
- > eMMC IF: for external Flash
- > IPC: up to 2x 320MBit/s





- L Single Lockstep Core
- D Dual Core
- T Triple Core
- Q Quadruple Core
- X Sextuple Core



<sup>\*\* 300</sup>MHz upgrade available





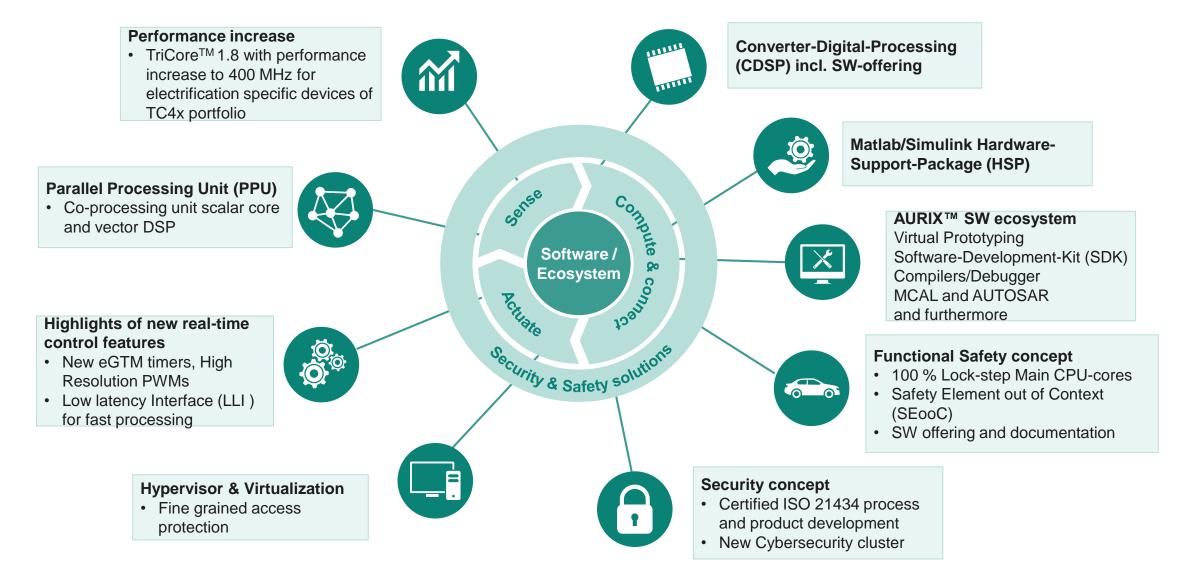
### The start of a new era...

**Automotive** market is facing two simultaneous, fast paced, paradigm shifts:

- E/E architecture innovation has brought new requirements to microcontrollers
  - More ASIL-D performance
  - Increased security & connectivity
  - New SW development methods
- Trend toward Electrification further accelerates
  - Emissions legislations towards Zero Emission
  - Major OEM with clear focus on Battery Electric Vehicle
  - Strong reduction of hybrid vehicles expected
  - Development of next generation of Engine & Transmission questionable

## **AURIX™** TC4x offers a unique feature-set for Inverters from Hardware to SW-ecosystem





### AURIX™ successfully covers Inverter customer needs & market trends (infineon to differentiate from competition in a challenging market environment





### **Efficiency** increase

to save HV-battery costs or increase range



### **Cost Innovation**

on system level to replace / complement other components



### Lean R&D development

for optimized cost and resource usage



### Safety & security

ISO26262 and ISO21434 compliance

### AURIX<sup>TM</sup> TC4x for Inverter is empowering cost-innovation, best-inclass efficiency, fast time-to-market and latest ISO compliance



**Efficiency increase** Increased ASII-D performance of Main-CPUs in Lockmain-CPU to implement optimized control step strategies or further x-in1- integration TM-ADC **Best in-class accuracy** DS-ADC with strong AURIX peripherals Parallel Processing High switching frequency control loop Unit (PPU) could be offloaded from Main-CPU for eGTM w/ HR-PWM further optimization Low latency interface Improved robustness and accuracy also of distorted signals Converter-Digital-Processing (CDSP) Reduced Main-Core utilization or + SW Filter-chains replacement of external ASICs Hypervisor & Virtualization Enabling of SW-sharing with ensured Fine grained access **Freedom For Interference** protection Virtual Sensing replaces/complements Parallel Processing physical sensors (eg. Rotor-position Unit (PPU) sensing, temperature sensing) AI with NN

AURIX<sup>™</sup> optimized (TriCore<sup>™</sup>, PPU, peripherals)

model-based-development for a

fast time-to-market

Matlab/Simulink
 Hardware-Support-Package (HSP)

Lean R&D development

#### **Unique SW-ecosystem**

simplifies development activities and saves further R&D costs and resources

AURIX™ SW ecosystem

Accelerated Inverter application development with production ready Complex-Device-Drivers (CDD) Autosar and ASPICE conform

 Infineon & KPIT partnership

ISO 26262 compliance is part of AURIX™ DNA. helps customers to reduce risk, keep reputation and meet latest regulations with strong system approach.

- 100 % Lock-step Main CPU-cores
- Safety Element out of Context (SEooC)

Compliance with ISO 21434 is certified by TÜV.

Cutting edge security concept prepares with

post-quantum cryptography

- Certified ISO 21434 process and product development
- CSRM & CSS\*

Safety & Security

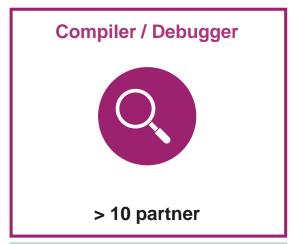


**Cost Innovation** 

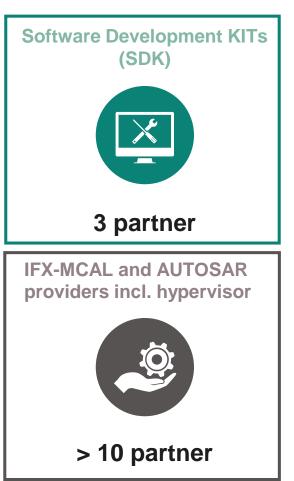
## AURIX<sup>™</sup> TC4x unique and proven SW-ecosystem enables fast time-to-market and minimized R&D effort



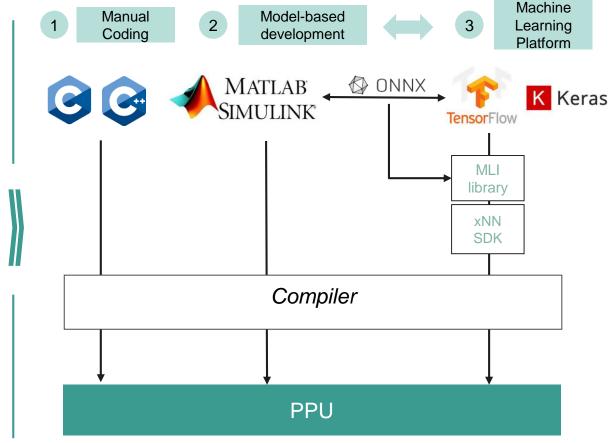
#### SW-Ecosystem







#### Example PPU ecosystem



## **AURIX™ TC4x PPU** empowers the e-Drivetrain of the future for best-in-class system efficiency and cost-innovation

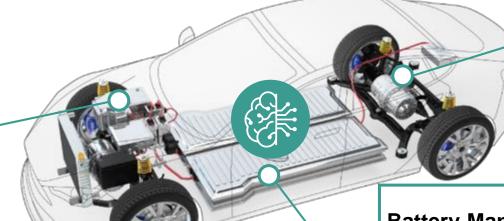


### TC4x PPU is enabling

#### **Power-Conversion**

 Combining control and communication functions and reducing number of system MCUs from up to 7 to 1

clear cost-down path and further efficiency increase



#### **HV Traction Inverter**

- Motor Position Sensing
- Health Observing
- Temperature Estimation
- Model Predictive Control

best-in-class system efficiency and cost-innovation

#### **Battery-Management**

- Electrochemical models
- Hybrid ML accelerated models
- Artificial intelligence

optimized Charging, extended vehicle range and battery life



12X

TriCore performance, eg. for AI-applications





#1 Safety
keep physical sensor
and combine with
virtual sensor for
redudancy

#2 Simplied
physical sensor
Usage of cheaper
physical sensor in
combination with
virtual sensor

#3 Sensorless
Usage virtual sensor and replacement of physical sensor

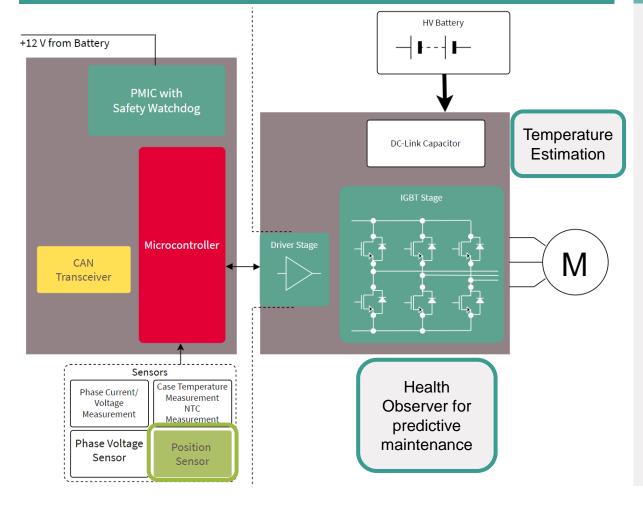
Complexity of implementation

## Observers in AURIX™ TC4x PPU enables Artificial Intelligence in Inverter-Applications



\* Neural Network (NN)

### **Example: B6-bridge and Motors**

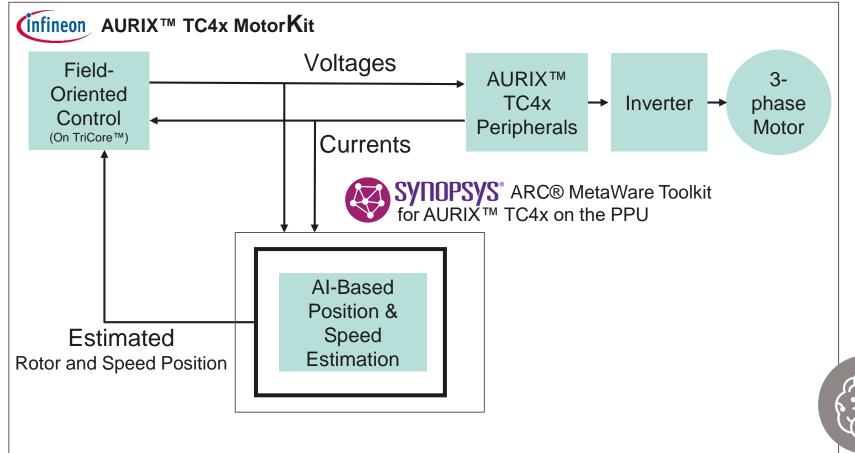


#### **Al Application Benefits**

- Al-possibilities in Inverter-applications:
   Position Sensor, Health Observer, Temperature
   Estimation
- Virtual Sensors
  - Cost-savings: Virtual sensor replacing physical
  - Accuracy/Efficiency: NN\* instead of Kalman Filter
  - **Enabling**: Real sensor not applicable or not available
  - Availability: Virtual sensor as redundancy
- Observers
  - Safety: "is the system output close to the expected output?"
  - Anomaly: "is the system output different than the normal output?"
  - Health: "is the system still operating as intended?"
- Computational Efficiency Increases
  - Reduce memory: NN\* instead of LUT
  - Reduce execution time: NN\* instead of complex algorithm

## **AURIX™ TC4x PPU and Synopsys MetaWare SDK AI virtual sensing**





By combining AURIX™
 PPU and the and Synopsys
 ARC® MetaWare Toolkit
 for AURIX™ TC4x the
 position sensor has been
 replaced entirely with AI



Al can replace or enhance physical sensors, saving BOM costs

## **AURIX™ TC4x PPU Tj estimation in real-time is enabling** double-digit cost savings on system level



Details, see Level 2) presentation

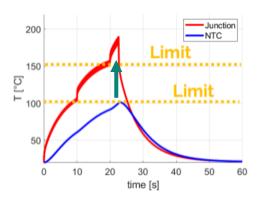


#### Today's challenge

- As more precise Tj temperature of a power module can be estimated, the better the module can be utilized
- Current NTC sensors are not very accurate. Picture below shows a typical behavior of a NTC (blue) and real junction temperature (red)
  - → higher power module safety margin and module chip size needed

#### Innovation based on AURIX™ TC4x

- PPU will be trained with real power module Tj data during development
- PPU is overtaking the Tj estimation in real-time during operation with much higher accuracy than NTC and is closing the gap to real Tj by ~10 °C, leading to a power module chip-size decrease and therefore ~5 % power module cost savings

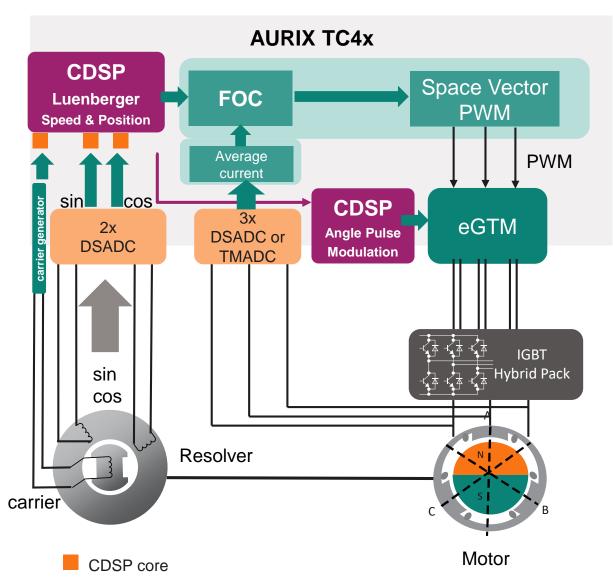


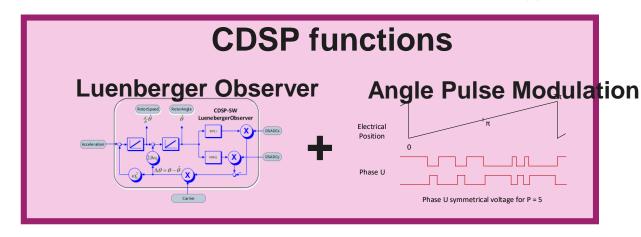


\* typical SiC power module price > 200 EUR

## Luenberger observer and Angle Pulse Modulation can be executed on CDSP for a best-in-class efficient Inverter control







#### **CDSP SW Library:**

 CDSP digital signal processing library offers flexible filter and accumulations functions (filter taps, filter coeff, ....)

#### **CDSP Benefits:**

- Extract information about rotor position without CPU intervention
- Digital filters demodulate the AM signal from the resolver
- Processing sin/cos and carrier by Luenberger
   Observer for robust high accurate speed/motor position
- Optional angle pulse modulation control mode
   selectable

# **OPTIREG PMIC**Power management IC

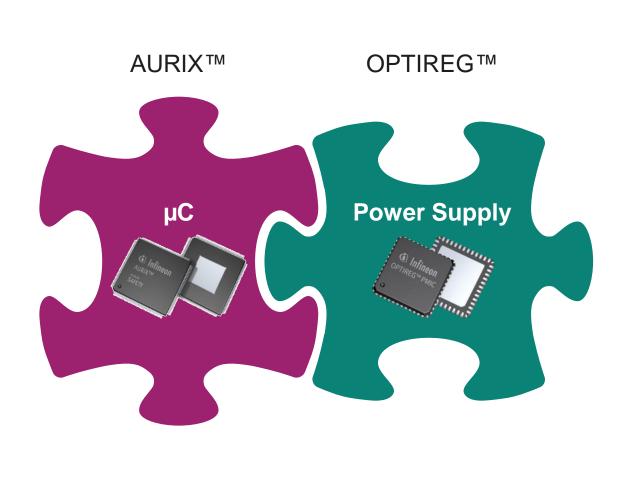


## OPTIREG™ PMIC together with OPTIREG™ TLF11251 for a safe and optimized multi-channel power supply of Infineon µC families



IFX offers a scalable PMIC portfolio which can cover the complete AURIX™ TC2x/TC3x portfolio







**OPTIREG™ PMIC** 

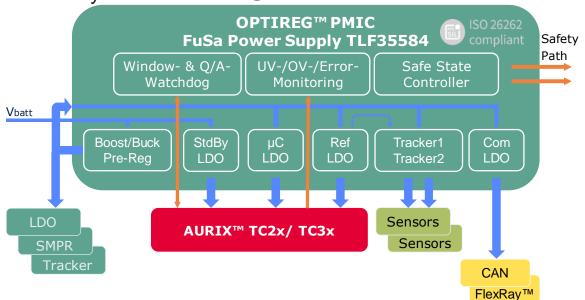
### TLF35584QVVSx/KVSx OPTIREG™ PMIC Functional Safety



#### **Key Features**

- > Buck/Boost-Pre-Regulator
  - $I_{load} = 1.3A$ ; f: 300kHz-2.5MHz
- μC-Supply: 3.3V/5V @ 600mA
- Reference-LDO: 5V @ 150mA (±1%)
- 2x Tracker: 5V @ 150mA
- Communication-Supply: 5V @ 200mA

> StandBy-LDO: 3.3V/5V @ 10mA



- > EN/Wake (T15 and CAN/FlexRay™)
- > SPI
- Safety Features
  - Multiple bandgap (supply vs V-monitoring)
  - UV/OV-Monitoring, ERR-Monitoring
  - Functional-WD & Window-WD
  - Safe State Control Secondary Safety Path
  - Protected safety area
  - Built In Self Test
  - Development acc. ISO26262
- Vin: 3V .. 40V



#### **Package**









## **OPTIREG™ TLF35584 PMIC Functional Safety Features - Benefits**



Features	Benefits				
ISO 26262-compliant	Usage in applications with ASIL-requirement				
Boost capability	Ensure operation in cold cranking condition				
Pre-/Post-Regulator architecture	High Efficiency				
Multiple voltage supplies	System supply: μC, communication, sensors				
Dedicated reference voltage supply	ADC-supply independent of μC-load				
Bandgap for both safety and supply plus electrical isolation	Avoid common cause failures				
WWD & Q/A-WD	Flexible WD to achieve proper ASIL-level				
BIST (analog & logic)	Ensuring "safe" operation				
UV/OV-monitoring	Flexible RESET/interrupt management				
Flexible safe state control	Ensuring "safe" operation				
Enable/Wake	Flexible wake-up management				

## OPTIREG™ PMIC: Strong commitment to General Purpose and Application Specific PMIC solutions











e.g. T-PMIC

e.g. I-PMIC











#### **POWERTRAIN**

ICE - PMICs

System Safety
Functions

System Power
Supply Functions

ICE
Base Functions

### Product idea

xEV - PMICs

System Safety
Functions

System Power
Supply Functions

xEV
Base Functions









#### **General Purpose PMICs**

System Safety Functions

System Power Supply Functions





#### **MOTOR DRIVES**

#### SAFETY

**ADAS - PMICs** 

e.g. R-PMIC

e.g. M-PMIC

System Safety Functions

System Power Supply Functions

ADAS
Base Functions

Product idea

Chassis - PMICs

**System Safety** 

**Functions** 

**System Power** 

**Supply Functions** 

Chassis

**Base Functions** 













## **LV MOSFETs**

















HVAC

Inverter

**Battery Disconnect** 

**DC-DC** converter

A hybrid car has

# 180 MOSFETs

in 2025

# **INFINEON** can cover them all











Pumps

**Seat Control** 

**ABS Control** 

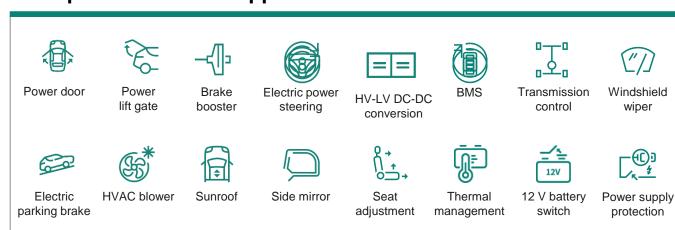
Window Lift

**Belt Starter Generator** 

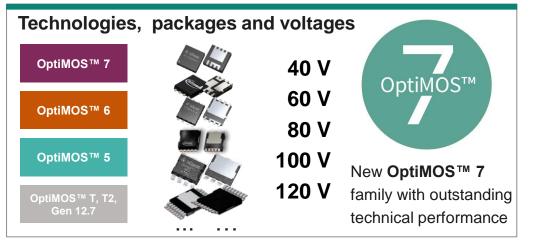
# Number of power MOSFETs per car continues to increase, and drives accelerated growth for the leading portfolio



#### **Examples of MOSFET applications**



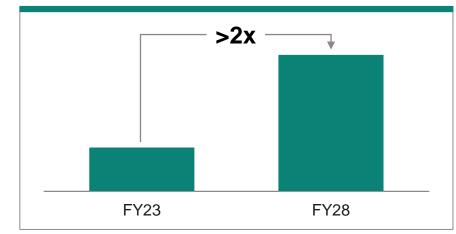
#### Latest portfolio with constant innovation



### 100 to 180 MOSFETs are used per vehicle in ~90 different applications in all segments: body, chassis, safety, ADAS/AD, powertrain

- Infineon offers broadest portfolio (>600 products) and eco-system to address specific and high-margin applications:
  - embedded control, gate driver, MOSFETs, software, P2S
  - entire eco-system with digital twins
  - simulation environment (esp. for motor control)

### Infineon's revenue growth



## OptiMOS™ 7:

# setting industry standard with lowest R<sub>DS(on) X</sub> Area





Outstanding electrical & thermal conductivity



Less switching losses



Unique copper metallization



Ruggedness improvement



High avalanche current capability



2019 OptiMOS™ 6 OptiMOS<sup>TM</sup> 7

-25%

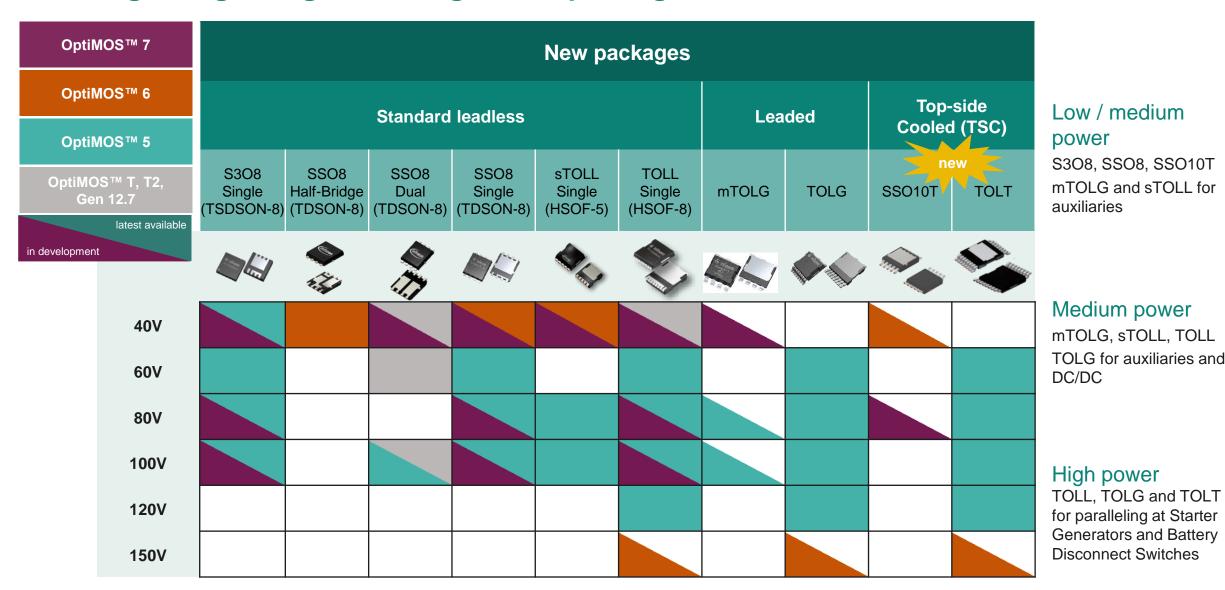
R<sub>DS(on)</sub> vs. OptiMOS™ 6

-40%

R<sub>DS(on)</sub> vs. OptiMOS™ *t* 

# Infineon offers the most comprehensive automotive MOSFET portfolio featuring a large range of voltages and packages





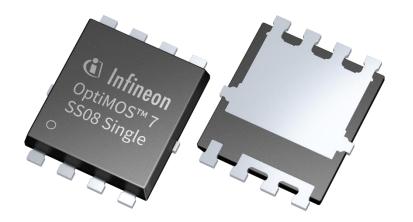
# OptiMOS™ 7: leading products in mass production more in sample phase



## In Production

40V family for 12V board-net

<u>IAUCN04S7N004</u> (SSO8, 0,44mOhm) <u>IAUCN04S7N005</u> (SSO8, 0,55mOhm)



# In development

80&100V family for 48V board-net

Engineering sample available SOP 2024

# F-RAM External flash



## F-RAM supports high endurance data logging for predictive maintenance

### WHY

- Inverter is the most essential part of EV
- Log key parameters motor position, current, voltage, temperature, etc...
- Enables predictive maintenance or failure analysis
- Capture real-time data instantly in a continuous fashion
- Achieve highly reliable inverter design



### **HOW**

- F-RAM with high endurance, without software overhead
- Memory with high reliability
- Instant data capture, no software/firmware overhead
- Endurance for 100 trillion write-cycles to log data for 20 years, data retention for 100 years
- AEC-Q100 qualified



# FRAM enables data logging & software update use cases esp. for predictive maintenance



## **Features**

- 2, 4, 8 & 16Mb densities
- SPI &QSPI interfaces
- Ultra-low-energy
- 1.71V to 1.89V & 1.8V to 3.6V operating voltages
- Datalogging of vital parameters e.g. current, frequency and case temperature to support predictive maintenance & condition monitoring
- EXCELON™ F-RAM homepage



## **Benefits**

- Instant data capture. No software/firmware overhead.
- Low Power Memory.
- Endurance for 100 trillion write-cycles to log data at 10 µs for 20 years
- Data retention for 100 years
- AEC-Q100 qualified and ASIL-B functional safety compliant

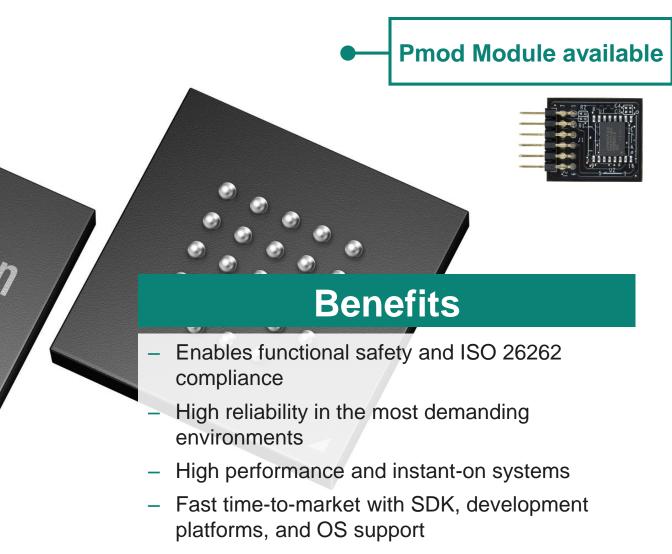
QS available

# SEMPER™ NOR Flash enables expansion Memory for software update use cases



## **Features**

- S25HL512T, ASIL-B compliant and ASIL-D ready
- Endurance flex architecture: Up to 25 years of data retention or 1+ million cycles endurance
- Up to 400 MB/s read bandwidth and <100ns access time</li>
- SEMPER™ Solutions Hub design enablement
- Pmod connector for Flash memory expansion as part of Hybridkit reference design
- Update Inverter software without down time
- Support eXecute in Place (XiP)
- SEMPER™ NOR Flash homepage



# **Evaluation kits**

## **HybridPACK™ Drive G2 Inverter Evaluation Kit**





Power Module	Driver	Sensor	Order code
IGBT 750V 1150A FS1150R08A8P3	1EDI3025AS	Swoboda CSM510HP2x	SP005739456 EV INV HPD2 SI FS1150 08
IGBT 1200V/520A FS520R12A8P1	1EDI3025AS	Swoboda CSM510HP2x	SP006038374 EV INV HPD2 SI FS520 12
SiC 750V/1 mOhm FS01MR08A8MA2	1EDI3035AS	Swoboda CSM510HP2x	SP005739468 EV INV HPD2 SIC FS01 08
SiC 1200V/2 mOhm FS02MR12A8MA2	1EDI3035AS	Swoboda CSM510HP2x	SP006056146 EV INV HPD2 SIC FS02 12

The inverter evaluation kits comes with two boards: power board & logic board.

- power board includes 1)power module 2) cooler 3)DC-link capacitor 4)gate driver
- logic board includes AURIX 2G TC3x7, pre-installed software, USB stick

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