Fast EV-Charging with CoolSiC™

Application Presentation

Fast DC EV Charging empowered by Infineon

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Electro-mobility market - key influence factors

To **increase sustainability, electrification of mobility** is inevitable – in both, **private and public** transport segment

OEMs strategies
Fast growing demand for electric vehicles

Technologies
Improvements in technologies and better application knowledge increase attractiveness of e-Mobility

Buyer decision

Regulations
Government regulations on CO_2 emissions

Costs
Continuous decrease in battery costs

Infrastructure
Fast growing demand for electric charging infrastructure

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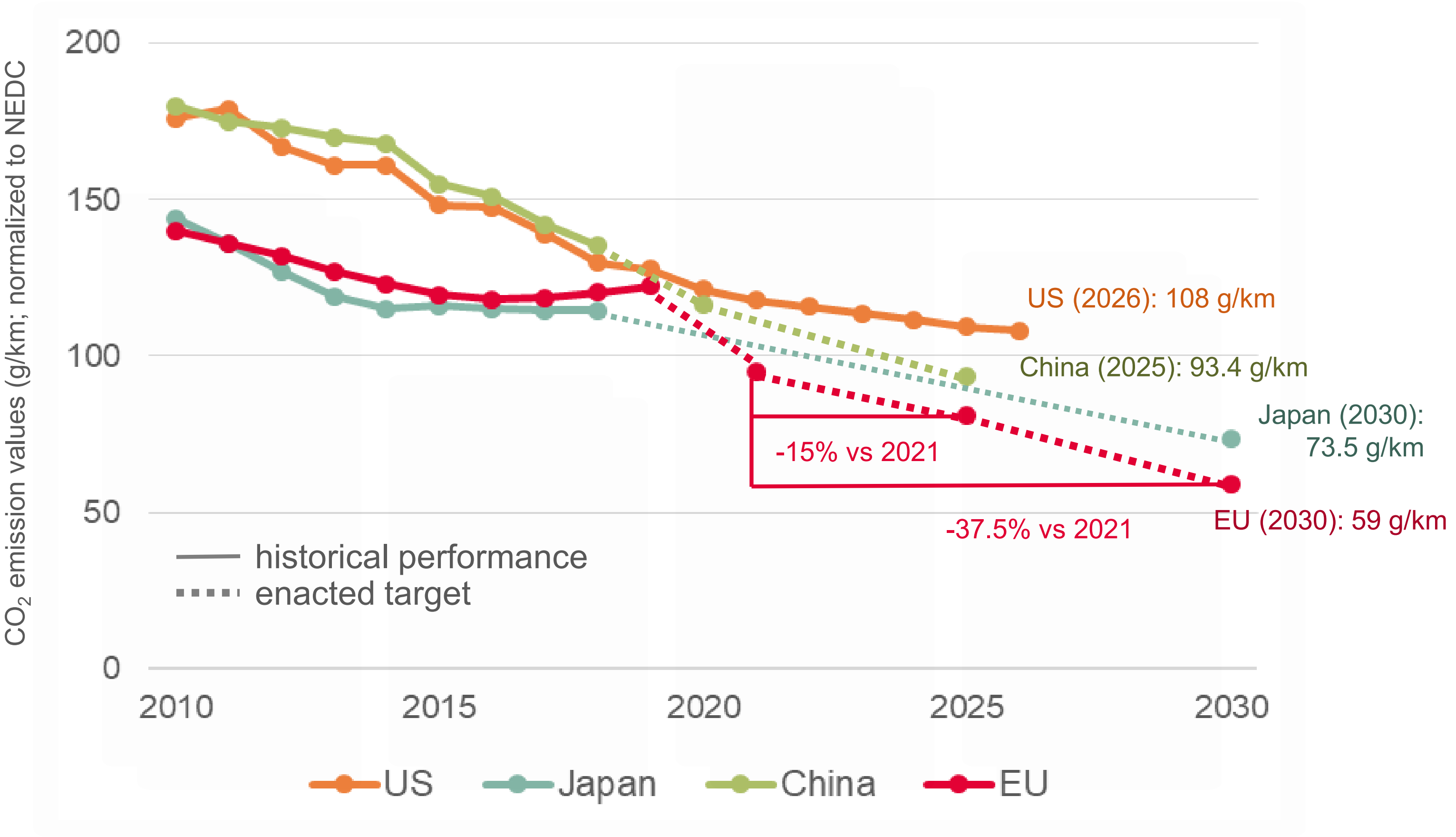
The EV market is witnessing strong growth driven by more stringent legal guidelines, demanding significant infrastructure investment

Passenger car CO_2 emission development and regional regulations



Source: The International Council on Clean Transportation (ICCT): *Passenger vehicle fuel economy*. May 2020.

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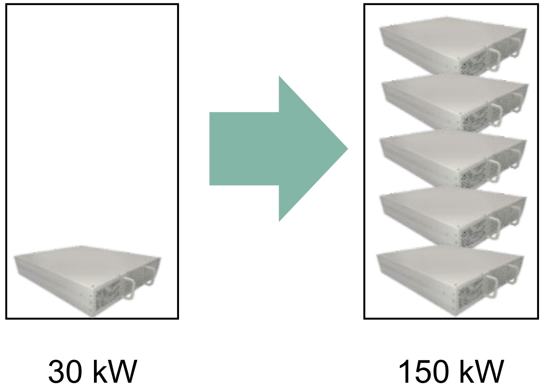
Growing penetration of electro-mobility will drive roll-out of DC charging infrastructure

DC charging system		Charging time**
DC wall box and subunit* Uni- and bi-directional topologies	20 kW (2 subunit of 10 kW)	120 min
Commercial high power charger Single unit and modular subunit designs	50 kW (3 subunits of 20 kW each)	48 min
	150 kW (5 subunits of 30 kW each)	16 min
Hyper fast charger Single unit and modular subunit designs	350 kW (6 subunits of 60 kW each)	7 min



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*) Subunit: A power electronic arrangement build from both active and passive components to convert AC input to dedicated DC output. Often referred to as "module".

**) Charging time for 200 km

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Europe's most powerful 400 kW DC charger: CoolSiC™ for ultra-fast pit stops

INGEREV® RAPID ST400 from Ingeteam

- Charging time for EV at a level of refueling a conventional car: A stop for 10 minutes allows for an 80% battery charge
- Operates successfully at real life conditions
- Ultra-fast charging points guarantee optimal distribution of the available power between the four vehicles that can be connected simultaneously

Latest Infineon chip and module technology

- CoolSiC™ enables high switching speeds with lower switching losses for shorter charging times and charging stations that are about one-third smaller
  - EasyDUAL™ power modules with CoolSiC™ technology

Market News: Link, 8 Jul 2020

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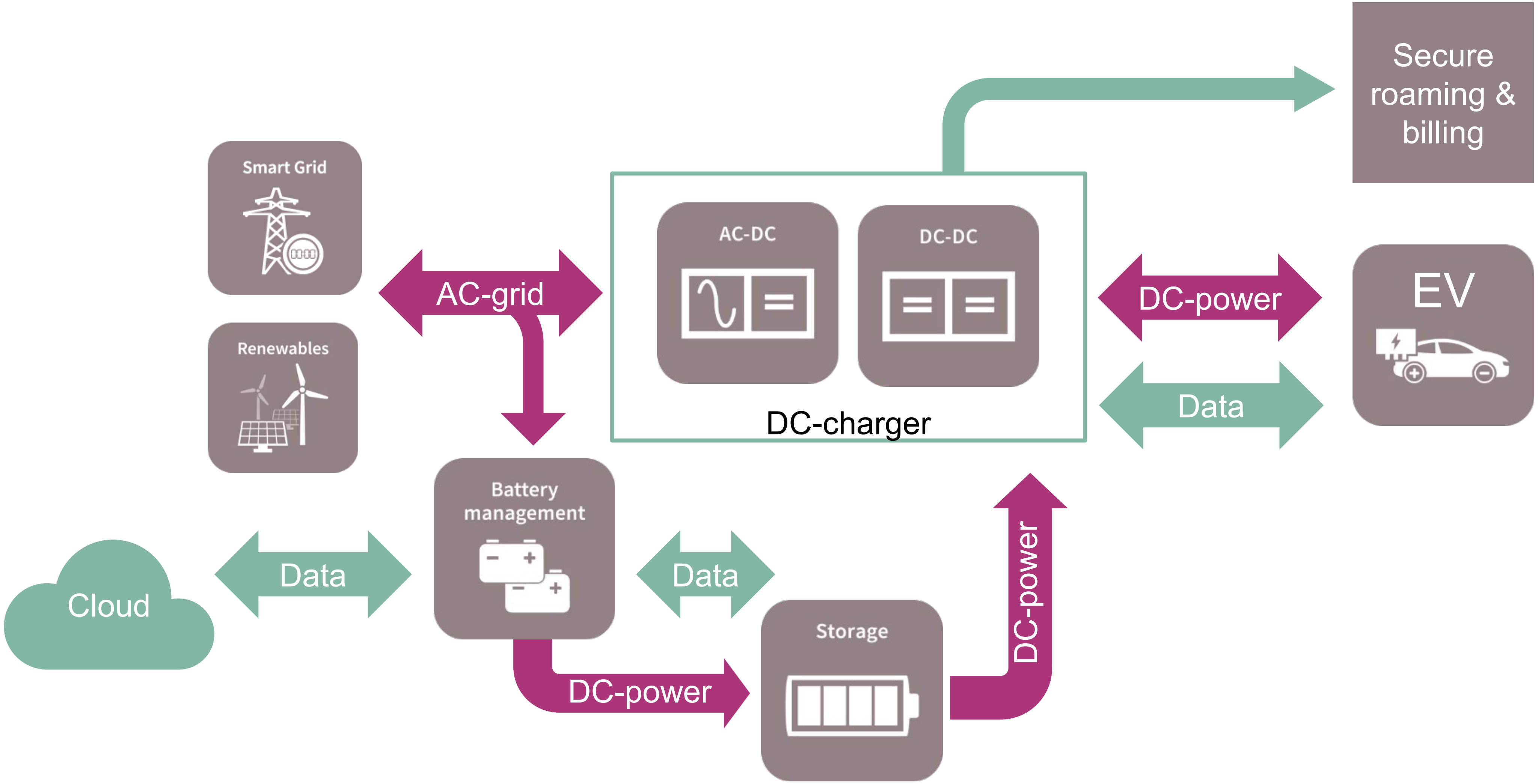
Structure of DC EV charging system



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Application trends are supported by Infineon's comprehensive DC charging ecosystem portfolio

High power density

Efficiency

High charging power

Scalability

Control

Security

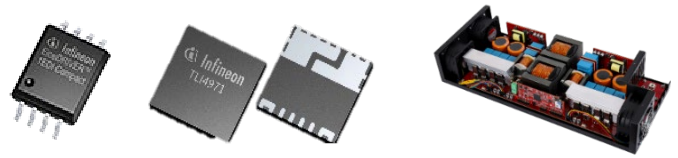
Safe drive and Sense

Easy to use

CoolMOS™ , IGBTs and CoolSiC™

Discrete components and modules like Easy and Econo family

AURIX™, XMC™, OPTIGA™



EiceDRIVER™, XENSIV™, Reference Designs

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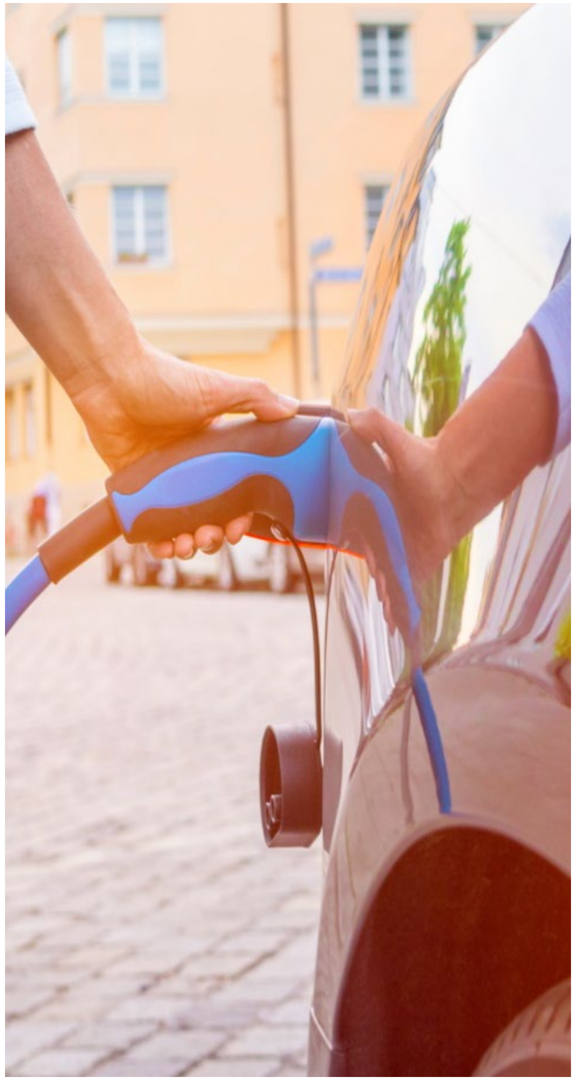
Efficiency is the key for modular high power DC charging

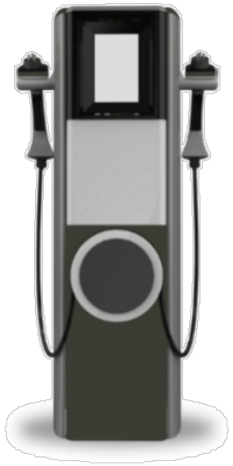


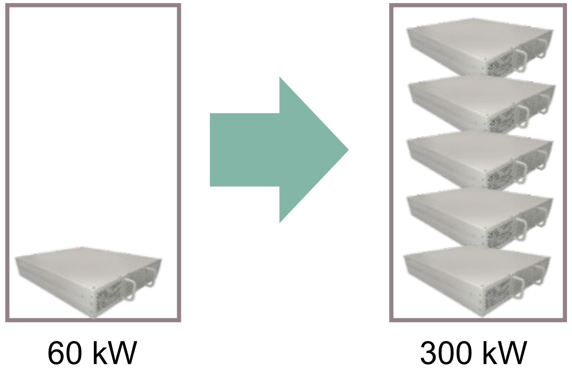
High-power charging stations

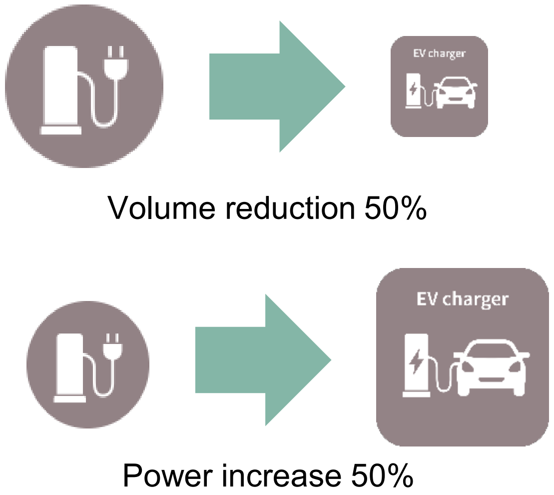
- Reduced size and weight of high power charging stations
- Charging piles with > 150 kW are built by 30-50 kW subunits today
- Power per subunit increasing towards 75 kW
- Subunits targeting 19‘‘-rack x 800 mm design

Higher power density needs efficiency optimization

- Modular designs to upgrade system power levels on demand are state of the art
- High power density in 19‘‘-rack design requires liquid cooling
- Higher power density with SiC allows for system size reductions of up to 50 % or
- 50 % power increase from the same space







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DC EV charging applications – system requirements for the application

- **Battery charging** is a mostly **constant current** application with **typically low demand in dynamics**

- Thermal cycling 10,000 – 30,000 cycles/year
- 15 – 20 years of service

- Ultra-high-power charging > 350 kW
  - Up to 1000 V_{DC} and up to 500 A

- Wide variation of DC output voltage
  - 200 V to 920 V

- **Efficiency** target **98%** (currently 95%)

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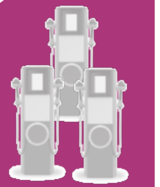
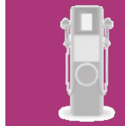
Infineon’s power solution positioning for DC EV charger



Charging station



Charging pile

Wallbox / DC-subunits

	Discrete solutions	Module solutions	Gate driver solutions
350 kW	Modular solution is recommended	Stacked modular solutions 6 x 60 kW 100 kW 100 kW 100 kW	EiceDRIVER™ Enhanced X3A/D (1ED34/38xx)
120/150 kW	4/5 x 30 kW	Stacked 50 kW modular solutions 50 kW 50 kW 50 kW EconoDUAL™ EconoPACK™4	EiceDRIVER™ Enhanced X3A/D (1ED34/38xx) EiceDRIVER™ Compact X3C (1ED31xx)
50/60 kW	Stacked 20 / 30 kW discrete solutions 20 kW 20 kW 20 kW 30 kW 30 kW	Easy CoolSiC™ EconoPACK™4	EiceDRIVER™ Enhanced X3A/D (1ED34/38xx) 1ED-F2 / 2ED-FI EiceDRIVER™ Compact X3C (1ED31xx) 1ED-MF/AF
30 kW*	CoolMOS™ 7 CoolSiC™ IGBT TRENCHSTOP™ 5	Discrete solution is recommended	EiceDRIVER™ Enhanced X3A/D (1ED34/38xx) 1ED-F2 / 2ED-FI EiceDRIVER™ Compact X3C (1ED31xx) 1ED-MF/AF
20 kW*	CoolMOS™ 7 CoolSiC™ IGBT TRENCHSTOP™ 5	Discrete solution is recommended	EiceDRIVER™ Enhanced X3A/D (1ED34/38xx) 1ED-F2 / 2ED-FI EiceDRIVER™ Compact X3C (1ED31xx) 1ED-MF/AF

Microcontroller: XMC1000, XMC4000, Optiga™
Current sensor: TLI4971

350 kW modular solutions

Up to 150 kW grey area

≤ 60 kW discrete solutions

* DC charger subunit or DC charger

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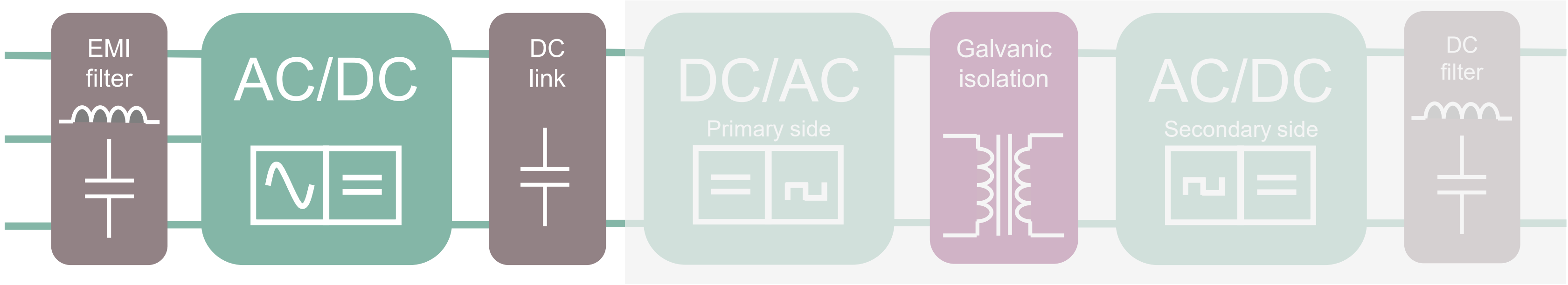
Commonly used topologies for AC/DC conversion

Rectifiers exist in different forms and types



EMI filter

AC/DC

DC link

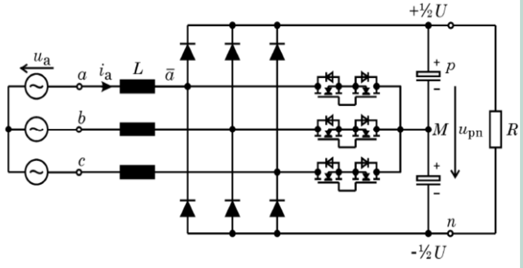
DC/AC Primary side

Galvanic isolation

AC/DC Secondary side

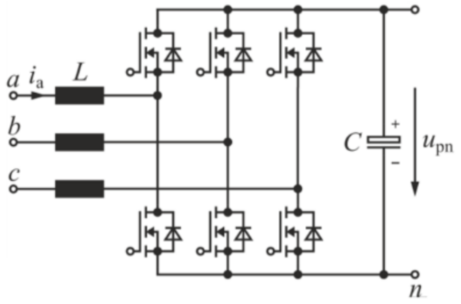
DC filter

< 50 kW design



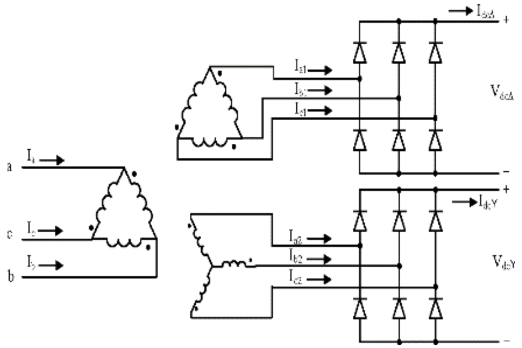
Vienna rectifier

> 50 kW design



Active front end

> 100 kW design



Diode rectifier

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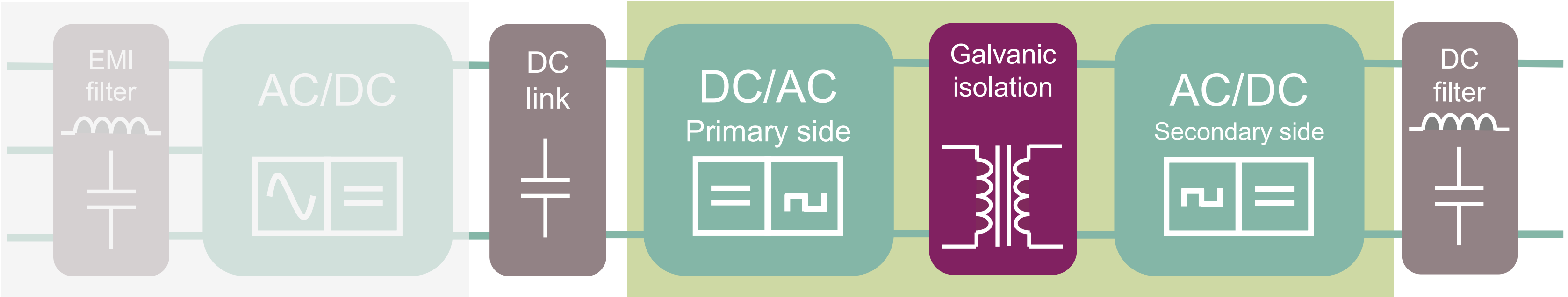
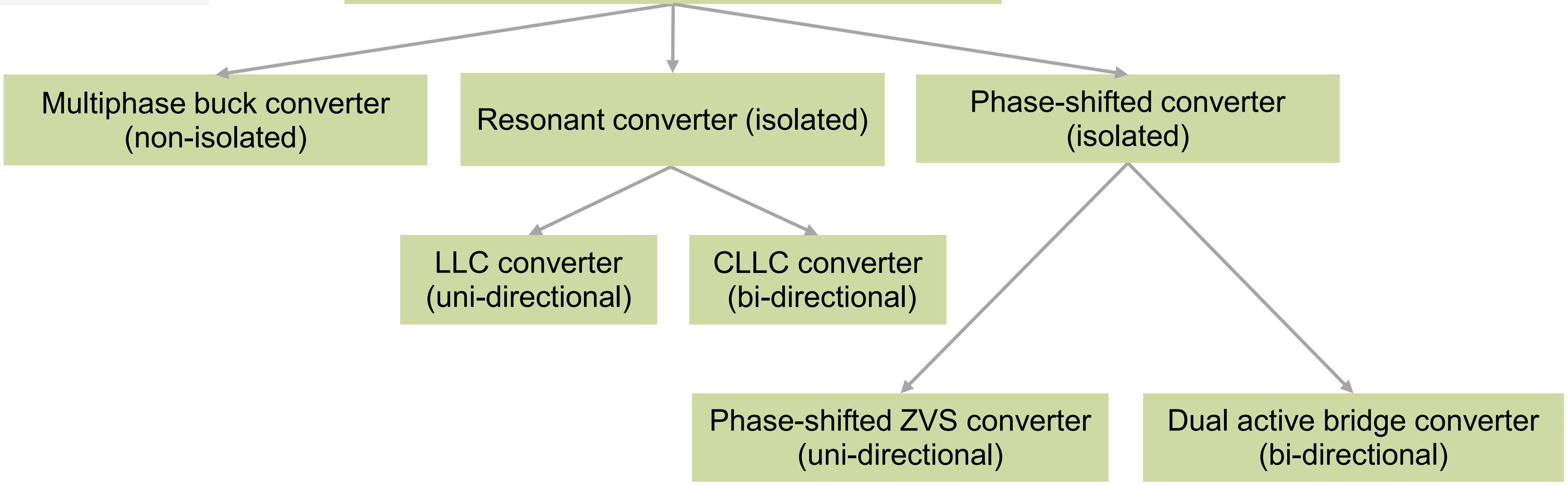
DC/DC power conversion topologies

DC-DC converter also exist in different types





Multiphase buck converter (non-isolated)

Resonant converter (isolated)

- LLC converter (uni-directional)
- CLLC converter (bi-directional)

Phase-shifted converter (isolated)

- Phase-shifted ZVS converter (uni-directional)
- Dual active bridge converter (bi-directional)

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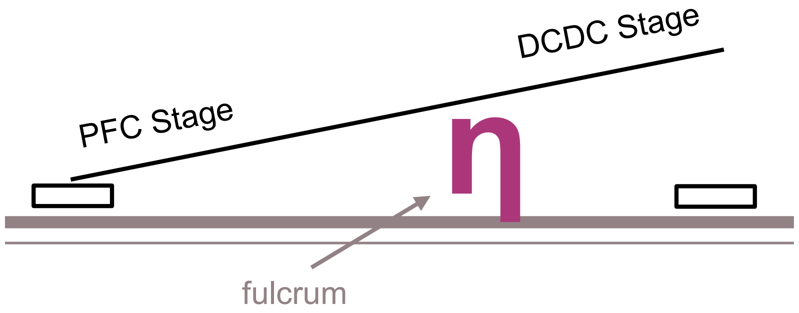
Infineon Proprietary

Power density is driven not only by technology: trade-offs in the inverter design

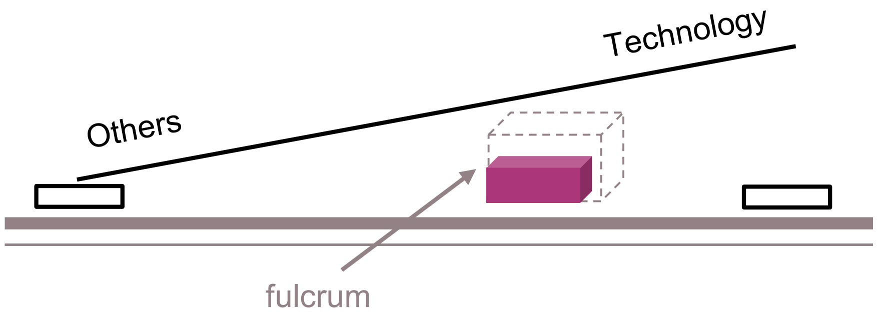
1. 2 level
2. Vienna
3. 3 level

1. LCC /CLLC
2. PS FB ZVS
3. Dual Active Bridge



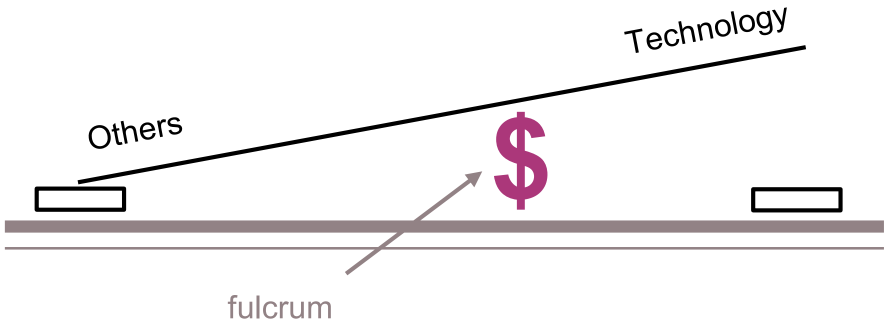
1. Functionality
2. Topology
3. Packaging

Switching frequency



1. Topology
2. Cooling
3. Switching frequency
4. Voltage Class

1. TRENCHSTOP^{TM}
2. CoolMOS^{TM}
3. CoolSiC^{TM}
4. CoolGaN^{TM}



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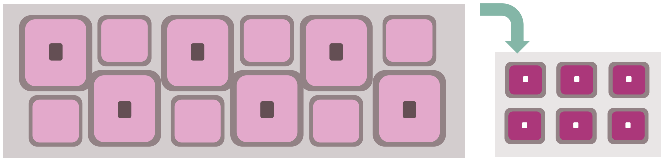
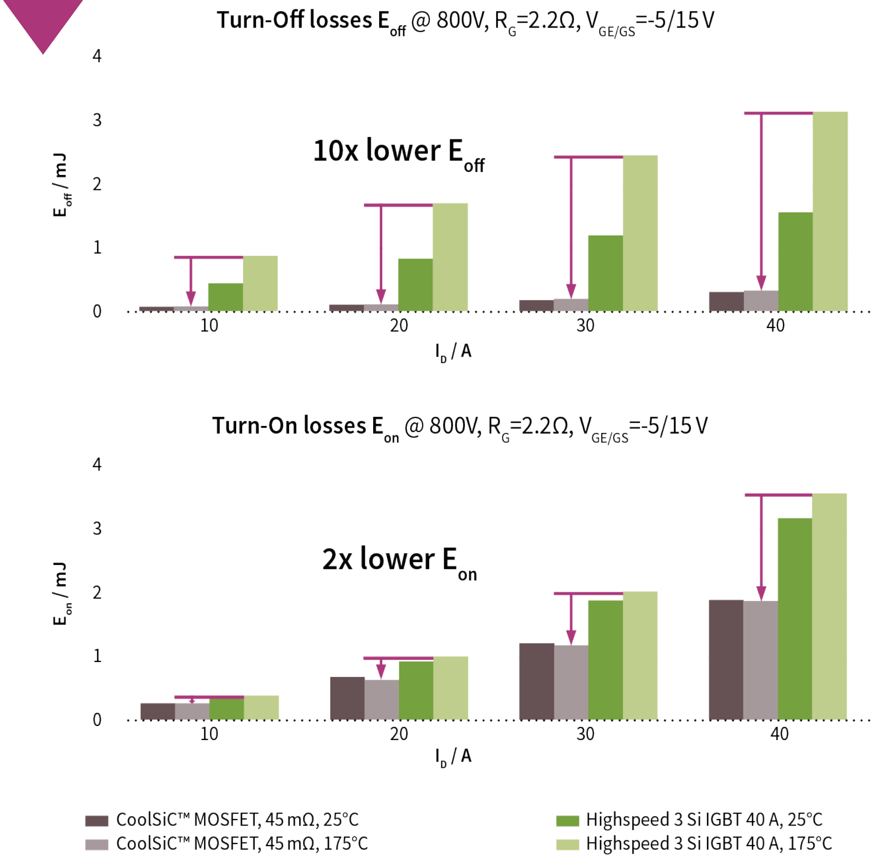
SiC MOSFETs – what differentiates them from IGBTs?

Benchmark in switching losses

Integrated freewheeling diode

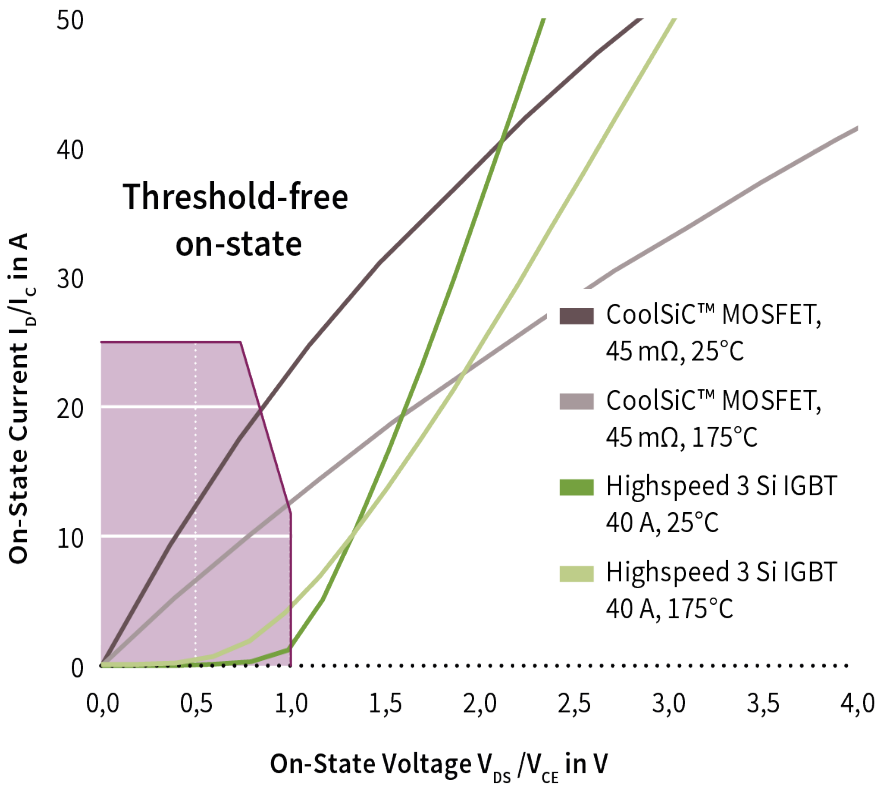
Knee voltage free on-state




Turn-Off losses E_{off} @ 800V, R_G=2.2Ω, $V_{GE/GS}$=-5/15 V

Turn-On losses E_{on} @ 800V, R_G=2.2Ω, $V_{GE/GS}$=-5/15 V

Output characteristic



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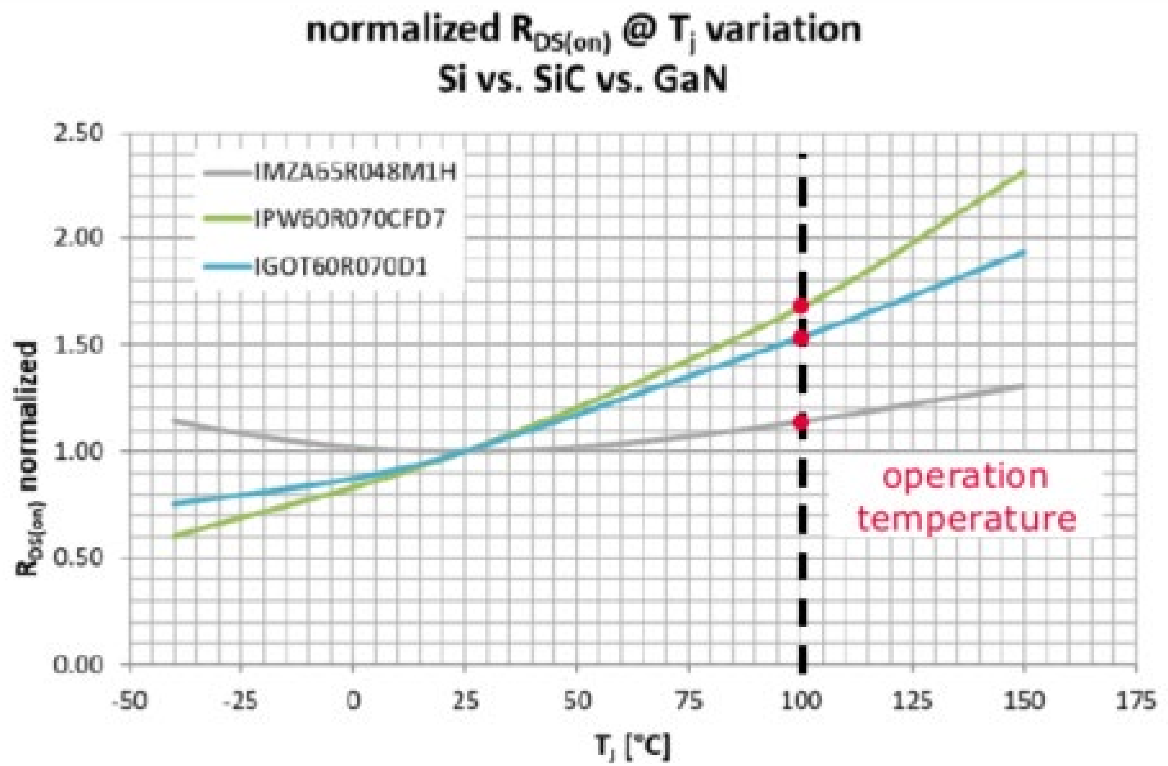
$R_{DS(on)}$ over junction temperature (normalized)



- Considering the thermal behavior of the $R_{DS(on)}$, CoolSiC™ shows the best performance as the $R_{DS(on)}$ increase over the T_J is much smaller
- Multiplication factor kappa (k) of the typical $R_{DS(on)}$ for hot operation:

Operation temperature T_J = 100 °C

CoolMOS™	→	**k = 1.67**
CoolSiC™	→	**k = 1.14**
CoolGaN™	→	**k = 1.53**

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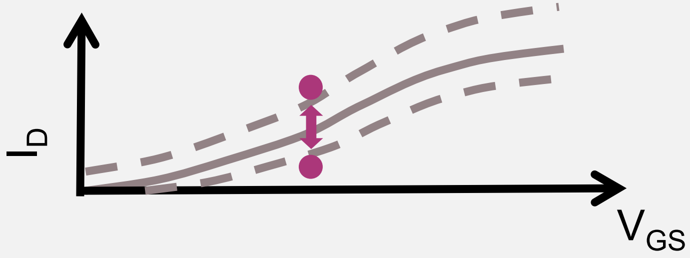
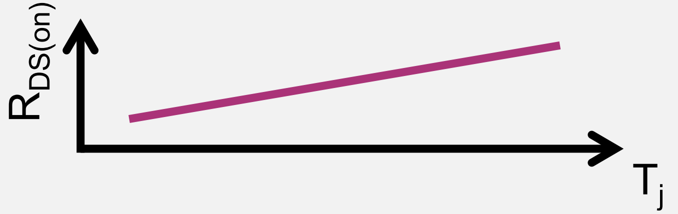
A practical example of a CoolSiC™-based EV Charger design

“Softer” transconductance



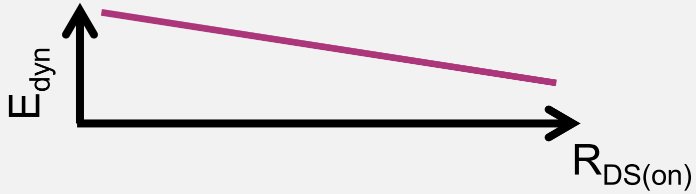
Larger increase in RDS(on) with temperature so a strong positive feedback



Paralleling CoolSiC™ devices

Slight increase in switching losses due to temperature

Correlation that higher RDS(on) parts have lower switching losses



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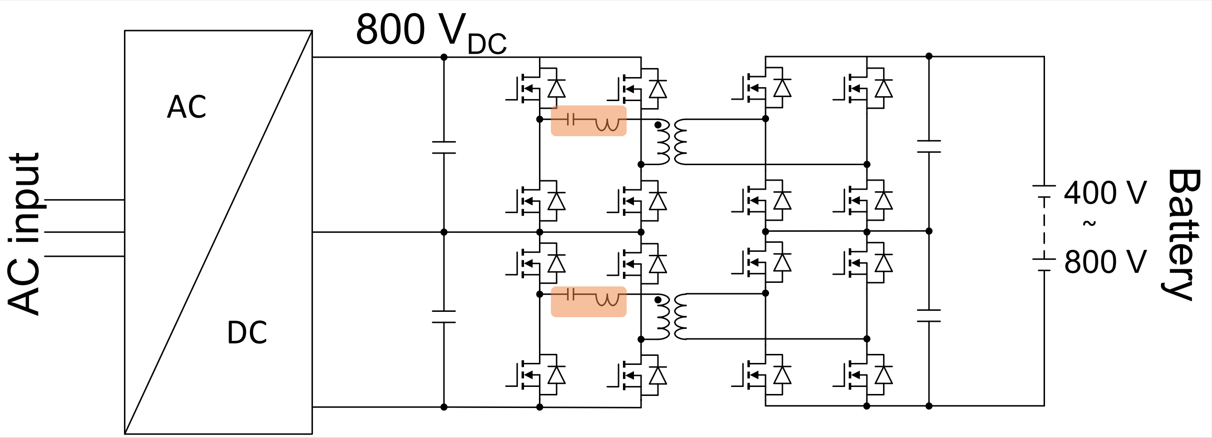
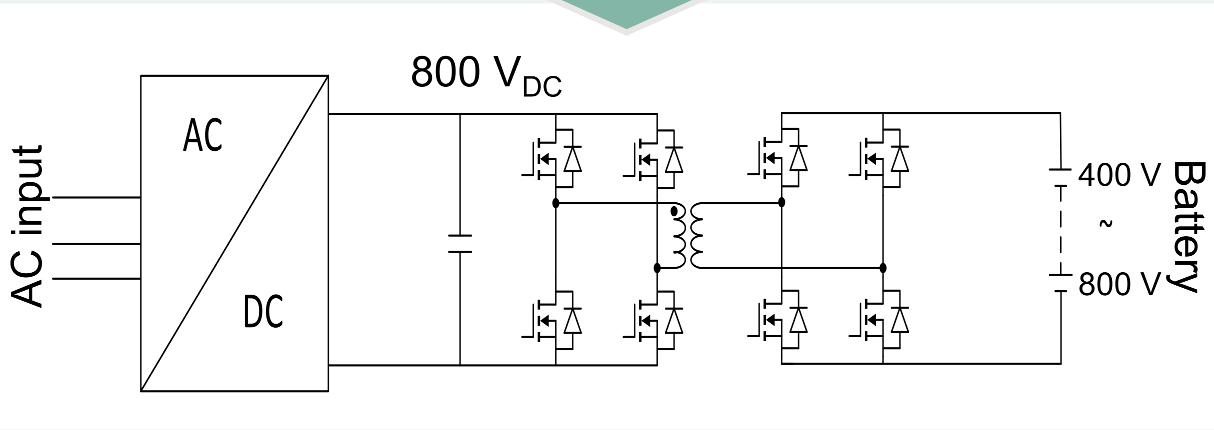
CoolSiC™ MOSFET
Enables simpler hard-switching solution



EV-Charging

**650 V Si SJ MOSFET in DC/DC stage:
2x full-bridge LLC**

Si to SiC



1200 V SiC MOSFET DC/DC:

- Simple hard-switching topology
- Less control effort
- Reduced part count by 50%
- Especially attractive for bidirectional charging

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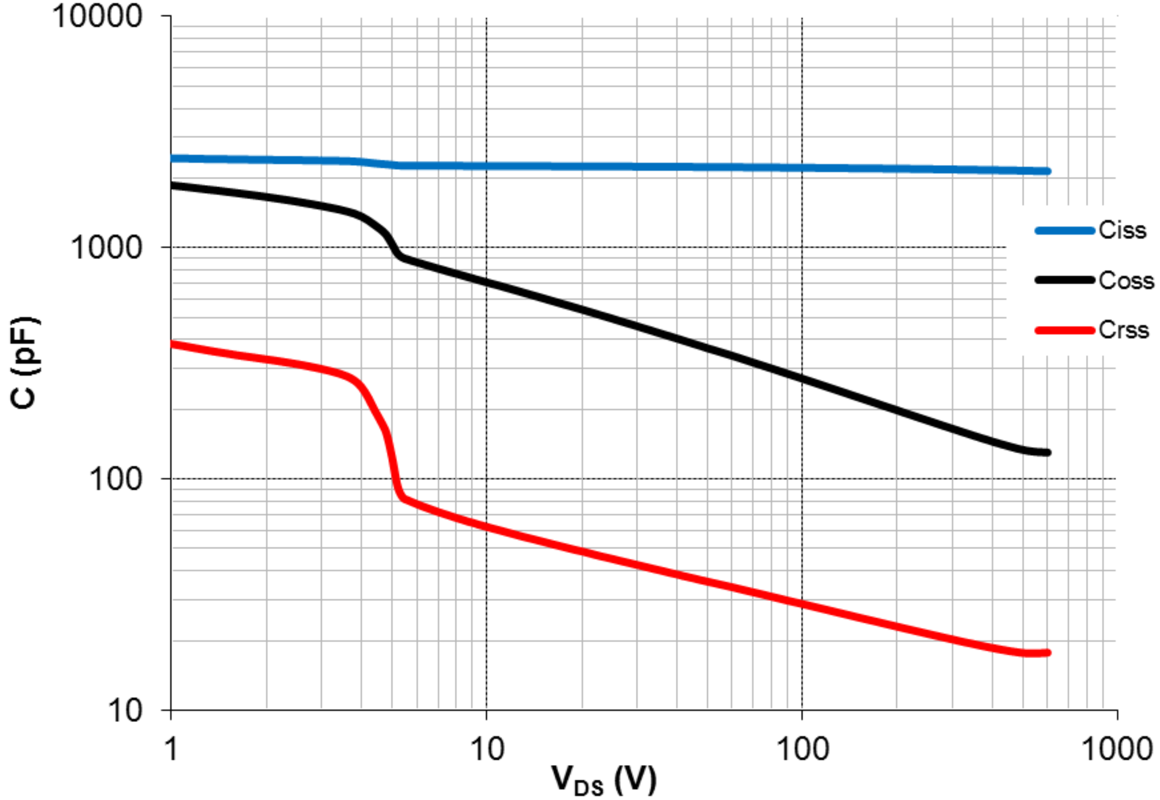
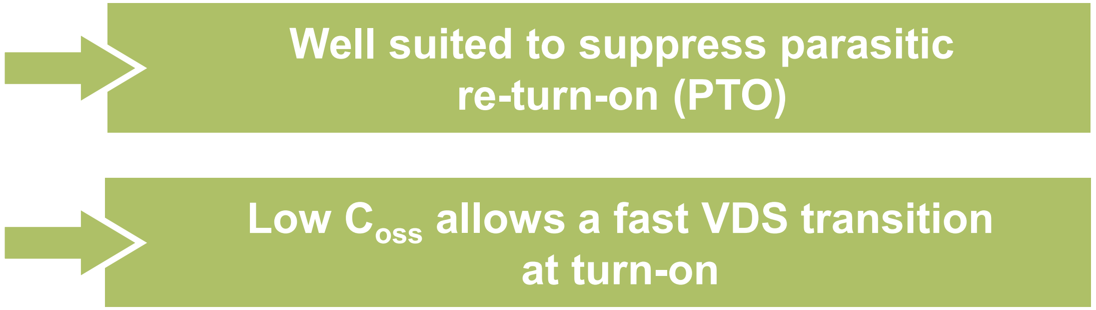
CoolSiC™ MOSFET suitable for ZVS operation

Device capacitances at 1 MHz, $V_{GS} = 0$



- $C_{iss} >> C_{oss} >> C_{rss}$
- Small C_{rss} (~10 smaller than C_{oss})



Well suited to suppress parasitic re-turn-on (PTO)

Low C_{oss} allows a fast VDS transition at turn-on

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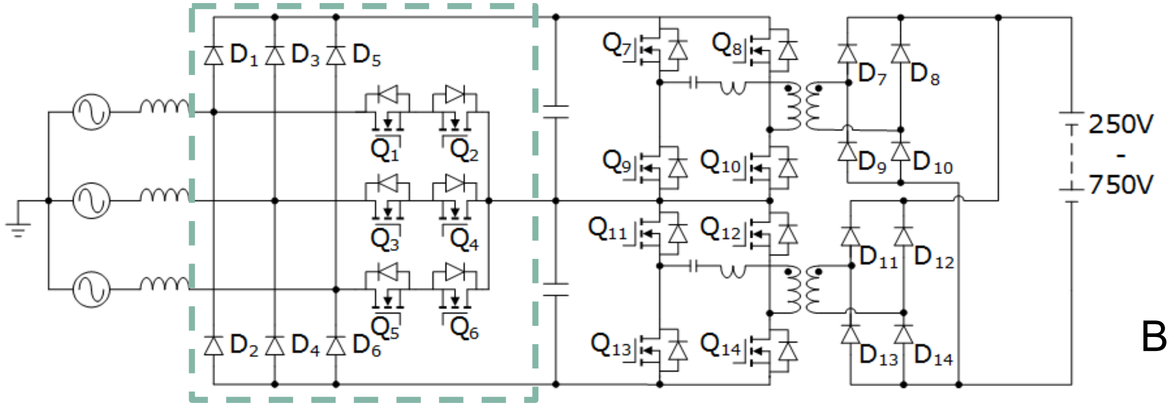
Charging station: 1200 V CoolSiC™ diode for high efficiency and high output power – 50% lower losses

Ev charging

Three-phase Vienna PFC

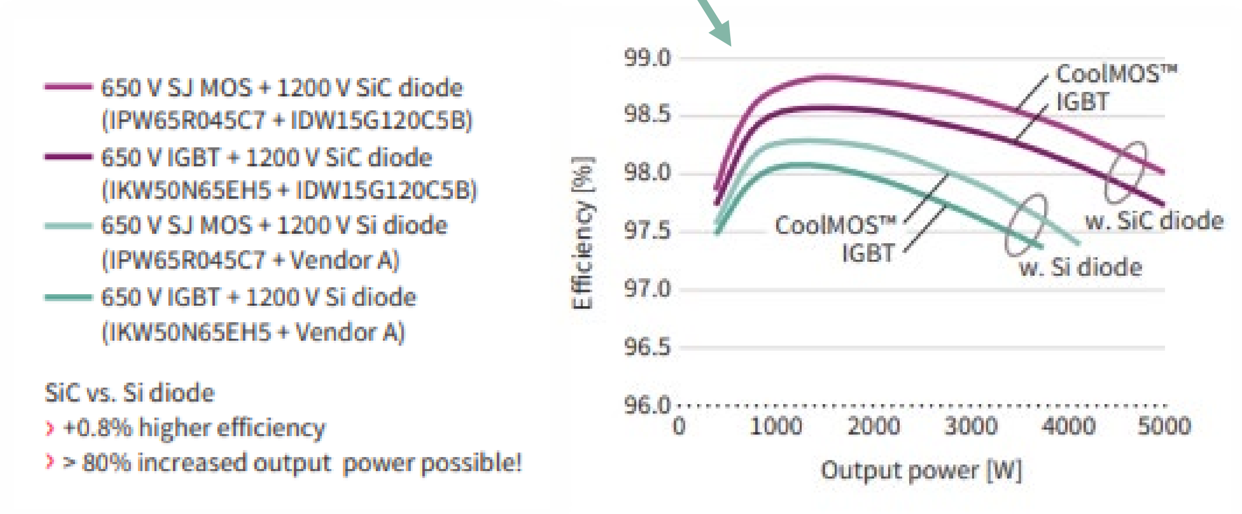
2x full-bridge LLC DC/DC converter

AC input



Battery

Comparison at 48 kHz



SiC vs. Si diode
- +0.8% higher efficiency
- > 80% increased output power possible!

SiC vs. Si diode:
- 0.8% higher efficiency
- Increased output power

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Figure of Merit: Correlation of device parameters

RDS(on)* Qoss

- Facilitates dead time / resonant current settings and enables higher frequency

⇄ **ZVS type DC-DC converter**

RDS(on)* Qrr

- Enables applications with repetitive hard commutation on the body diode

⇄ **PFC type AC-DC converter**

RDS(on)* Qg

- Reducing driving losses especially in light load conditions

⇄ **Light load efficiency**

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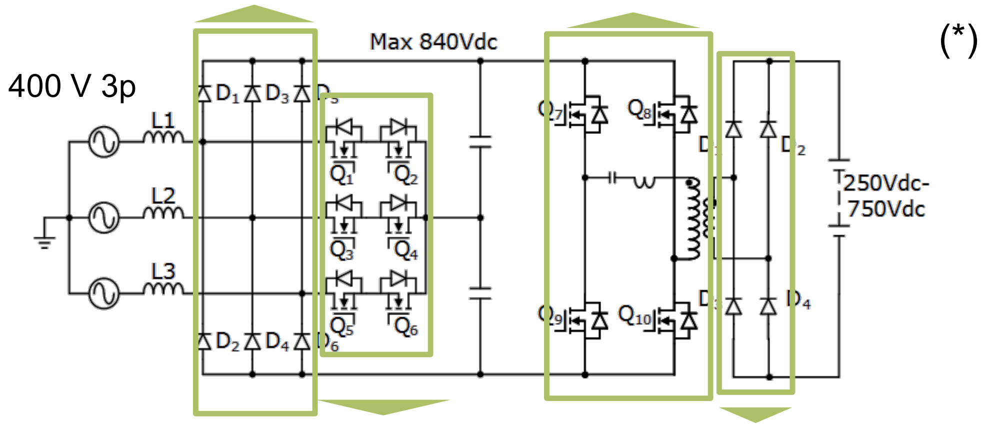
Proposed BOM for high efficiency 30 kW design

12x 1200 V CoolSiC™ Schottky diode

16x 1200 V CoolSiC™ MOSFET



12x 600 V CoolMOS™ P7

8x 1200 V CoolSiC™ Schottky diode

Stage	Switching Freq.	Devices	Product	Part number	Pcs
AC/DC	40 kHz		600 V CoolMOS™ P7	IPW60R024P7	12
			1200 V CoolSiC™ Schottky diode	IDWD40G120C5[2]	12
		Driver IC	EiceDRIVER™ 1ED	1EDI40I12AH	6
DC/DC	up to 300 kHz		1200 V CoolSiC™ MOSFET	IMW120R045M1	16
			1200 V CoolSiC™ diode	IDW40G120C5B	8
		Driver IC	EiceDRIVER™ 1ED	1EDI20I12AH	8
µC			XMC™ 4000 4x PWM timers	XMC4400-F100K512 BA	2

Key features & benefits

- Highest efficiency with CoolSiC™ technology
- BOM parts reduction
- Higher reliability
- Low design complexity
- Fast time to market

Application assumptions

- 30 kW, 75 A @400 V
- Air cooled
- Vienna rectifier
- 2 paralleled FB LLC
- DC link voltage 840 V

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and do not refer to the proposed bill of material.

[2]) coming soon

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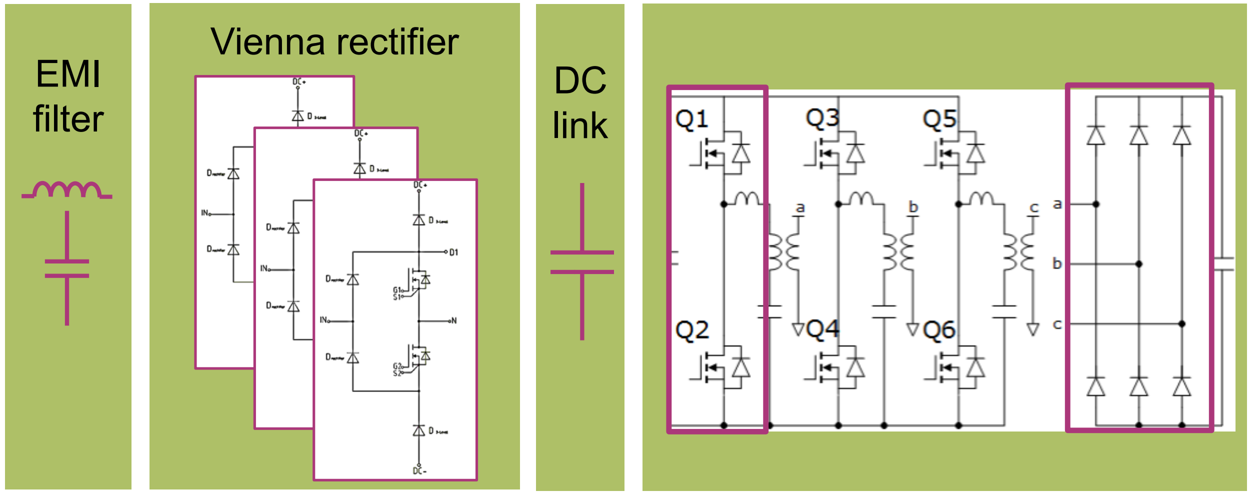
Proposed BOM for high efficiency 60 kW design

F3L15MR12W2M1

FF11MR12W1M1_B11

DDB2U60N12W1RF_B11



(*)

Stage	Switching Freq.	Devices	Product	Part number	Pcs
AC/DC	40 kHz		1200 V CoolSiC™ Easy 2B	F3L15MR12W2M1	3
		Driver IC	EiceDRIVER™ 1ED	1EDI40I12AH	6
DC/DC	120 to 140 kHz		1200 V CoolSiC™ MOSFET	FF11MR12W1M1_B11	3
			1200 V CoolSiC™ diode	DDB2U60N12W1RF_B11	2
		Driver IC	EiceDRIVER™ 1ED	1EDI20I12AH	6
µC			XMC™ 4000 4x PWM timers	XMC4400-F100K512 BA	2

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and do not refer to the proposed bill of material.

Key features and benefits

- Highest efficiency with CoolSiC™ technology
- BOM reduction
- Higher reliability
- Low design complexity
- Fast time to market
- Galvanic isolation
- No special infrastructure

Application assumptions

- 60 kW, 120 A @500 V
- Liquid cooled
- DC link voltage 840 V
- Switching frequency 120 kHz for DC/DC converter

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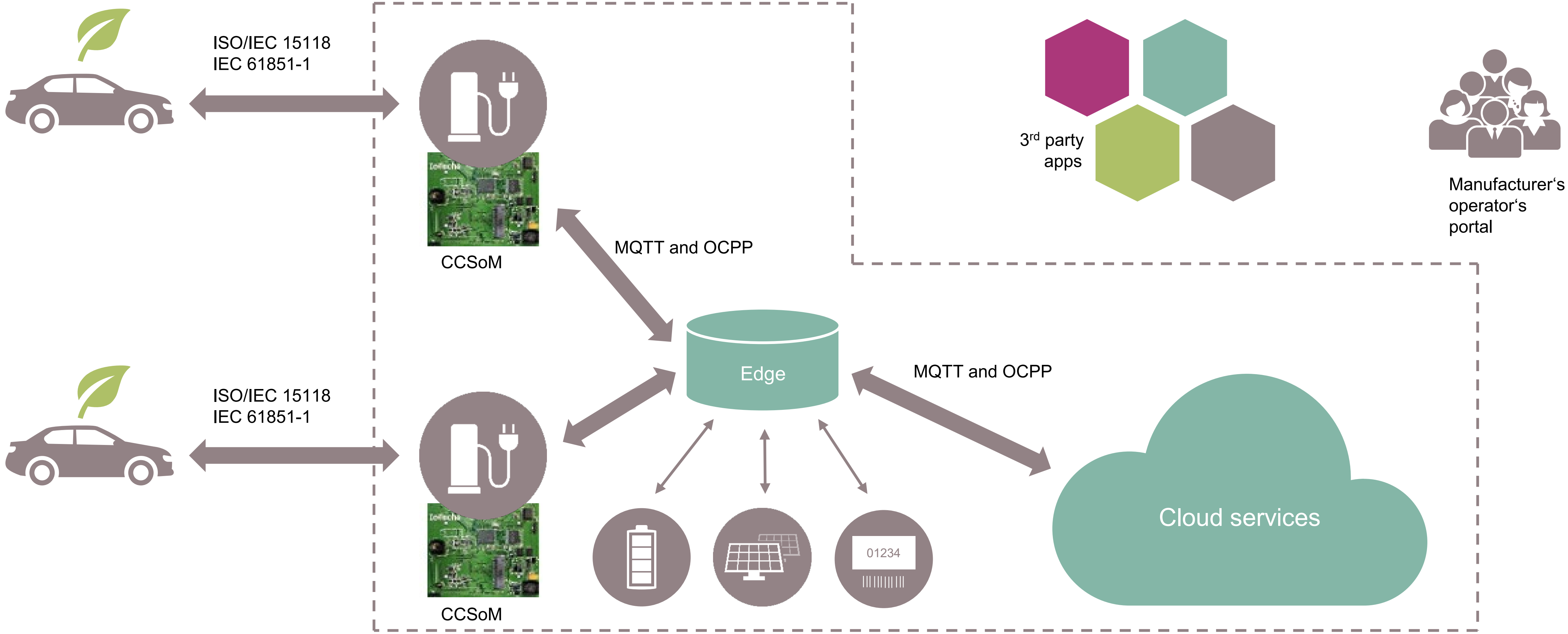
Why connectivity and security is relevant in EV charging



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Infineon overview on security, control and connectivity – Our Core Capabilities for DC EV Charging

Power

COMPUTE

Arm® Cortex® Processors

Mixed Signal MCU Architectures

Application Co-processors

PSoC®4
PSoC®6

XMC™1000
XMC™4000

HMI & Communication

CONNECT

Wi-Fi / BT Combo

embedded SIM

AIROC™
- CYW43/55xxx
- CYW20xxx, PSoC®4/6-BLE

OPTIGA™

ENHANCE

Graphics

NFC

PSoC®6
Next gen MCU
My-d™ NFC (SCS)

SECURE

Hardware security controllers

Device authentication

OPTIGA™
- Trust, TPM
- Connect
- Authenticate

CONTROL

Power Conversion

Motor Control

XMC™1000
XMC™4000

Capacitive / Inductive Sense

Wireless Charging

PSoC®4
PSoC®6

XMC™1000
(Spark)

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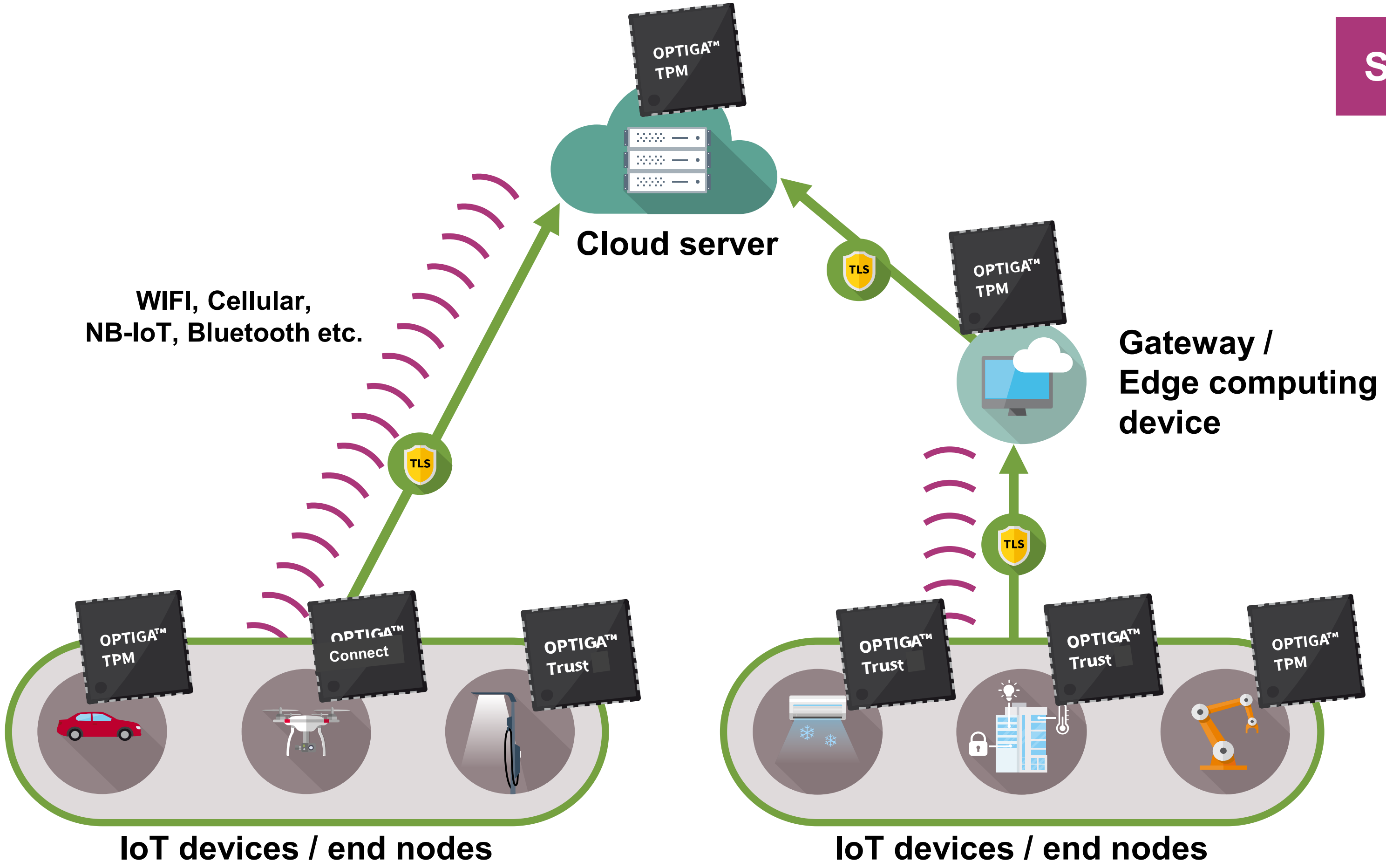
Security with OPTIGA^{TM} Trust & TPM
For Networks, Servers, Gateways and Connected Devices

CLOUD
Central Compute

EDGE-COMPUTE
Processing Data closer to where the data is generated

END-NODE
Device used to harvest Data



Secured Connectivity

The key for a secured delivery of Cloud-to-Edge connected applications is securing the device data flow that is transmitted in a client server architecture

Security controllers like OPTIGA^{TM} TPM and OPTIGA ™ Trust will enable a secured channel that is agnostic to the type of connectivity deployed

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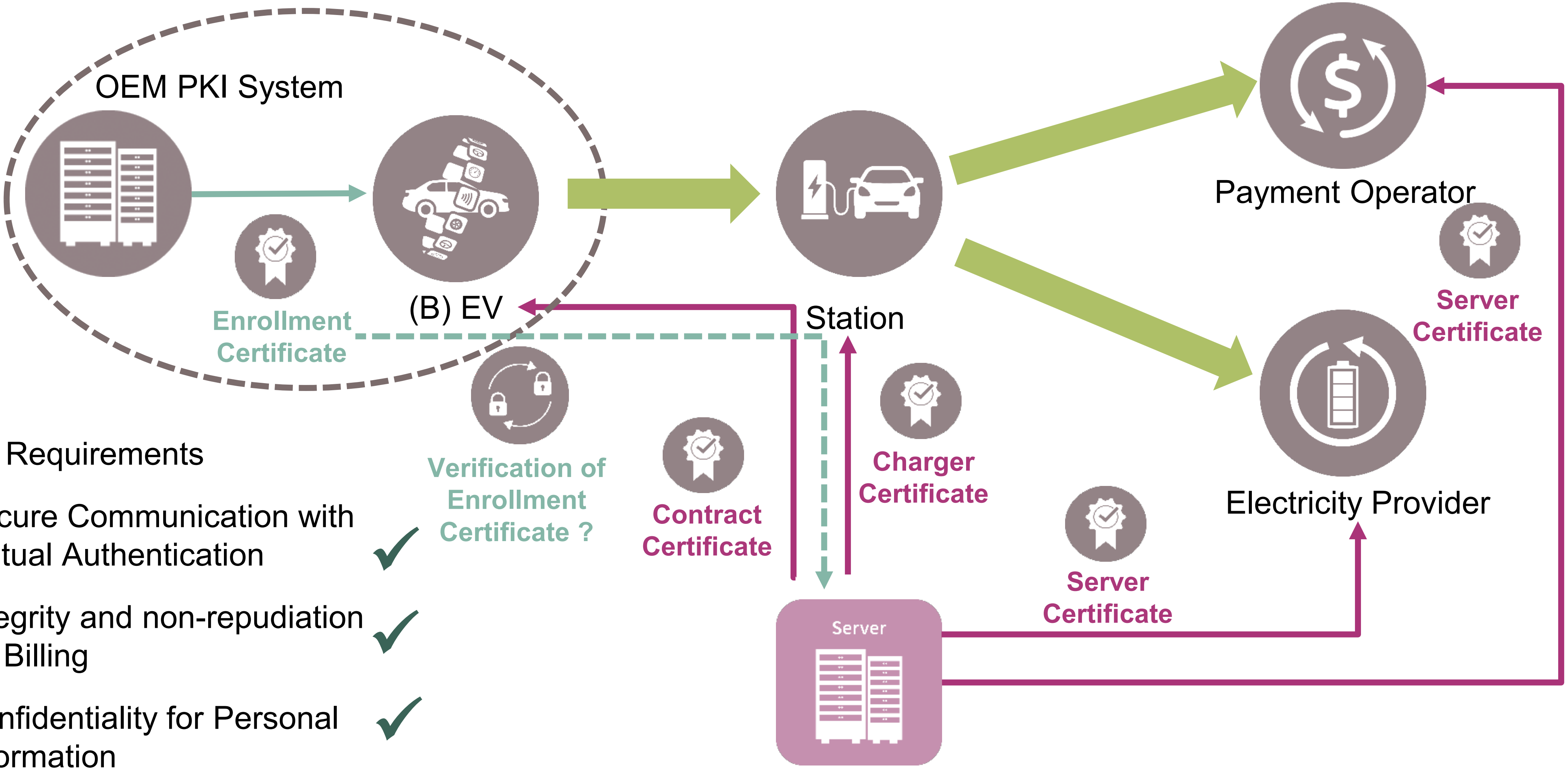
Securing an EV Charging Ecosystem using Security Controllers



Primary Requirements

- Secure Communication with Mutual Authentication ✓
- Integrity and non-repudiation for Billing ✓
- Confidentiality for Personal Information ✓

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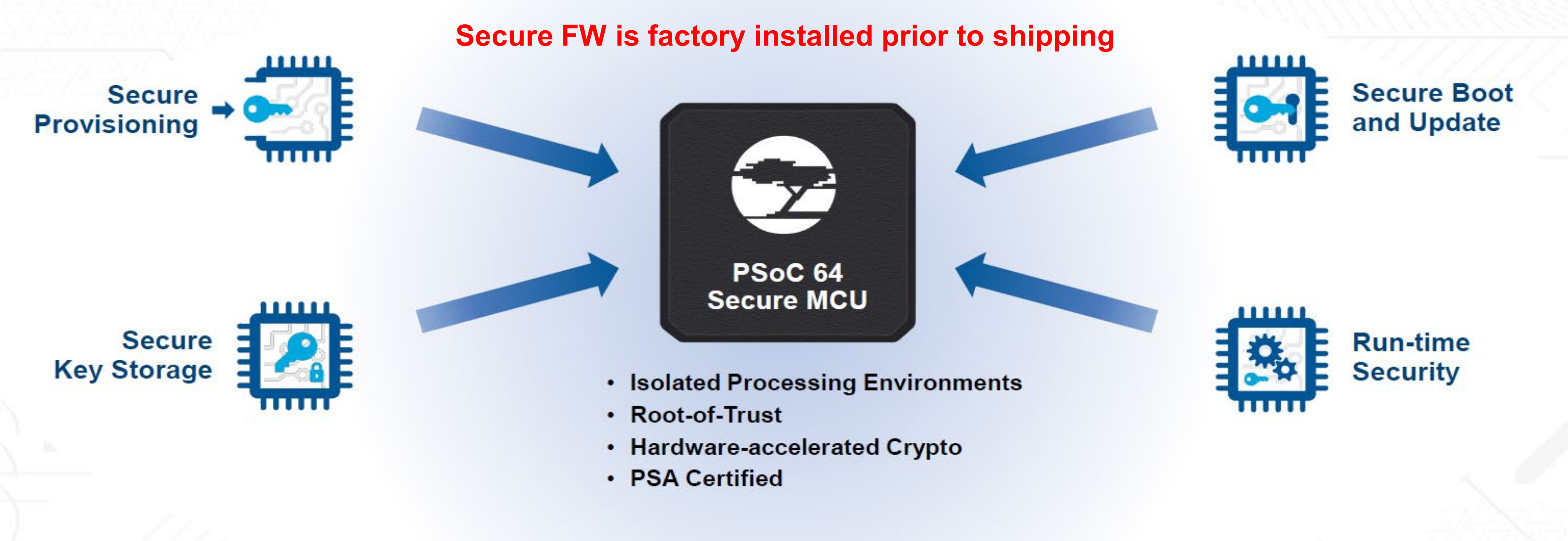
PSoC 64 – Packaging Option adds fully integrated Secure FW



Secure FW is factory installed prior to shipping

Secure Provisioning

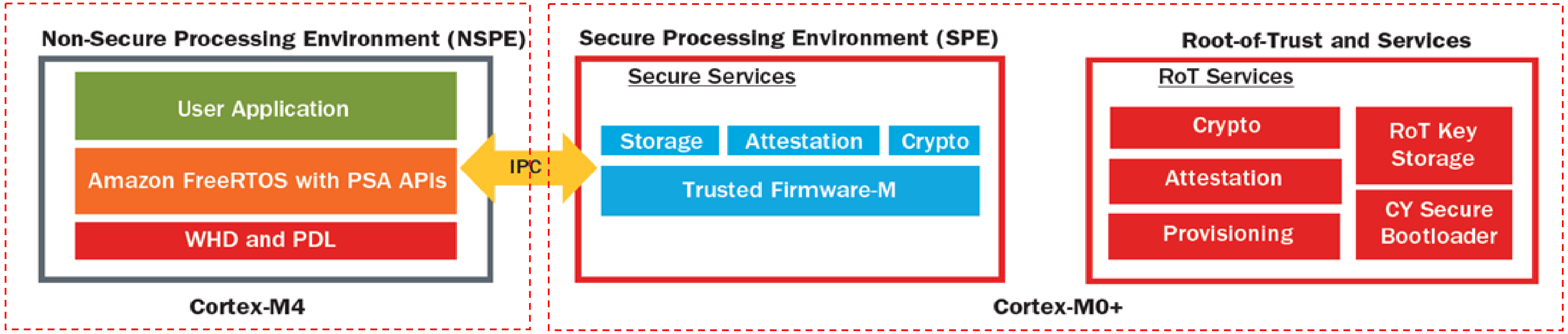
Secure Key Storage

Secure Boot and Update

Run-time Security

PSoC 64 Secure MCU

- Isolated Processing Environments
- Root-of-Trust
- Hardware-accelerated Crypto
- PSA Certified



Non-Secure Processing Environment (NSPE)

User Application

Amazon FreeRTOS with PSA APIs

WHD and PDL

Cortex-M4

IPC

Secure Processing Environment (SPE)

Secure Services

Storage | Attestation | Crypto

Trusted Firmware-M

Root-of-Trust and Services

RoT Services

Crypto

Attestation

Provisioning

RoT Key Storage

CY Secure Bootloader

Cortex-M0+

The best IoT MCU solution for managing data confidentiality, integrity and authenticity

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Cellular connectivity enabled – OPTIGA Connect IoT eSIM for Machine2Machine use cases

Connectivity anywhere in the world

eSIM

- Smallest size
- No physical SIM distribution
- Secure and remote updates
- High interoperability
- Robustness

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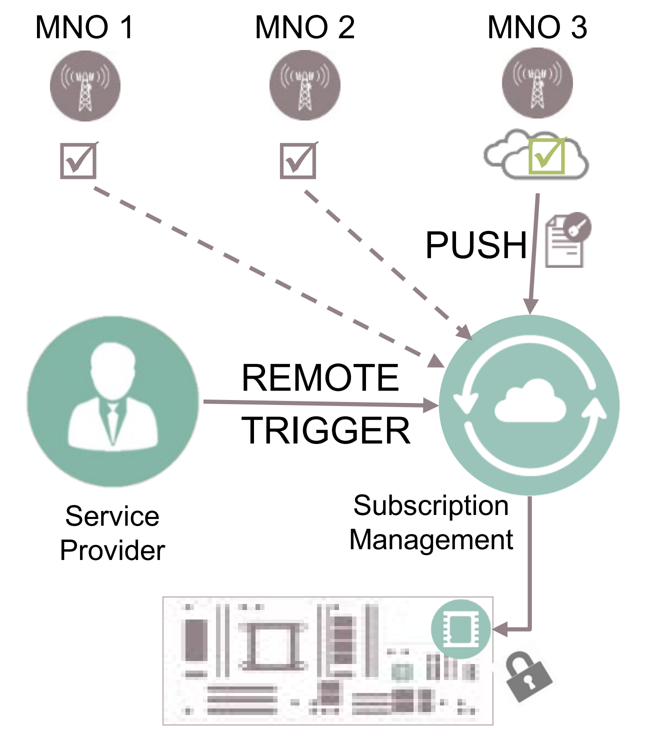
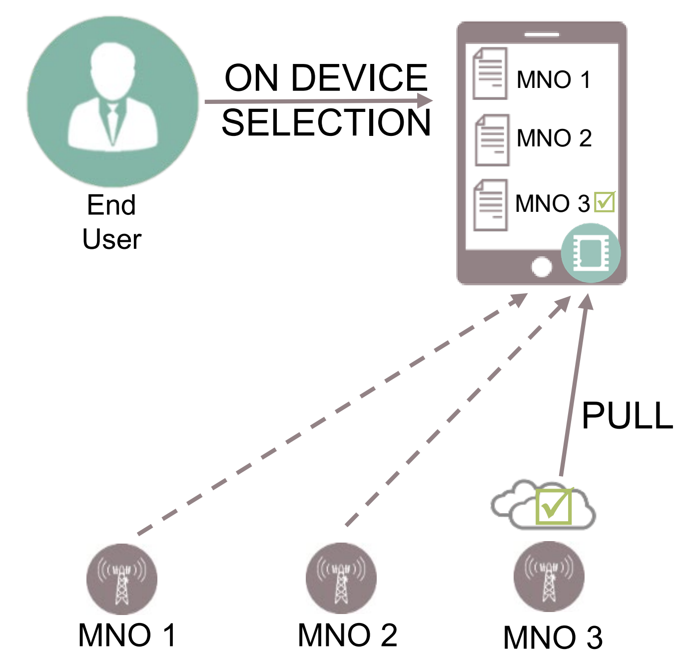
OPTIGA™ Connect IoT OC2321
Remote SIM Provisioning (RSP): M2M vs Consumer models

M2M Model (PUSH)



- eSIM comes with a pre-installed Profile for out of the box connectivity
- Service provider triggers MNO change
- New profile is pushed to the device

Consumer Model (PULL)



- eSIM is usually installed without pre-installed Profile. Wifi/BT connectivity is needed.
- End customer selects new operator using the device interface
- New profile is pulled by the device

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Fast DC EV Charging empowered by Infineon

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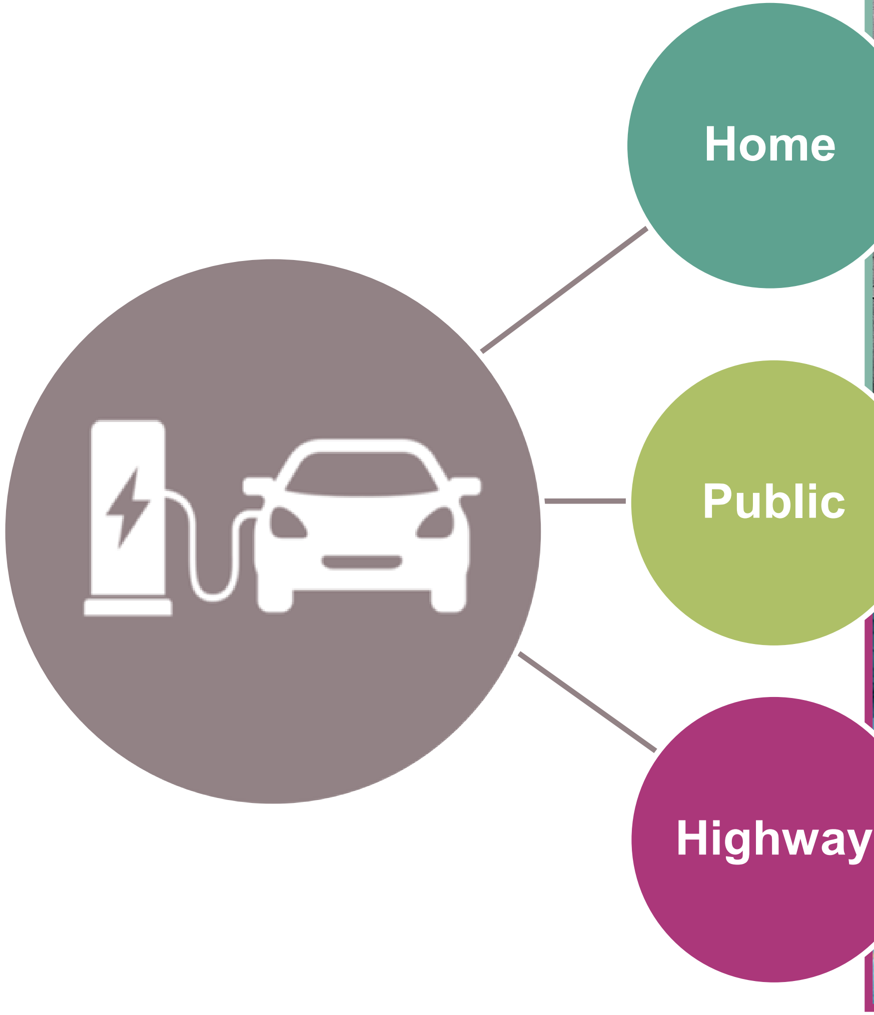
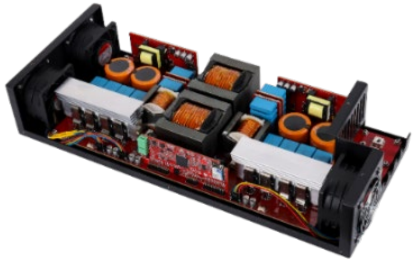
Infineon reference designs for different DC EV charging systems

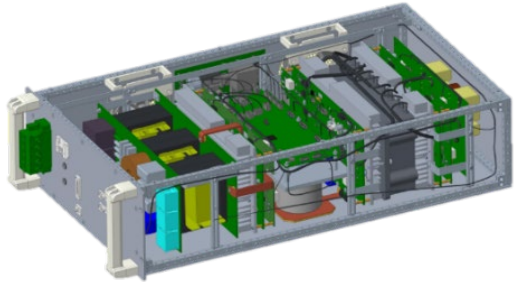


11 kW bi-directional DC-DC converter:
[REF-DAB11KIZSICSYS]



22 kW DC wallbox: in development

up to **50 kW DC charger subunit**
for high power charging systems:



Release planned for H2 - 2021

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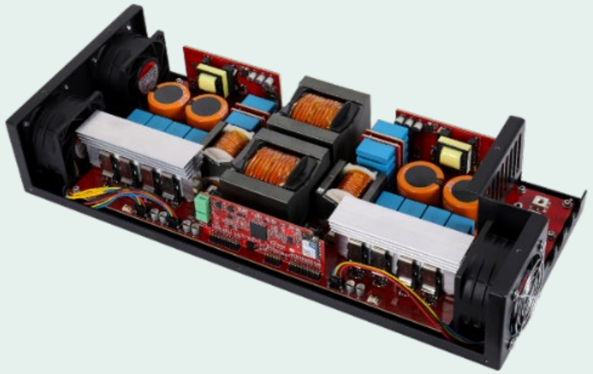
11 kW SiC bi-directional DC-DC converter (REF-DAB11KIZSICSYS)

Overview

- This reference design provides a blueprint for the fast realization of bi-directional DCDC converters with 11 kW and up to 800 V
- It is the ideal building block for any EV and ESS charger project due to its high power conversion efficiency and soft switching characteristics



Target application

- DC EV charging wall boxes
- Energy storage systems

Storage

EV charger

Key features and benefits

Attractive rating:	11kW @ up to 800 V
High peak efficiency:	97.2%
High power density:	4,1 kW/l
Supports V2G & V2H:	bi-directional power flow
Easy-to-use:	WiFi onboard plus software and GUI

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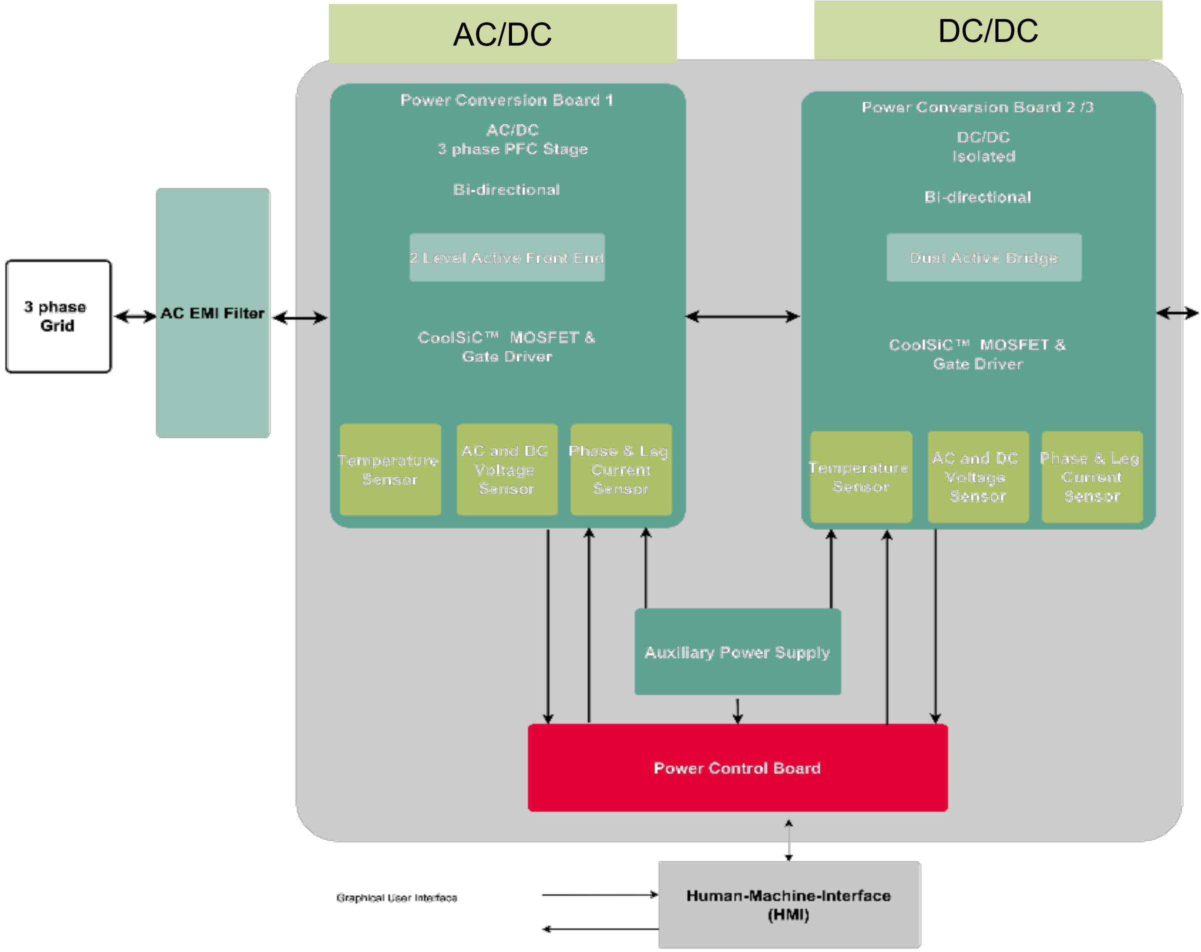
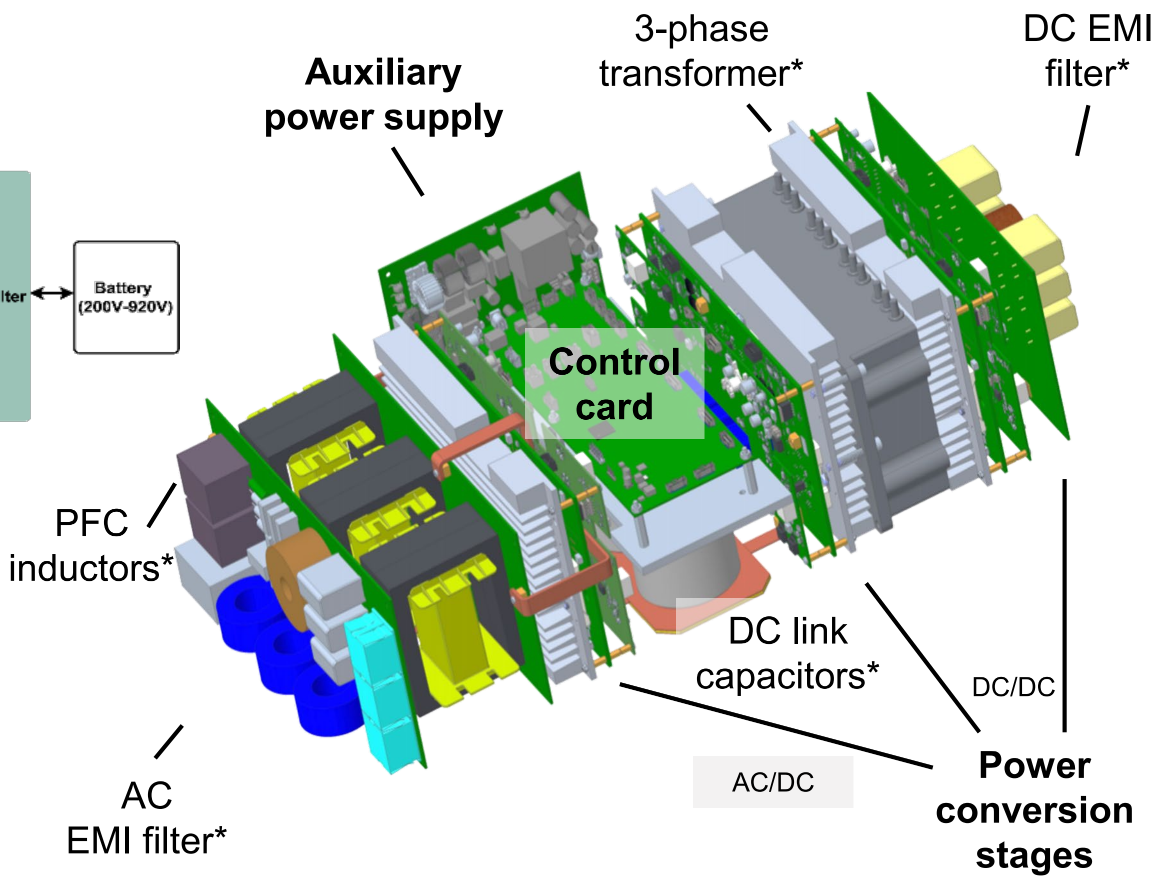
Concept offers great flexibility to adapt topology and components as well as thermal / mechanical design to different use cases

Block diagram



Subunit layout



* Passive components are not offered by Infineon

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Fast DC EV Charging empowered by Infineon

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What makes CoolSiC™ the perfect solution for EV charging designs

Major Trends

Power density

CoolSiC™:
- Reduced cooling effort
- Size reductions by using higher switching frequencies

Higher efficiency charger

CoolSiC™:
- Up to 99% overall efficiency
- Much lower energy costs

Bi-directional operation

CoolSiC™:
- Full utilization of the MOSFET

Flexibility

Modules & discretes using CoolSiC™:
- From highly integrated topologies like Vienna, NPC1, ANPC, NPC2 or simple 2-level topologies

Scalability

CoolSiC™:
- Scalability to upgrade system power levels on demand up to several hundred kVA (discretes) and kW (modules)

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Supporting material for Infineon's EV charging offering

Application pages

- Fast EV Charging
- Chargers up to 150 kW
- Chargers from 50 kW to 350 kW

Collaterals and brochures

- Application presentation
- Application brochure
- Whitepaper
- Product brochure
- Product selection guide
- Product presentation
- Articles

Simulation tools

- IPOSIM

Evaluation boards

- Boards fast EV charging
- Boards chargers up to 150 kW
- Boards chargers from 50 kW to 350 kW

Videos / podcasts/ trainings

- Videos
- Podcast
- Trainings

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Related SiC content

SiC Design Resources

- Get our SiC design resources for your application!

Download

SiC Podcast

- Listen to our podcast for a better understanding of SiC and GaN technology benefits and costs.

Listen Now

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