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

**Regulations**
Government regulations on CO₂ emissions

**Infrastructure**
Fast growing demand for electric charging infrastructure

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

**Costs**
Continuous decrease in battery costs

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

Passenger car CO\textsubscript{2} emission development and regional regulations

- US (2026): 108 g/km
- Japan (2030): 73.5 g/km
- EU (2030): 59 g/km
- China (2025): 93.4 g/km

-15\% vs 2021
-37.5\% vs 2021

\textbf{CO\textsubscript{2} emission values (g/km; normalized to NEDC)}

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

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

*) 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

30 kW → 150 kW
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
Structure of DC EV charging system

- **AC-grid**
- **EV**
- **Smart Grid**
- **Renewables**
- **Cloud**
- **Battery management**
- **Storage**
- **Data**
- **Secure roaming & billing**
- **DC-power**
- **DC-charger**
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
Efficiency is the key for modular high power DC charging

- 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

Volume reduction 50%
Power increase 50%
# Fast DC EV Charging empowered by Infineon

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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%)
**Infineon’s power solution positioning for DC EV charger**

<table>
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<tr>
<th>Discrete solutions</th>
<th>Module solutions</th>
<th>Gate driver solutions</th>
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<tbody>
<tr>
<td><strong>Modular solution is recommended</strong></td>
<td><strong>Stacked modular solutions</strong></td>
<td><strong>EiceDRIVER™ Enhanced X3A/D (1ED34/38xx)</strong></td>
</tr>
<tr>
<td>350 kW</td>
<td>6 x 60 kW</td>
<td>100 kW</td>
</tr>
<tr>
<td>120/150 kW</td>
<td>100 kW</td>
<td>100 kW</td>
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<tr>
<td>50/60 kW</td>
<td>100 kW</td>
<td>100 kW</td>
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<tr>
<td>Stacked 20 / 30 kW discrete solutions</td>
<td><strong>Stacked 50 kW modular solutions</strong></td>
<td><strong>EiceDRIVER™ Enhanced X3A/D (1ED34/38xx)</strong></td>
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<tr>
<td>20 kW</td>
<td>50 kW</td>
<td><strong>EconoDUAL™</strong></td>
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<tr>
<td>30 kW</td>
<td>50 kW</td>
<td><strong>EconoPACK™4</strong></td>
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<td>Discrete solutions is recommended</td>
<td><strong>Easy CoolSiC™ EconoPACK™4</strong></td>
<td><strong>EiceDRIVER™ Compact X3C (1ED31xx)</strong></td>
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<td>30 kW</td>
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<td>1ED-F2 / 2ED-FI</td>
<td>1ED-MF/AF</td>
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<td>≤ 60 kW discrete solutions</td>
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<td>10 kW</td>
<td></td>
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<td>100 kW</td>
<td></td>
<td>1ED-MF/AF</td>
</tr>
<tr>
<td><strong>Microcontroller</strong>: XMC1000, XMC4000, Optiga™ <strong>Current sensor</strong>: TLI4971</td>
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* DC charger subunit or DC charger
Commonly used topologies for AC/DC conversion

Rectifiers exist in different forms and types

- **EMI filter**
- **AC/DC**
- **DC link**
- **DC/AC**
- **Galvanic isolation**
- **AC/DC**
- **DC filter**

**< 50 kW design**
- Vienna rectifier

**> 50 kW design**
- Active front end

**> 100 kW design**
- Diode rectifier
DC/DC power conversion topologies

DC-DC converter also exist in different types

Multiphase buck converter (non-isolated)
Resonant converter (isolated)
Phase-shifted converter (isolated)
LLC converter (uni-directional)
CLLC converter (bi-directional)
Phase-shifted ZVS converter (uni-directional)
Dual active bridge converter (bi-directional)
Power density is driven not only by technology: trade-offs in the inverter design

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

1. TRENCHSTOP™
2. CoolMOS™
3. CoolSiC™
4. CoolGaN™

1. Functionality
2. Topology
3. Packaging
4. Switching frequency

Technology

Others

fulcrum

fulcrum

fulcrum

PFC Stage
DCDC Stage

$
SiC MOSFETs – what differentiates them from IGBTs?

Benchmark in switching losses
Integrated freewheeling diode
Knee voltage free on-state

Turn-Off losses $E_{\text{off}}$ @ 800V, $R_s=2.2\Omega$, $V_{\text{GCS}}=5/15\,\text{V}$

10x lower $E_{\text{off}}$

Turn-On losses $E_{\text{on}}$ @ 800V, $R_s=2.2\Omega$, $V_{\text{GCS}}=5/15\,\text{V}$

2x lower $E_{\text{on}}$

Output characteristic

Threshold-free on-state

On-State Current $I_{\text{on}}$ in A

On-State Voltage $V_{\text{ds}}/V_{\text{ct}}$ in V

CoolSiC™ MOSFET

Highspeed 3 Si IGBT
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 $T_J = 100 \, ^\circ$C
    
    - CoolMOS™: $k = 1.67$
    - CoolSiC™: $k = 1.14$
    - CoolGaN™: $k = 1.53$
A practical example of a CoolSiC™-based EV Charger design

“Softer” transconductance

Larger increase in $R_{DS(on)}$ with temperature so a strong positive feedback

Slight increase in switching losses due to temperature

Correlation that higher $R_{DS(on)}$ parts have lower switching losses
CoolSiC™ MOSFET Enables simpler hard-switching solution

650 V Si SJ MOSFET in DC/DC stage:
- Simple hard-switching topology
- Less control effort
- Reduced part count by 50%
- Especially attractive for bidirectional charging

1200 V SiC MOSFET DC/DC:
- Simple hard-switching topology
- Less control effort
- Reduced part count by 50%
- Especially attractive for bidirectional charging

Si to SiC
CoolSiC™ MOSFET suitable for ZVS operation

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

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

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

Low $C_{oss}$ allows a fast $V_{DS}$ transition at turn-on
Charging station: 1200 V CoolSiC™ diode for high efficiency and high output power – 50% lower losses

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
› Increased output power
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
Proposed BOM for high efficiency 30 kW design

### Stage Switching Freq. Devices Product Part number Pcs

#### AC/DC

- **40 kHz**
  - 600 V CoolMOS™ P7
  - IPW60R024P7
  - 12
  - 1200 V CoolSiC™ Schottky diode
  - IDWD40G120C52
  - 12
  - Driver IC
  - EiceDRIVER™ 1ED
  - 1EDI40112AH
  - 6

#### DC/DC

- **up to 300 kHz**
  - 1200 V CoolSiC™ MOSFET
  - IMW120R045M1
  - 16
  - 1200 V CoolSiC™ diode
  - IDW40G120C5B
  - 8
  - Driver IC
  - EiceDRIVER™ 1ED
  - 1EDI20112AH
  - 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]
# Proposed BOM for high efficiency 60 kW design

## 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

## Stage | Switching Freq. | Devices | Product | Part number | Pcs |
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<tbody>
<tr>
<td>AC/DC</td>
<td>40 kHz</td>
<td>1200 V CoolSiC™ Easy 2B</td>
<td>F3L15MR12W2M1</td>
<td>3</td>
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<tr>
<td></td>
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<td>Driver IC</td>
<td>EiceDRIVER™ 1ED</td>
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<tr>
<td>DC/DC</td>
<td>120 to 140 kHz</td>
<td>1200 V CoolSiC™ MOSFET</td>
<td>FF11MR12W1M1_B11</td>
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<tr>
<td></td>
<td></td>
<td>1200 V CoolSiC™ diode</td>
<td>DDB2U60N12W1RF_B11</td>
<td>2</td>
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Why connectivity and security is relevant in EV charging

ISO/IEC 15118
IEC 61851-1

CCSoM

MQTT and OCPP

Edge

Cloud services

3rd party apps

Manufacturer's operator's portal

ISO/IEC 15118
IEC 61851-1
Infineon overview on security, control and connectivity – Our Core Capabilities for DC EV Charging

### Power

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<th>HMI &amp; Communication</th>
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<tr>
<td>PSoC®6</td>
<td></td>
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<td><strong>Mixed Signal MCU Architectures</strong></td>
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<tr>
<td>XMC™1000</td>
<td></td>
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<tr>
<td><strong>Application Co-processors</strong></td>
<td></td>
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<tr>
<td>XMC™4000</td>
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| ENHANCE                                      |                                      | embedded SIM                                 |
| **Graphics**                                 |                                      | PSoC®6                                       |
|                                               |                                      | Next gen MCU                                 |
| **NFC**                                      |                                      | My-d™ NFC (SCS)                              |

| SECURE                                       |                                      | Device authentication                        |
| **Hardware security controllers**            |                                      | OPTIGA™                                      |
|                                               |                                      | Trust, TPM                                   |
|                                               |                                      | Connect                                      |
|                                               |                                      | Authenticate                                 |

| CONNECT                                      |                                      | OPTIGA™                                      |
| **Power Conversion**                         |                                      | OPTIGA™                                      |
| XMC™1000                                     |                                      | OPTIGA™                                      |
| XMC™4000                                     |                                      | OPTIGA™                                      |

| CONTROL                                      |                                      |                                 |
| **Capacitive / Inductive Sense**             |                                      |                                 |
| PSoC®4                                       |                                      |                                 |
| PSoC®6                                       |                                      |                                 |
| **Motor Control**                            |                                      |                                 |
| XMC™1000                                     |                                      |                                 |
| XMC™4000                                     |                                      |                                 |
| **Wireless Charging**                        |                                      |                                 |
| XMC™1000                                     |                                      |                                 |
| spark                                         |                                      |                                 |
Security with OPTIGA™ 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

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.

Secured Connectivity

Security controllers like OPTIGA™ TPM and OPTIGA™ Trust will enable a secured channel that is agnostic to the type of connectivity deployed.
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
PSoC 64 – Packaging Option adds fully integrated Secure FW

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

Secure FW is factory installed prior to shipping

- 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

Secure Processing Environment (SPE)
- Secure Services
  - Storage
  - Attestation
  - Crypto
  - Trusted Firmware-M

Root-of-Trust and Services
- RoT Services
  - Crypto
  - RoT Key Storage
  - Attestation
  - Provisioning
  - CY Secure Bootloader

Cortex-M4

Cortex-M0+
Cellular connectivity enabled – OPTIGA Connect IoT eSIM for Machine2Machine use cases

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

Connectivity anywhere in the world with eSIM
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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Infineon reference designs for different DC EV charging systems

- **Home**
  - 11 kW bi-directional DC-DC converter: REF-DAB11KIZSICSYS

- **Public**
  - 22 kW DC wallbox: in development

- **Highway**
  - up to 50 kW DC charger subunit for high power charging systems:
    - Release planned for H2 - 2021
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

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
Concept offers great flexibility to adapt topology and components as well as thermal / mechanical design to different use cases.
# Fast DC EV Charging empowered by Infineon

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What makes CoolSiC™ the perfect solution for EV charging designs

**Major Trends**

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

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

- **CoolSiC™:**
  - Full utilization of the MOSFET

- **Power density**
  - Reduced cooling effort
  - Size reductions by using higher switching frequencies

- **Higher efficiency charger**
  - Up to 99% overall efficiency

- **Bi-directional operation**
  - Much lower energy costs

- **Flexibility**
  - Scalability to upgrade system power levels on demand up to several hundred kVA (discretes) and kW (modules)

- **Scalability**
  - From highly integrated topologies like Vienna, NPC1, ANPC, NPC2 or simple 2-level topologies
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› Listen to our podcast for a better understanding of SiC and GaN technology benefits and costs.

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