11 kW bi-directional CLLC DC-DC converter with 1200 V and 1700 V CoolSiC™ MOSFETs

About this document

Scope and purpose

This document introduces a complete Infineon Technologies AG system solution for an 11 kW bi-directional DC-DC converter. The REF-DAB11KIZSICSYS board is a DC-DC stage with a wide range output using two inductors and two capacitors (CLLC) resonant network with bi-directional capability. This converter can operate under high power conversion efficiency, as the symmetric CLLC resonant network has zero-voltage switching capability for primary power switches and synchronous-rectification commutation capability for secondary-side output rectifiers. The converter could change the power flow direction, and its maximum power conversion efficiency was around 98% during the operation.

This document shows the board using 1200 V CoolSiC™ MOSFETs in TO247-4 package and EiceDRIVER™ 1ED compact gate driver ICs, which leverage the advantages of SiC technology including improved efficiency, space and weight savings, part count reduction, and enhanced system reliability.

Intended audience

This document is intended for engineers who want to use 1200 V and 1700 V CoolSiC™ MOSFETs with EiceDRIVER™ driver ICs for bi-directional resonant topology applications such as EV-charger wall box, energy storage systems to achieve reliable main-circuit design and increased power density.

Reference board/kit

Product(s) embedded in a PCB, with focus on specific applications and defined use cases that can include software. PCB and auxiliary circuits are optimized for the requirements of the target application.

Note: Boards do not necessarily meet safety, EMI, quality standards (for example UL, CE) requirements.
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### Safety precautions

#### Note:
Please note the following warnings regarding the hazards associated with development systems.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Safety precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warning:</strong> The DC link potential of this board is up to 1000 V&lt;sub&gt;dc&lt;/sub&gt;. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.</td>
<td></td>
</tr>
<tr>
<td><strong>Warning:</strong> The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.</td>
<td></td>
</tr>
<tr>
<td><strong>Warning:</strong> The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.</td>
<td></td>
</tr>
<tr>
<td><strong>Warning:</strong> Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.</td>
<td></td>
</tr>
</tbody>
</table>
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The board at a glance

E-mobility is well on its way to revolutionizing private and public transportation, reducing air pollution and making the earth a better place to live. Energy storage systems can also help save energy consumption by maximizing the allocation of energy. Infineon is proud to be a key player in this green megatrend. Being a one-stop shop for high-quality components and solutions, the target of the REF-DA811KIZSiCYS board is to build up a solution for bi-directional DC-DC converters, which will enable customers to implement unique bi-directional charger designs in a very short time. This featured 11 kW CLLC resonant DC-DC converter with bi-directional power flow capability and soft-switching characteristics is the ideal choice for on- & off-board chargers and energy storage systems (ESS). This reference design provides a complete and fully characterized hardware and firmware solution, and user-friendly graphical user interface (GUI). It ensures that CoolSiC™ MOSFETs integrate with Infineon driver IC, XMC controller, flyback controller, voltage regulator MOSFETs, current sensor, Cypress memory, and security & safety chip. It is the perfect way to improve cost-effective power density with high reliability, and easy usage up to the next level!

In UG-2020-31, Figure 1 shows the placement of the different components on the 11 kW bi-directional DC-DC converter. The outer dimensions of the board, enclosed in the case, are 33.1 mm x 13.4 mm x 6 mm, which results in a power density in the range of 4.1 W/cm³ (5.5 W/g).
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The board at a glance

Figure 1  Placement of the different sections in the 11 kW bi-directional CLLC DC-DC converter with Infineon CoolSiC™ MOSFETs.

1.1  Delivery content

The 11 kW bi-directional board is a CLLC DC-DC converter developed with Infineon power semiconductors as well as Infineon drivers, current sensor, controllers, communication chip, security chip and memory chip. The combination of these devices can provide customers with an optimized system solution. The Infineon devices used in the implementation of the 11 kW bi-directional board include:

Main power board
- 1200 V CoolSiC™ MOSFETs discretes - [JMZ120R030M1H](#)
- 1200V Single channel IGBT gate driver IC in wide body package - [1EDC2012AH](#)
- XENSIV™ - high-precision coreless current sensors for industrial applications - [TLI4971](#)

Auxiliary power board
- 1700 V CoolSiC™ MOSFET discretes - [IMBF170R1K0M1](#)
- PWM-QR (quasi resonant) flyback control ICs - [ICE5QSAG](#)

Controller board
- 32-bit XMC4000 industrial microcontroller ARM® Cortex®-M4 family - [XMC4400-F100k512 BA](#)
- High speed CAN transceiver generation-TLE9251VSJ
- OPTIGA™ TRUST M - [SLS32AIA](#)
- Low voltage drop linear voltage regulators - [IFX25001TFV33](#)
- 256-Kbit (32K × 8) serial (SPI) F-RAM: FM25V02A from Cypress

More information concerning these devices is available on the Infineon website.

1.2  Block diagram

The REF-DAB11KIZSICSYS design consists of a CLLC in full-bridge configuration (Figure 2). The CLLC resonant converter is widely used as a DC transformer to interlink the AC/DC to DC bus, because of its advantages of high power density and the capacity of bi-directional power transfer. In both forward and reverse modes, the resonant tank possesses almost the same operational characteristics of the conventional LLC resonant tank. Thus the ZVS+ZCS soft switching can be achieved both in forward and reverse modes, and the switching losses can be minimized, thereby improving charger efficiency.

This architecture showed in the block diagram contains three parts, the main power circuit, the auxiliary power board and the control board.
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The board at a glance

Figure 2  11 kW bi-directional CLLC DC-DC converter (REF-DAB11KIZSICSYS) – simplified diagram showing the Infineon semiconductors used in the system

The main power circuit includes 1200 V CoolSiC™ MOSFETs make high efficiency possible.

The auxiliary power supply uses 1700 V CoolSiC™ MOSFETs for an efficient design, as it is as small as a card.

The control is implemented in an XMC4400 Infineon microcontroller, which includes the following features:

- ARM® Cortex™-M4, 120MHz, incl. single cycle DSP MAC and floating point unit (FPU)
- 8-channel DMA + dedicated DMAs for USB and Ethernet
- USIC 4ch [Quad SPI, SCI/UART, I²C, I²S, LIN]
- Supply voltage range: 3.13 - 3.63V
- USB 2.0 full-speed, on-the-go
- CPU frequency: 120MHz
- Peripherals' clock: 120 [MHz]
- eFlash: 512 kB including hardware ECC
- 80 kB SRAM
- 10/100 Ethernet MAC (/w IEEE 1588)
- 2x CAN, 64 MO
- Package: PG-LQFP-100
- 4x ΔΣ demodulator
- Temperature range from -40° to 125°

Further details about the digital control implementation and other functionalities of CLLC in the XMC™ 4000 family can be found on the Infineon website.
The board at a glance

1.3 Main features

A bi-directional full-bridge CLLC resonant converter using a symmetric CLLC-type resonant network is proposed for a bi-directional power distribution system. This converter can operate under high power conversion efficiency, as the symmetric LLC resonant network has zero-voltage switching capability for primary power switches and synchronous rectification capability for secondary-side rectifiers.

In addition, the proposed topology does not require any snubber circuits to reduce the voltage stress of the switching devices because the switch voltage of the primary and secondary power stage is confined by the input and output voltage, respectively. In addition, the power conversion efficiency of any direction is similar. Intelligent digital-control algorithms are also proposed to regulate output voltage, control bi-directional power conversions and to achieve synchronous rectification.

1.4 Board parameters and technical data

Table 2 shows the specifications of the board.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>P</td>
<td>( V_{bus}=750V, ) ( V_{in}=800V, Ta=25^\circ C, I_{pri}=15A )</td>
<td>11</td>
<td>KW</td>
</tr>
<tr>
<td>Primary side bus voltage</td>
<td>( V_{bus} )</td>
<td>-</td>
<td>750</td>
<td>V</td>
</tr>
<tr>
<td>Secondary side bus voltage</td>
<td>( V_{in} )</td>
<td>-</td>
<td>550~800</td>
<td>V</td>
</tr>
<tr>
<td>Primary side current</td>
<td>( I_{pri} )</td>
<td>( V_{bus}=750V, ) ( V_{in}=800V, Ta=25^\circ C, I_{pri}=15A )</td>
<td>15</td>
<td>A</td>
</tr>
<tr>
<td>Secondary side current</td>
<td>( I_{sec} )</td>
<td>( V_{in}=550V, P=11KW, Ta=25^\circ C )</td>
<td>20</td>
<td>A</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>( f_s )</td>
<td>-</td>
<td>40~200</td>
<td>KHz</td>
</tr>
<tr>
<td>Auxiliary power output voltage</td>
<td>( V_{aux} )</td>
<td>( P_{aux}=32W )</td>
<td>15/20</td>
<td>V</td>
</tr>
<tr>
<td>Auxiliary power output power</td>
<td>( P_{aux} )</td>
<td>( V_{aux}=20V, Ta=25^\circ C )</td>
<td>32</td>
<td>W</td>
</tr>
<tr>
<td>Board net weight</td>
<td>( W )</td>
<td>Without encloser</td>
<td>2</td>
<td>Kg</td>
</tr>
</tbody>
</table>
2 System and functional description

2.1 Commissioning

This chapter presents the set-up on how to evaluate the performance and behavior of the 11 kW bi-directional DC-DC converter using CoolSiC™ MOSFETs.

- DC source provides the power to the converter prototype
- Secondary side of converter prototype connect with the DC electric load
- The host computer controls the start and stop of the prototype and sets the working parameters through GUI
- Observe the corresponding waveforms with an oscilloscope

![System and functional description](image)

Figure 3  11 kW bi-directional CLLC DC-DC converter measuring environment

2.2 Description of the functional blocks

The 11 kW bi-directional CLLC DC-DC converter can operate as an isolated buck or as an isolated boost converter, with the power flowing from the bus side to the isolated HV side or vice versa.

For validation of the buck mode, the suggested set-up includes:
- Bus supply capable of 700 V–800 V and at least 11 kW (when testing up to full load)
- HV electronic load (500 V to 800 V), in constant current mode, capable of at least 11 kW (when testing up to full load). Nominal input voltage of the converter is 750 V. The converter works as indicated in Figure 4.
2.2.1 Description of the functional blocks

The output gain function of CLLC topology is generally analyzed by the fundamental wave-analysis method. Based on this analysis method, the parameters of the key resonant components in the current design are shown in the Figure 4:

By using this parameter, the resonance parameter Q of the primary and secondary transformers is consistent, and the natural resonance frequency is 73 kHz. In the design, we chose a switching frequency of the topology in the range of 40 kHz to 200 KHz.

The structure of CLLC topology on the primary side and the secondary side is the same. On the contrary, the fundamental wave-analysis method is also valid. The relationship between the output/input gain and the switching frequency of the circuit is shown in Error! Reference source not found. (reverse energy transmission):

The current of the primary/secondary resonant cavity and the V_{ds} waveform of the SiC MOSFET in the steady state can be obtained as follows with the help of PLECS simulation software for verification:

Buck mode (forward-energy transmission), input voltage 800 V, and output voltage 550 V with load 27.5 Ω. At this time, the CLLC topology switching frequency is 86.2 KHz:

Ilr_pri is the primary side resonant tank current.
Ilr_sec is the secondary side resonant tank current.
VHB is the V_{ds} voltage of Q2 (The position of SiC MOSFETs Q1~Q8 can be seen in Figure 4.).
Fsw is the switching frequency.
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**Figure 5**  Simulation result of CLLC buck mode

Forward-energy transmission, input voltage 750 V, output voltage 750 V, load 51.1 Ohm. The switching frequency of CLLC topology is 54.0 KHz at this condition, the simulation waveform can be seen in Figure 6.

**Figure 6**  Simulation result of CLLC

Boost mode (forward-energy transmission), input voltage 700 V, output voltage 800 V, load 58.1 Ohm. At this time, the CLLC topology switching frequency is around 48.2 KHz:
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In the case of no load or light load, the CLLC topology must work in frequency-modulation mode (PFM), otherwise the power devices in the circuit may work at a very high switching frequency. Due to the existence of parasitic parameters, the output voltage cannot be reduced to the target value under the circumstances of continuous wave mode. The topology will work in this mode:

Channel 1 is the controller board output pulse-width modulation (PWM) signal.

Channel 2 is the output voltage.

---

**Figure 7  Simulation result of CLLC boost mode**

**Figure 8  Test result of light load**

In the “burst” state, the output voltage waveform is as follows when a sudden load is added:

Channel 3 is the output voltage.
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System and functional description

Channel 4 is the load current.

Figure 9  Test result of added sudden load

At this time, there is an obvious overshoot of resonant cavity current according to Figure 10. If the peak value is more than 40 A, it will trigger the overcurrent protection:

Channel 2 is the gate PWM signal of Q2.

Channel 3 is the V_{ds} voltage of Q2.

Channel 4 is the primary side resonant tank current.

Figure 10  Test result of added sudden load
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Steady state, the $V_{gs}/V_{ds}$ voltage waveform of SiC MOSFET and current waveform in the resonation tank can be seen in Figure 11.

![Figure 11 Test waveform when the load is 10KW](image)

For more expanded waveform details, please see Figure 12 below.

![Figure 12 Details of $V_{gs}/V_{ds}$](image)

In Figure 13, the output voltage ripple is around 16.5 V; here we have considered the peak-to-peak value.

Channel 1 is the controller output PWM signal.

Channel 2 is the output voltage, here we consider the peak-to-peak value.
System and functional description

2.2.2 Special operation modes

The CLLC circuit used CoolSiC™ MOSFETs in the primary and secondary sides, so under normal work conditions when one side of the transformer is in the switching state, the other side works in the diode rectification mode. As known, MOSFET body diodes have considerable conduction voltage drops. Fortunately, the channel of the MOSFET has reverse-conduction capability with a much smaller conducting voltage drop than its body diode. Therefore it is necessary to adopt the synchronous rectification method to reduce the conduction loss on the rectifier side, and improve the conversion efficiency.

Here explain a basic principle of the synchronous rectification scheme:

Under normal circumstances, dedicated synchronous rectifier drive controllers are widely used to detect the $V_{ds}$ of the rectifier tube, and to control the gate drive in time. However, we cannot use this method in bi-directional...
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System and functional description

DC/DC converters. In this board, we adopted another low-cost method to achieve synchronous rectification control:

- By sampling the current on the secondary side of the transformer through the current transformer CT, and converting the periodic positive and negative current sampling signal into a DC current via the rectifier circuit, then sending it to the non-inverting input of the comparator;
- The comparator compares the rectified current sampling signal with a fixed threshold \( V_{\text{ref}} \), which is set to be slightly more than 0;
- The output inversion signal of the comparator and the primary pulse-width modulation (PWM) signal are subjected to the AND operation and then sent to the corresponding rectifier drive circuit as the drive signal. This process can also be completed by the MCU.

Below is the implementation block diagram of the synchronous rectification function:

![Implementation block diagram of the synchronous rectification function](image)

Figure 14  Synchronous rectification function

With this method, it is easy to achieve synchronous rectification. At present, the AND operation between the flip signal output by the comparator and the primary PWM signal is carried out inside the MCU. The MCU recognizes that the comparator outputs a high level, and triggers an external interrupt, which is combined with the current cycle of the PWM wave-sending sequence in the interrupt service routine. The corresponding synchronous rectification drive is issued, but there is a certain delay in the actual measurement software processing. The actual measurement current delay is about 1 \( \mu \)s, and software optimization is required to reduce this delay time.

Channel 1 is the \( V_{\text{ref}} \).

Channel 2 is output signal of the comparator.

Channel 3 is secondary side gate PWM signal.

Channel 4 is primary side gate PWM signal.
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System and functional description

Figure 15  Synchronous rectification gate signal

2.3  Auxiliary power boards

2.3.1  The technical specification of auxiliary power boards

The reference board is intended to support customers designing an auxiliary power supply for three-phase converters using the Infineon 1700 V CoolSiC™ MOSFET. Potential applications include solar inverters, energy storage, EV chargers, UPS and motor drives. Table 2 lists the key board specifications.

Table 3  Technical specifications

<table>
<thead>
<tr>
<th>Input voltage</th>
<th>300 V&lt;sub&gt;dc&lt;/sub&gt; to 900 V&lt;sub&gt;dc&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>32 W</td>
</tr>
<tr>
<td>Topology</td>
<td>Single-ended flyback</td>
</tr>
<tr>
<td>Output voltage</td>
<td>15 V</td>
</tr>
<tr>
<td>Tolerance</td>
<td>2%</td>
</tr>
<tr>
<td>Output current</td>
<td>2 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>65~130 kHz, QR mode</td>
</tr>
<tr>
<td>Derating of switches V&lt;sub&gt;ds&lt;/sub&gt;</td>
<td>85% (1450 V)</td>
</tr>
<tr>
<td>Efficiency at full load</td>
<td>&gt;85%</td>
</tr>
</tbody>
</table>

2.3.2  Auxiliary power board description

The auxiliary power boards was developed using the 1700 V CoolSiC™ MOSFET in a single-ended flyback topology to provide auxiliary power for these DC-DC converters.

The board has 20V outputs with up to 32 W output power working in a wide input voltage range from 200 V<sub>dc</sub> to 850 V<sub>dc</sub>. Its potential applications are any power electronic system having a high input voltage DC link.

This user guide contains an overview of the reference board’s operation, product information and technical details with measurement results. The board uses 1700 V CoolSiC™ MOSFET in a TO-263 7L surface-mounted
System and functional description

device (SMD) package as the main switch, which is well suited for high input voltage DC link, with single-ended flyback topology. With low $R_{DS(on)}$, high efficiency and low device temperature rise can be achieved with this board.

The controller works in quasi-resonant mode to help reduce EMI noise. This information can help customers during their design-in phase, and for re-use of the reference design board for their own specific requirements.

Figure 16  Pictures of auxiliary power board

2.3.3  1700 V CoolSiC™ MOSFET overview

The auxiliary power board was developed using the 1700 V CoolSiC™ MOSFET in a single-ended flyback topology to provide auxiliary power for this DC-DC. The 1700 V CoolSiC™ MOSFET from Infineon is an excellent choice for high input voltage DC link systems like those found in auxiliary power supplies for three-phase converters. The TO-263 7L surface-mounted device (SMD) package is an optimized package for up to 1700 V high voltage power device. There is a creepage distance of about 7 mm width between drain and source, so safety standards are easily met. The separate driver source pin is helpful in reducing parasitic inductance of the gate loop to prevent gate-ringing effects.

Using Infineon’s 1700 V CoolSiC™ MOSFET can simplify the current auxiliary power supply designs by developing a single-ended flyback reference design board. For a low-power auxiliary power supply, a flyback is the most common topology due to its simple design. However, the flyback topology requires a switching device with a high-blocking voltage. Currently, silicon MOSFETs only have a blocking voltage of up to 1500 V that leaves low design margins, which affects the reliability of the power supply at a given input voltage DC link of 1000 V$_{DC}$. Moreover, most 1500 V silicon MOSFETs have very large on-state resistance ($R_{DS(on)}$), which will lead to higher losses, and thus lower system efficiency.
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The ICE5QSAG gate drive output stage has a 0.9 A source capability, and output voltage up to 13 V, so the SiC MOSFET can be driven directly, which simplifies the driver circuit design.

The auxiliary power board was developed using the 1700 V CoolSiC™ MOSFET in a single-ended flyback topology to provide auxiliary power for this DC-DC. The 1700 V CoolSiC™ MOSFET from Infineon is an excellent choice for high input voltage DC link.

2.4 User interface

The 11 kW bi-directional DC-DC converter includes Wi-Fi wireless communication and the corresponding protocol, allowing the converter system to implement the following functions through the GUI interface of the computer:

- System parameter setting (output direction, synchronous rectification function, output voltage/current, voltage/current protection)
- Working status control (connection, start/stop)
- Running status display (measured value)
- Abnormal status monitoring (fault register)
- Abnormal analysis data reading (tools)

The signal chain between the GUI control interface and the converter system is the computer GUI interface -> PC Wi-Fi connection -> DC-DC converter system.

The corresponding human-machine interface realizes corresponding functions through the combination of graphics + data + buttons. The detailed interface is shown in the figure below:
System and functional description

There are two ways for the GUI to display real-time data:

- **Data pattern:** Data parameter interface displays:
  
  Working status, operating voltage/current, resonance parameters, temperature of key components, abnormal status monitoring and display.
System and functional description

Figure 19  Data pattern in GUI user

- Graph Pattern: Graphical parameter interface displays:
  Relevant real-time operating data of components in the corresponding position of topology of the system.

Figure 20  Graph pattern in GUI user
3 System design

3.1 Schematics

Figure 21 Main board primary side schematic
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

Figure 22  Main board secondary side schematic
System design

11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

Figure 23  32 W auxiliary power supply schematic.
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

Figure 24  Sensor circuit schematic
System design

3.2 Layout

Figure 25  Layer 1
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

Figure 26  Layer 2
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

Figure 27  Layer 3
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

Figure 28  Layer 4
3.3 Bill of material

The complete bill of material is available on the download section of the Infineon homepage. A log-in is required to download this material.

Table 4 BOM of the most important/critical parts of the reference board

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<td>C69, C134, C164, C184</td>
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<td><strong>5.60V</strong></td>
<td>1.5 Watt Plastic Surface Mount Zener Voltage Regulator</td>
<td>D5</td>
<td>DIOM5226X220N</td>
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<td><strong>BAS321</strong></td>
<td>General Purpose Diode</td>
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<td>Schottky Power Rectifier</td>
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### System design

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### 11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

**System design**

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11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

System design

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11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

References and appendices

References and appendices

4.1 Abbreviations and definitions

Table 5: Abbreviations

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<th>Meaning</th>
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<td>CE</td>
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<td>EMI</td>
<td>Electromagnetic interference</td>
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<td>UL</td>
<td>Underwriters Laboratories</td>
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4.2 References

[1] “800 W ZVS phase-shift full-bridge evaluation board. Using 600 V CoolMOS™ CFD7 and digital control by XMC4200”, AN_201709_PL52_027


[4] Design of CLLC Resonant Converters for the Hybrid AC/DC Microgrid Applications

[5] IMBF170R1K0M1 datasheet, 1700 V CoolSiC™ MOSFET


[7] Gate resistor for power devices, Infineon Technologies, application note AN2015-06

4.3 Additional information

This user guide describes the first design version. In case of any future design changes, this document will be updated accordingly.

Board hardware will available in ISAR from February 2021 onwards.
11 kW bi-directional CLLC DC-DC converter with 1200V and 1700V CoolSiC™ MOSFETs

Revision history

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