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

About this document

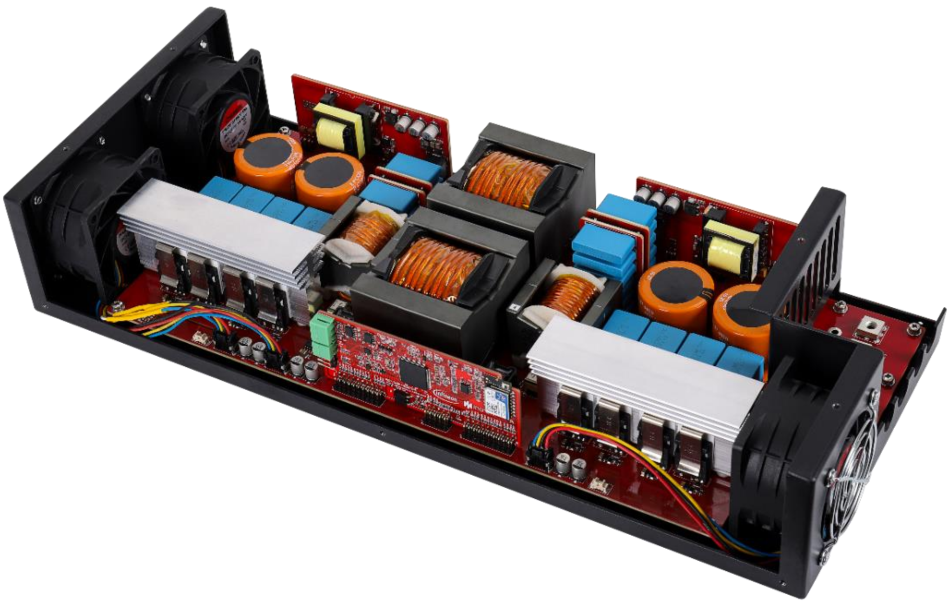
Scope and purpose

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 (ZVS) 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 97.2% during the operation without synchronous-rectification.

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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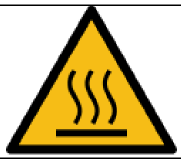
Safety precautions

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

Table 1 **Safety precautions**

	**Warning:** *The DC link potential of this board is up to 1000 V_{DC}. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *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.*
	**Warning:** *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.*
	**Warning:** *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.*
	**Caution:** *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.*
	**Caution:** *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.*
	**Caution:** *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.*
	**Caution:** *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.*
	**Caution:** *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.*

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1 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-DAB11KIZSICSYS 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 fully characterized hardware and firmware solution proposal with a user-friendly graphical user interface (GUI). It integrates CoolSiC™ MOSFETs integrate with Infineon gate driver ICs, XMC controller, flyback controller, voltage regulator MOSFETs, current sensor, memory and security & safety chip.
Figure 1 shows the placement of the different main components on the 11 kW bi-directional DC-DC converter.

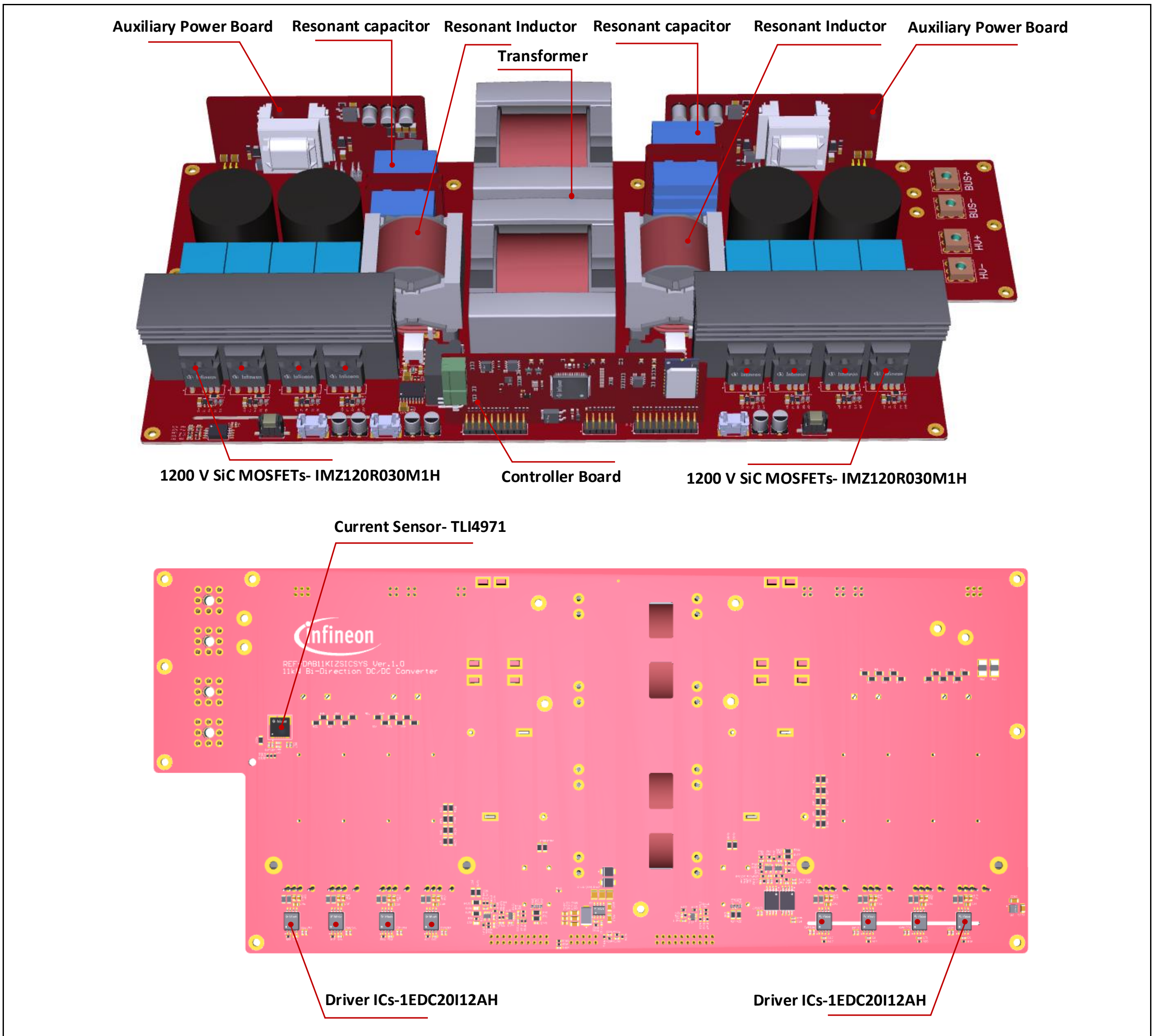

Figure 1 Placement of the different sections in the 11 kW bi-directional CLLC DC-DC converter with Infineon CoolSiC™ MOSFETs.

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 discrete - IMZ120R030M1H
- 1200V Single channel gate driver IC in wide body package - 1EDC20I12AH
- XENSIV™ - high-precision coreless current sensors for industrial applications - TLI4971

Auxiliary power supply board

- 1700 V CoolSiC™ MOSFET discrete - IMBF170R1K0M1
- PWM-QR (quasi resonant) flyback control ICs - ICE5QSAG
- OptiMOS™ 5 Power-Transistor - BSZ068N06NS

Controller board

- 32-bit XMC4000 industrial microcontroller ARM® Cortex®-M4 family - XMC4400-F100k512 BA
- High speed CAN transceiver generation - TLE9251VSJ
- OPTIGA™ TRUST M - SLS32AIA
- 256-Kbit (32K × 8) serial (SPI) F-RAM: FM25V02A

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 and 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.

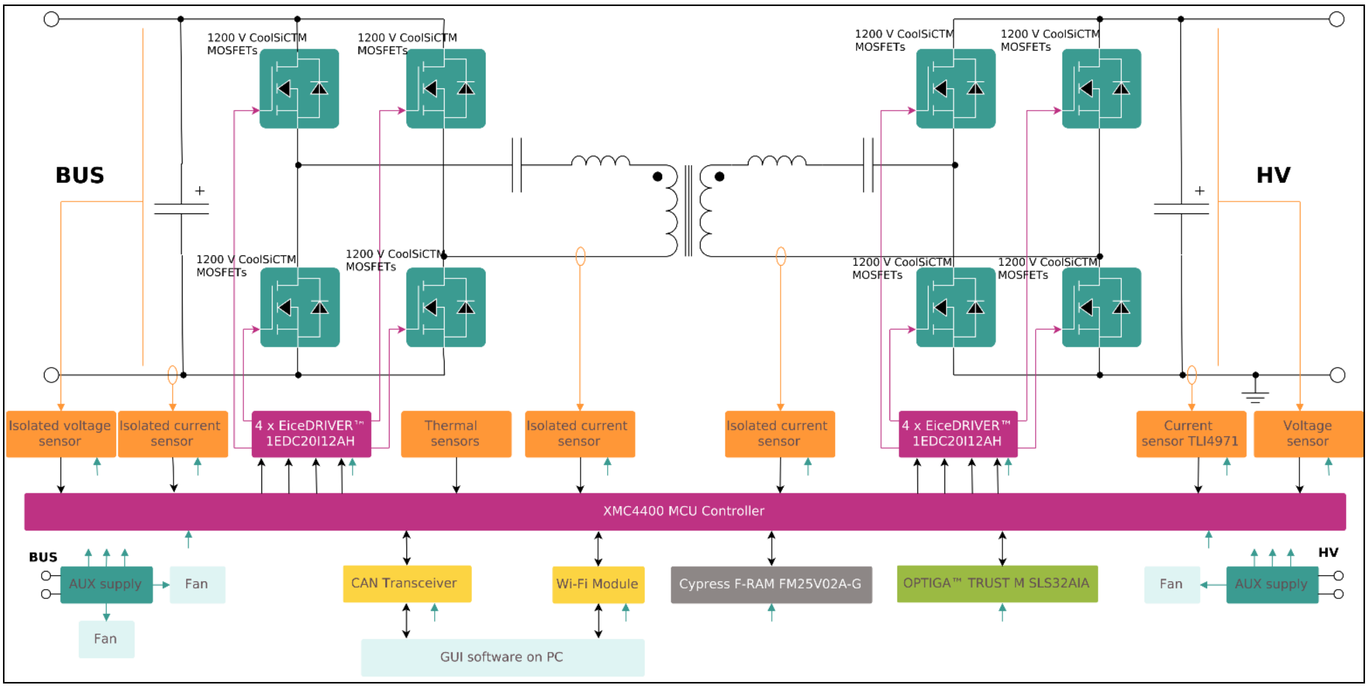

Figure 2 11 kW bi-directional CLLC DC-DC converter (REF-DAB11KIZSICSYS) – simplified diagram showing the Infineon semiconductors used in the system

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: 120 MHz
- Peripherals' clock: 120 MHZ
- eFlash: 512 kB including hardware ECC
- SRAM: 80 kB
- 10/100 Ethernet MAC (/w IEEE 1588)
- 2x CAN, 64 MO
- 4x ΔΣ demodulator
- Package: PG-LQFP-100
- 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.

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. For controlling output voltage and power flow, the frequency modulation (FM) is applied in the control system.

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 2 Parameter

Parameter	Symbol	Conditions	Value	Unit
Rated power	P	V_{bus} = 750 V, V_{HV} = 800 V, T_a = 25 ^{0}C, I_{pr} =15 A	11	KW
Voltage at bus side	V_{bus}	-	700 - 800	V
Voltage at high voltage side	V_{HV}	-	550 - 800	V
Maximum current at bus side	$I_{bus(max)}$	V_{bus} = 750 V, V_{HV} = 800 V, T_a = 25^0 C I_{pri} = 15 A	15	A
Maximum current at high-voltage side	$I_{HV(max)}$	V_{HV} = 550 V, P = 11 kW, Ta=25^{0}C	20	A
Switching frequency	f_s	-	40~250	kHz
Auxiliary power output voltage	$V_{aux.}$	P_{aux} = 32 W	20	V
Auxiliary power output power	$P_{aux.}$	V_{aux} = 20 V, T_a = 25 ^{0}C	32	W
Board net weight	W	Without encloser	2	Kg

The outer dimensions of the board, enclosed in the case, are 360 mm x 160 mm x 65 mm, which results in a power density of around 2.938 W/cm^3.

The control system of the converter includes various protections, as listed in Table 3. All protection points and recovery points may have ± 1% accuracy due to hardware, such as resistors and operational amplifier.

Table 3 Protection levels in the control system

Item	Parameter	Value	Recovery value	Unit	Response time
BUS side	Over voltage (software)	850	840	V	200 ms
	Over voltage (hardware)	876	876	V	5 ms
	Under voltage (forward mode)	580	590	V	200 ms
	Under voltage (inverse mode)	590	-	V	200 ms
	Over current	17	16	A	5 s
	Short circuit protection	35.7	-	A	-
HV side	Over voltage (software)	850	840	V	500 ms
	Over voltage (hardware)	876	876	V	5 ms
	Under voltage	350	360	V	500 ms
	Under voltage (quick)	80	-	V	20 ms
	Over current	22	21	A	1 s
	Short circuit protection	47.6	-	A	-
Temperature	Over-temperature (ambient)	90	85	°C	1 s
	Over-temperature (MOSFETs)	104	94	°C	1 s
	Over-temperature (PCB)	100	95	°C	1 s

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.

The following equipment has been used for testing the converter:

- DC source is connected to the bus side and provides the power to the converter
- The HV side of converter is connected to the DC electronic load
- The host computer controls the start and stop of the prototype and sets the working parameters through the GUI software
- An oscilloscope is used to observe the corresponding waveforms

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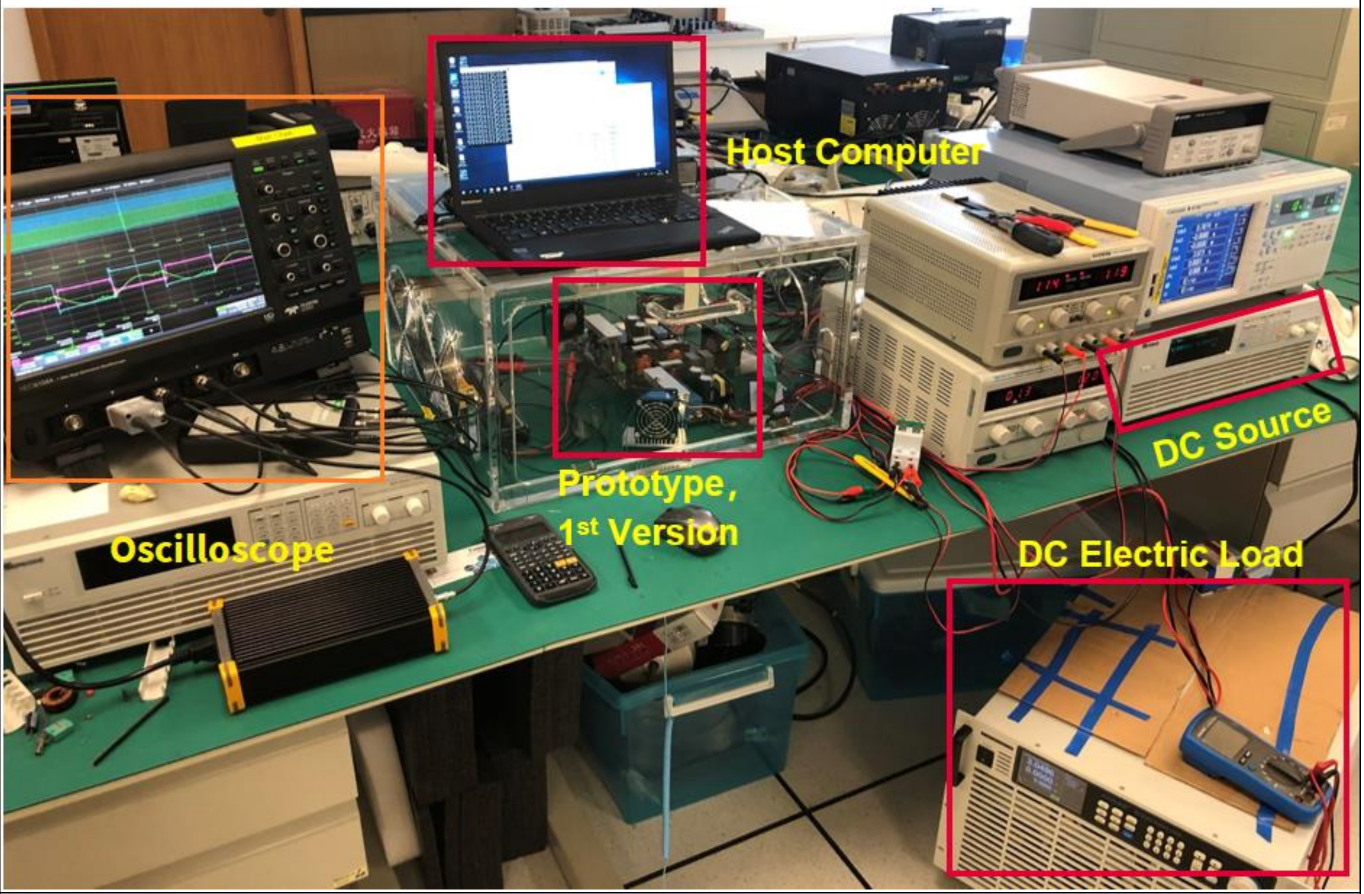

Figure 3 11 kW bi-directional CLLC DC-DC converter with measurement equipment

2.2 Description of the functional blocks

The 11 kW bi-directional CLLC DC-DC converter can operate as an isolated buck or boost converter, with the power flowing from the bus side to the 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). The nominal input voltage of the converter is 750 V.

For validation of the boost mode, the suggested set-up is exactly the same as for the buck mode, except for thing: the output voltage parameter must be changed in the GUI window.

2.2.1 Description of the functional blocks

The output gain function of the CLLC converter is generally analyzed by using the fundamental harmonic analysis. Based on this analysis, the parameters of the key resonant components in the current design are shown in **Error! Reference source not found.**.

Figure 4 Key parameters of the CLLC converter

According to the parameter of the converter, the resonance frequency of the resonant tank is 73 kHz. As result, the switching frequency of the converter has been chosen in the range of 40 kHz to 250 kHz.

The topology of the CLLC converter is symmetrical. Therefore, the same analysis can be applied at the reverse power flow.

To obtain steady-state waveforms of currents and voltages in the CLLC converter, a simulation model of the converter has been used in PLECS simulation software. Figures 5, 6, and 7 show steady-state waveforms in the buck, the normal, and the boost modes, respectively in the forward power flow:

- Ilr_pri is the transformer current at the bus side
- Ilr_sec is the transformer current at the HV side
- VHB is the drain-source voltage of the MOSFET Q2
- Fsw is the switching frequency

The simulation result in Figure 5 has been obtained at the following parameters:

- Bus voltage: 800 V
- HV voltage: 550V
- Resistance of load: 27.5 Ω
- Switching frequency: 86.2 kHz

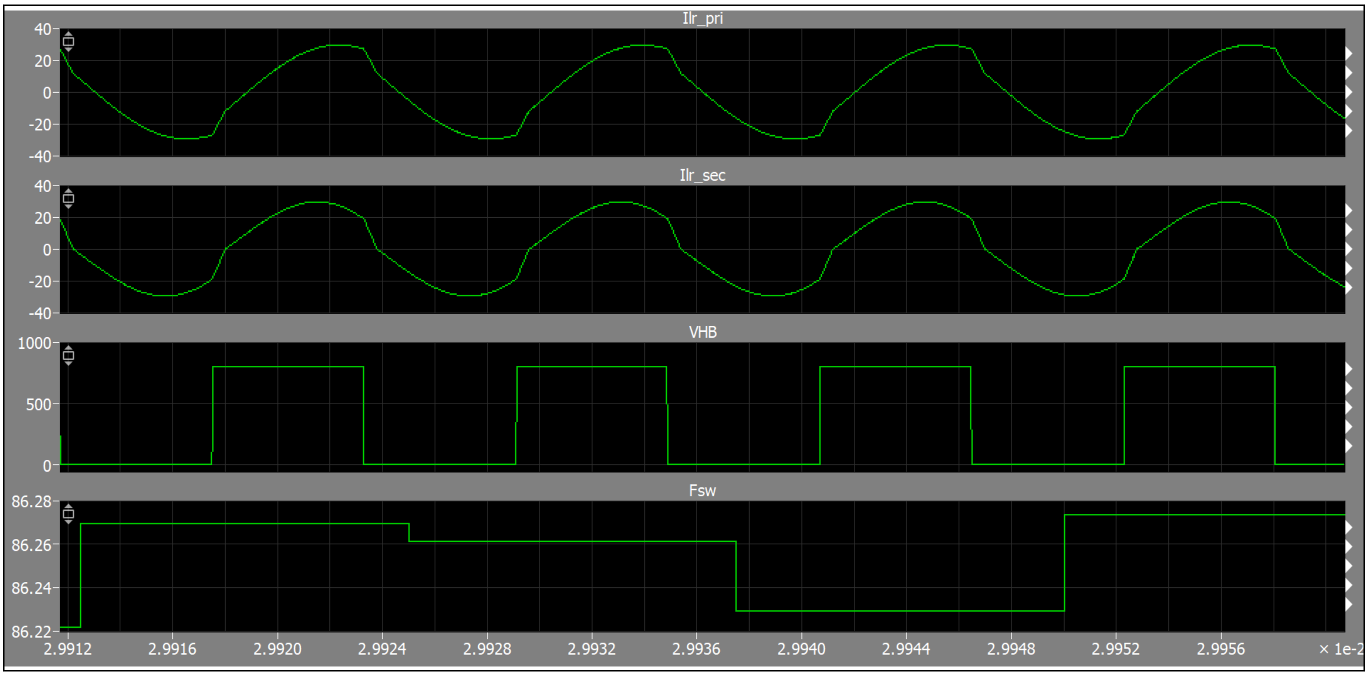

Figure 5 Simulation result of CLLC in the buck mode (forward power flow)

The simulation result in Figure 6 has been obtained at the following parameters:

- Bus voltage: 750 V
- HV voltage: 750 V
- Resistance of load: 51.1 Ω
- Switching frequency: 54.0 kHz

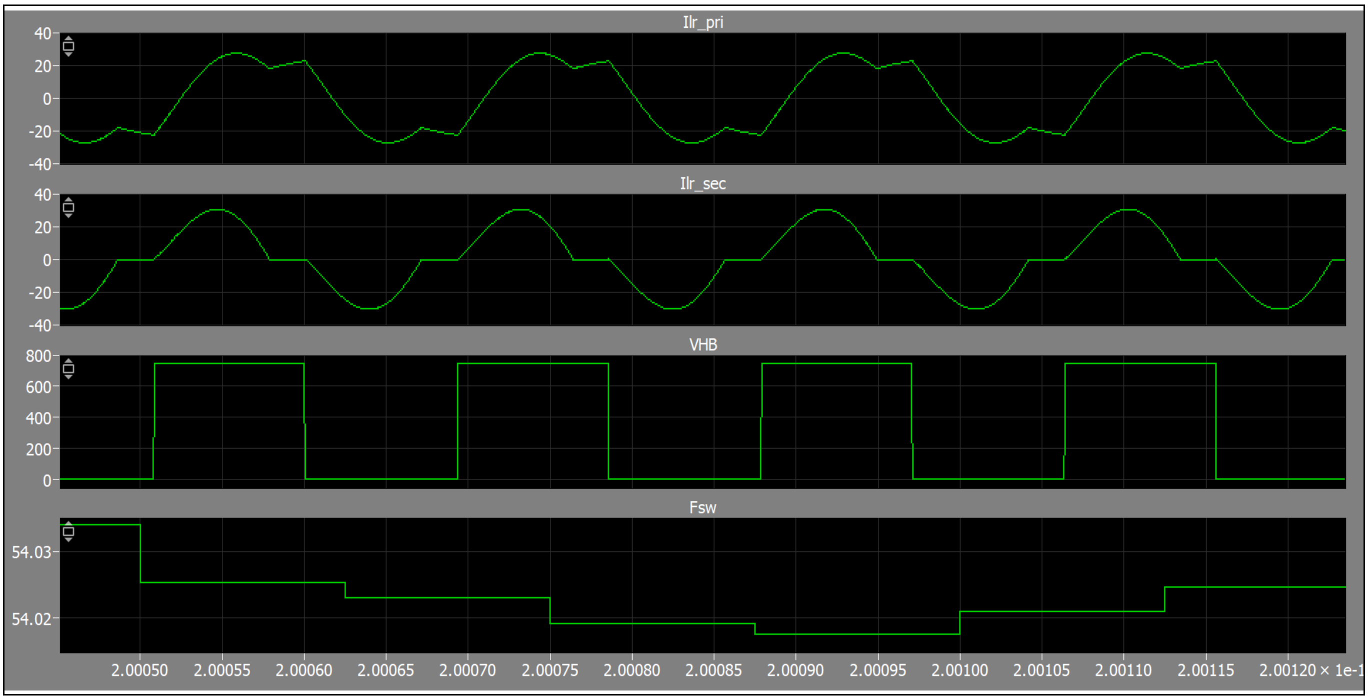

Figure 6 Simulation result of CLLC in the normal mode (forward power flow)

The simulation result in Figure 7 has been obtained at the following parameters:

- Bus voltage: 700 V
- HV voltage: 800 V
- Resistance of load: 58.1 Ω
- Switching frequency: 48.2 kHz

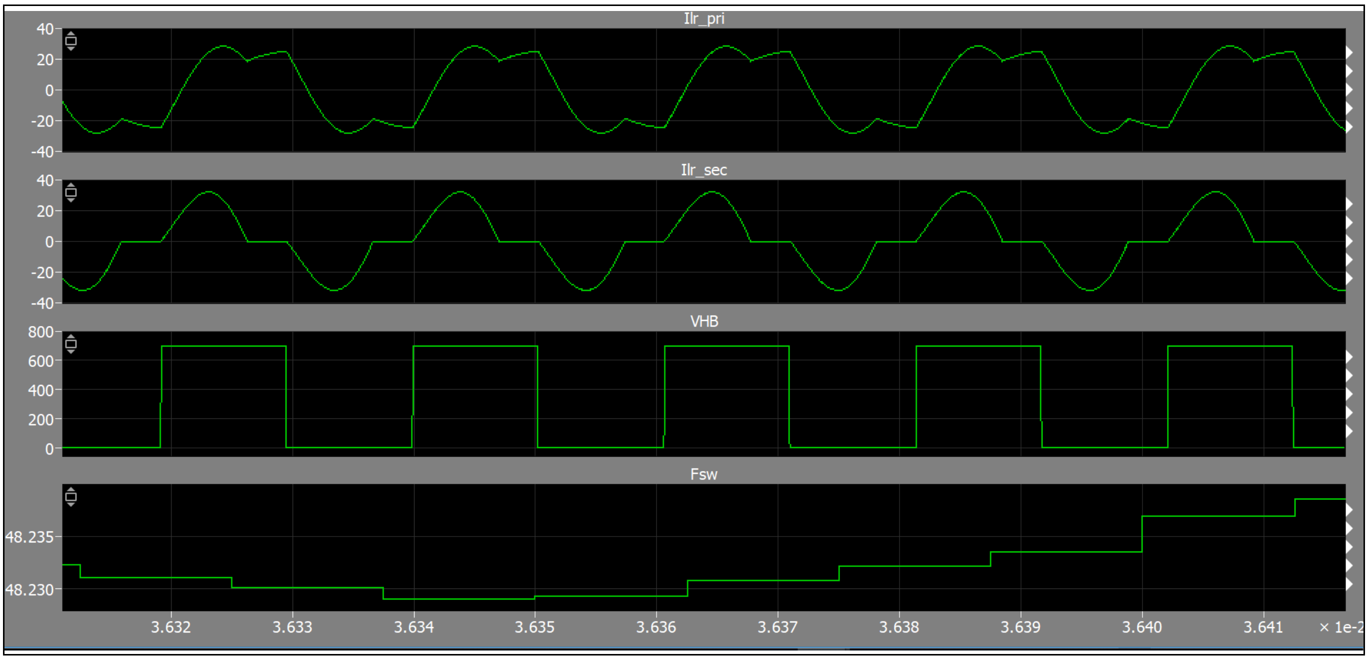

Figure 7 Simulation result of CLLC in the boost mode (forward power flow)

Experimental results of the CLLC DC-DC converter are shown in Figures 8 – 13. Figure 8 shows the operation of the converter with no load. At light load (<10%) or with no load, the control system switches in the burst control mode. In this control mode, the microcontroller skips pulses to transfer energy proportionally from one side of the converter to another side.

Figure 8 includes the following signals:

- Channel 1 is the controller board output pulse-width modulation (PWM) signal
- Channel 2 is the HV voltage

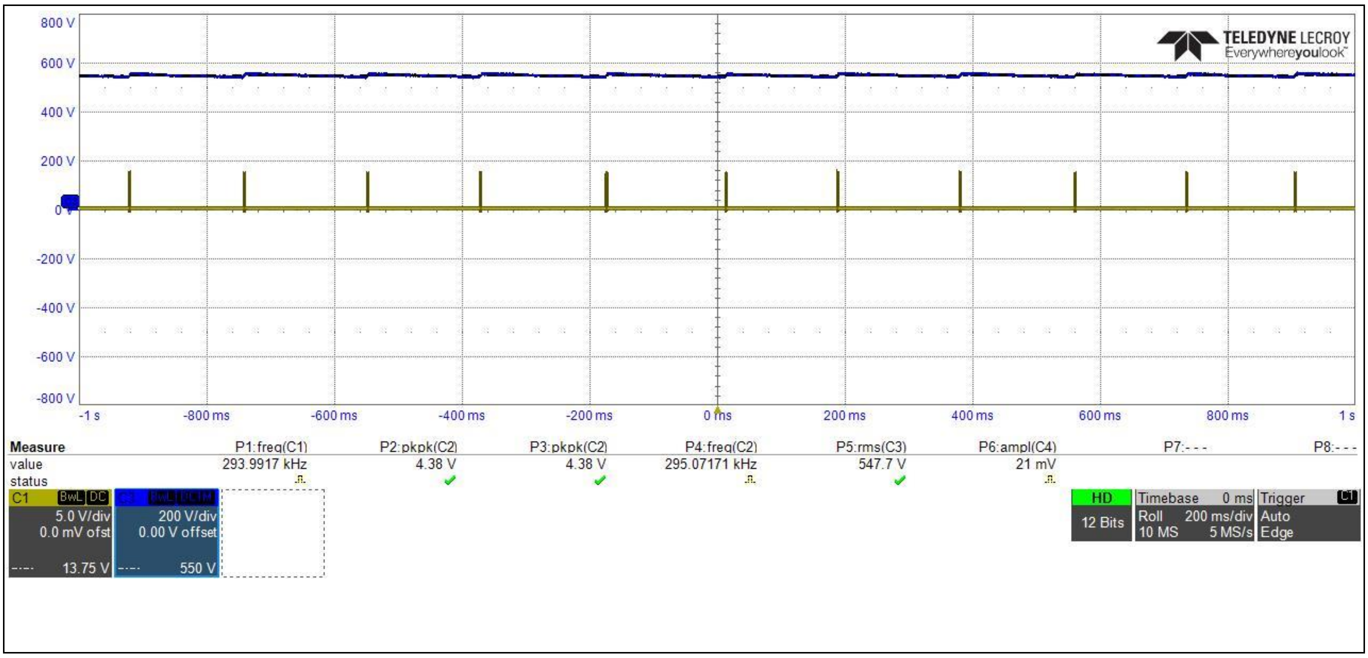

Figure 8 Experimental test result at no load

Figure 9 shows step-up of load at the HV side from near 0 A to 4 A:

- Channel 3 is the HV voltage.
- Channel 4 is the load current.

As can be seen in Figure 9, the control system switches from the burst mode to the FM mode during increasing load.

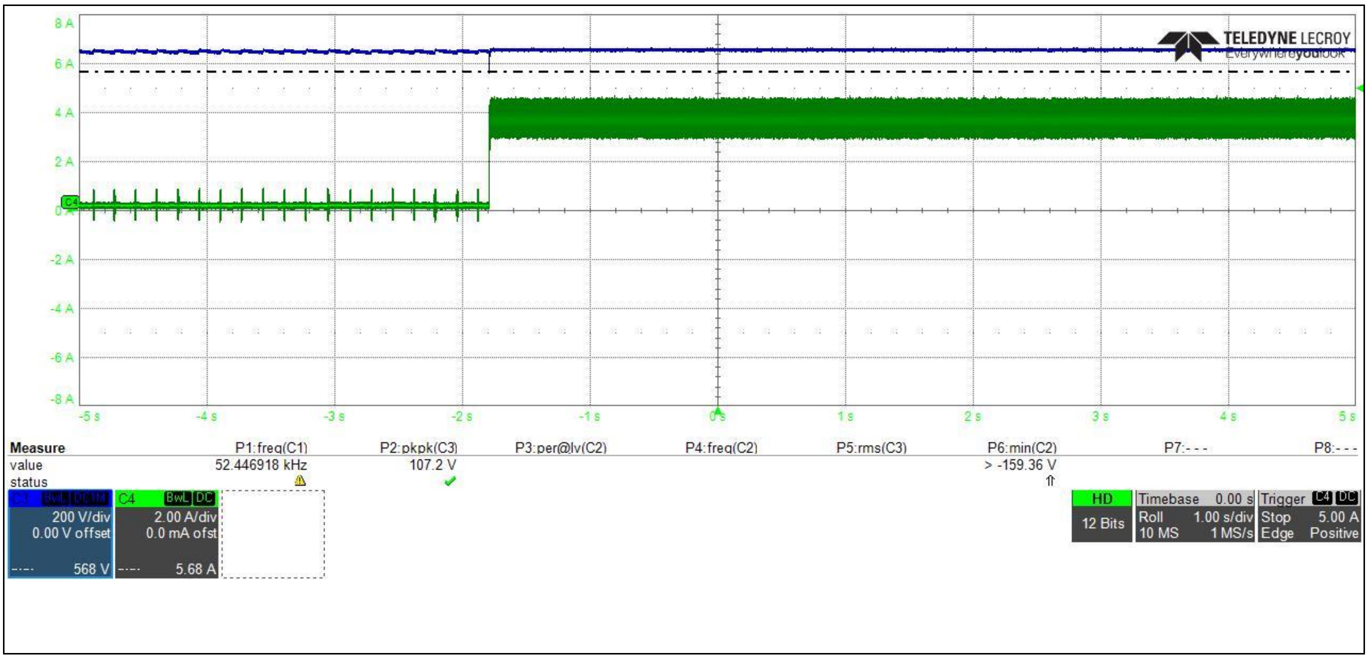

Figure 9 Experimental test result at step-up of load

Increasing of the load current is shown in Figure 10:

- Channel 2 is the gate signal of Q2
- Channel 3 is the drain-source voltage V_{ds} of Q2
- Channel 4 is the transformer current at the bus voltage side

As can be seen in Figure 10, there is no overshoots or speaks in the transformer current. If the peak value of the current is higher than 40 A, the control system triggers the overcurrent protection.

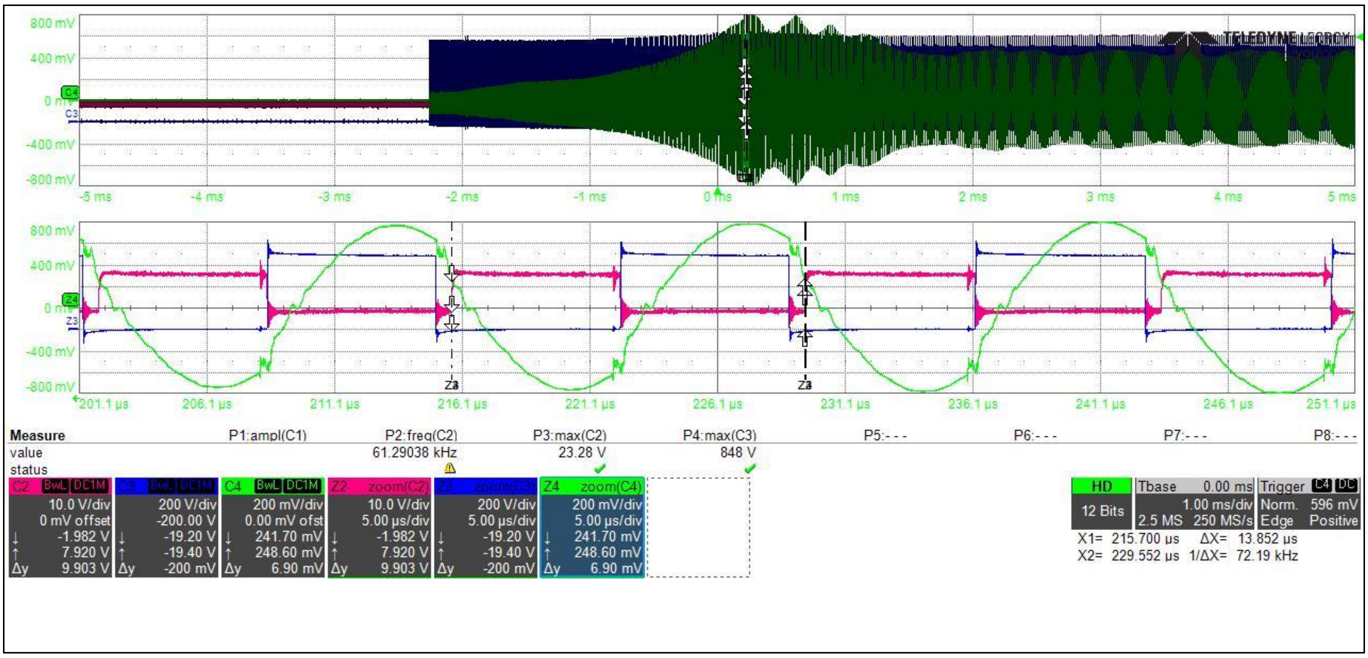

Figure 10 Experimental test result of increasing load current

Figure 11 shows the following steady-state waveforms at the load of 10 kW:

- Channel 2 is the gate signal of Q2
- Channel 3 is the drain-source voltage V_{ds} of Q2
- Channel 4 is the transformer current at the bus voltage side

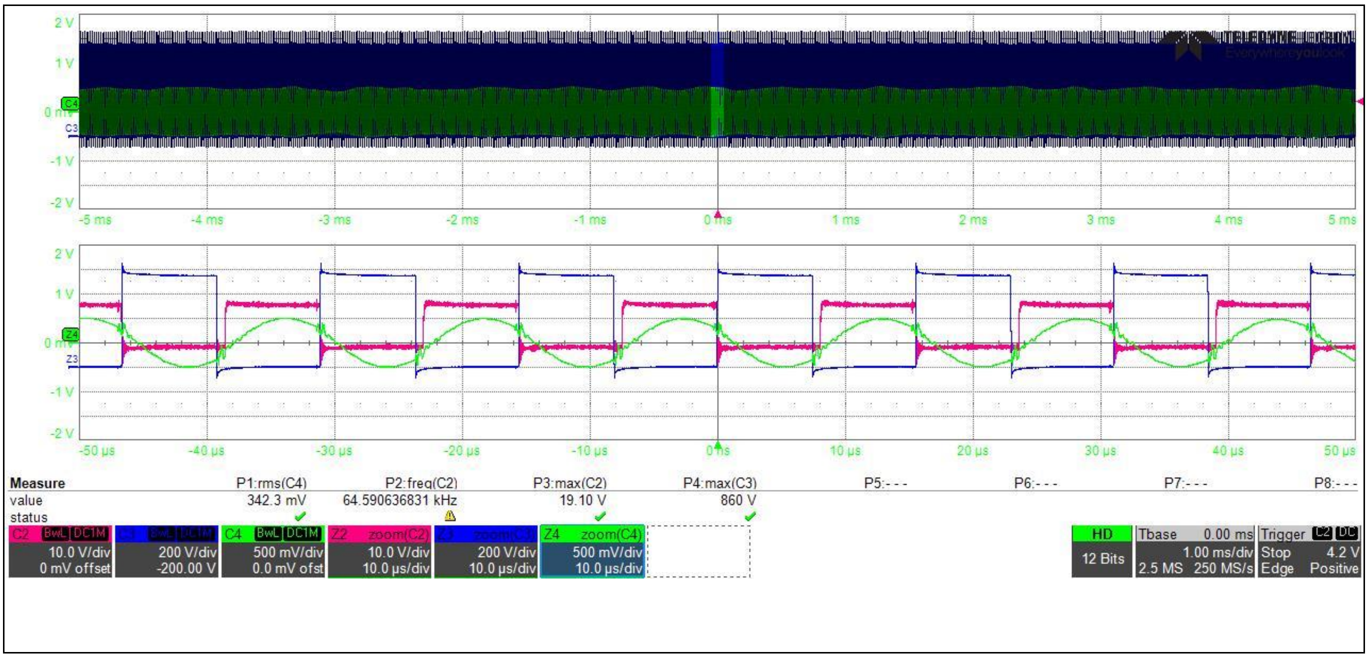

Figure 11 Experimental steady-state waveforms at load of 10 kW

Zoomed waveforms from Figure 11 is shown in Figure 12.

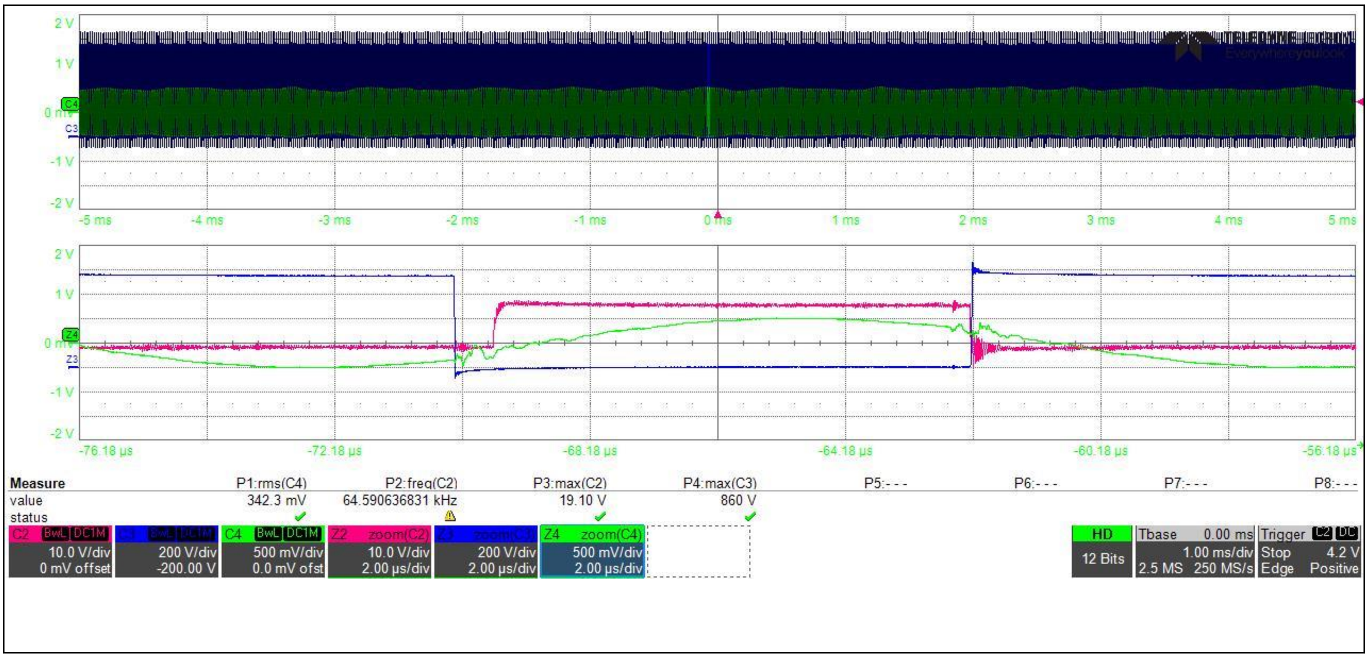

Figure 12 Zoomed experimental steady-state waveforms at load of 10 kW

Ac ripple of the HV voltage is shown in Figure 13:

- Channel 1 is the gate signal of Q2
- Channel 2 is AC component of the HV voltage

As can be seen in Figure 13, the HV voltage ripple is around 16.5 V.

Figure 13 Output voltage ripple

2.2.2 Special operation modes

The CLLC circuit used CoolSiC™ MOSFETs in the bus and the HV sides, therefore, in the normal operation conditions when one side of the converter is in the switching state, the other side works in the 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, the synchronous rectification method can be applied to reduce the conduction loss on the rectifier side and improve the conversion efficiency.

For continuous resonant current, dedicated synchronous rectifier controllers are widely used to detect zero crossing in the resonant current to turn off rectifier switches. However, the CLLC DC-DC operates with a discontinuous resonant current at the low switching frequency, as can be seen in Figure 7. Therefore, another low-cost method to achieve synchronous rectification control based on current transformers (CT) can be used (Figure 14):

- The CT provides scaled positive and negative signal of the resonant current
- After rectification, the unipolar signal of the resonant current is compared with a fixed threshold Vref, which is set to be slightly more than 0
- Resulted square signal of the comparator and the primary pulse-width modulation (PWM) signal are subjected to the AND operation and then sent to the corresponding drive circuit as the drive signal

This process can also be completed by the MCU.

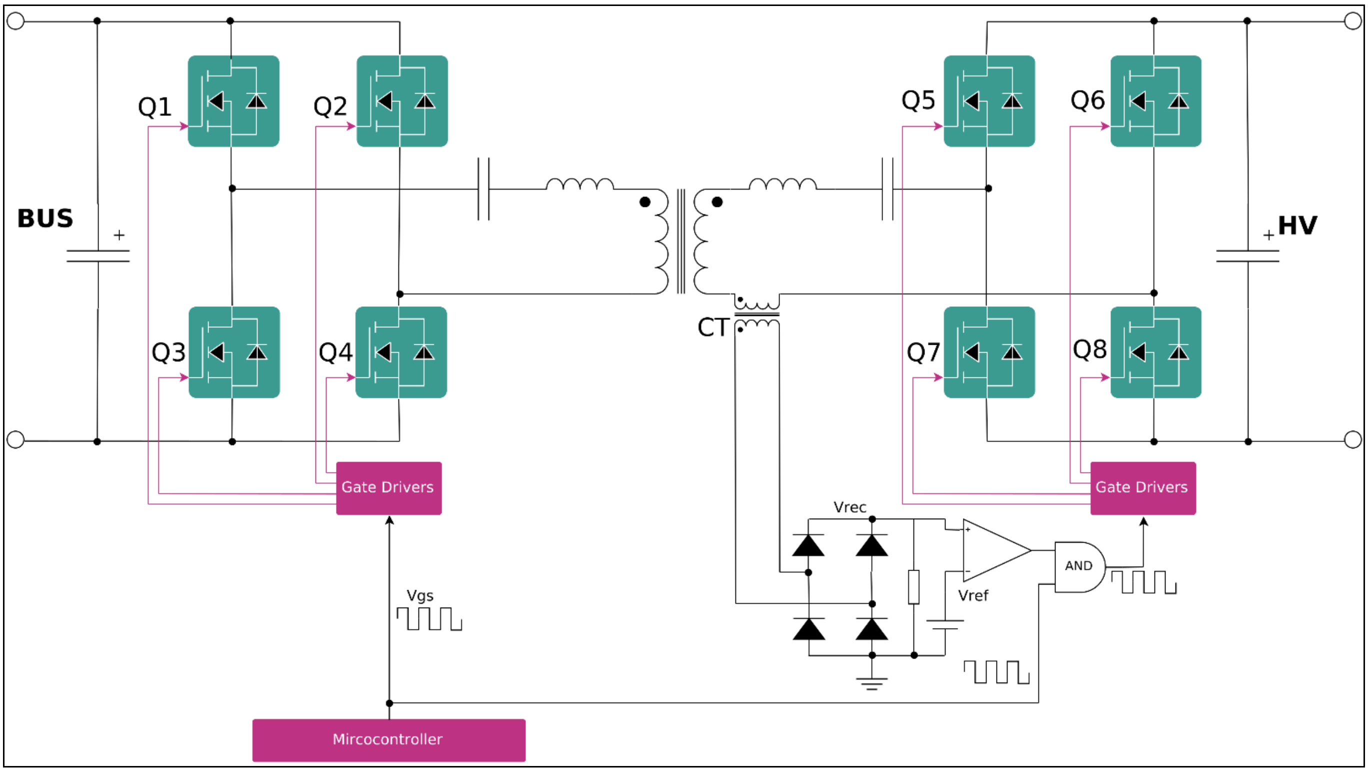

Figure 14 Synchronous rectification circuit

This simple method allows easily to achieve synchronous rectification at discontinuous resonant current. In the CLLC DC-DC this method has been realized in the MCU where AND operation, the comparator, PWM timers are periphery of 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 µs, and software optimization is required to reduce this delay time.

Figure 15 shows experimental waveforms of the synchronous rectifier:

- Channel 1 is the V_{ref}
- Channel 2 is output signal of the comparator
- Channel 3 is the gate PWM signal of the synchronous rectifier
- Channel 4 is the gate PWM signal of the primary side

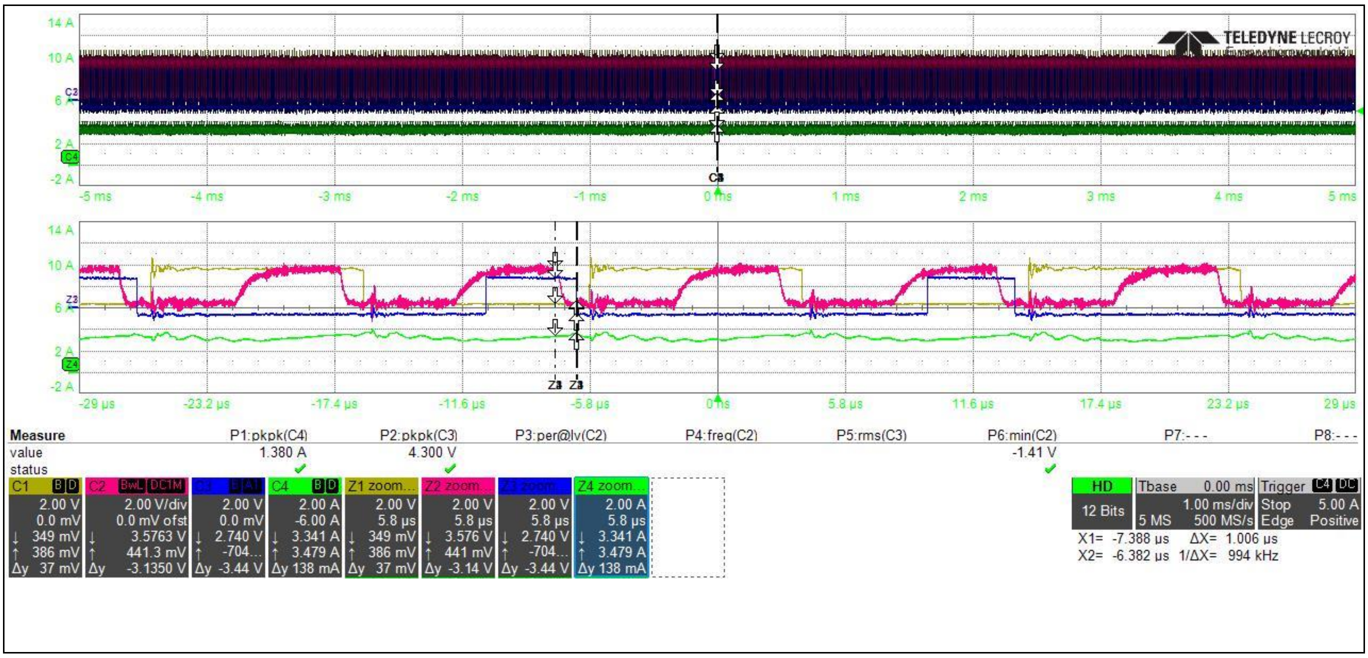

Figure 15 Synchronous rectification gate signal

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 4 lists the key board specifications.

Table 4 Technical specifications

Input voltage	300 V_{DC} to 900 V_{DC}
Output power	32 W
Topology	Single-ended flyback
Output voltage	20 V
Voltage ripple	2%
Output current	2 A
Frequency	65~130 kHz, QR mode
Derating of switches V_{DS}	85% (1450 V)
Efficiency at full load	>85%

2.3.2 Auxiliary power board description

The auxiliary power boards has been 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 300 V_{DC} to 850 V_{DC}. 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 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.

Due to the system has three fans, 8 drivers, and different sensors, two auxiliary boards are required to supply components.

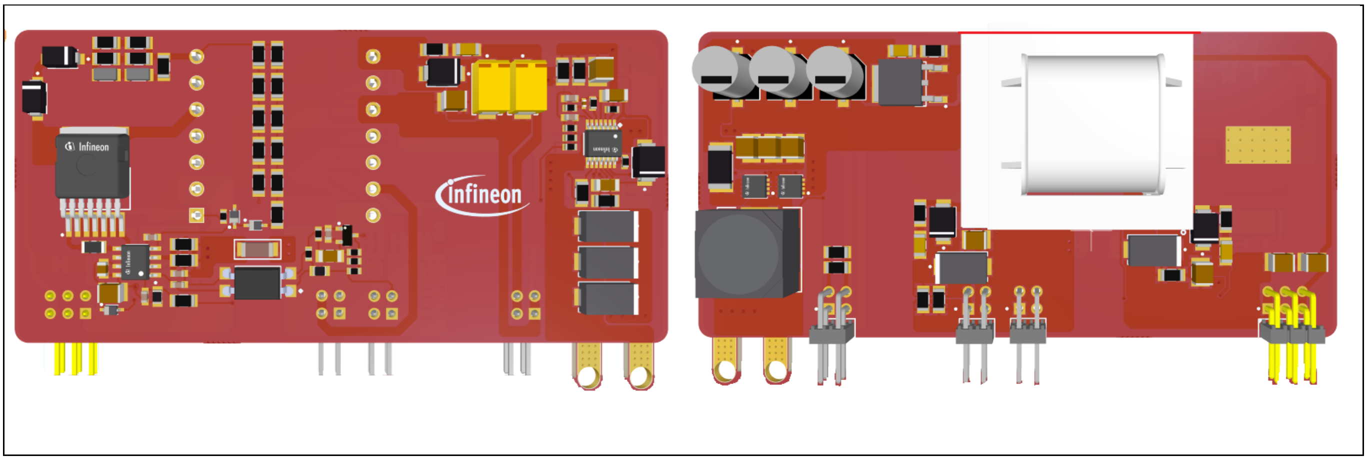

Figure 16 Pictures of auxiliary power board

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.

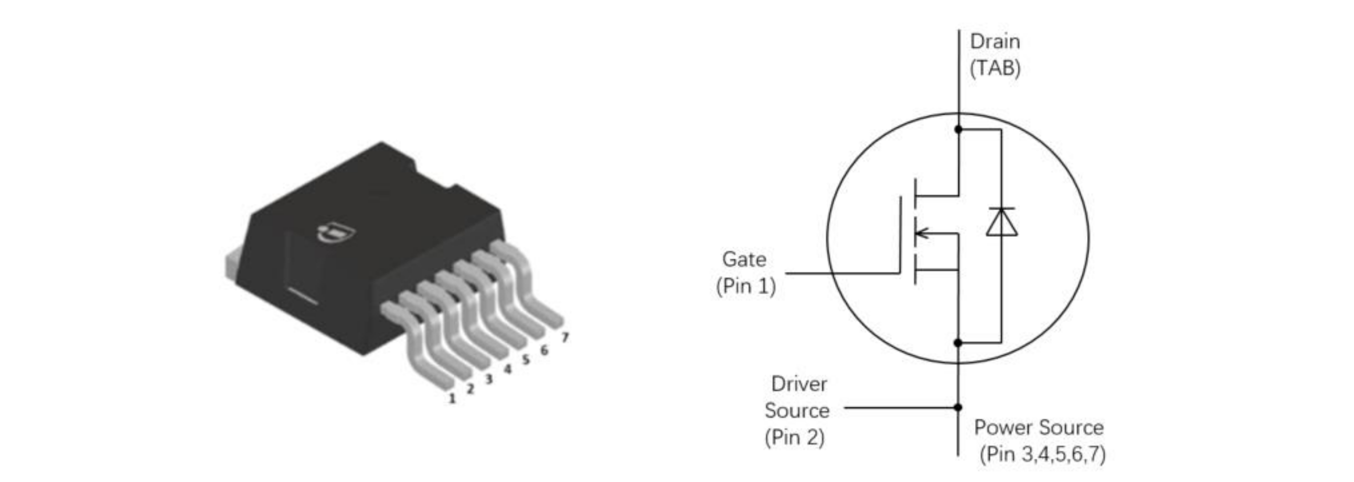

Figure 17 1700 V CoolSiC™ MOSFET IMBF170R1K0M1

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 as shown in Figure 18.

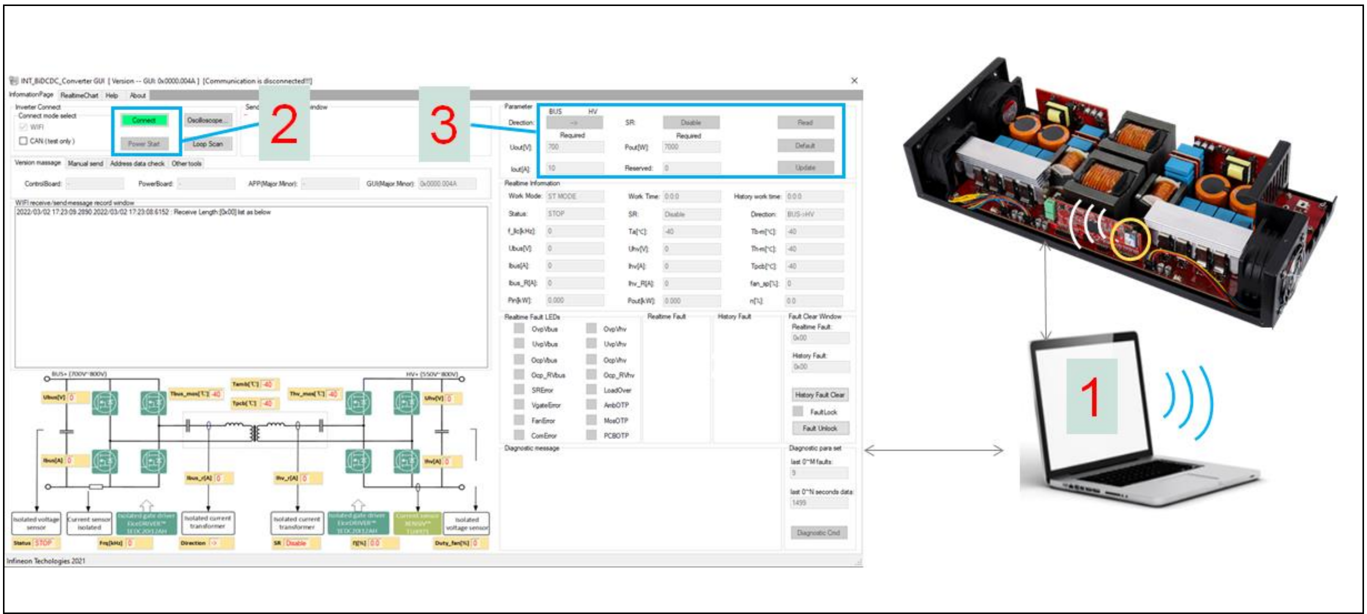

Figure 18 Signal chain between the GUI control interface and the converter system

The below steps to be followed for GUI software setup

1) Open the GUI software,
2) Find INT_BiDCDC-Converter in network settings and connect it
3) Click the 'Connect' button, then the 'Power Start' button becomes settable after successful connection
4) Set the parameters, click 'Update' button, and then click the 'Power Start' button

The corresponding human-machine interface realizes corresponding functions through the combination of graphics + data + buttons. The detailed interface is shown in Figure 19.

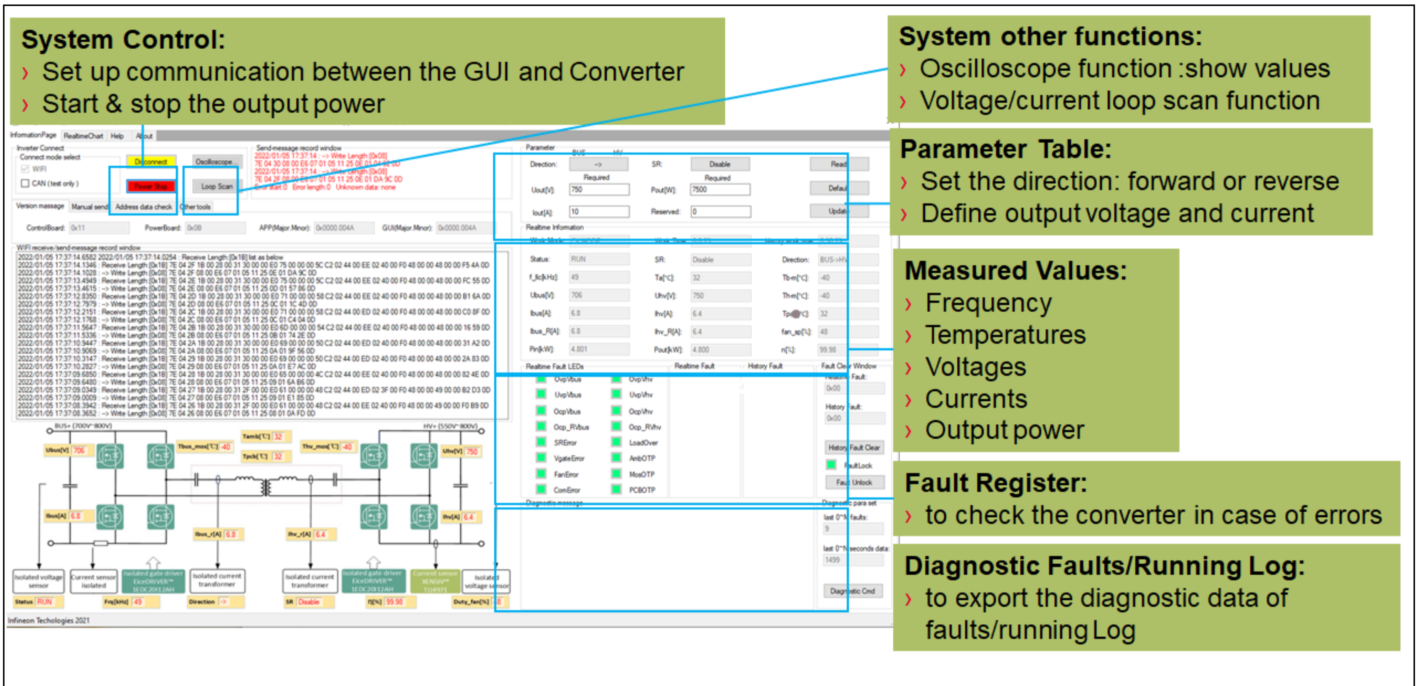

Figure 19 Graphical user interface (GUI)

The GUI has an option to display real-time data of the DC-DC converter. The real-time display is having four sections which are shown in Figure 20.

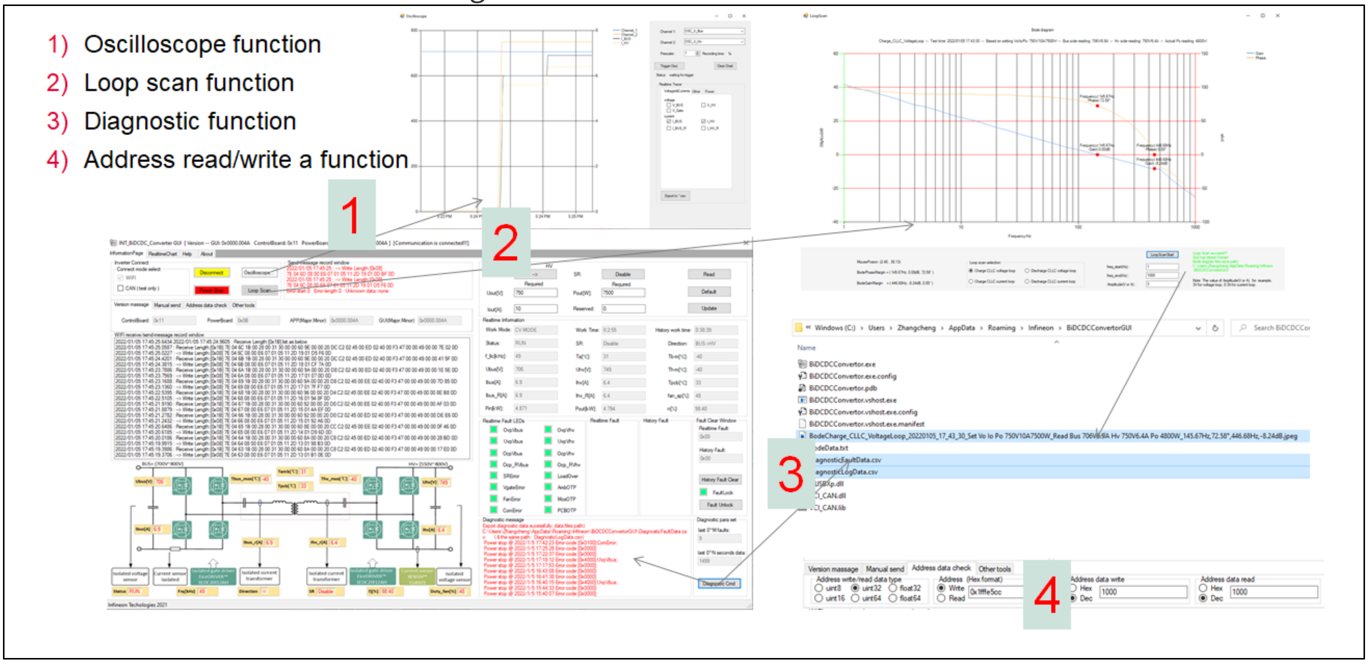

Figure 20 Data patterns in GUI

2.5 Efficiency plots

The measured efficiency plots in the forward and inverse power direction are reported in Figures 22 and 23. A high precision power analyzer has been used for measurements as shown in Figure 21:

- The power analyzer WT1800 is on the right side
- A DC power supply is below
- The 11 kW bi-directional CLLC DC-DC converter is on the left side

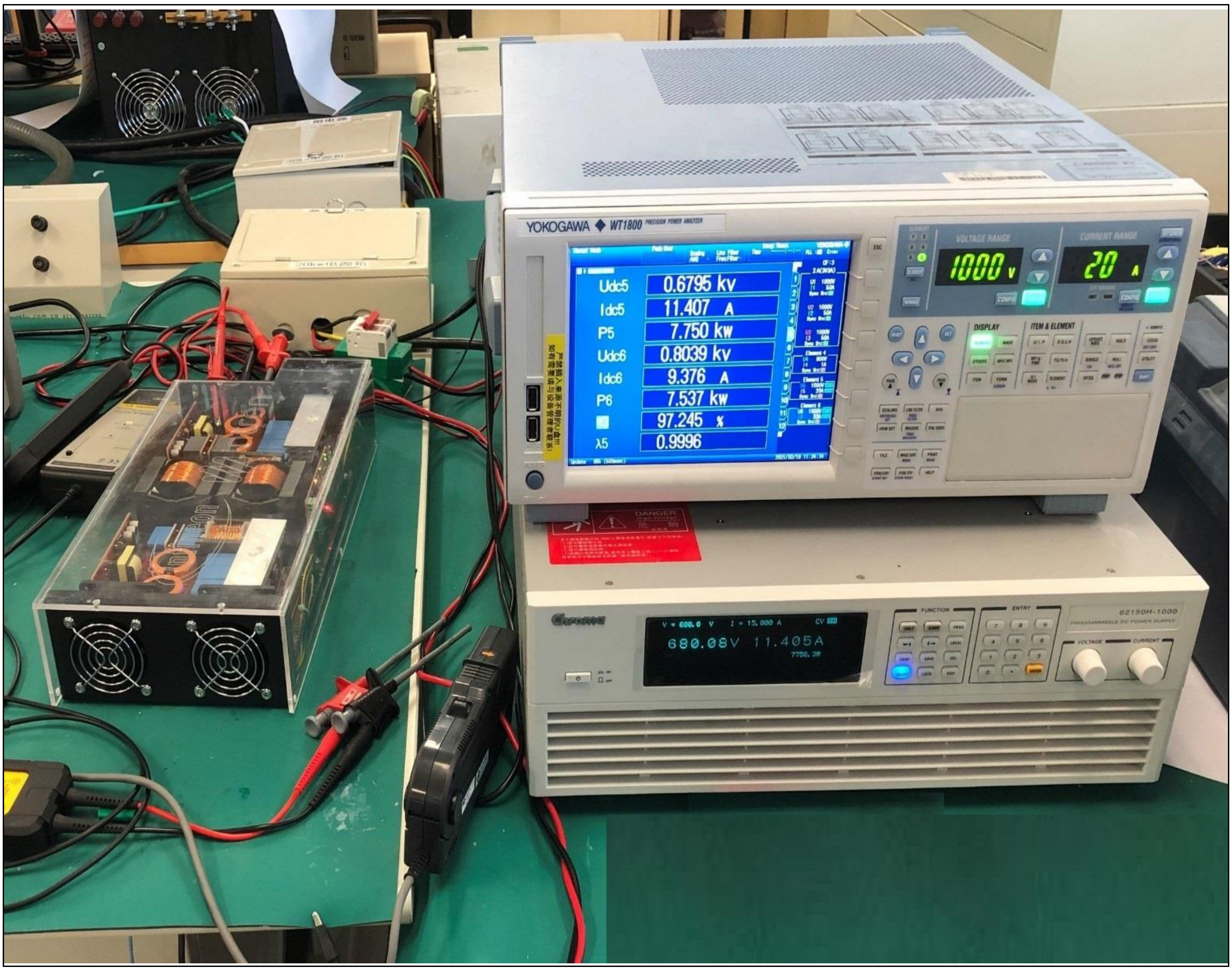

Figure 21 Efficiency test environment

The efficiency plots shown in Figure 22 and Figure 23 has been measured under different conditions with different output power & voltage. The measured plots also include the power losses from fans which are supplied by the auxiliary power board inside the system. The maximum efficiency is 97.26% in reverse working mode at the HV voltage of 800 V, the bus voltage of 680 V, and output power of 6.67 kW. A further improvement with the implantation of synchronous rectification is in progress, it is expected that the efficiency can be improved by 0.2~0.3%.

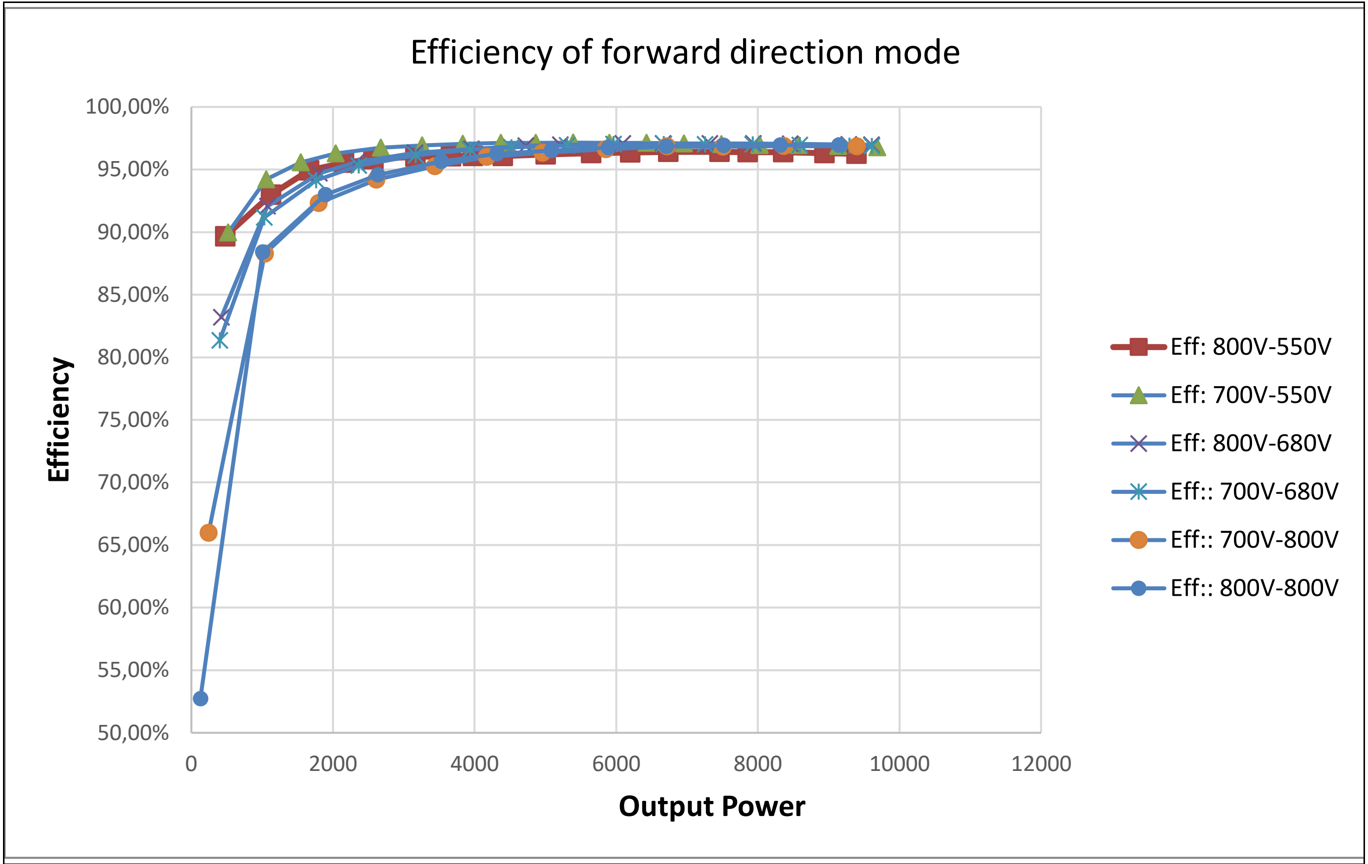

Figure 22 Efficiency in the forward power direction

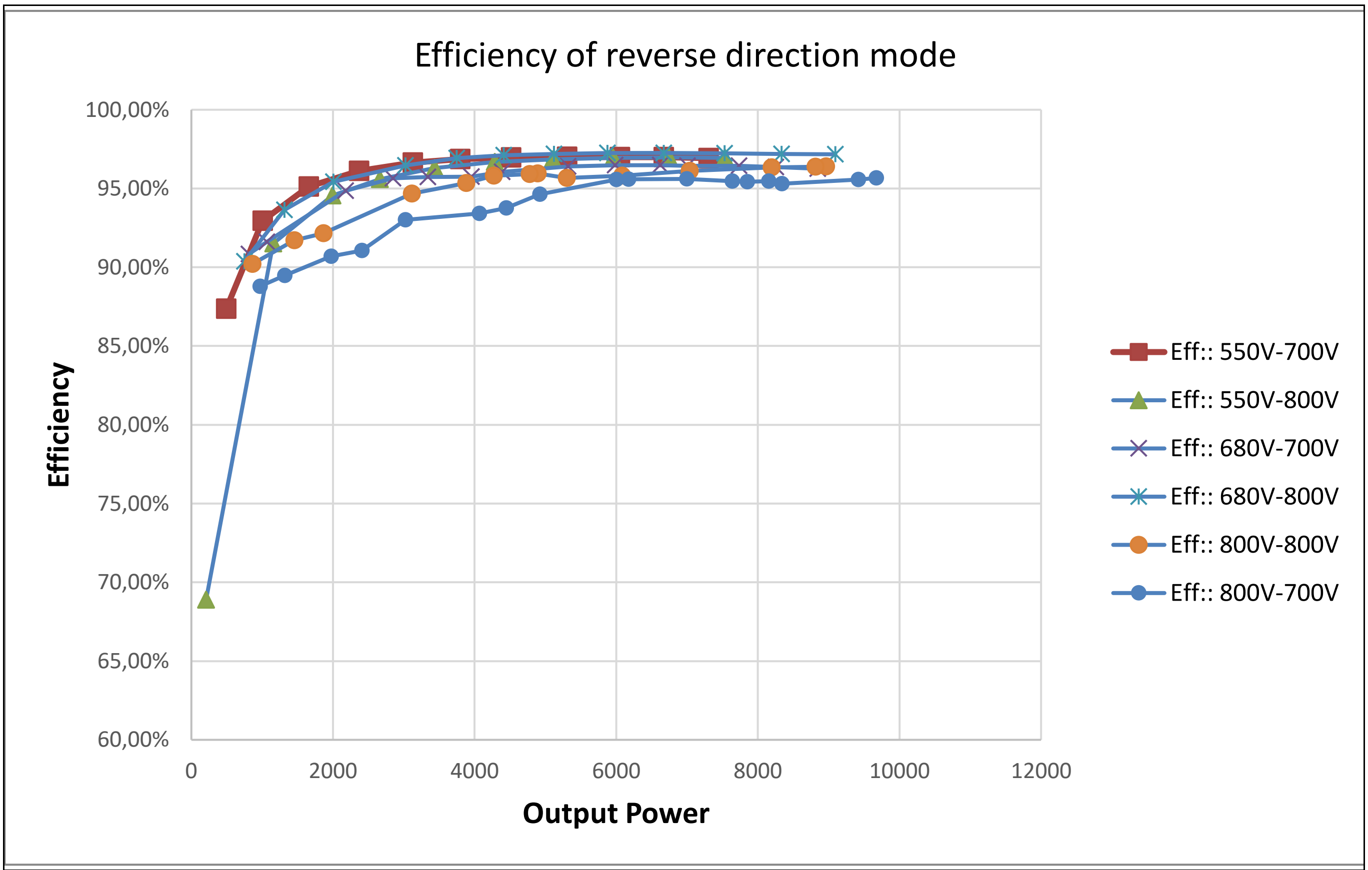

Figure 23 Efficiency in the forward power direction

3 System design

3.1 Schematics

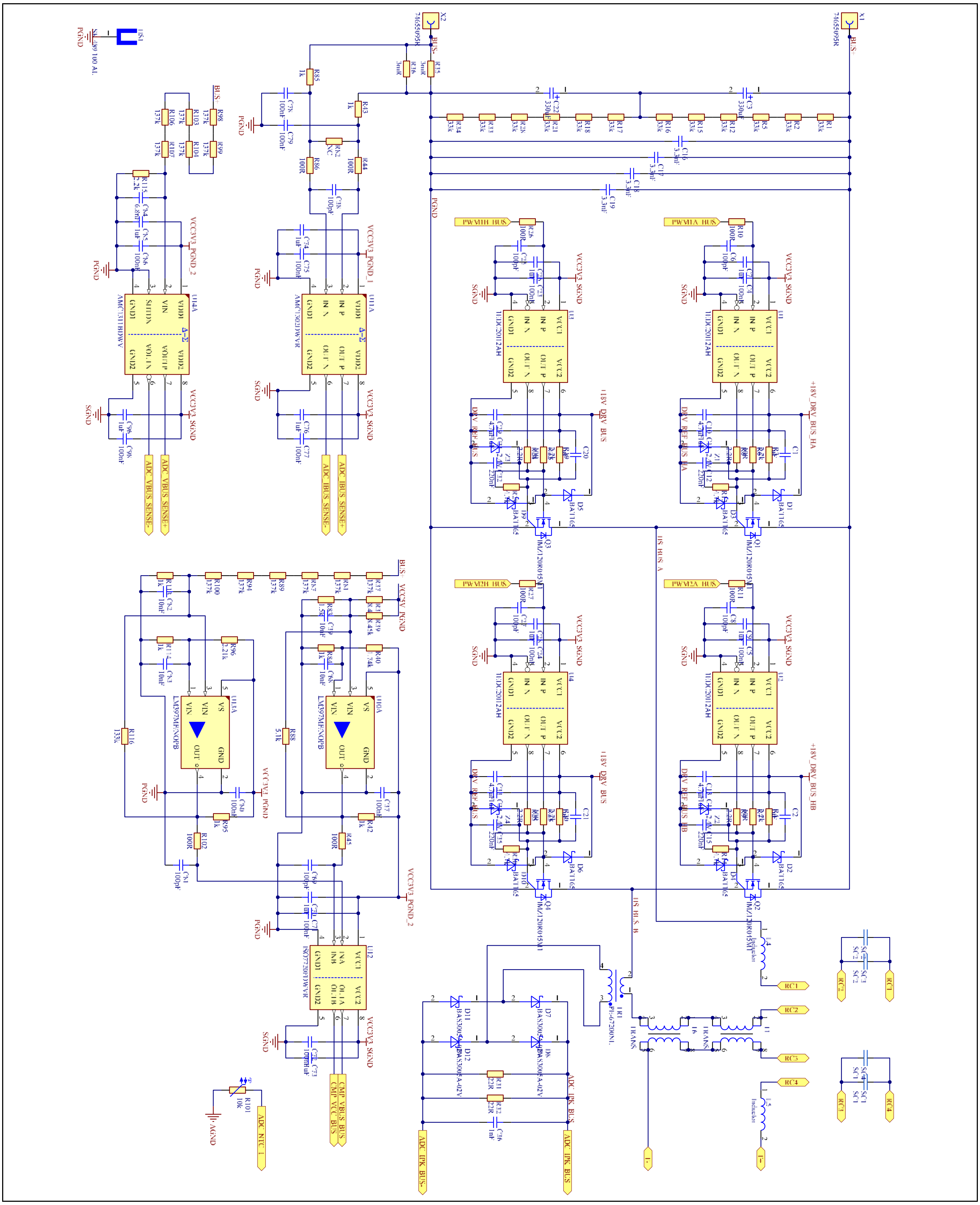

Figure 24 Main board primary side schematic

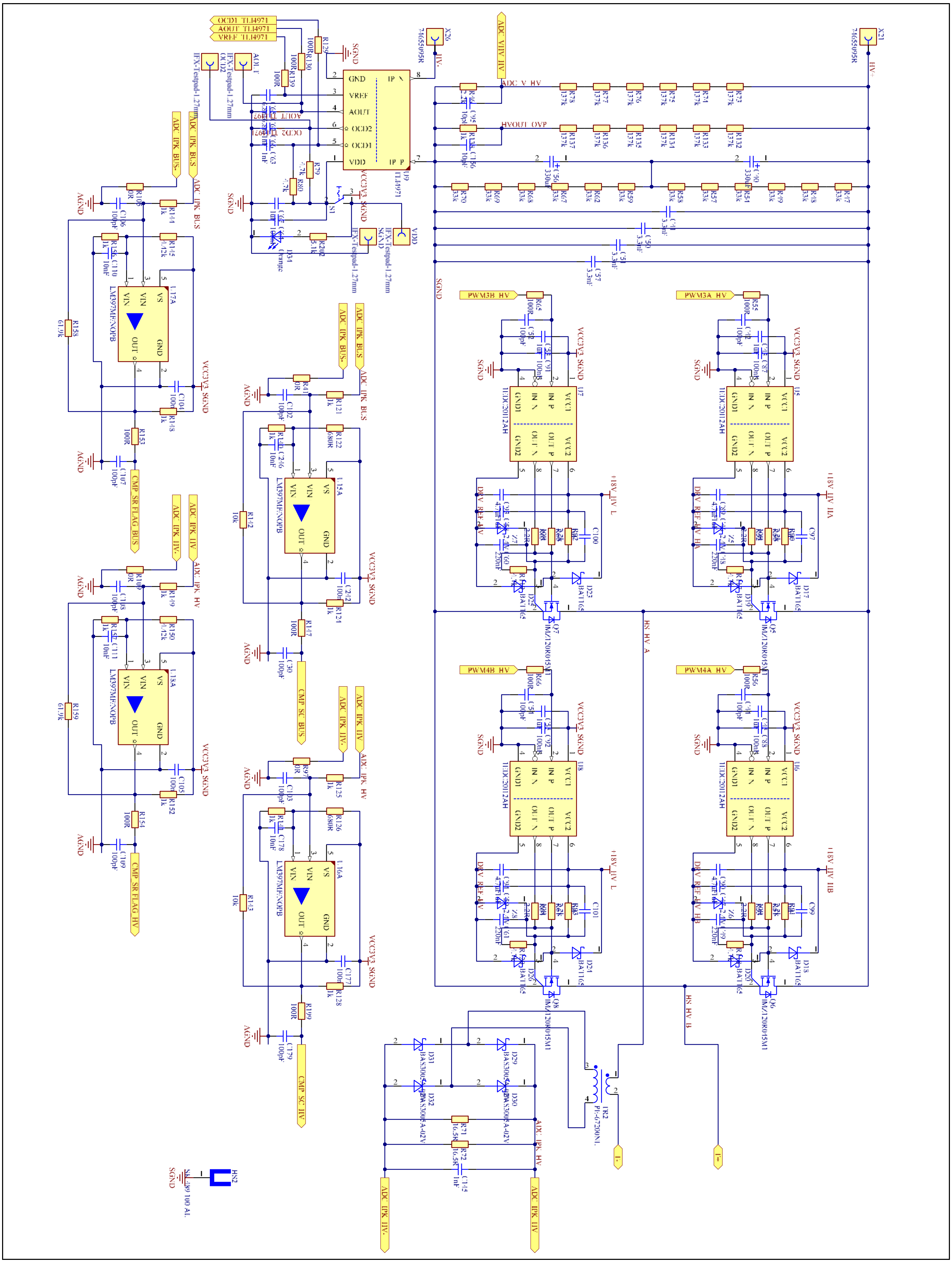

Figure 25 Main board secondary side schematic

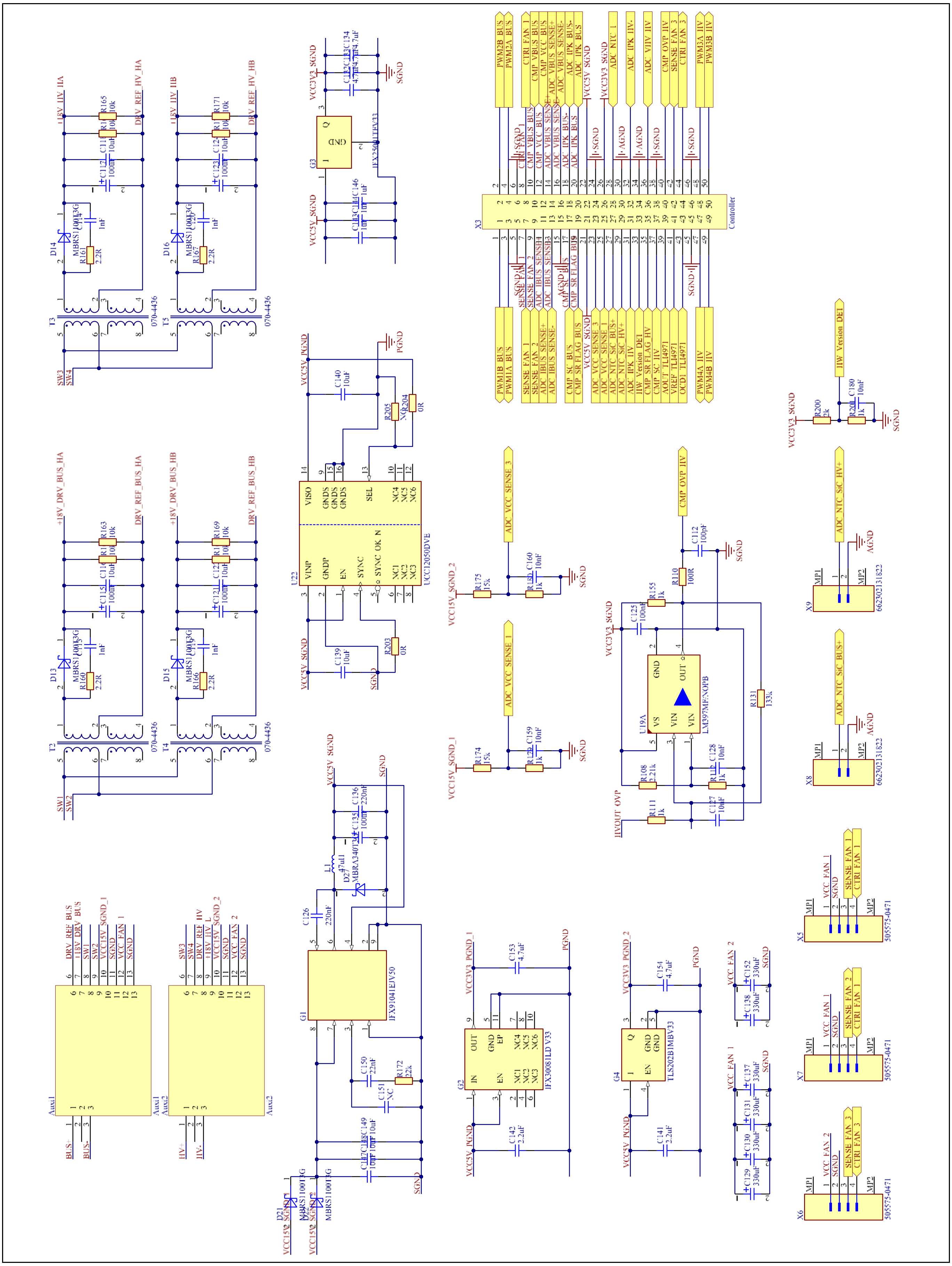

Figure 26 Sensor circuit schematic

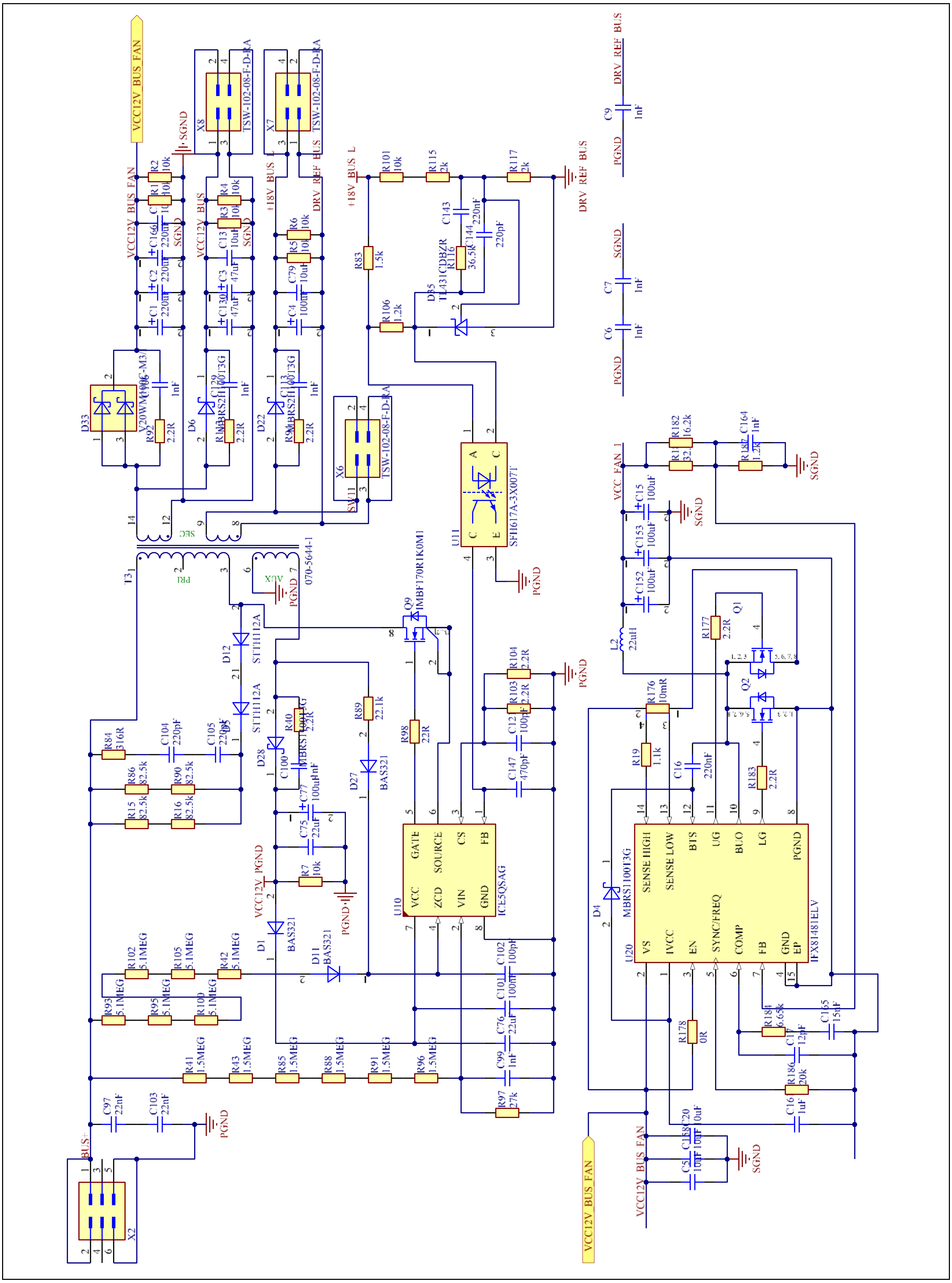

Figure 27 Primary side 32 W auxiliary power supply schematic.

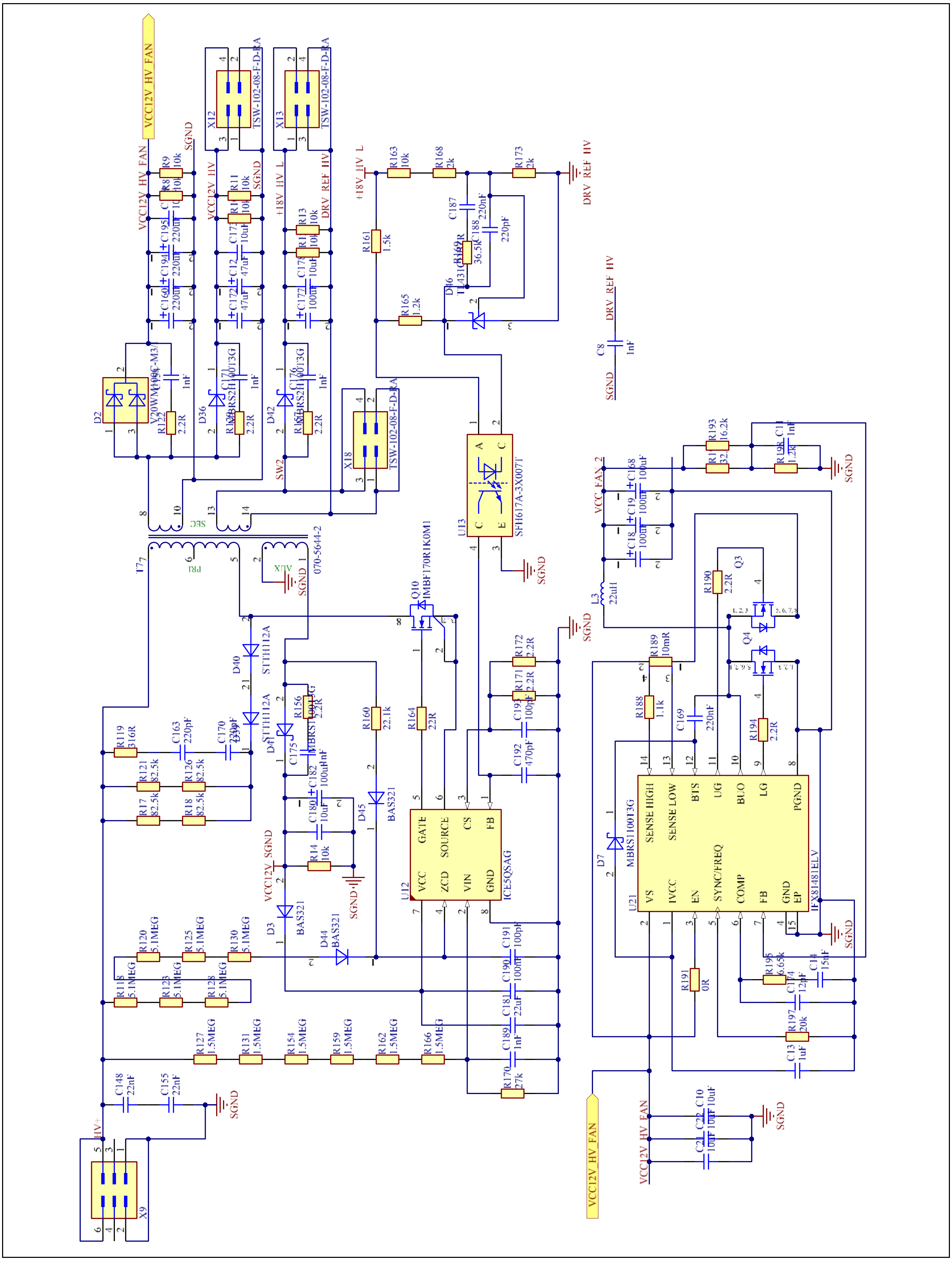

Figure 28 Secondary side 32 W auxiliary power supply schematic.

3.2 Layout

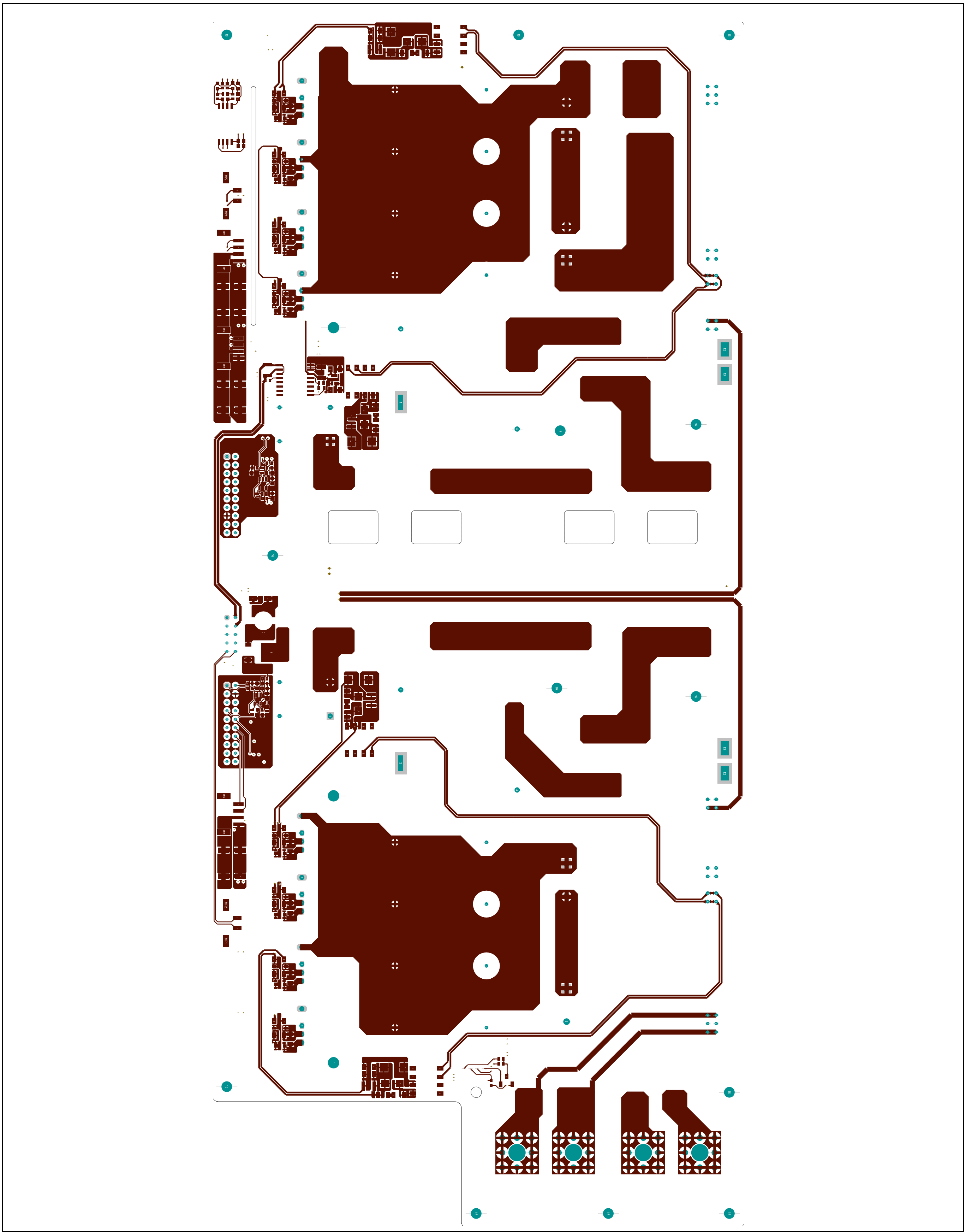

Figure 29 Top Layer

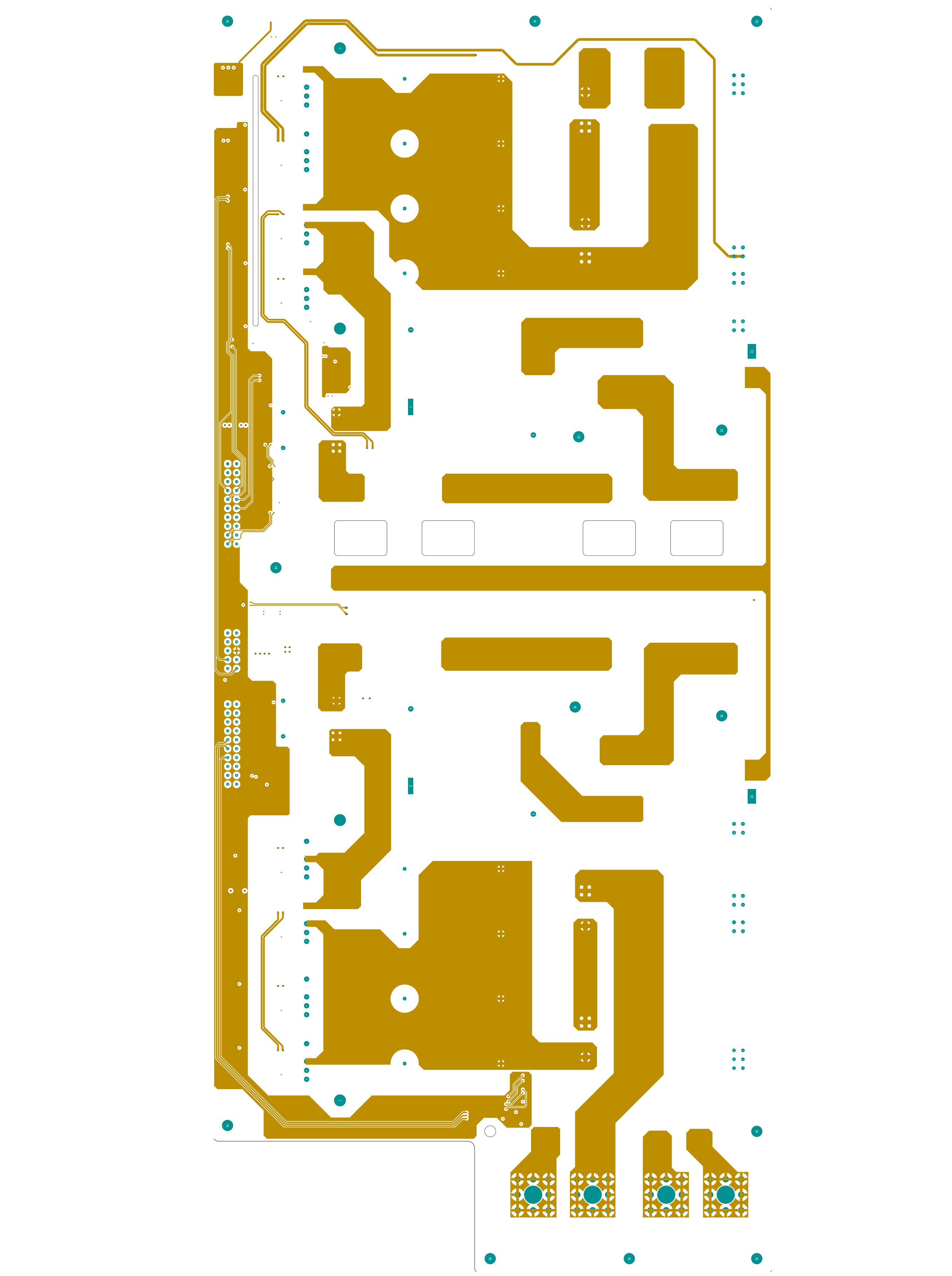

Figure 30 Layer 2

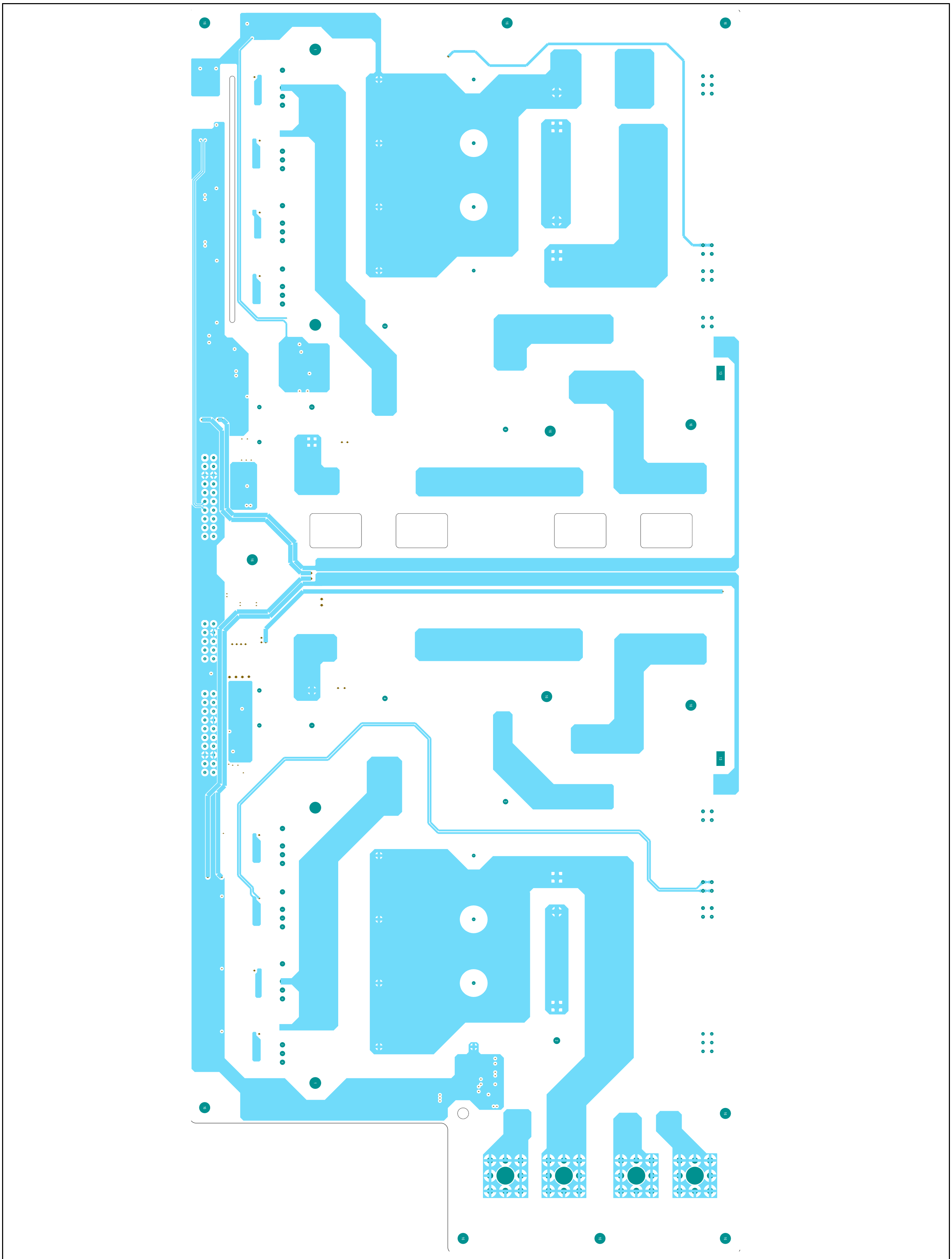

Figure 31 Layer 3

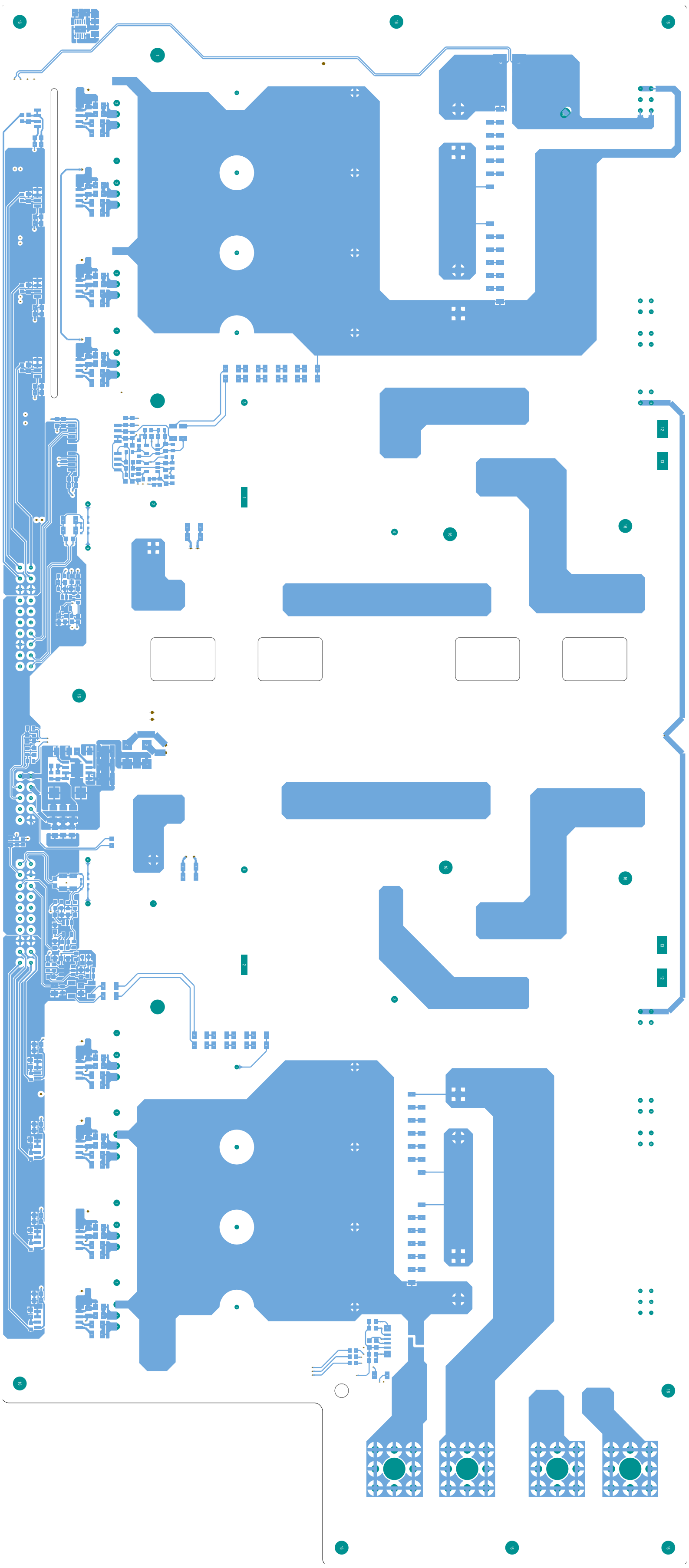

Figure 32 Bottom Layer

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 5 BOM of the most important/critical parts of the reference board

Quantity	Designator	Value	Footprint	Description	Manufacturer
2	C107, C115	12nF	CAPRR2250W80L2650T600H1500B	CAP / FILM / 12nF / 2kV / 5% / MKP (Metallized Polypropylene) / -55 °C to 110 °C / 22.50mm C X 0.80mm W 26.50mm L X 6.00mm T X 15.00mm H / - / -	TDK Corporation
18	C108, C109, C110, C111, C112, C114, C116, C117, C118, C119, C120, C138, C139, C140, C141, C142, C196, C197	18nF	CAPRR2250W80L2650T600H1500B	CAP / FILM / 18nF / 2kV / 5% / MKP (Metallized Polypropylene) / -55 °C to 110 °C / 22.50mm C X 0.80mm W 26.50mm L X 6.00mm T X 15.00mm H / - / -	TDK Corporation
2	C107, C115	12nF	CAPRR2250W80L2650T600H1500B	CAP / FILM / 12nF / 2kV / 5% / MKP (Metallized Polypropylene) / -55 °C to 110 °C / 22.50mm C X 0.80mm W 26.50mm L X 6.00mm T X 15.00mm H / - / -	TDK Corporation
18	C108, C109, C110, C111, C112, C114, C116, C117, C118, C119, C120, C138, C139, C140, C141, C142, C196, C197	18nF	CAPRR2250W80L2650T600H1500B	CAP / FILM / 18nF / 2kV / 5% / MKP (Metallized Polypropylene) / -55 °C to 110 °C / 22.50mm C X 0.80mm W 26.50mm L X 6.00mm T X 15.00mm H / - / -	TDK Corporation
2	C107, C115	12nF	CAPRR2250W80L2650T600H1500B	CAP / FILM / 12nF / 2kV / 5% / MKP (Metallized Polypropylene) / -55 °C to 110 °C / 22.50mm C X 0.80mm W 26.50mm L X 6.00mm T X 15.00mm H / - / -	TDK Corporation
3	C1, C2, C166	220uF	CAPAE660X800N-3	CAP / ELCO / 220uF / 25V / 20% / Aluminiumelectrolytic / -55 °C to 105 °C / 6.60mm L X 6.60mm W X 8.00mm H / SMD / -	Panasonic
4	C3, C12, C130, C172	47uF	CAPMP7343X430N	CAP / ELCO / 47uF / 35V / 10% / Tantalumoxide / -55 °C to 125 °C / 7.30mm L X 4.30mm W X 4.30mm H / - / -	Kemet
10	C4, C15, C18, C19, C77, C152, C153, C168, C177, C182	100uF	CAPMP7343X310N-1	Polymer Surface Mount Chip Capacitor Molded Case, High Performance Type, CAP / ELCO / 100uF / 25V / 20% / Tantalumelectrolytic /	Vishay

				-55 °C to 105 °C / 7.30mm L X 4.30mm W X 3.10mm H / SMD / -	
14	C5, C10, C20, C21, C22, C71, C75, C79, C131, C158, C159, C173, C178, C180	10uF	1210	CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / - / 10uF / 50V / 20% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / CERA / 10uF / 50V / 20% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -	TDK Corporation
4	C6, C7, C8, C9	1nF	1808	Multilayer Ceramic Chip Capacitor	TDK Corporation
4	C11, C99, C164, C189	1nF	0603	CAP / CERA / 1nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
2	C13, C161	1uF	1206	CAP / - / 1uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
2	C14, C165	15nF	0603	CAP / - / 15nF / 35V / 5% / C0G (EIA) / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
4	C16, C143, C169, C187	220nF	1206	CAP / - / 220nF / 100V / 5% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -, CAP / - / 220nF / 16V / 5% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
2	C17, C174	12pF	0402	CAP / - / 12pF / 50V / 2% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0402(1005) / SMD / -	TDK Corporation
2	C76, C181	22uF	1210	CAP / CERA / 22uF / 25V / 20% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -	TDK Corporation
4	C97, C103, C148, C155	22nF	1206	Chip Monolithic Ceramic Capacitor	TDK Corporation
8	C100, C106, C113, C129, C154, C171, C175, C176	1nF	1206	CAP / CERA / 1nF / 630V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
2	C101, C190	100nF	0805	CAP / CERA / 100nF / 100V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
4	C102, C121, C191, C193	100pF	0603	CAP / CERA / 100pF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
4	C104, C105, C163, C170	220pF	CAPC3216X100N	Chip Monolithic Ceramic Capacitor	MuRata
2	C144, C188	220pF	0603	CAP / CERA / 220pF / 50V / 5% / C0G (EIA) / NP0 / -55 °C	TDK Corporation

				to 125 °C / 0603(1608) / SMD / -	
2	C147, C192	470pF	0603	CAP / CERA / 470pF / 50V / 2% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
3	C160, C194, C195	220uF	CAPAE660X800N-1	CAP / ELCO / 220uF / 25V / 20% / Aluminiumelectrolytic / -55 °C to 105 °C / 6.60mm L X 6.60mm W X 8.00mm H / SMD / -	Panasonic
6	D1, D3, D11, D27, D44, D45	BAS321	SOD2513X110N-1	General Purpose Diode	Nexperia
2	D2, D33	V20WM100C-M3/I	TO229P1003X238-4_3N	Dual Trench MOS Barrier Schottky Rectifier	Vishay
4	D4, D7, D28, D41	MBRS1100T3G	DIOM5436X247N	Schottky Power Rectifier	ON Semiconductor
4	D5, D12, D39, D40	STTH112A	DIOM5126X265N	High voltage ultrafast rectifier	STMicroelectronics
4	D6, D22, D36, D42	MBRS2H100T3G	DIOM5436X247N	Surface Mount Schottky Power Rectifier, 2.0A/100V	ON Semiconductor
2	D35, D46	TL431CDBZR	SOT95P237X112-3N-1	Precision Programmable Reference	Texas Instruments
2	L2, L3	22uH	INDP120120X81N	IND / STD / 22uH / 2.9A / 20% / -40 °C to 125 °C / 35.5mR / SMD / 12mmx12mmx8.1mm / SMD / -	Coilcraft
4	Q1, Q2, Q3, Q4	BSZ068N06NS	INF-PG-TSDSON-8-FL	OptiMOS Power - MOSFET, 60 V	Infineon Technologies
2	Q9, Q10	IMBF170R1K0M1	TO127P1500X470-8N-1	Coolsic Trench Silicon Carbide MOSFET, very loss switching losses, optimized for fly-back topologies, applications in energy generation, industrial power supplies, infrastructure-charger	Infineon Technologies
14	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14	10k	RESC3216X60N	RES / STD / 10k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
8	R15, R16, R17, R18, R86, R90, R121, R126	82.5k	RESC3216X60N	RES / STD / 82.5k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R19, R188	1.1k	RESC1609X50N	RES / STD / 1.1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
16	R40, R92, R94, R103, R104, R113, R122, R129, R156, R157, R171, R172, R177, R183, R190, R194	2.2R	RESC3216X60N	Standard Thick Film Chip Resistor, RES / STD / 2.2R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -, RES / STD / 2.2R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
12	R41, R43, R85, R88, R91, R96,	1.5MEG	RESC3216X60N	RES / STD / 1.5MEG / 250mW / 1% / 100ppm/K / -55 °C to	Vishay

	R127, R131, R154, R159, R162, R166			155 °C / 1206 / SMD / -	
12	R42, R93, R95, R100, R102, R105, R118, R120, R123, R125, R128, R130	5.1MEG	RESC3216X60N	RES / STD / 5.1MEG / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R83, R161	1.5k	RESC2113X50N	Standard Thick Film Chip Resistor	Vishay
2	R84, R119	316R	RESC3216X60N	Standard Thick Film Chip Resistor	Vishay
2	R89, R160	22.1k	RESC1609X50N	RES / STD / 22.1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R97	27k	RESC1609X50N	RES / STD / 27k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R98, R164	22R	RESC3216X65N-1	RES / STD / 22R / 500mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R101, R163	12k	RESC1609X50N	RES / STD / 12k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
4	R106, R165, R187, R198	1.2k	RESC1609X50N	RES / STD / 1.2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
4	R115, R117, R168, R173	2k	RESC1609X50N	Standard Thick Film Chip Resistor	Vishay
2	R116, R169	36.5k	RESC1609X50N	Standard Thick Film Chip Resistor	Vishay
1	R170	27k	RESC2113X50N	RES / STD / 27k / 125mW / 1% / 100ppm/K / -55 °C to 155 °C / 0805 / SMD / -	Vishay
2	R176, R189	10mR	RESC6432X89N-1_4p	RES / - / 10mR / 3W / 1% / 75ppm/K / - / 2512 / SMD / -	Vishay
2	R178, R191	0R	RESC1609X50N	RES / STD / 0R / - / 0R / - / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R181, R192	32.4k	RESC1609X50N	RES / STD / 32.4k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R182, R193	16.2k	RESC1609X50N	RES / STD / 16.2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R184, R195	6.65k	RESC1609X50N	RES / STD / 6.65k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R186, R197	20k	RESC1609X50N	RES / STD / 20k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	T3	2.5mH	EE25-13-7_5644	Flyback Transfomer	Würth Elektronik

1	T7	2.5mH	EE25-13-7_5644	Flyback Transfomer	Würth Elektronik
2	U10, U12	ICE5QSAG	SOIC127P600X175-8N-6	Quasi-Resonant PWM Controller	Infineon Technologies
2	U11, U13	SFH617A-3X007T	SFH617A-3X007T	Optocoupler, Phototransistor Output, High Reliability, 5300 VRMS, 110 °C Rated	Vishay
2	U20, U21	IFX81481ELV	SOP65P600X170-15N	10A Synchronous DC/DC Step-Down Controller	Infineon Technologies
2	X2, X9	TSW-103-08-F-D-RA	CON-M-THT-TSW-103-08-F-D-RA	Through Hole .025 SQ Post header, 6 pins, Double Row, Right angle	Samtec
6	X6, X7, X8, X12, X13, X18	TSW-102-08-F-D-RA	HDRRA4W64P254_2X2_508X556X556B	2.54mm Pitch Header Strip, 4 pins, right angle, double row	Samtec
3	C66, C70, C71	1uF	CAPC1608X50N	CAP / CERA / 1uF / 10V / 10% / X5R (EIA) / -55 °C to 85 °C / 0603(1608) / SMD / -	MuRata
8	C1, C2, C11, C22, C23, C60, C69, C82	4.7uF	CAPC1608X90N	CAP / CERA / 4.7uF / 10V / 10% / X5R (EIA) / -55 °C to 85 °C / 0603(1608) / SMD / -	MuRata
35	C4, C5, C6, C7, C9, C10, C14, C15, C16, C17, C18, C19, C20, C21, C24, C26, C28, C29, C30, C31, C32, C33, C35, C54, C61, C64, C67, C68, C80, C81, C83, C87, C93, C96, C98	100nF	CAPC1608X90N	CAP / CERA / 100nF / 25V / 5% / X7R (EIA) / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
2	C12, C13	15pF	CAPC1608X90N	CAP / CERA / 15pF / 50V / 2% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
8	C25, C50, C51, C53, C63, C65, C92, C99	10nF	CAPC1608X90N	CAP / CERA / 10nF / 25V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -, CAP / CERA / 10nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
9	C27, C39, C46, C47, C52, C59, C86, C95, C97	1nF	CAPC1608X90N	CAP / CERA / 1nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
2	C57, C58	100pF	CAPC1608X90N	CAP / CERA / 100pF / 50V / 2% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
1	C3	22uF	CAPC2013X95N	CAP / CERA / 22uF / 10V / 20% / X5R (EIA) / -55 °C to 85 °C / 0805(2012) / SMD / -	MuRata

1	X4	61301021021	CON-M-THT-61301021021	Connector, 10Pins, 2.54mm Pitch, Board to Board	Wurth Elektronik
2	X2, X3	61302021021	CON-M-THT-61302021021	WR-PHD Angled Dual Pin Header, 20 Pins	Wurth Elektronik
1	CN3	691322110002	CON-TER-THT-691322110002	3.50mm Horizontal PCB Header WR-TBL	Wurth Elektronik
1	CN1	691322110003	CON-TER-THT-691322110003	3.50mm Horizontal PCB Header WR-TBL	Wurth Elektronik
1	CN2	TSW-103-08-F-S-NA	HDRRA3W64P254_1X3_762X302X302B	Through hole .025 SQ Post Header, 2.54mm pitch, 3 pin, right angle, single row	Samtec
2	L1, L2	300R	INDC2012X105N	IND / FERR / 300R / 600mA / 25% / -55 °C to 125 °C / 150mR / SMD / Inductor,Chip;2.00mm L X 1.25mm W X 1.05mm H / SMD / -	TDK Corporation
6	Q1, Q2, Q3, Q4, Q5, Q6	2N7002	INF-PG-SOT23_N-0	OptiMOS Small-Signal-Transistor	Infineon Technologies
1	U9	IFX25001TFV33	INF-PG-TO252-3-11_N	Low Dropout Voltage Regulator, 3.3 V Output	Infineon Technologies
3	D2, D6, D9	BAT54-04	INT_SOT23-3 - IFX	Silicon Schottky Diode	Infineon Technologies
8	LED1, LED2, LED3, LED4, LED5, LED6, LED8, LED9	Green	LEDSC160X80X80-2N	Surface Mount LED, Green, 570nm	OSRAM Opto Semiconductors
1	LED7	Red	LEDSC160X80X80-2N	Surface Mount LED, Super Red, 633nm	OSRAM Opto Semiconductors
1	U3	IFX_XMC4400-F100K512ABXUMA1	QFP50P1600X1600X160-101N	XMC4000 Family Microcontroller for Industrial Applications, ARM Cortex-M4, 32-bit processor core, Flash 512 Kbytes,SRAM 80 Kbytes (Temperature Range -40 °C to 125 °C)	Infineon Technologies
1	RT1	10k	RESC1608X95N-1	RES / NTC / 10k / 100mW / 1% / - / -40 °C to 125 °C / 0603(1608) / SMD / -	MuRata
24	R1, R3, R4, R6, R13, R14, R15, R16, R17, R31, R33, R63, R67, R69, R70, R77, R89, R100, R101, R102, R103, R106, R136, R137	22R	RESC1609X50N	RES / STD / 22R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
13	R2, R7, R8, R9, R19, R92, R96, R97, R98, R99, R120, R140, R141	0R	RESC1609X50N	RES / STD / 0R / - / 0R / - / -55 °C to 155 °C / 0603 / SMD / -	Vishay
27	R5, R21, R22, R24, R25, R26, R27, R28, R29, R30, R37, R40, R45, R48, R71, R72, R73,	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay

	R74, R75, R76, R78, R85, R86, R90, R91, R95, R114				
4	R11, R12, R87, R88	4.7k	RESC1609X50N	RES / STD / 4.7k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
23	R18, R20, R32, R34, R35, R38, R44, R47, R51, R79, R80, R81, R104, R108, R110, R111, R112, R130, R131, R132, R133, R134, R135	10k	RESC1609X50N	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
19	R23, R53, R54, R55, R56, R57, R58, R59, R60, R61, R64, R65, R66, R68, R82, R84, R93, R94, R127	100R	RESC1609X50N	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
4	R41, R43, R49, R52	100k	RESC1609X50N	RES / STD / 100k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R83, R139	2.2k	RESC1609X50N	RES / STD / 2.2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R118, R119	60.4R	RESC1609X50N	RES / STD / 60.4R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R138	5.1k	RESC1609X50N	RES / STD / 5.1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	D8	STPS1L60ZFY	SODFL3516X110N	Automotive low drop power Schottky rectifier, Temp Range (-40 °C to 175 °C)	STMicroelectronics
1	U1	ADuM3201ARZ-RL7	SOIC127P600X175-8N-1	Dual-Channel, Digital Isolators, Enhanced System-Level ESD Reliability	Analog Devices
1	U2	TLE9251VSJ	SOIC127P600X175-8N-3	High Speed CAN Transceiver	Infineon Technologies
1	U5	FM25040B-G	SOIC127P602X173-8N	4-Kbit (512 8) Serial (SPI) F-RAM, Temp Range (-40 °C to +85 °C)	Cypress Semiconductor
1	U4	OPTIGA TRUST X SLS 32AIA	SON50P300X300X60-11N-V	OPTIGA Trust X, 5.5V (VCC Max), Upto 10KB User Memory	Infineon Technologies
1	U7	REF3318AIDBZR	SOT95P237X112-3N-1	1.8-V, 30-ppm/ °C drift, 3.9-A, 3-pin SOT-23 voltage reference	Texas Instruments

1	U8	REF3333AIDBZR	SOT95P237X112-3N-1	3.9-A SOT-23-3 30-ppm/ °C Drift Voltage Reference	Texas Instruments
2	D5, D7	BAT54-04	SOT95P240X110-3N-1	Silicon Schottky Diode	Infineon Technologies
3	TP1, TP2, TP3	IFX-Testpad-1.27mm	testpad_1.27mm	Testpad, SMD, 1.27 mm	Infineon Technologies
1	MD1	USR-C216	USR-C216	Low Power IoT Wifi Module	-
1	X1	12MHz	XTAL-SMD-CX3225CA	SMD Crystal, 12MHz, Temperature Range (-40 °C to 125 °C)	Kyocera
8	C12, C15, C32, C35, C48, C49, C60, C61	220nF	CAPC2013X140N	CAP / CERA / 220nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
8	C16, C17, C18, C19, C41, C50, C51, C57	3.3uF	CAPRR2750W80L3150T1800H2750B	CAP / - / 3.3uF / 1.1kV / 5% / MKP (Metallized Polypropylene) / -40 °C to 105 °C / 27.50mm C X 0.80mm W 31.50mm L X 18.00mm T X 27.50mm H / - / -	TDK Corporation
4	C36, C63, C66, C145	1nF	0603	CAP / CERA / 1nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
13	C39, C68, C82, C83, C110, C111, C127, C128, C159, C160, C178, C180, C246	10nF	CAPC1608X90N	CAP / CERA / 10nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -, CAP / CERA / 10nF / 25V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
3	C62, C65, C84	6.8nF	0603	Chip Monolithic Ceramic Capacitor, CAP / CERA / 6.8nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
2	C95, C156	10pF	CAPC2013X100N	CAP / CERA / 10pF / 200V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0805(2012) / SMD / -	MuRata
4	C113, C114, C119, C120	1nF	1206	CAP / CERA / 1nF / 630V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
5	C115, C117, C121, C123, C135	100uF	CAPMP7343X310N-1	Polymer Surface Mount Chip Capacitor Molded Case, High Performance Type, CAP / ELCO / 100uF / 25V / 20% / Tantalumelectrolytic / -55 °C to 105 °C / 7.30mm L X 4.30mm W X 3.10mm H / SMD / -	Vishay
9	C116, C118, C122, C124, C139, C140, C147, C148, C149	10uF	1210	CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) /	TDK Corporation

				SMD / -, CAP / - / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -	
2	C126, C136	220nF	1206	CAP / CERA / 220nF / 100V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
6	C129, C130, C131, C137, C138, C152	330uF	CAPAE660X800N-3	CAP / ELCO / 330uF / 16V / 20% / Aluminiumelectrolytic / -55 °C to 105 °C / 6.60mm L X 6.60mm W X 8.00mm H / SMD / -	Panasonic
3	C132, C133, C134	4.7uF	0805	CAP / CERA / 4.7uF / 25V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
2	C141, C142	2.2uF	1206	CAP / CERA / 2.2uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
3	C143, C144, C146	1uF	1206	CAP / - / 1uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
1	C150	22nF	0603	CAP / CERA / 22nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
1	C151	4.7nF	0603	CAP / - / 4.7nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
16	D1, D2, D3, D4, D5, D6, D9, D10, D17, D18, D19, D20, D23, D24, D25, D26	BAT165	SOD2513X110N	Medium Power AF Schottky Diode	Infineon Technologies
8	D7, D8, D11, D12, D29, D30, D31, D32	BAS3005A-02V	SODFL1608X59N	Low VF Schottky Diode	Infineon Technologies
6	D13, D14, D15, D16, D21, D22	MBRS1100T3G	DIOM5436X247N	Schottky Power Rectifier	ON Semiconductor
1	D27	MBRA340T3G	DIOM5226X220N	Schottky Barrier Rectifier 3.0A /40V	ON Semiconductor
1	D34	Orange	LED-SMD-LO L29K-XXXX-24	Surface Mount LED, Orange, 606nm	OSRAM Opto Semiconductors
1	G1	IFX91041EJV50	SOIC127P600X170-9N-1	1.8A DC/DC Step-Down Voltage Regulator - 5V Output Voltage	Infineon Technologies
1	G2	IFX30081LD V33	SON50P330X330X110-11N-V	3.3V, 50mA Linear Voltage Regulator with Ultra Low Quiescent Current,	Infineon Technologies
1	G3	IFX25001TFV33	INF-PG-TO252-3-11_N	Low Dropout Voltage Regulator, 3.3 V Output	Infineon Technologies
1	G4	TLS202B1MBV33	PG-SCT595	Fixed Linear Voltage Post Regulator, 3.3V	Infineon Technologies
2	HS1, HS2	SK 489 100 AL	HS SK 489 100	Extruded Heatsink for Lock-in Retaining Spring, PCB mounting, 100mm L X 29.44mm W X	Fischer Elektronik

				45mm H, Raw degreased aluminum	
1	L1	47uH	INDP7373X41N	IND / STD / 47uH / 1.5A / 20% / -40 °C to 125 °C / 127mR / SMD / 7.3mmx7.3mmx4.1mm / SMD / -	Coilcraft
1	L4	36uH	PQ4044	Resonant Inductor	Sunlord
1	L5	22uH	PQ4044	Resonant Inductor	Sunlord
8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	IMZ120R045M1	INF-PG-TO247-4	CoolSiC 1200 V SiC Trench MOSFET	Infineon Technologies
24	R1, R2, R5, R12, R15, R16, R17, R18, R21, R28, R33, R34, R47, R48, R49, R54, R57, R58, R59, R62, R67, R68, R69, R70	33k	RESC3216X60N	Standard Thick Film Chip Resistor	Vishay
8	R3, R4, R19, R20, R90, R91, R92, R93	2.2k	RESC3216X60N	RES / STD / 2.2k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
8	R6, R7, R22, R23, R50, R51, R60, R61	10R	RESC3216X65N-1	RES / STD / 10R / 500mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206(3216) / SMD / -	Vishay
8	R8, R9, R24, R25, R52, R53, R63, R64	2.2R	RESC3216X65N-1	RES / STD / 2.2R / 500mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
20	R10, R11, R26, R27, R44, R45,R55, R56, R65, R66, R86, R102, R110, R129, R130, R139, R147, R153, R154, R199	100R	RESC1609X50N	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
8	R13, R14, R29, R30, R117, R118, R119, R120	4.7k	RESC3216X60N	RES / STD / 4.7k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R31, R32	22R	RESC3216X60N	RES / STD / 22R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R35, R36	3mR	RESC6432X90N	High Power Current Sense Chip Resistor	Bourns
24	R37, R73, R74, R75, R76, R77, R78, R81, R87, R89, R94, R98, R99, R100, R103, R104, R106, R107, R132, R133, R134, R135, R136, R137	137k	RESC3216X60N	RES / STD / 137k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay

2	R38, R39	8.45k	RESC1609X50N	RES / STD / 8.45k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R40	1.74k	RESC1609X50N	RES / STD / 1.74k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
6	R41, R97, R105, R109, R203, R204	0R	RESC1609X50N	RES / STD / 0R / - / 0R / - / -55 °C to 155 °C / 0603 / SMD / -	Vishay
26	R42, R43, R84, R85, R95, R111, R112, R113, R114, R121, R124, R125, R128, R138, R140, R141, R144, R148, R149, R152, R155, R156, R157, R179, R180, R201	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -, RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R46, R115	2.2k	RESC1609X50N	RES / STD / 2.2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R71, R72	16.5R	RESC3216X60N	RES / STD / 16.5R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R79, R80	4.7k	RESC1609X50N	RES / STD / 4.7k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R82	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R83	1.5k	RESC1609X50N	RES / STD / 1.5k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R88	5.1k	RESC1609X50N	RES / STD / 5.1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R96, R108	2.21k	RESC1609X50N	RES / STD / 2.21k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R101	10k	RESC1608X95N-1	RES / NTC / 10k / 100mW / 1% / - / -40 °C to 125 °C / 0603(1608) / SMD / -	MuRata
2	R116, R131	133k	RESC1609X50N	RES / STD / 133k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R122, R126	680R	RESC1609X50N	RES / STD / 680R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay

2	R142, R143	10k	RESC1609X50N	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R145, R150	4.42k	RESC1609X50N	RES / STD / 4.42k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R158, R159	61.9k	RESC1609X50N	RES / STD / 61.9k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
4	R160, R161, R166, R167	2.2R	RESC3216X60N	Standard Thick Film Chip Resistor	Vishay
8	R162, R163, R164, R165, R168, R169, R170, R171	10k	RESC3216X60N	RES / STD / 10k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
1	R172	22k	RESC1609X50N	RES / STD / 22k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R174, R175	15k	RESC1609X50N	Standard Thick Film Chip Resistor, RES / STD / 15k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R200	2k	RESC1609X50N	RES / STD / 2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R202	5.1k	RESC3216X60N	RES / STD / 5.1k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
1	S1	CAS-120A1	CAS-120A1	Single-pole changeover slide switch	NIDEC COPAL ELECTRONICS, Inc.
2	T1, T6	80uH	TRANSFORMER PQ6558	LLC Transformers	Sunlord
4	T2, T3, T4, T5	410uH	EP7_4436	Transformer 8-Terminal EXT, SMD, Horizontal, EP Style Bobbins, EP7	Würth Elektronik
2	TR1, TR2	PE-67200NL	TR-THT-PE-67200NL	Current Sense Transformer, 4250VRMS primary to secondary breakdown voltage	Pulse Electronics
8	U1, U2, U3, U4, U5, U6, U7, U8	1EDC20I12AH	SOIC127P1030X265-8N-V	Single channel IGBT gate driver IC Up to 10 A typical peak current , ±2.0 A Output current configuration	Infineon Technologies
1	U9	TLI4971	INF-PG-TISON-8	High Precision Coreless Current Sensor	Infineon Technologies
7	U10, U13, U15, U16, U17, U18, U19	LM397MF/NOPB	SOT95P280X145-5N-2-V	This Device is a single voltage comparator	Texas Instruments
1	U11	AMC1302DWVR	SOIC127P1150X280-8N	Reinforced Isolated Amplifier With High CMTI Input Voltage Range of ±50 mV, and High Bandwidth of 280 kHz	Texas Instruments

1	U12	ISO7720FDWVR	SOIC127P1150X280-8N	High-Speed, Robust EMC, Reinforced and Basic Dual-Channel Digital Isolator	Texas Instruments
1	U14	AMC1311BDWV	SOIC127P1150X280-8N	High-Impedance, 2-V Input, Reinforced Isolated Amplifier	Texas Instruments
1	U22	UCC12050DVE	SOIC127P1030X265-16N-1	High-Efficiency, Low-EMI, 5-kVRMS Reinforced Isolation DC-DC Converter	Texas Instruments
4	X1, X2, X21, X26	74655095R	CON-TER-THT-74655095R	REDCUBE THR with internal thru hole thread	Wurth Elektronik
3	X5, X6, X7	505575-0471	CON-M-SMD-505575-0471	Micro-Lock Plus Wire-to-Board Connector System	Molex
2	X8, X9	662302131822	CON-M-SMD-662302131822	CONNECTOR HEADER SMD 4POS 1.25MM	Wurth Elektronik
8	Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8	2.4V	SOD3715X145N	Zener-Diode, 2.4V	Diodes Incorporated
8	C12, C15, C32, C35, C48, C49, C60, C61	220nF	CAPC2013X140N	CAP / CERA / 220nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
8	C16, C17, C18, C19, C41, C50, C51, C57	3.3uF	CAPRR2750W80L3150T1800H2750B	CAP / - / 3.3uF / 1.1kV / 5% / MKP (Metallized Polypropylene) / -40 °C to 105 °C / 27.50mm C X 0.80mm W 31.50mm L X 18.00mm T X 27.50mm H / - / -	TDK Corporation
4	C36, C63, C66, C145	1nF	0603	CAP / CERA / 1nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
13	C39, C68, C82, C83, C110, C111, C127, C128, C159, C160, C178, C180, C246	10nF	CAPC1608X90N	CAP / CERA / 10nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -, CAP / CERA / 10nF / 25V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
3	C62, C65, C84	6.8nF	0603	Chip Monolithic Ceramic Capacitor, CAP / CERA / 6.8nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
2	C95, C156	10pF	CAPC2013X100N	CAP / CERA / 10pF / 200V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0805(2012) / SMD / -	MuRata
4	C113, C114, C119, C120	1nF	1206	CAP / CERA / 1nF / 630V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
5	C115, C117, C121, C123, C135	100uF	CAPMP7343X310N-1	Polymer Surface Mount Chip Capacitor Molded Case, High Performance Type, CAP / ELCO / 100uF / 25V / 20% / Tantalumelectrolytic / -55 °C to 105 °C / 7.30mm L X 4.30mm	Vishay

				W X 3.10mm H / SMD / -	
9	C116, C118, C122, C124, C139, C140, C147, C148, C149	10uF	1210	CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / - / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -	TDK Corporation
2	C126, C136	220nF	1206	CAP / CERA / 220nF / 100V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
6	C129, C130, C131, C137, C138, C152	330uF	CAPAE660X800N-3	CAP / ELCO / 330uF / 16V / 20% / Aluminiumelectrolytic / -55 °C to 105 °C / 6.60mm L X 6.60mm W X 8.00mm H / SMD / -	Panasonic
3	C132, C133, C134	4.7uF	0805	CAP / CERA / 4.7uF / 25V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
2	C141, C142	2.2uF	1206	CAP / CERA / 2.2uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
3	C143, C144, C146	1uF	1206	CAP / - / 1uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
1	C150	22nF	0603	CAP / CERA / 22nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
1	C151	4.7nF	0603	CAP / - / 4.7nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
16	D1, D2, D3, D4, D5, D6, D9, D10, D17, D18, D19, D20, D23, D24, D25, D26	BAT165	SOD2513X110N	Medium Power AF Schottky Diode	Infineon Technologies
8	D7, D8, D11, D12, D29, D30, D31, D32	BAS3005A-02V	SODFL1608X59N	Low VF Schottky Diode	Infineon Technologies
6	D13, D14, D15, D16, D21, D22	MBRS1100T3G	DIOM5436X247N	Schottky Power Rectifier	ON Semiconductor
1	D27	MBRA340T3G	DIOM5226X220N	Schottky Barrier Rectifier 3.0A /40V	ON Semiconductor
1	D34	Orange	LED-SMD-LO L29K-XXXX-24	Surface Mount LED, Orange, 606nm	OSRAM Opto Semiconductors
1	G1	IFX91041EJV50	SOIC127P600X170-9N-1	1.8A DC/DC Step-Down Voltage Regulator - 5V Output Voltage	Infineon Technologies
1	G2	IFX30081LD V33	SON50P330X330X110-11N-V	3.3V, 50mA Linear Voltage Regulator with Ultra Low Quiescent Current,	Infineon Technologies

1	G3	IFX25001TFV33	INF-PG-TO252-3-11_N	Low Dropout Voltage Regulator, 3.3 V Output	Infineon Technologies
1	G4	TLS202B1MBV33	PG-SCT595	Fixed Linear Voltage Post Regulator, 3.3V	Infineon Technologies
2	HS1, HS2	SK 489 100 AL	HS SK 489 100	Extruded Heatsink for Lock-in Retaining Spring, PCB mounting, 100mm L X 29.44mm W X 45mm H, Raw degreased aluminum	Fischer Elektronik
1	L1	47uH	INDP7373X41N	IND / STD / 47uH / 1.5A / 20% / -40 °C to 125 °C / 127mR / SMD / 7.3mmx7.3mmx4.1mm / SMD / -	Coilcraft
1	L4	36uH	PQ4044	Resonant Inductor	Sunlord
1	L5	22uH	PQ4044	Resonant Inductor	Sunlord
8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	IMZ120R045M1	INF-PG-TO247-4	CoolSiC 1200 V SiC Trench MOSFET	Infineon Technologies
24	R1, R2, R5, R12, R15, R16, R17, R18, R21, R28, R33, R34, R47, R48, R49, R54, R57, R58, R59, R62, R67, R68, R69, R70	33k	RESC3216X60N	Standard Thick Film Chip Resistor	Vishay
8	R3, R4, R19, R20, R90, R91, R92, R93	2.2k	RESC3216X60N	RES / STD / 2.2k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
8	R6, R7, R22, R23, R50, R51, R60, R61	10R	RESC3216X65N-1	RES / STD / 10R / 500mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206(3216) / SMD / -	Vishay
8	R8, R9, R24, R25, R52, R53, R63, R64	2.2R	RESC3216X65N-1	RES / STD / 2.2R / 500mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
20	R10, R11, R26, R27, R44, R45,R55, R56, R65, R66, R86, R102, R110, R129, R130, R139, R147, R153, R154, R199	100R	RESC1609X50N	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
8	R13, R14, R29, R30, R117, R118, R119, R120	4.7k	RESC3216X60N	RES / STD / 4.7k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R31, R32	22R	RESC3216X60N	RES / STD / 22R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R35, R36	3mR	RESC6432X90N	High Power Current Sense Chip Resistor	Bourns
24	R37, R73, R74, R75, R76, R77,	137k	RESC3216X60N	RES / STD / 137k / 250mW / 1% / 100ppm/K / -55 °C to	Vishay

	R78, R81, R87, R89, R94, R98, R99, R100, R103, R104, R106, R107, R132, R133, R134, R135, R136, R137			155 °C / 1206 / SMD / -	
2	R38, R39	8.45k	RESC1609X50N	RES / STD / 8.45k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R40	1.74k	RESC1609X50N	RES / STD / 1.74k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
6	R41, R97, R105, R109, R203, R204	0R	RESC1609X50N	RES / STD / 0R / - / 0R / - / -55 °C to 155 °C / 0603 / SMD / -	Vishay
26	R42, R43, R84, R85, R95, R111, R112, R113, R114, R121, R124, R125, R128, R138, R140, R141, R144, R148, R149, R152, R155, R156, R157, R179, R180, R201	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -, RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R46, R115	2.2k	RESC1609X50N	RES / STD / 2.2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R71, R72	16.5R	RESC3216X60N	RES / STD / 16.5R / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
2	R79, R80	4.7k	RESC1609X50N	RES / STD / 4.7k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R82	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R83	1.5k	RESC1609X50N	RES / STD / 1.5k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R88	5.1k	RESC1609X50N	RES / STD / 5.1k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R96, R108	2.21k	RESC1609X50N	RES / STD / 2.21k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R101	10k	RESC1608X95N-1	RES / NTC / 10k / 100mW / 1% / - / -40 °C to 125 °C / 0603(1608) / SMD / -	MuRata
2	R116, R131	133k	RESC1609X50N	RES / STD / 133k / 100mW / 1% /	Vishay

				100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	
2	R122, R126	680R	RESC1609X50N	RES / STD / 680R / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R142, R143	10k	RESC1609X50N	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R145, R150	4.42k	RESC1609X50N	RES / STD / 4.42k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R158, R159	61.9k	RESC1609X50N	RES / STD / 61.9k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
4	R160, R161, R166, R167	2.2R	RESC3216X60N	Standard Thick Film Chip Resistor	Vishay
8	R162, R163, R164, R165, R168, R169, R170, R171	10k	RESC3216X60N	RES / STD / 10k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
1	R172	22k	RESC1609X50N	RES / STD / 22k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
2	R174, R175	15k	RESC1609X50N	Standard Thick Film Chip Resistor, RES / STD / 15k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R200	2k	RESC1609X50N	RES / STD / 2k / 100mW / 1% / 100ppm/K / -55 °C to 155 °C / 0603 / SMD / -	Vishay
1	R202	5.1k	RESC3216X60N	RES / STD / 5.1k / 250mW / 1% / 100ppm/K / -55 °C to 155 °C / 1206 / SMD / -	Vishay
1	S1	CAS-120A1	CAS-120A1	Single-pole changeover slide switch	NIDEC COPAL ELECTRONICS, Inc.
2	T1, T6	80uH	TRANSFORMER PQ6558	LLC Transformers	Sunlord
4	T2, T3, T4, T5	410uH	EP7_4436	Transformer 8-Terminal EXT, SMD, Horizontal, EP Style Bobbins, EP7	Würth Elektronik
2	TR1, TR2	PE-67200NL	TR-THT-PE-67200NL	Current Sense Transformer, 4250VRMS primary to secondary breakdown voltage	Pulse Electronics
8	U1, U2, U3, U4, U5, U6, U7, U8	1EDC20I12AH	SOIC127P1030X265-8N-V	Single channel IGBT gate driver IC Up to 10 A typical peak current , ±2.0 A Output current configuration	Infineon Technologies
1	U9	TLI4971	INF-PG-TISON-8	High Precision Coreless Current Sensor	Infineon Technologies

7	U10, U13, U15, U16, U17, U18, U19	LM397MF/NOPB	SOT95P280X145-5N-2-V	This Device is a single voltage comparator	Texas Instruments
1	U11	AMC1302DWVR	SOIC127P1150X280-8N	Reinforced Isolated Amplifier With High CMTI Input Voltage Range of ±50 mV, and High Bandwidth of 280 kHz	Texas Instruments
1	U12	ISO7720FDWVR	SOIC127P1150X280-8N	High-Speed, Robust EMC, Reinforced and Basic Dual-Channel Digital Isolator	Texas Instruments
1	U14	AMC1311BDWV	SOIC127P1150X280-8N	High-Impedance, 2-V Input, Reinforced Isolated Amplifier	Texas Instruments
1	U22	UCC12050DVE	SOIC127P1030X265-16N-1	High-Efficiency, Low-EMI, 5-kVRMS Reinforced Isolation DC-DC Converter	Texas Instruments
4	X1, X2, X21, X26	74655095R	CON-TER-THT-74655095R	REDCUBE THR with internal thru hole thread	Wurth Elektronik
3	X5, X6, X7	505575-0471	CON-M-SMD-505575-0471	Micro-Lock Plus Wire-to-Board Connector System	Molex
2	X8, X9	662302131822	CON-M-SMD-662302131822	CONNECTOR HEADER SMD 4POS 1.25MM	Wurth Elektronik
8	Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8	2.4V	SOD3715X145N	Zener-Diode, 2.4V	Diodes Incorporated
8	C12, C15, C32, C35, C48, C49, C60, C61	220nF	CAPC2013X140N	CAP / CERA / 220nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
8	C16, C17, C18, C19, C41, C50, C51, C57	3.3uF	CAPRR2750W80L3150T1800H2750B	CAP / - / 3.3uF / 1.1kV / 5% / MKP (Metallized Polypropylene) / -40 °C to 105 °C / 27.50mm C X 0.80mm W 31.50mm L X 18.00mm T X 27.50mm H / - / -	TDK Corporation
4	C36, C63, C66, C145	1nF	0603	CAP / CERA / 1nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
13	C39, C68, C82, C83, C110, C111, C127, C128, C159, C160, C178, C180, C246	10nF	CAPC1608X90N	CAP / CERA / 10nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -, CAP / CERA / 10nF / 25V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	MuRata
3	C62, C65, C84	6.8nF	0603	Chip Monolithic Ceramic Capacitor, CAP / CERA / 6.8nF / 50V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation
2	C95, C156	10pF	CAPC2013X100N	CAP / CERA / 10pF / 200V / 5% / C0G (EIA) / NP0 / -55 °C to 125 °C / 0805(2012) / SMD / -	MuRata
4	C113, C114, C119, C120	1nF	1206	CAP / CERA / 1nF / 630V / 5% / C0G (EIA) / NP0 / -55 °C	TDK Corporation

				to 125 °C / 1206(3216) / SMD / -	
5	C115, C117, C121, C123, C135	100uF	CAPMP7343X310N-1	Polymer Surface Mount Chip Capacitor Molded Case, High Performance Type, CAP / ELCO / 100uF / 25V / 20% / Tantalumelectrolytic / -55 °C to 105 °C / 7.30mm L X 4.30mm W X 3.10mm H / SMD / -	Vishay
9	C116, C118, C122, C124, C139, C140, C147, C148, C149	10uF	1210	CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / CERA / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -, CAP / - / 10uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1210(3225) / SMD / -	TDK Corporation
2	C126, C136	220nF	1206	CAP / CERA / 220nF / 100V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
6	C129, C130, C131, C137, C138, C152	330uF	CAPAE660X800N-3	CAP / ELCO / 330uF / 16V / 20% / Aluminiumelectrolytic / -55 °C to 105 °C / 6.60mm L X 6.60mm W X 8.00mm H / SMD / -	Panasonic
3	C132, C133, C134	4.7uF	0805	CAP / CERA / 4.7uF / 25V / 10% / X7R (EIA) / -55 °C to 125 °C / 0805(2012) / SMD / -	TDK Corporation
2	C141, C142	2.2uF	1206	CAP / CERA / 2.2uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
3	C143, C144, C146	1uF	1206	CAP / - / 1uF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 1206(3216) / SMD / -	TDK Corporation
1	C150	22nF	0603	CAP / CERA / 22nF / 50V / 10% / X7R (EIA) / -55 °C to 125 °C / 0603(1608) / SMD / -	TDK Corporation

4 References and appendices

4.1 Abbreviations and definitions

Table 6 Abbreviations

Abbreviation	Meaning
CE	Conformité Européenne
EMI	Electromagnetic interference
UL	Underwriters Laboratories
DC	Direct current
DAB	Dual active bridge
PWM	Pulse-width modulation
QR	Quasi resonant
MOSFET	Metal oxide semiconductor field effect transistor
SiC	Silicon carbide
CAN	Controller area network interface

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

[2] "1400 W ZVS phase-shift full-bridge evaluation board. Using 600 V CoolMOS™ CFD7 and digital control by XMC4200", AN_201711_PL52_003

[3] Jared Huntington, "6 W bias supply. Using the new 800 V CoolMOS™ P7, ICE5QSAG QR flyback controller, and snubberless flyback for improved auxiliary power-supply efficiency and form factor", AN_201709_PL52_030

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

[5] IMBF170R1K0M1 datasheet, 1700 V CoolSiC™ MOSFET

[6] UCC28600 datasheet, 8-Pin Quasi-Resonant flyback Green-Mode Controller

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

Revision history

Document version	Date of release	Description of changes
1.0	2020-11-03	First version
1.1	2021-03-03	Updated layout, schematic, and bill of materials
1.2	2024-05-03	New GUI layout, updated block diagrams, description of protections

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