6 kW high-frequency and high-density IBC module user guide

REF_6KW_800V_50V_HB

About this document

Scope and purpose

This document provides a comprehensive overview and implementation for the REF_6KW_800V_50V_HB reference board, which is a high-frequency and high-power-density isolated intermediate bus converter (IBC) designed by Infineon. This evaluation board utilizes a full gallium nitride (GaN) design to achieve superior performance, supporting a 6 kW power rating and ±400 V (or 800 V) to 50 V voltage conversion capability. It is specifically designed to meet the power demands of modern, high-performance applications, such as data centers and AI server architectures.

The reference board is implemented as a compact, fully integrated module in a half-brick form factor (64 mm × 61 mm × 11 mm), which optimizes power density and simplifies system integration. It delivers industry-leading performance with a 98.5% peak efficiency and 98.0% efficiency at a full 6 kW load.

This guide includes technical specifications, system architecture, hardware setup, and performance characterization to assist engineers in evaluating and implementing this high-efficiency power solution.

Intended audience

The intended audiences for this document are applications engineers, power supply design engineers for brick modules, server power systems, and telecom related applications.

About this product group

Target applications

- Data center power solutions
- Server rack power management

Reference Board

Product(s) embedded on a PCB with a focus on specific applications and defined use cases that may 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.

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 VDC. 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 Introduction

This application is driven by accelerating performance of AI accelerators like graphics processing units (GPUs) and tensor processing units (TPUs), modern data centers are experiencing a rapid surge in power requirements. Consequently, power architecture is transitioning from traditional 48 V distribution to higher voltage buses, such as ±400 V or 800 V. In this context, High-Voltage Intermediate Bus Converters (HV-IBC) have become indispensable, as they efficiently step down high-voltage inputs to intermediate rails (48 V to 60 V) to ensure stable and high-efficiency power delivery for advanced workloads.

1.1 Reference board overview

The REF_6KW_800V_50V_HB is a high-frequency, 6 kW isolated intermediate bus converter (IBC) reference board designed for data center architectures. It efficiently converts a ±400 V (800 V bus) input into an un-regulated 50 V output at currents up to 120 A. By utilizing a full GaN-based power stage, the board achieves industry-leading efficiency, including a 98.5% peak efficiency and 98.0% efficiency at a full 6 kW load.

The converter adopts a stacked half-bridge LLC topology with an input-series output-parallel (ISOP) structure. This design utilizes two identical LLC stages operating with a 90-degree phase shift to enable interleaved operation, which minimizes current ripple and enhances overall system efficiency. To ensure high efficiency and fast dynamic response, the module is designed to operate in an open-loop configuration, which is standard for IBC topologies.

Figure 1 shows the board top view, the module is implemented in a compact standard half-brick form factor (64 mm × 61 mm × 11 mm). Achieving an extreme power density exceeding 2000 W/in^3, the design integrates all essential functional blocks into a single unit, including GaN power switches, gate drivers, the digital controller, and auxiliary power circuits.

To meet requirements for a small footprint and low profile, the module relies on highly optimized magnetic components. The main power stage features a custom-designed planar transformer using a custom EI core (ML95S) with windings realized directly within the PCB copper layers for superior thermal spreading and repeatable parasitic control. Similarly, the integrated auxiliary power circuit utilizes a custom-designed transformer to maintain the compact half-brick dimensions while providing necessary isolated bias supplies.

The LLC transformer uses a planar design, with both leakage and magnetizing inductance integrated and precisely calculated during the design phase. This eliminates the need for external leakage inductors, streamlining the circuit and improving module reliability.

All primary and secondary power switches are located on the top layer using top-side-cooled packages, allowing for direct attachment to a heatsink for optimal thermal management during full-power operation.

The module features system management driven by the XDP™ XDPP1188 digital power controller. Through a standard I^{2}C/PMBus®-compliant interface, the board provides comprehensive real-time telemetry, enabling precise monitoring of voltages, currents, critical component temperatures, and fault conditions. By leveraging the XDP™ Designer GUI, you can perform high-speed data visualization and on-the-fly parameter optimization, significantly accelerating design characterization and system-level validation.

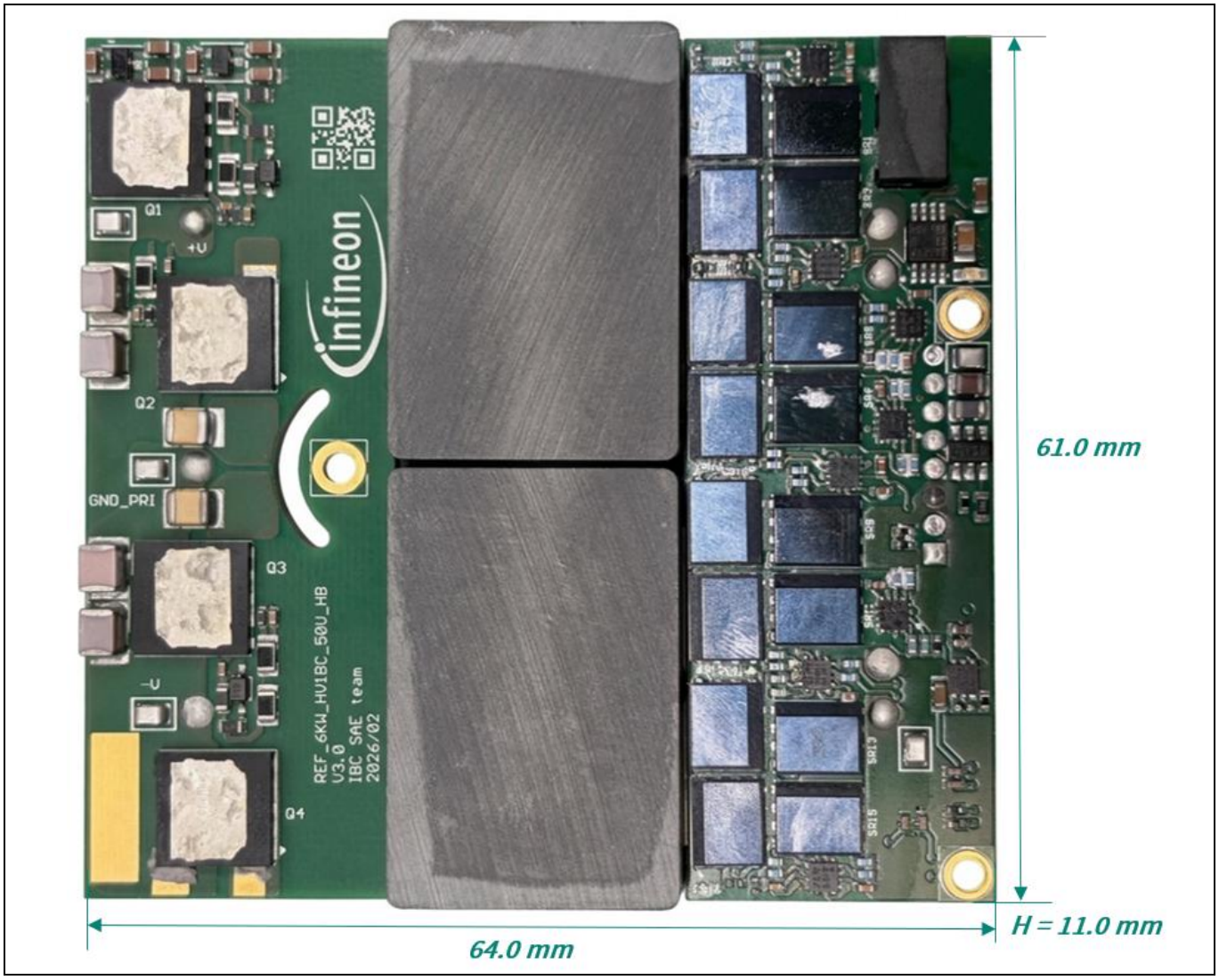


Figure 1 REF_6KW_800V_50V_HB Module

1.2 System architecture

Figure 2 shows a simplified block diagram of the module. The converter employs a stacked half-bridge LLC architecture to interface the ±400 V bus with an unregulated 50 V output. The power stage consists of two identical LLC stages: the upper stage handles +400 V to 0 V, while the lower stage covers 0 V to –400 V. This symmetric arrangement evenly distributes the total bus voltage, reducing voltage stress on switching devices and simplifying insulation requirements.

Both the primary and secondary sides utilize GaN devices for superior efficiency and high-frequency operation. On the primary side, 650 V GaN FETs form the half-bridge of each LLC stage. On the secondary side, each LLC stage drives two full-bridge synchronous rectifiers, resulting in four full-bridge rectifiers connected in parallel at the 50 V output. The rectifiers use 100 V GaN FETs to minimize conduction losses. Parallel operation and current sharing among the four rectifier bridges lower device stress and improve thermal management.

The primary-side high-voltage GaN are controlled by dual-channel drivers with reinforced isolation, ensuring a safe and reliable signal interface from the secondary-side digital controller. On the secondary side, the synchronous rectifiers are driven by high-speed half-bridge GaN drivers. These secondary drivers feature integrated bootstrap switches, which minimize the external component count and PCB footprint, while supporting the fast-switching transitions required for high-frequency LLC operation.

1 Introduction

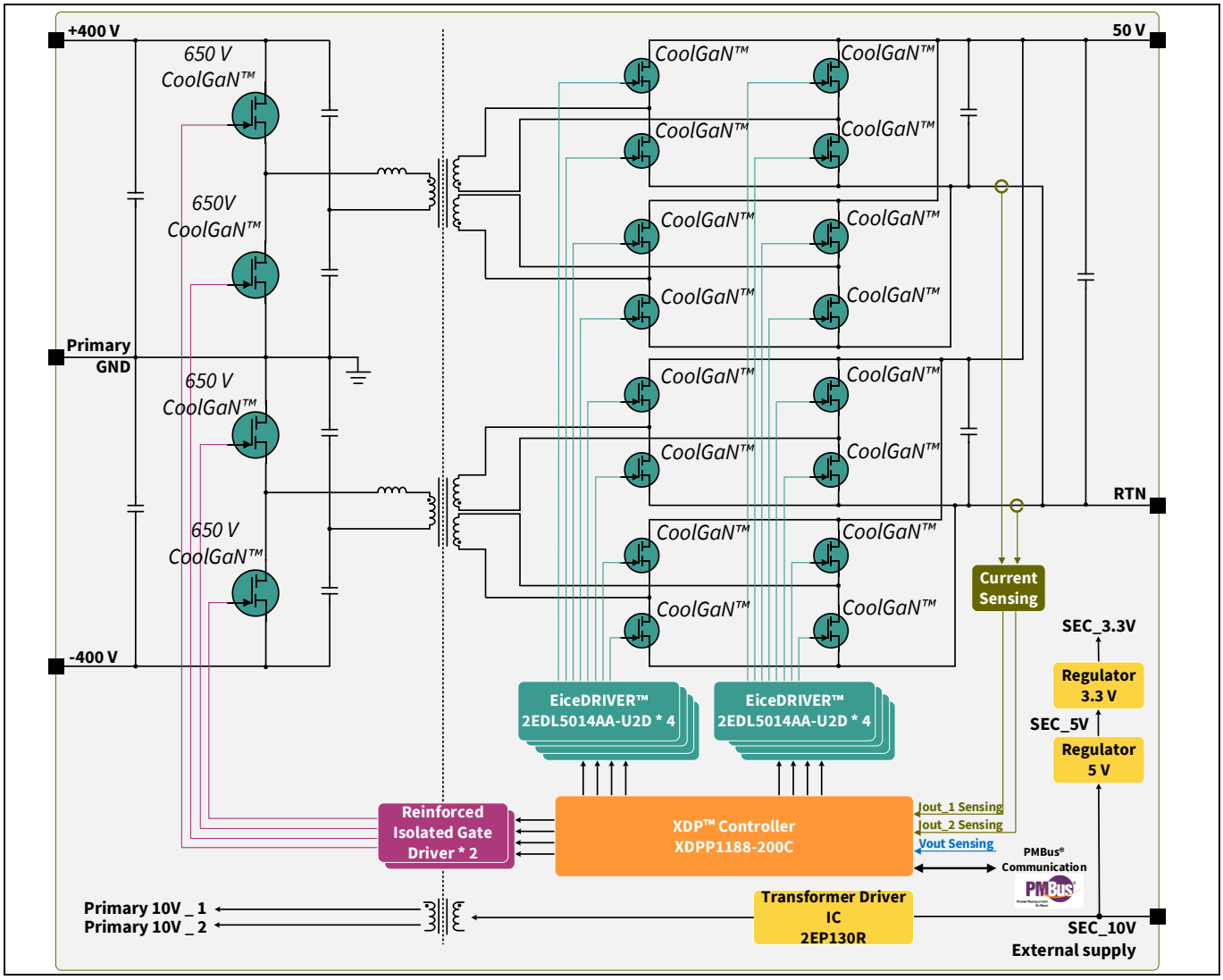


Figure 2 Simplified schematic of REF_6KW_800V_50V_HB module

A single secondary-side auxiliary supply generates regulated 5 V and 3.3 V rails for the controller and drivers, while isolated drivers and transformers provide two independent bias supplies for the primary-side gate drivers, ensuring reliable operation of all power stages.

System control is managed by the XDPP1188 digital power controller, which is based on an Arm® Cortex®-M0 processor operating at 100 MHz and features eight PWM channels for flexible power stage management. Located on the secondary side, the controller coordinates timing between the primary and secondary stages and supports advanced system monitoring and protection functions.

Communication with external systems is achieved via a standard I²C/PMBus® interface, supporting configuration, parameter read/write, and real-time status monitoring.

Comprehensive output protection features are integrated, including overvoltage protection (OVP), undervoltage protection (UVP), overcurrent protection (OCP), and short-circuit protection (SCP). These protections ensure reliable operation and protect both the board and connected systems against abnormal loading or fault conditions.

The key Infineon components used in the REF_6KW_800V_50V_HB are as follows:

- **Primary-side switches:** CoolGaN™ IGLC65R020D2 (650 V, 27 mΩ, VHSON-10)
- **Primary-side HB drivers:** EiceDRIVER™ 2EDR7259X
- **Secondary-side synchronous rectifier (SR) switches and drivers:** CoolGaN™ IGD01xK10S2 (100 V, 0.9 mΩ, WRTFN-9)
- **Secondary-side SR driver:** EiceDRIVER™ 2EDL5014AA-U2D
- **Auxiliary power driver:** EiceDRIVER™ 2EP130R transformer driver IC
- **Digital controller:** XDPP1188-200C (VQFN-40)

1.3 Main features

- High-voltage IBC module
- 6 kW, ±400 V (800 V bus) input with 50 V output up to 120 A
- Full GaN-based power stage
- Stacked half-bridge LLC topology with input-series, output-parallel (ISOP) architecture
- 98.5% peak efficiency and 98.0% efficiency at full load
- Integrated planar magnetics
- Integrated auxiliary power circuit
- Optimized thermal management, including top-side cooling
- Digital interface and operating condition telemetry

1.4 Board specifications

Table 2 lists the specifications for the Infineon REF_6KW_800V_50V_HB.

Specifications are given for ambient temperature (T_a) = 25°C unless otherwise specified.

Table 2 Specifications

Parameter	Symbol	Values			Unit	Conditions/notes
		Min.	Typ.	Max.		
DC input voltage (+)	V_{IN+}	0	–	400	V	Dual rail HV input
DC input voltage (-)	V_{IN-}	–400	–	0	V	Dual rail HV input
DC input current	I_{IN}	–	–	15.2	A	V_{IN} = ±400 V, P_{OUT} = 6 kW
DC output voltage	V_{OUT}	–	50	–	V	–
Maximum output current	I_{OUT}	–	–	120	A	–
Maximum output power	P_{OUT}	–	–	6000	W	–
Peak efficiency	η_{PEAK}	–	98.5	–	%	At I_{OUT} = 60 A, P_{OUT} = 3 kW
Full load efficiency	η_{FULL_LOAD}	–	98.0	–	%	At I_{OUT} =120 A, P_{OUT} = 6 kW
Switching frequency	f_{SW}	–	800	–	kHz	Fixed frequency
Power density	–	–	>2000	–	W/in^3	Based on the half-brick
Dimensions	64 × 61 × 11				mm	L x W x H
Operating temperature	T_{OP}	–	–	90	°C	Heatsink with fan

2 Hardware setup and evaluation environment

The evaluation environment consists of all necessary equipment and setup required to safely and accurately operate the 6 kW high-voltage intermediate bus converter (HV-IBC) reference board. A typical setup includes the HV-IBC reference board, fixture board, dongle board, programmable DC power supply, electronic load, and measurement instruments such as an oscilloscope and digital multimeter.

Figure 3 shows the actual test setup and main connections, including the HV-IBC module with heatsink, the fixture board, and the dongle board. The diagram illustrates input and output power connections, as well as the 10 V bias supply. The fixture board also provides a 12 V fan power connector for cooling. For communication, the I^2C interface allows a PC to connect via the dongle and access the I^2C pins on the fixture board, enabling module monitoring and configuration from the PC.

The testing should be performed on a heat-resistant and non-conductive surface in a well-ventilated area. Proper personal protection equipment (PPE) and adherence to high-voltage safety procedures are mandatory during all testing activities to ensure operator safety.

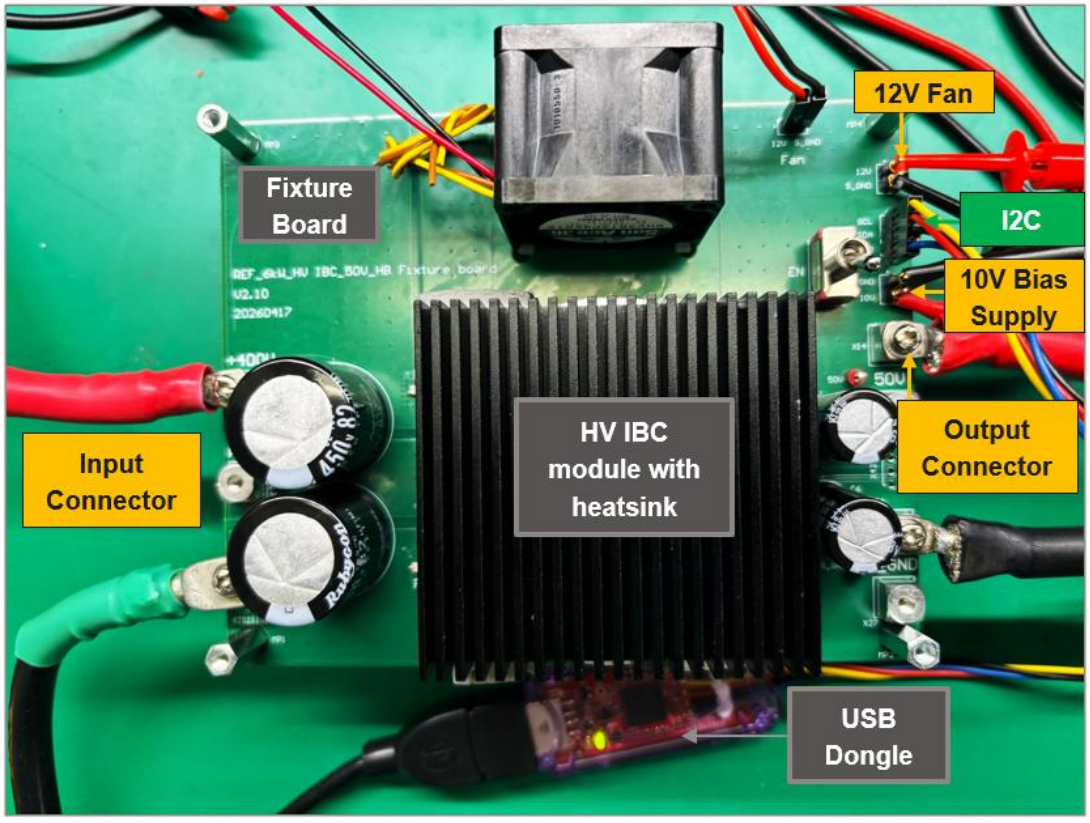


Figure 3 Hardware setup and system interconnections

2.1.1 HV-IBC power module

The REF_6KW_800V_50V_HB is a highly integrated power conversion module that combines the entire power stage, digital controller, auxiliary power circuits, magnetic components, and all necessary passive elements into a single unit. As shown in Figure 4, all key components are clearly arranged on the module. The design follows the industry-standard half-brick form factor, with pin placement that is fully compatible with standard footprints. This allows the module to be easily inserted into the REF_6KW_800V_50V_HB Fixture Board for streamlined evaluation.

For thermal management, the module is equipped with an extruded aluminum heatsink. As shown in Figure 4(a), three mounting holes are provided for secure and stable heatsink installation. To ensure efficient heat transfer from the power devices, a thermal interface material (TIM) should be applied between the module surface and the heatsink base prior to fastening with mounting screws.

As shown in Figure 4(b), the module features seven standard pins for power delivery. On the primary side, there are three pins: +400 V, GND, and –400 V. On the secondary side, there are four pins: two for the 50 V output and two for the S_GND return, supporting high current operation.

In addition to the power terminals, an 8-pin connector is provided for auxiliary functions. This header supports I^2C communication, power good (PG) signaling, address configuration, and the 10V bias supply.

The following table summarizes the terminal and connector assignments for the module:

Table 3 REF_6KW_800V_50V_HB board headers and connectors

Name	Description	Comment
+400V	High-voltage positive input (+400 V)	Primary side
PRI_GND	High-voltage primary ground	Primary side
-400V	High-voltage negative input (–400 V)	Primary side
50V	50 V DC output	Secondary side
S_GND	Ground return	Secondary side
X1 header	Auxiliary header I^2C, EN, XADDR, PWOK, 10 V bias supply, etc.	8-pins header

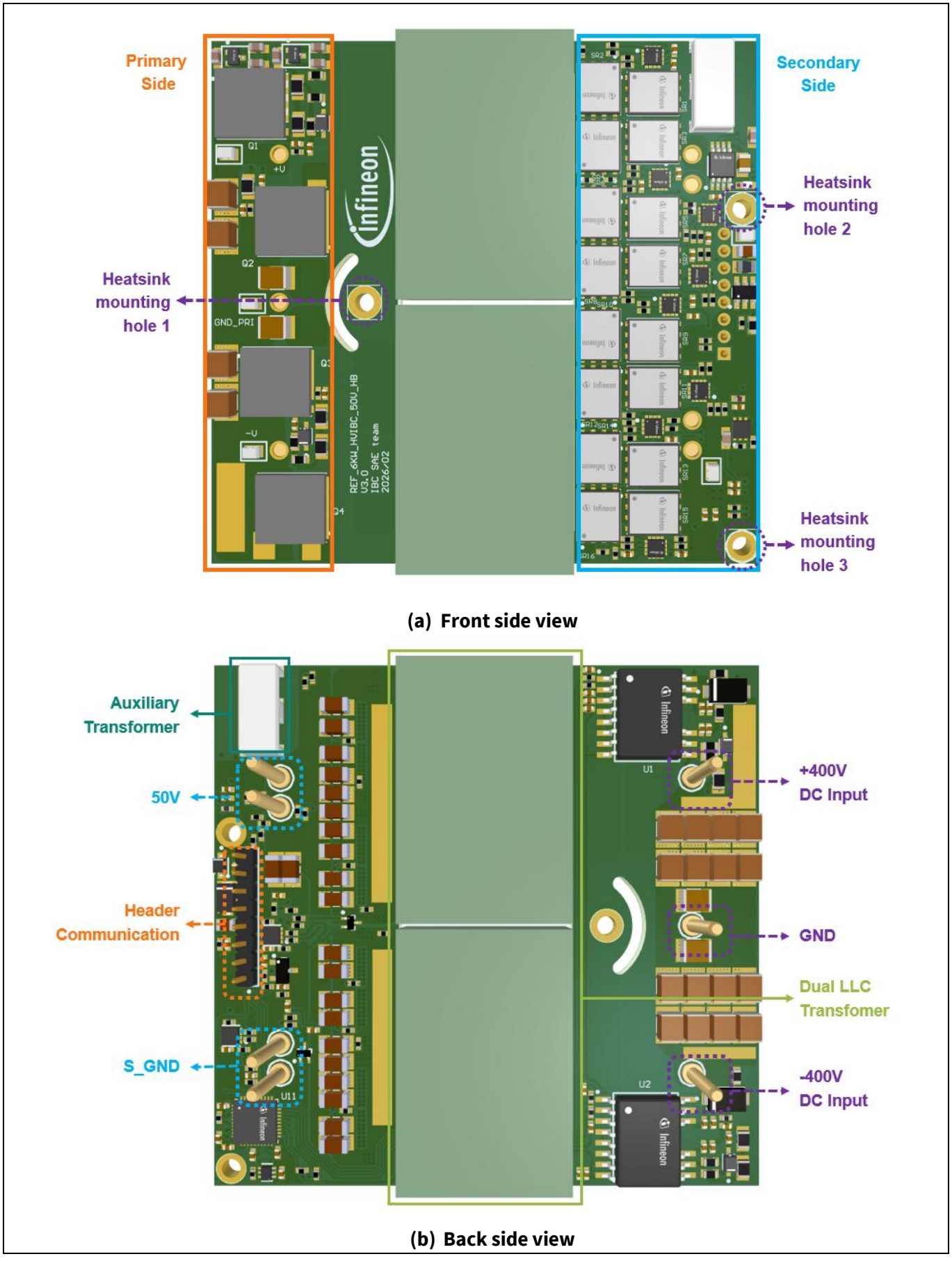


Figure 4 REF_6KW_800V_50V_HB module (a) Front side view and (b) Back side view

2.1.2 REF_6kW_HV IBC_50V_HB Fixture Board

Figure 5 shows the REF_6KW_800V_50V_HB Fixture Board that is specifically designed to support the REF_6KW_800V_50V_HB Module. It integrates all essential components and interfaces required for convenient testing and evaluation. The board features input and output capacitors, dedicated input and output terminals, a cooling fan, an enable switch, an external bias supply interface, I^2C communication port, and multiple test points for easy signal monitoring and measurement. These elements make the fixture board an optimal platform for comprehensive validation of the HV-IBC module's performance and functionality.

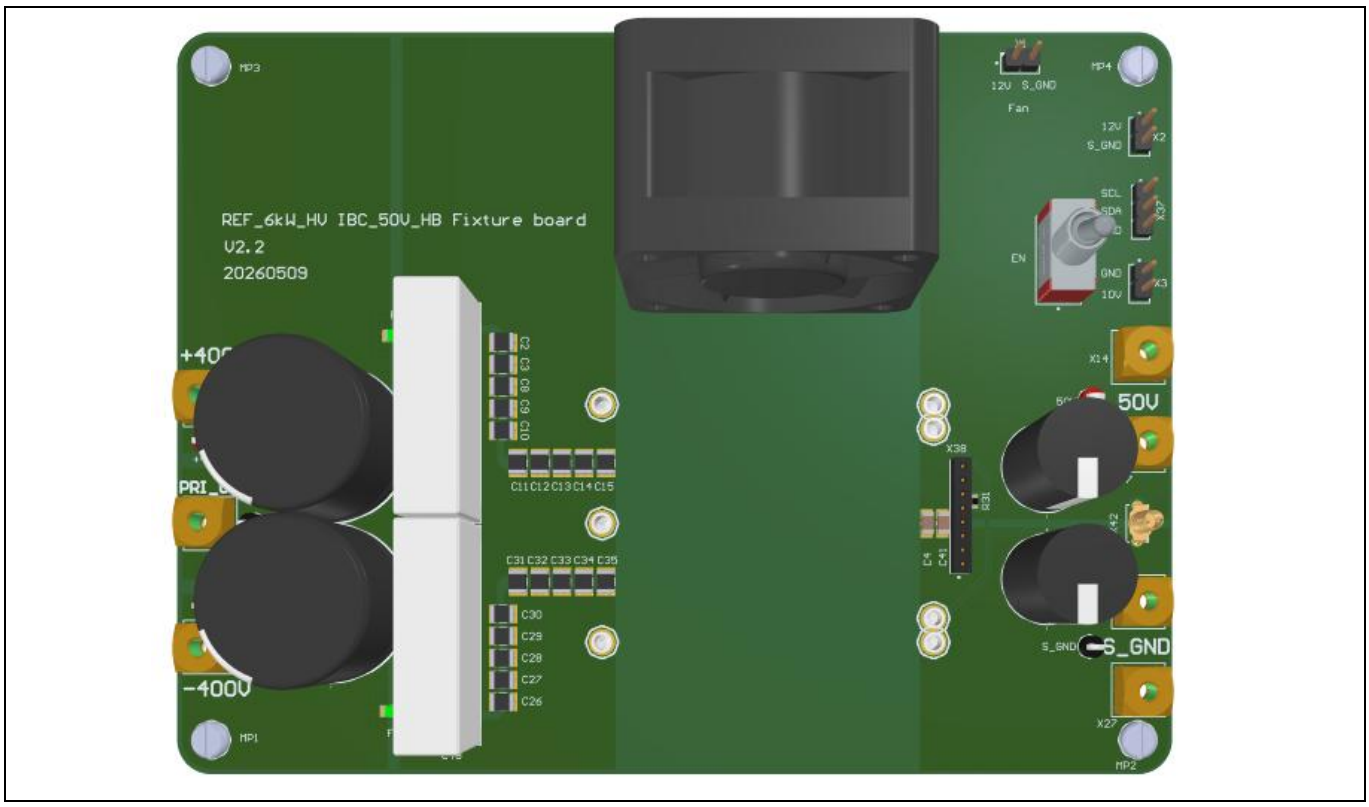


Figure 5 REF_6kW_HV IBC_50V_HB Fixture Board

Table 4 lists the REF_6kW_HV IBC_50V_HB Fixture Board headers and connectors.

Table 4 REF_6kW_HV IBC_50V_HB Fixture Board headers and connectors

Name	Description	Notes
+400V	High-voltage input connector for +400 V DC input	–
PRI_GND	High-voltage primary ground connection	–
-400V	High-voltage input connector for -400 V DC input	–
50V	Output connector for 50 V DC output voltage	–
S_GND	Output ground	Main ground reference for 50 V DC output side
X1	2-pin header for external fan connection	–
X2	2-pin header providing 12V DC power for the cooling fan	Used to supply power to an external or onboard fan for heatsink cooling
X3	2-pin header providing 10V DC bias supply	Supplies external bias power for the HV-IBC module

Name	Description	Notes
X37	3-pin header for I²C communication	Allows PC or controller connection for monitoring and configuration
X38	8-pin header including PG, address, 10 V, enable, and I²C pins for module connection	Provides all necessary control, communication, and bias signals between the fixture board and HV-IBC module

2.1.3 USB0010 Dongle Board

The USB0010 dongle serves as the essential communication bridge between the host PC and the REF_6KW_800V_50V_HB Fixture Board, enabling efficient system control, real-time monitoring, and parameter optimization through the XDP™ Designer GUI.

Figure 6 shows the dongle board; the USB port is on the left, and the interface to the fixture board's I²C header (X37) is on the right. For proper signal integrity and to avoid hardware damage, the 3-pin I²C connection must follow the defined color coding:

- **Black:** Ground (GND)
- **Red:** Serial Data (SDA)
- **Yellow:** Serial Clock (SCL)

As shown in Figure 7, the complete setup demonstrates the physical connection between the PC, the USB0010 dongle, and the fixture board, highlighting the dongle's role as a reliable and convenient bridge for real-time data exchange and system optimization during testing and validation.



Figure 6 USB0010 V1.0 Dongle Board with I²C pinout definitions

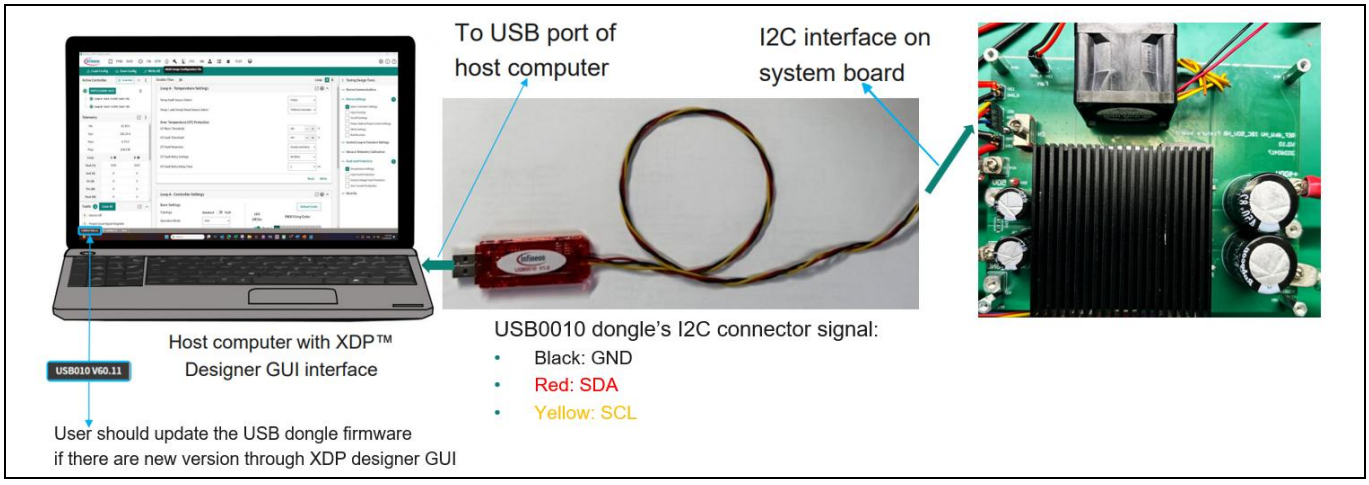


Figure 7 Complete system connection for GUI-based evaluation

2.2 XDP™ Designer GUI configuration tool

The XDP™ Designer design tool is a PC-based software GUI that provides an intuitive and user-friendly interface for configuring, monitoring, and controlling XDPP series controllers, including the XDPP1188 utilized on this reference board. Through its graphical environment, you can easily access key system parameters, adjust operating settings, and monitor device performance in real time.

The GUI communicates seamlessly with the hardware via the USB0010 dongle, enabling essential functions, such as registers configuration, telemetry data visualization, and firmware/patch updates. With its intuitive layout and interactive controls, the XDP™ Designer simplifies the evaluation process, improves development efficiency, and allows engineers to quickly optimize system performance during testing and validation.

Communication with the HV-IBC module is established via the USB0010 dongle, enabling essential functions such as register configuration, telemetry data visualization, and firmware updates. With its efficient workflow and interactive controls, the XDP™ Designer tool streamlines the evaluation process, enhances development efficiency, and allows engineers to quickly optimize system performance during testing and validation.

Download and install XDP™ Designer design tool through Infineon Developer Center Launcher.

1. Once the Launcher is installed, enter “XDP” in the search bar as shown in Figure 8 to locate the software
2. Click **Start** to begin installation

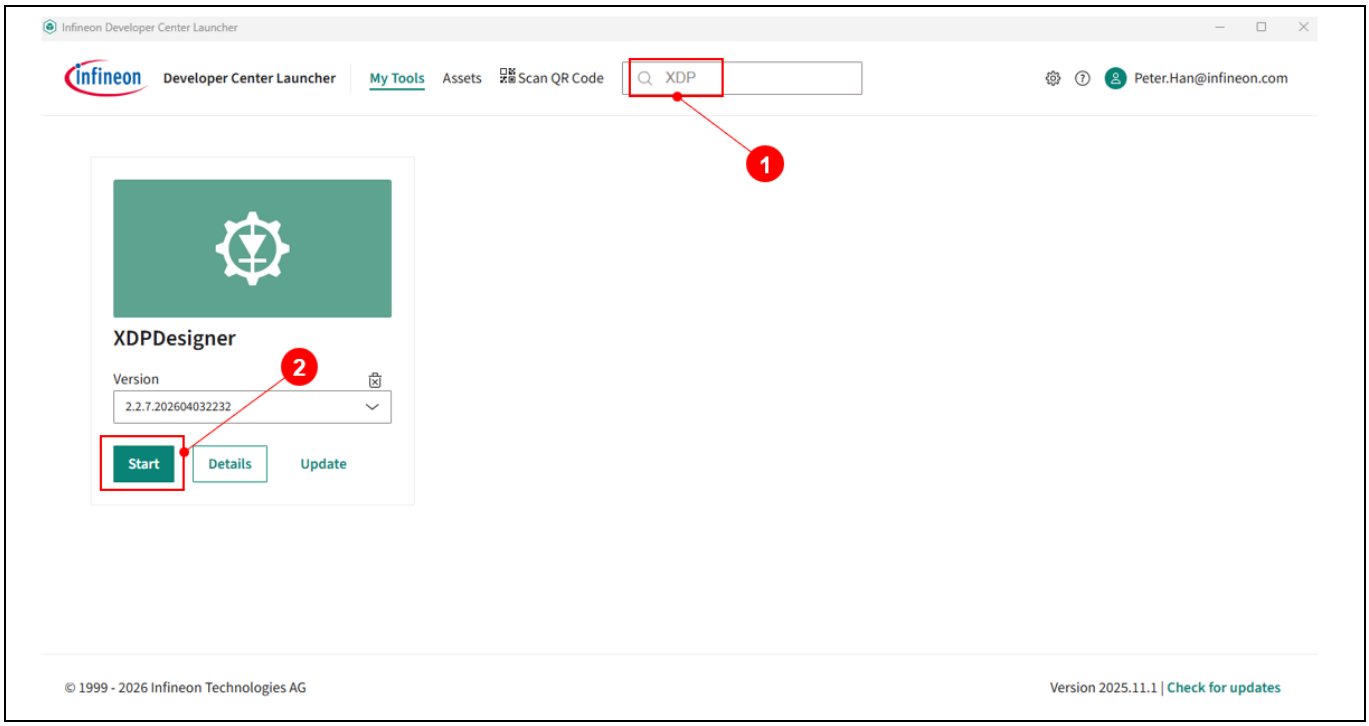


Figure 8 XDP™ Designer in Infineon Developer Center

Figure 9 shows the XDP™ Designer tool interface. Through this interface, you can modify PMBus® commands and register settings, such as write, read, and store operations. It also provides real-time monitoring of connection status, telemetry data, and any fault or protection events.

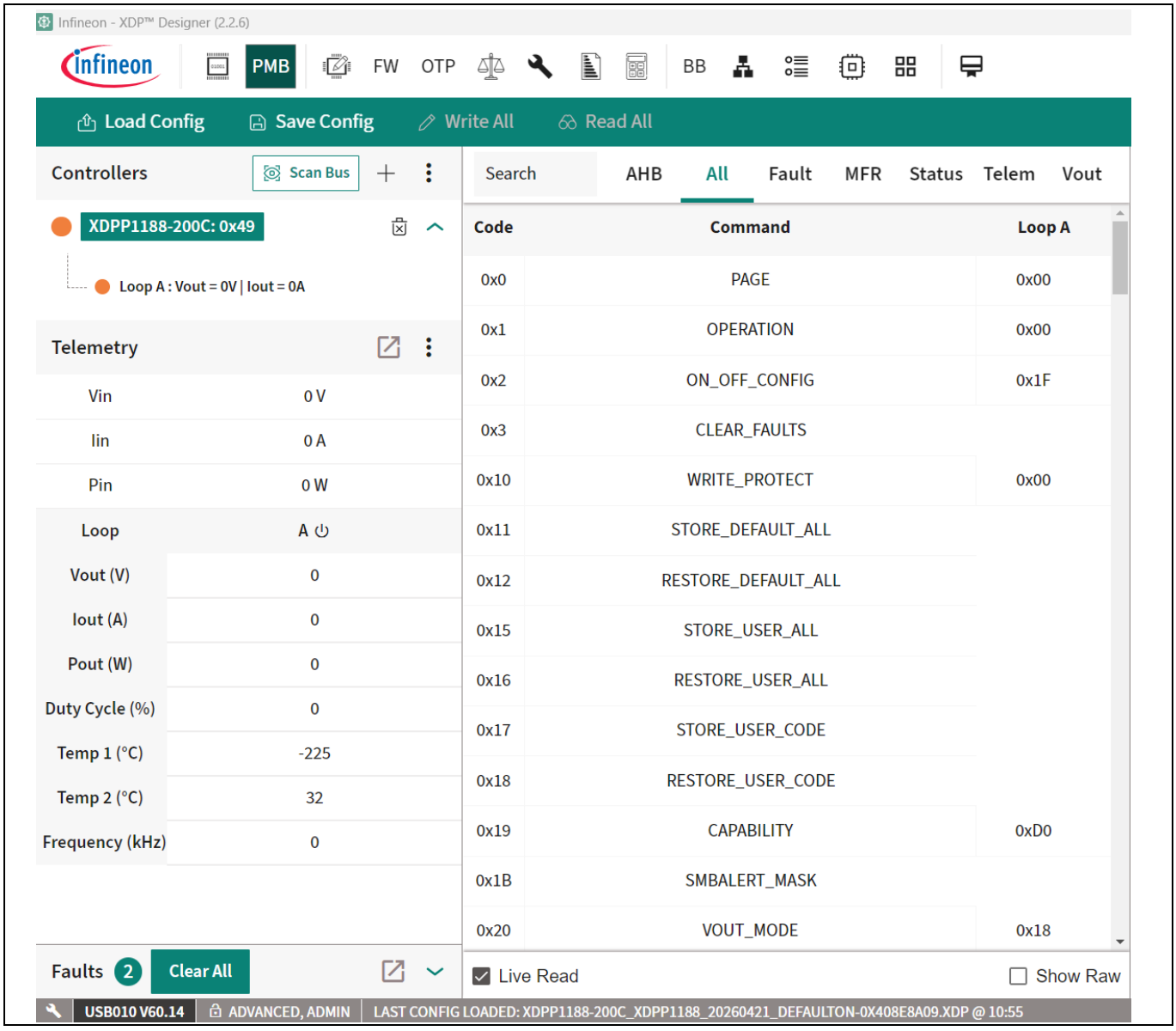


Figure 9 XDP™ Designer GUI with main dashboard

2.3 Required test equipment

- **DC power supply:** It should deliver up to ±400 V (or 800 V) and appropriate current for full-power testing
- **Electronic load:** It should have sink up to 120 A at 50 V
- **Oscilloscope and probes:** (≥100 MHz) For monitoring voltage, current, and switching waveforms. High-voltage differential probes are recommended
- **Digital multimeter:** For measuring input/output voltage and current
- **Thermal measurement tools:** Infrared thermometer or thermal imager for monitoring component temperatures
- **Fixture and dongle boards:** As required for proper operation
- **Insulated cables and connectors:** Rated for high-voltage and high-current use
- **Personal protective equipment (PPE):** Safety glasses, gloves, and any other necessary protection for high-voltage work

3 Functional description

3.1 Power stage

The power stage is based on an LLC resonant converter topology with an input-series output-parallel (ISOP) architecture. It consists of two interleaved phases: upper and lower LLCs. Each phase incorporates a primary-side half-bridge LLC circuit and two parallel full-bridge rectifiers on the secondary side. The primary-side half-bridges are connected in series, while all four secondary full-bridges are connected in parallel.

In total, the design employs four high-voltage GaN switches on the primary side and sixteen medium-voltage GaN switches on the secondary side. The upper and lower LLCs operate with a 90-degree phase shift, enabling interleaved operation that minimizes current ripple and improves overall system efficiency.

3.2 Primary-side gate driver

The controller is located on the secondary side; therefore, a reinforced-isolated, 2-channel gate driver is used to drive the primary-side half-bridge LLC GaN switches (high-side and low-side). The gate-drive network follows a standard high-voltage gate injection transistor (GIT) GaN drive implementation to achieve robust switching behavior and stable gate control.

Based on the selected GaN device's gate charge, dynamic characteristics, and the target switching performance (dV/dt control, ringing mitigation, and reliable turn-off), the following resistor values are used in the primary gate-drive path: Rss = 150 Ω, Rtr_on = 22 Ω, and Rtr_off = 4.7 Ω. The split turn-on/turn-off resistance enables asymmetric drive strength to balance switching loss and EMI, while maintaining strong turn-off immunity.

Figure 10 shows one of the primary-side gate-drive circuits, highlighting the key components used to achieve optimal switching performance.

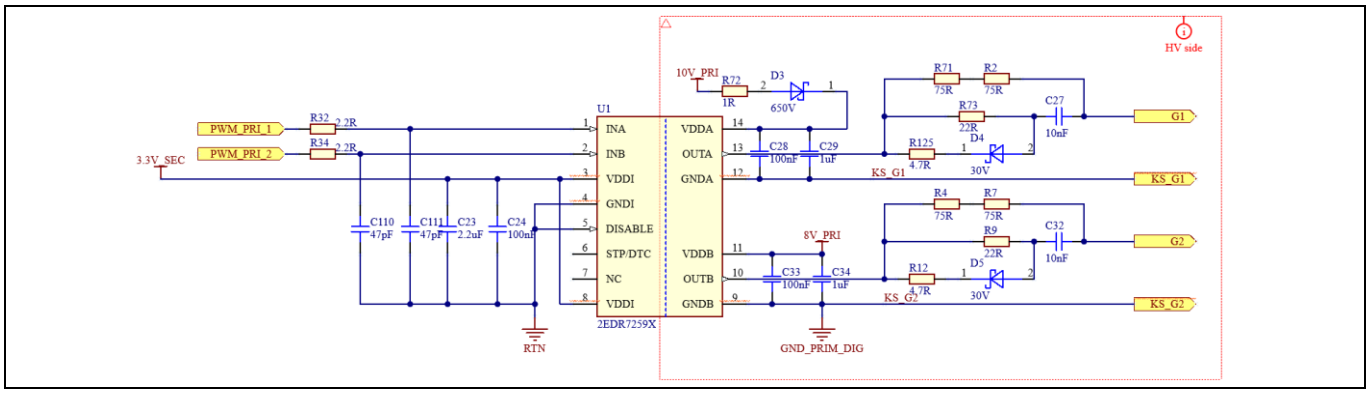


Figure 10 Primary-side isolated gate driver circuitry

3.3 Secondary-side gate driver

The secondary-side GaN switches are driven by the 2EDL5014AA-U2D, a 120 V half-bridge gate driver with an integrated bootstrap switch in a small TSNP-12 (2 mm × 2 mm) package. The device provides 4 A/4 A peak source/sink capability and a typical propagation delay of 20 ns.

Figure 11 shows the driver's circuit and the package/size information. Since each full-bridge stage requires two half-bridge drivers to manage its four GaN switches, a total of eight 2EDL5014AA-U2D devices are integrated into the module to ensure precise synchronous rectification.

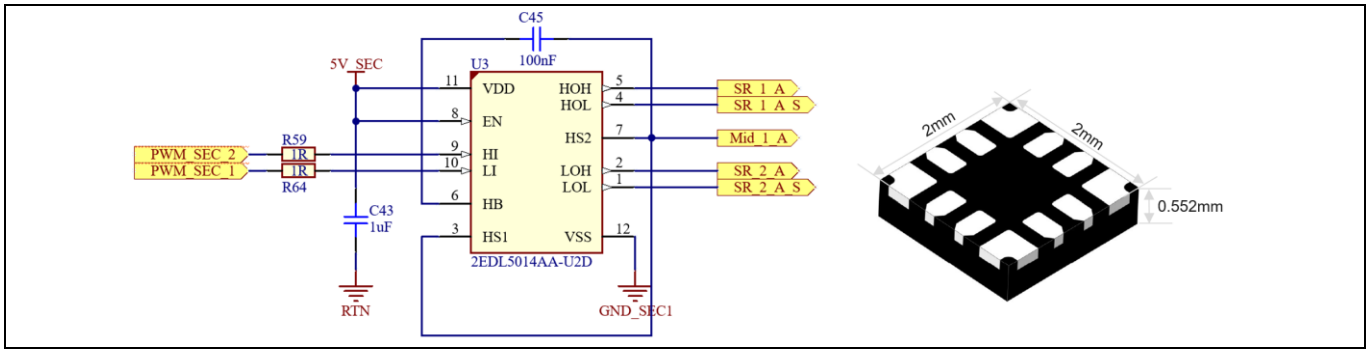


Figure 11 Secondary-side SR gate driver and package dimensions

3.4 Current-sensing circuit

Current is sensed using a PCB copper trace as the shunt impedance, providing a compact and cost-effective integrated solution. The small voltage drop generated across this trace is amplified by a high-precision opamp stage and then routed to the XDPP1188 digital controller ADC for real-time processing.

To enable independent monitoring, separate current-sensing circuits are implemented for the upper and lower LLC stages. Each circuit utilizes a dual-channel precision opamp (OPA2392):

- **Channel 1:** Configured as a voltage follower to buffer a stable 1.1 V reference, providing the necessary DC offset for the sensing signal
- **Channel 2:** Configured to amplify the shunt voltage from the copper trace with high accuracy

Figure 12 shows the architecture of one of these current-sensing circuits.

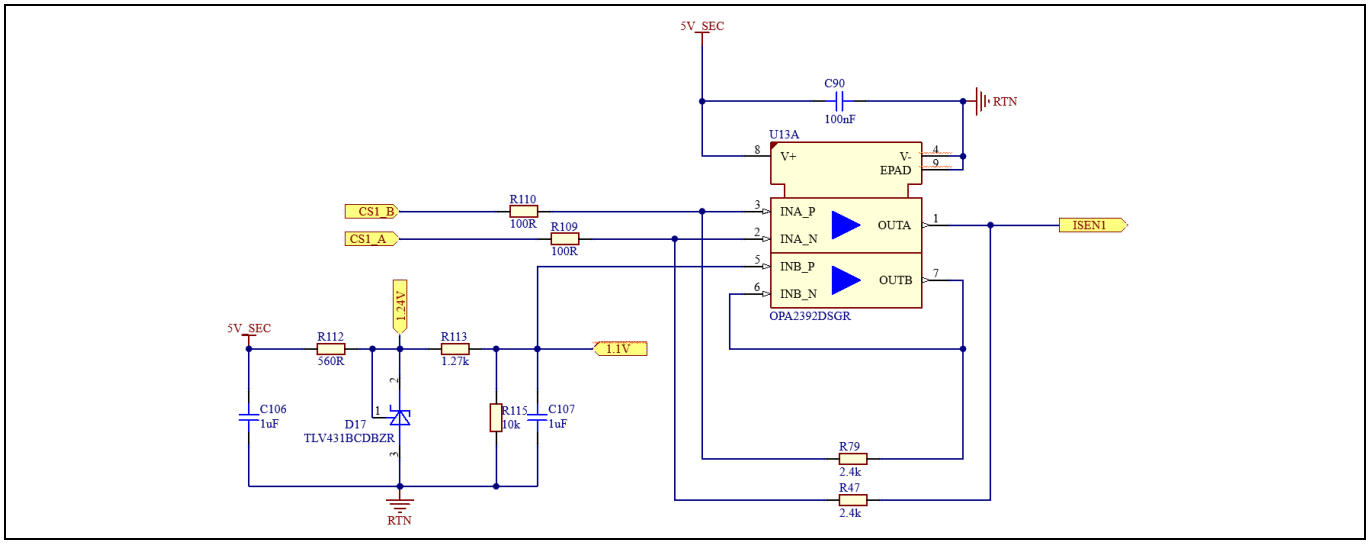


Figure 12 Output current-sensing circuit

3.5 10 V bias supply circuit and voltage regulator

The system uses a single external 10 V supply on the secondary side as its only auxiliary input. This 10 V rail provides the required bias power for both the primary-side and secondary-side circuitry. For the primary side, an isolated bias supply is generated using the 2EP130R transformer driver IC together with a 1:1:2 isolation transformer, resulting in two isolated 10 V outputs to support the primary-side gate driver and related bias requirements. The isolated bias supply circuit is shown in Figure 13.

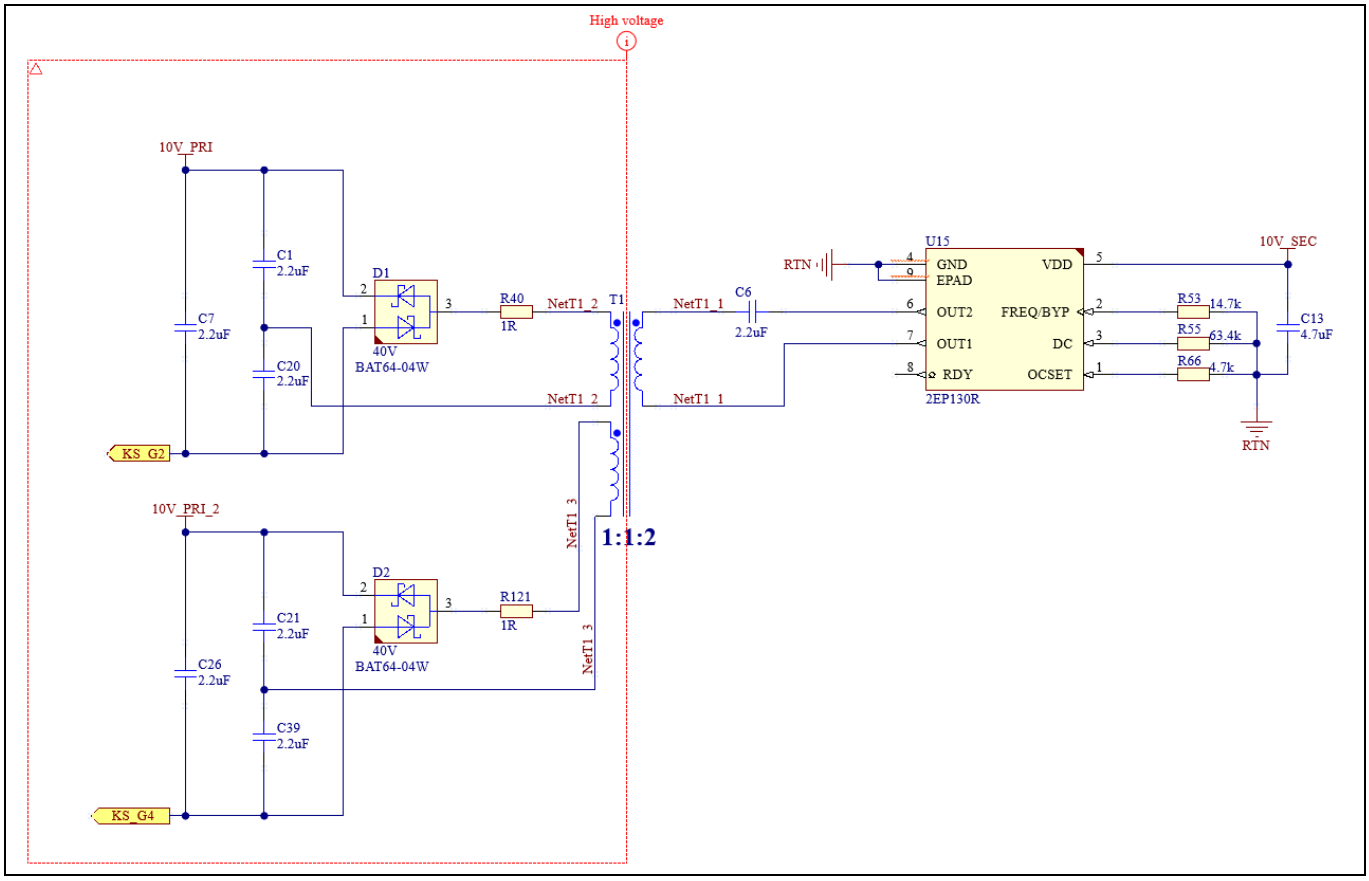


Figure 13 Isolated bias supply generation

On the secondary side, the external 10 V auxiliary input is stepped down to 5 V using a switching regulator, providing an efficient intermediate supply rail. This 5 V rail is then further regulated to 3.3 V by a linear regulator (LDO) to supply low-noise logic, control circuitry, and other 3.3 V peripherals. The regulator circuits are shown in Figure 14.

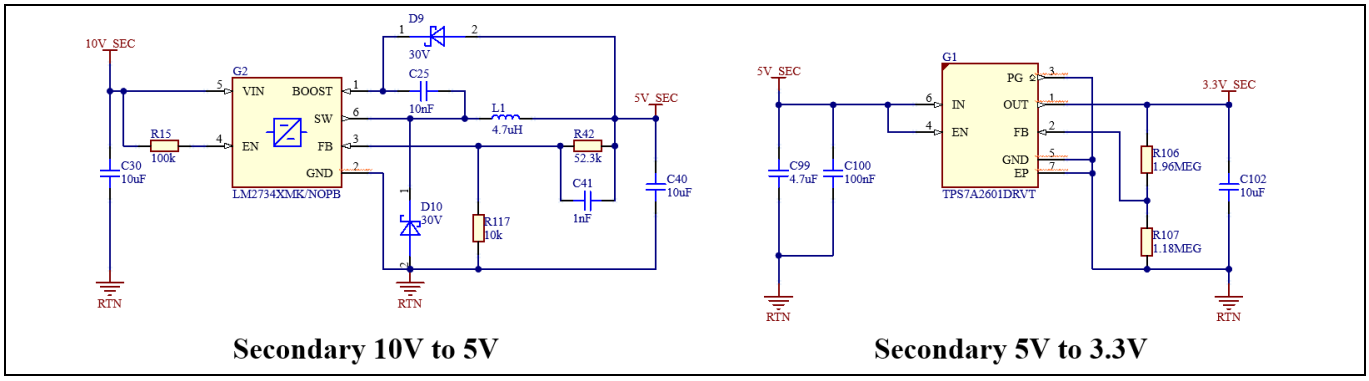


Figure 14 Secondary-side voltage regulators

3.6 8-pin header

This 8-pin header consolidates essential low-voltage signals, including the 10 V external bias supply input, the I²C/PMBus® communication interface (SDA and SCL), and critical control/status signals such as Enable (EN), Power Good (PG), and Address configuration (ADDR). The detailed pin assignment and signal mapping for this connector are shown in Figure 15.

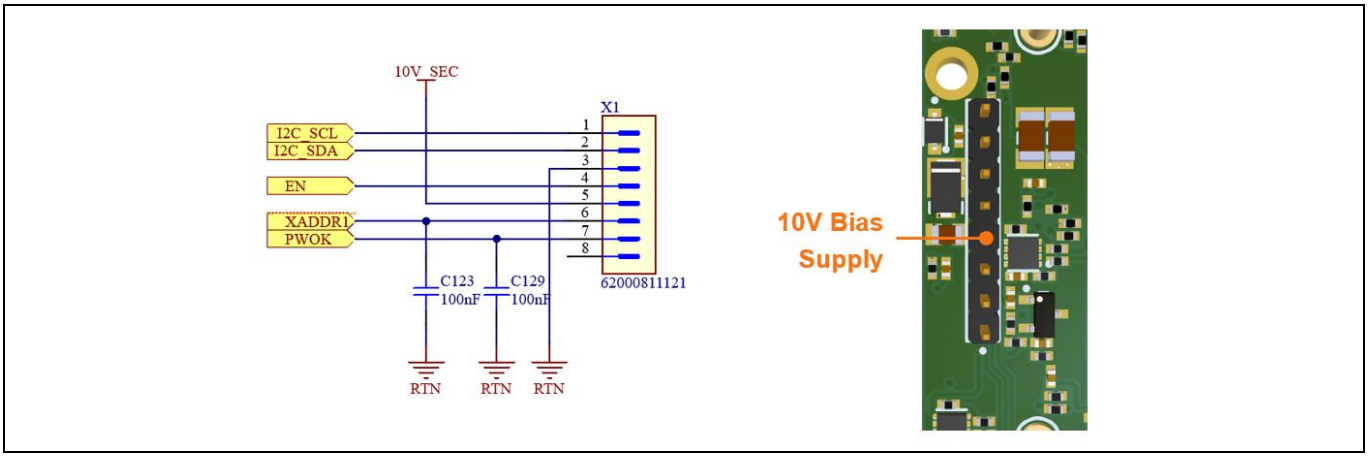


Figure 15 8-pin functional header

3.7 Planar transformer design

The transformer is implemented as a planar transformer, with the windings realized using PCB copper layers to achieve a compact and low-profile structure. The PCB uses 3 oz. copper thickness, which helps reduce DC resistance and improve current handling capability, while also enhancing thermal performance through better heat spreading across the board. Compared to conventional wire-wound implementations, the planar approach provides improved repeatability, tighter control of parasitic parameters, and a more suitable solution for high-frequency operation.

A custom-designed EI core is used to match the planar winding structure and optimize magnetic performance. The core material is ML95S, selected for its low core loss characteristics at the target switching frequency and its suitability for high-efficiency LLC operation. The core geometry is designed to provide sufficient magnetizing inductance while maintaining good coupling and minimizing leakage.

The transformer is designed with a 4:1 turns ratio to achieve the required voltage conversion for the LLC resonant stage. The primary and secondary windings are distributed across multiple PCB layers to improve coupling and reduce leakage inductance.

Overall, the planar transformer design enables a compact, thermally efficient, and well-controlled magnetic solution, meeting the high-power density, and high-frequency requirements of the HV-IBC system.

4 System performance

The system supports both standalone operation and GUI-based control. With firmware and configuration pre-programmed, the default setting allows the system to be operated by toggling the EN pin; no additional setup via the GUI is required. You can power up and use the system in standalone mode without any software intervention.

Alternatively, the system can be controlled and monitored through the XDP™ Designer GUI. This interface provides the flexibility to either quickly load the default environment with the supplied patches and configuration files, or to perform full system customization as needed.

4.1 System setup and operation modes

4.1.1 Standalone mode

In standalone mode, the REF_6KW_800V_50V_HB system can be operated using its pre-programmed firmware without any external software control. Follow these steps for safe and proper operation.

- Power on the 12 V fan supply for the cooling fan
- Power on the 10 V DC external auxiliary (AUX) supply
- Apply high-voltage (HV) DC input set to 800 V
- Enable system operation by switching the EN pin to the ON position
- Apply load to the 50 V output as needed
- To shut down, switch the EN pin to the OFF position

This sequence ensures reliable standalone operation of the HV-IBC module. Always observe appropriate safety precautions when working with high-voltage systems.

4.1.2 Operation with XDP™ Designer tool

When operating the system using the XDP™ Designer GUI, you can leverage the full digital control capabilities of the XDPP1188 controller. This mode allows for either a quick setup using default configurations or deep system customization.

- Power on the 12 V fan supply for the cooling fan
- Connect the USB dongle between the PC and the I^2C header on the fixture board
- Power on the 10 V DC external auxiliary (AUX) supply
- Launch the XDP™ Designer tool and perform the following:
  - **Loading defaults:** Import the provided *.xdp* configuration file and the firmware patch (e.g., “xx_patch.bin”) for standard operation
  - **Customization:** Adjust PMBus® commands or registers settings via the GUI and update the register manifest using the configuration Excel file if needed
  - **Memory storage:** Store the finalized patch and configuration to one-time programmable (OTP) or RAM memory to apply the settings
- Apply high-voltage (HV) DC input set to 800 V
- In the XDP™ Designer GUI, click the **OPERATION** command to turn the system ON
- Connect and adjust the output load as required for your test conditions
- To turn the system OFF, click the **OPERATION** command again in the GUI

Note: Ensure to follow high-voltage safety protocols during all operations and setup steps.

4.2 Test results

The following sections shows typical test results obtained with the HV-IBC module. The following waveforms and data shows the operation, protection, and efficiency characteristics of the system under various conditions. You can refer to these results to better understand system behavior and verify correct operation during evaluation.

4.2.1 Startup waveform

Figure 16 shows the soft start behavior of the system at power-up under no-load conditions. The waveform includes the output voltage (VOUT), the resonant currents for both phases (Icr_ph1, Icr_ph2), and the switching node voltages of the primary-side half-bridges (Vhb-ph1, Vhb-ph2).

During startup, the output voltage rises smoothly and reaches its targeted value, while the resonant currents stabilize and gradually settles to steady-state levels. The switching node voltages exhibit voltage spikes that remain within specified safe limits throughout the startup sequence.

In typical operation, the output remains disconnected from the load by a relay during startup and is only connected to the load after the output voltage stabilizes. This demonstrates effective soft start control and reliable system behavior during initial power-up.

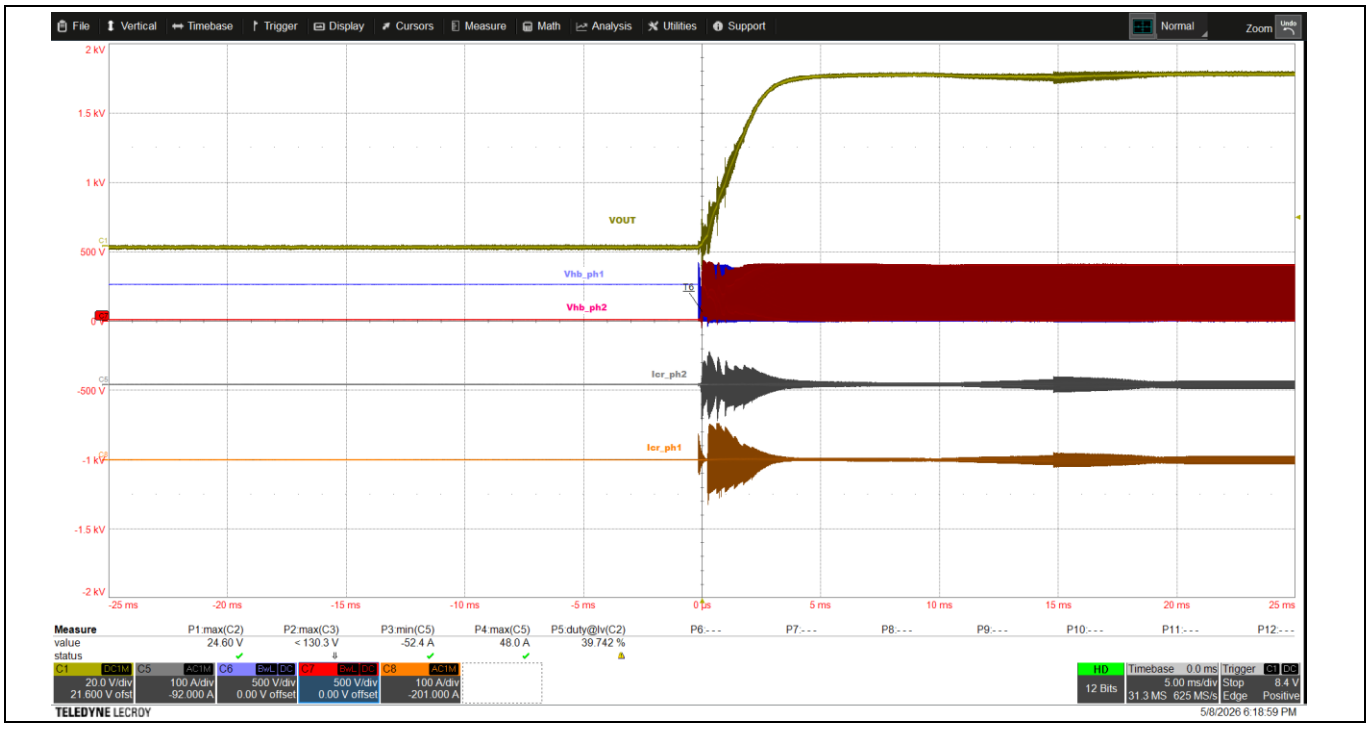


Figure 16 Startup waveform

4.2.2 Steady-state operation

Figure 17 shows the steady-state waveforms of the system operating at full load. The captured signals include the switching node voltages (Vhb_ph1, Vhb_ph2) and the resonant currents (Icr_ph1, Icr_ph2) for both phases. With an 800 V input, the two phases demonstrate balanced voltage sharing across the series-connected half-bridges.

Additionally, the phase angle between the two phases is clearly maintained at 90 degrees, confirming proper interleaved operation and effective load sharing. These waveforms verify stable and efficient performance under normal operating conditions.

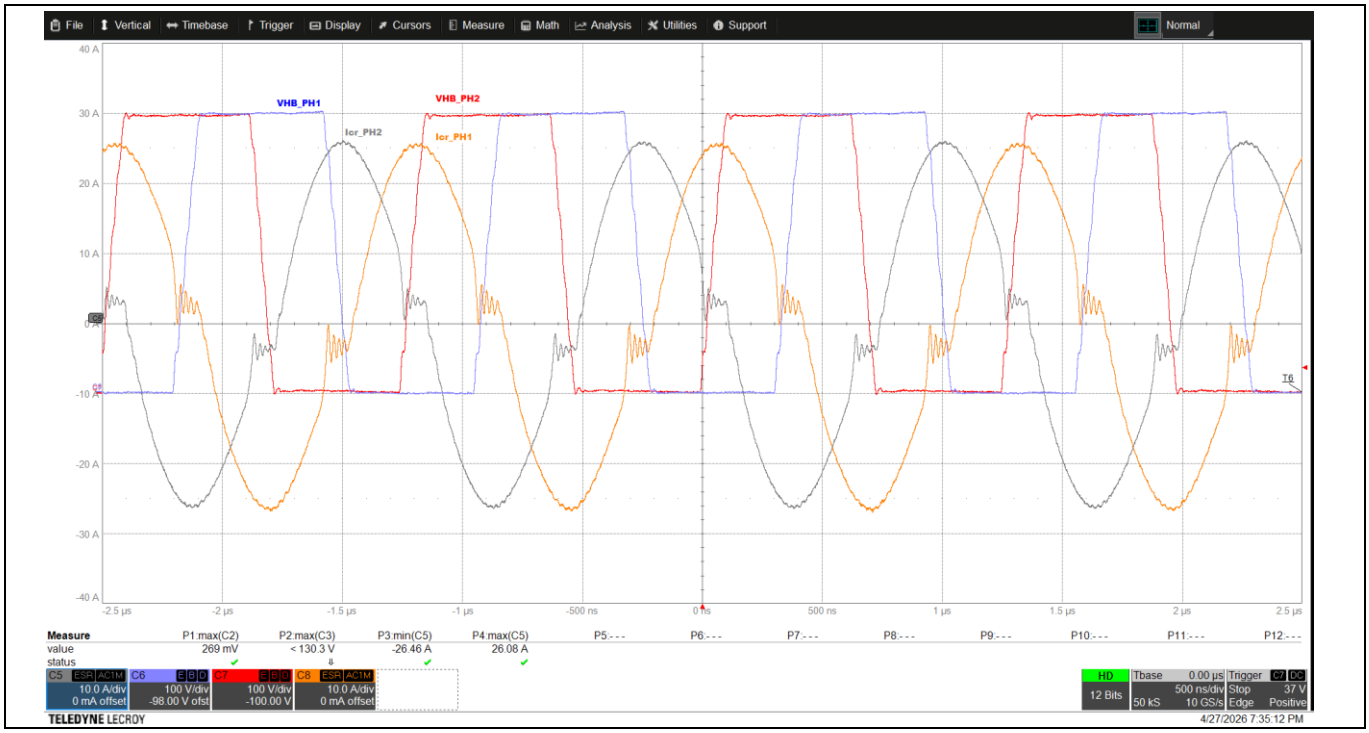


Figure 17 Steady-state waveform at 6 kW full-load condition

4.2.3 Unregulated Vout accuracy and output current telemetry

Figure 18 and Figure 19 show the unregulated output voltage accuracy and real-time output current measurement capabilities of the IBC module, which operates with an open-loop topology and does not use output voltage feedback.

Figure 18 shows that the output voltage remains stable across a load range from 10 A to 120 A. Figure 19 demonstrates precise and reliable output current telemetry during these tests. Together, these results confirm the system's ability to maintain voltage stability and provide accurate current monitoring throughout its operating range.

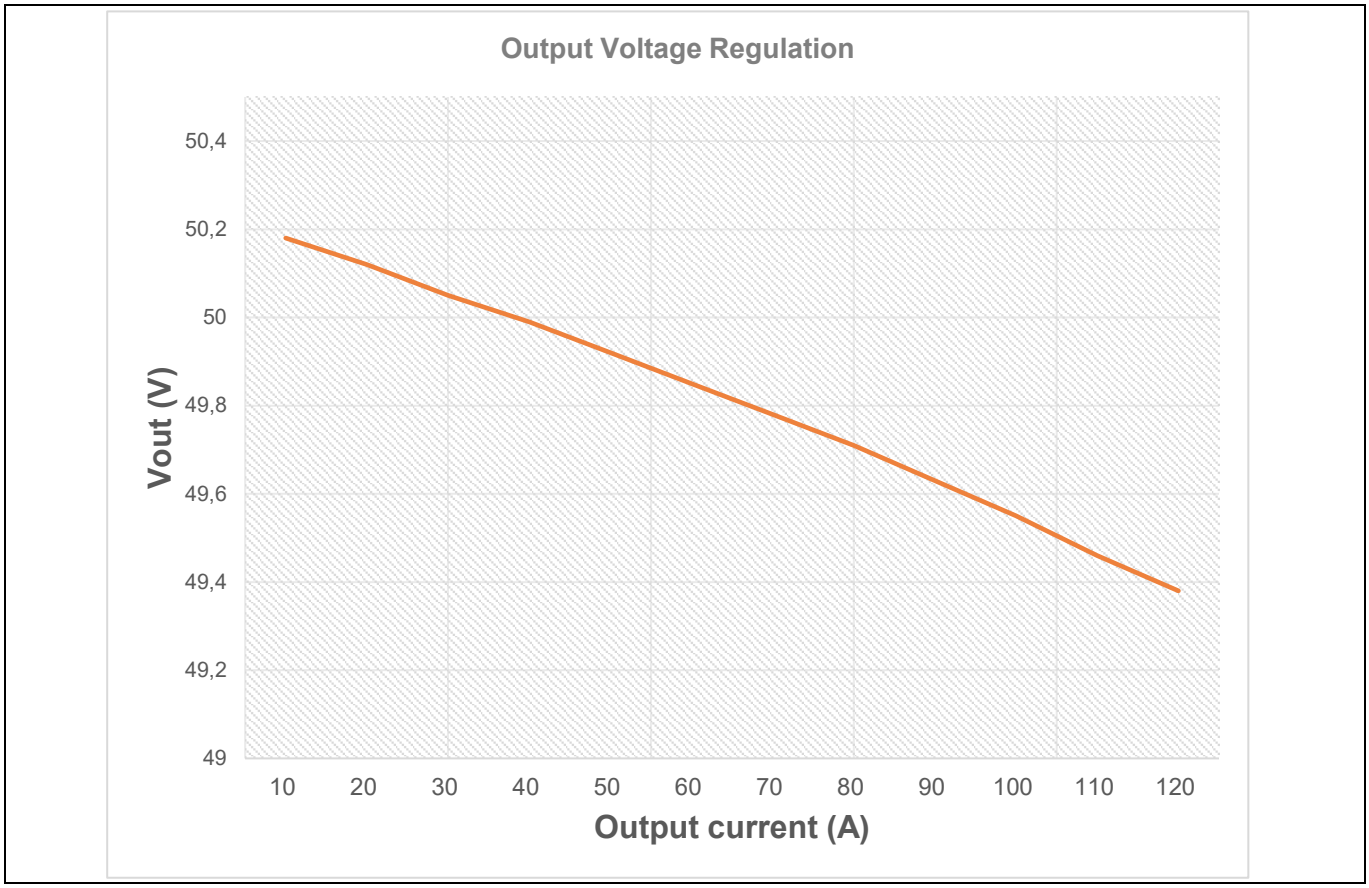


Figure 18 Unregulated output voltage across 10 A to 120 A load range

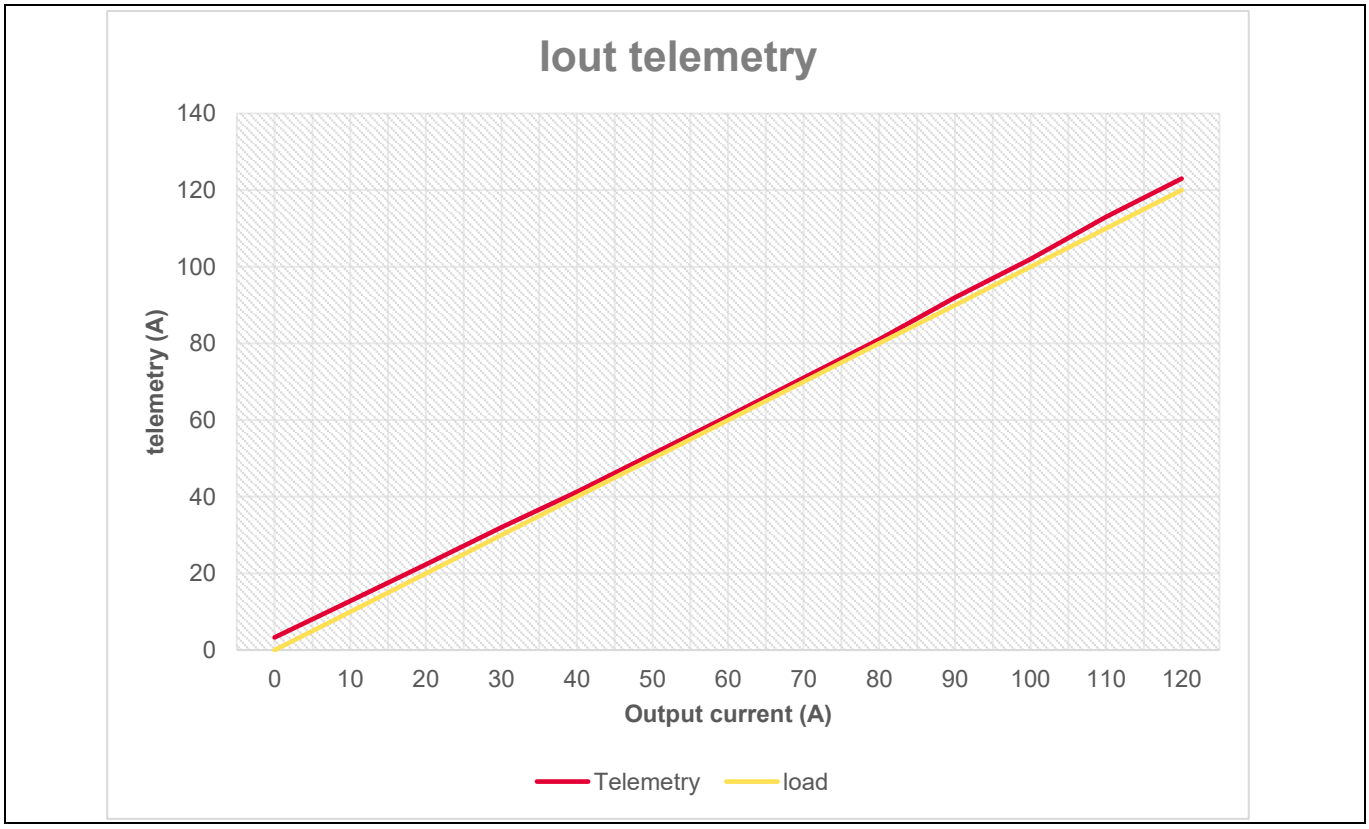


Figure 19 Telemetry accuracy verification for output current

4.2.4 Protection features

4.2.4.1 Overcurrent protection (OCP)

Overcurrent protection (OCP) performance is evaluated using a step load response from 100 A to 150 A. Figure 20 shows the captured waveforms, including output voltage (Vout), output current (Iout), and the switching node voltages for both phases (VHB_PH1 and VHB_PH2). The results show that OCP is reliably triggered when the output current exceeds the set threshold, as indicated by the rapid response in the waveforms.

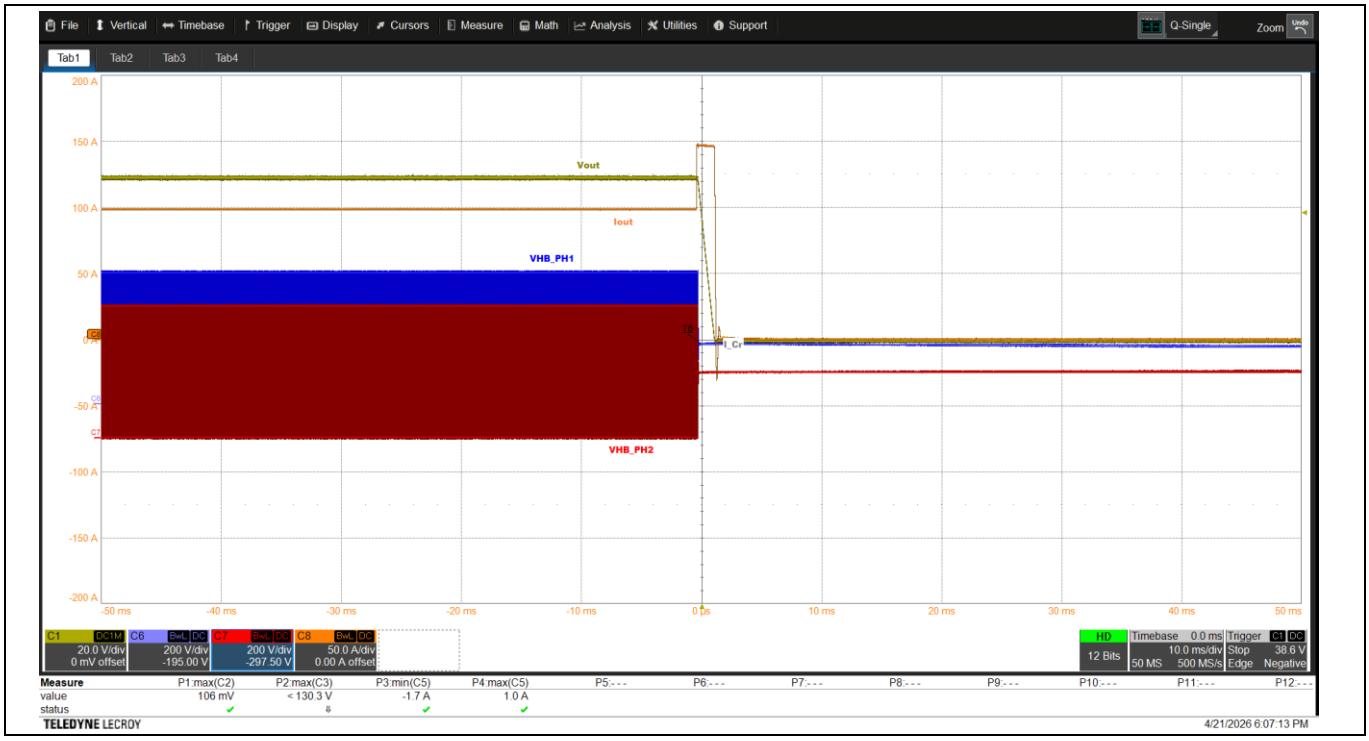


Figure 20 Overcurrent protection (OCP) trigger

4.2.4.2 Overtemperature protection (OTP)

For the OTP evaluation, the system is operated at full load while the fan speed was gradually reduced, causing the board temperature to rise. Once the temperature reached the OTP threshold, protection is triggered. Figure 21 shows the OTP event, with waveforms including output voltage (VOUT), resonant currents (Icr_ph1, Icr_ph2), and the primary-side half-bridge switching node voltages (Vhb-ph1, Vhb-ph2).

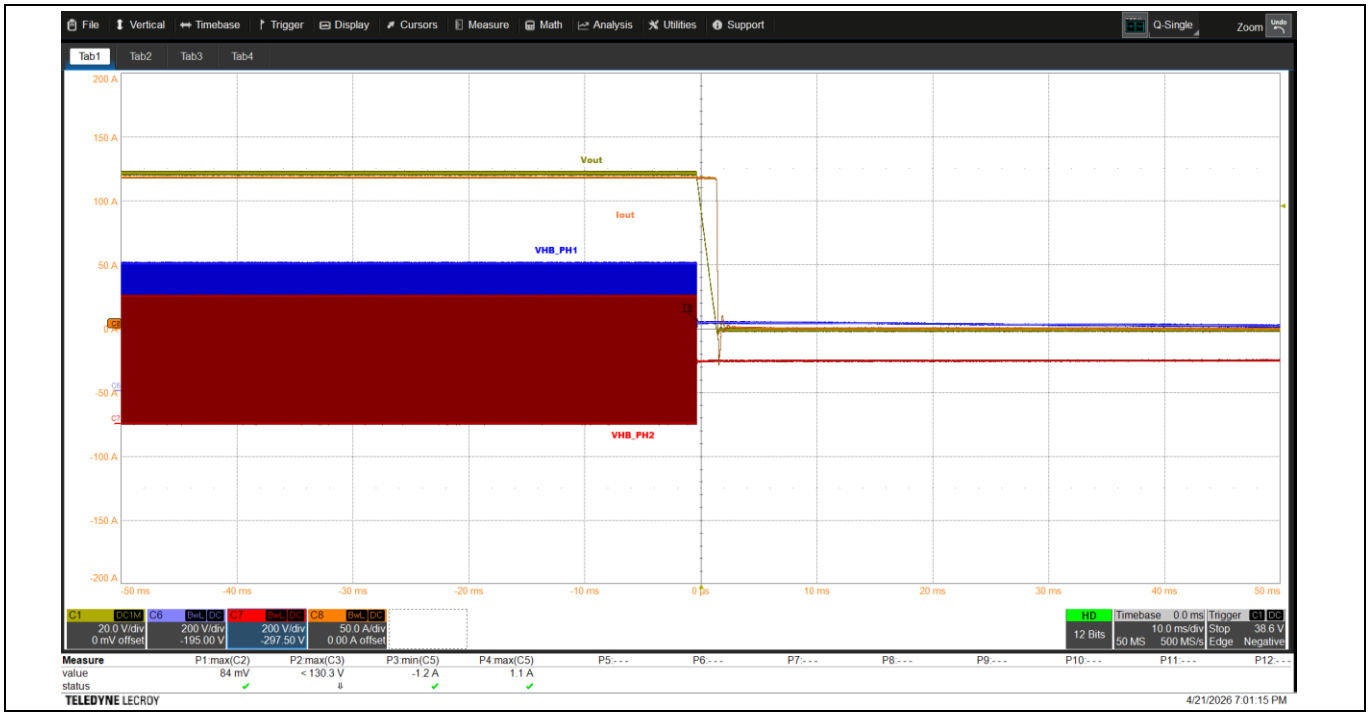


Figure 21 Overtemperature protection (OTP) trigger

4.2.4.3 Output undervoltage protection (UVP)

The UVP function is evaluated by gradually reducing the input voltage, which caused the output voltage to decrease until the UVP threshold is reached and protection is triggered. Figure 22 shows the corresponding waveforms, including output voltage and the switching node voltages for both phases (Vhb-ph1, Vhb-ph2). The results confirm that the UVP operates as expected, with the system effectively detecting undervoltage conditions and responding appropriately to protect the output.

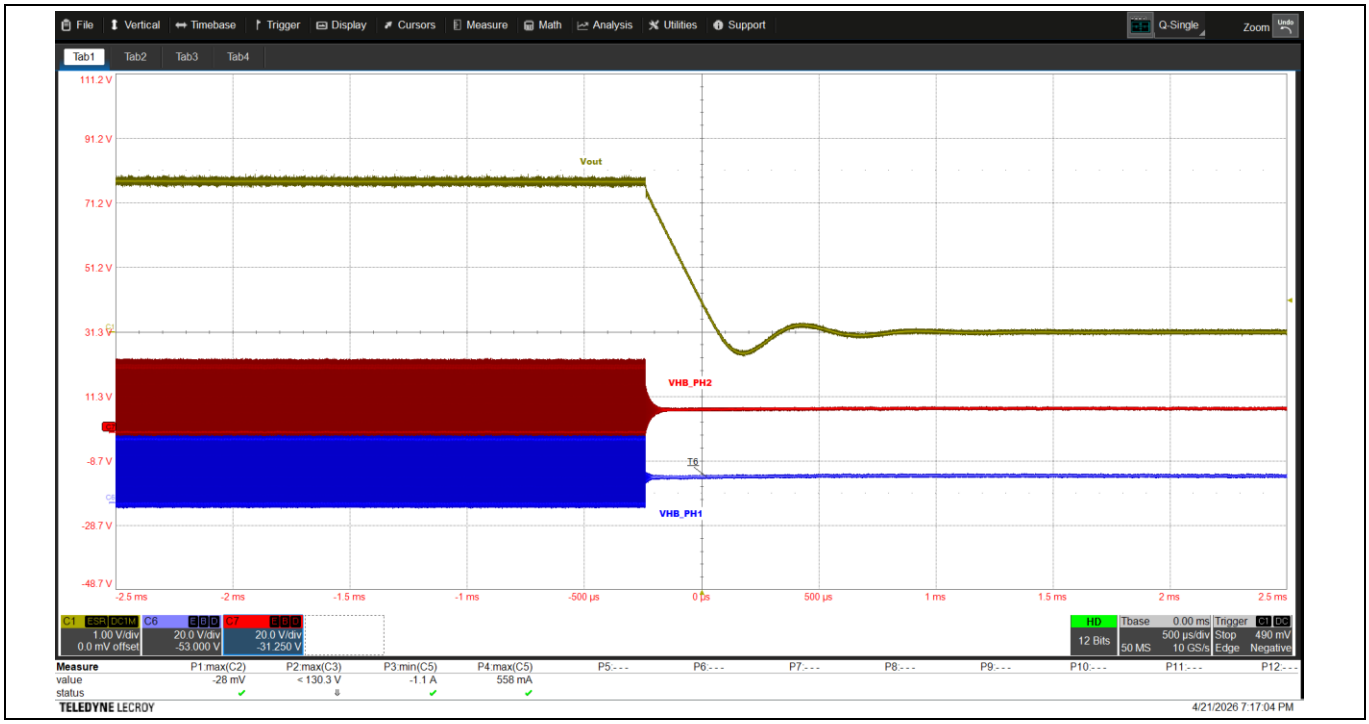


Figure 22 Output undervoltage protection (UVP) during input reduction

4.2.5 Efficiency analysis

Efficiency measurements were conducted under a range of load conditions, with two sets of curves shown in Figure 23 to provide a comprehensive evaluation. One set includes auxiliary power consumption, while the other excludes it, allowing for a clearer understanding of the intrinsic conversion efficiency of the power stage.

As shown in Figure 23, the module achieves a peak efficiency of 98.5% at approximately half-load operation. Moreover, it maintains a high efficiency of 98.0% even at full-load conditions, indicating minimal efficiency degradation at higher power levels. These results highlight not only the excellent energy conversions of the system but also its stable and robust performance across a wide operating range. Overall, the measured efficiency characteristics validate the effectiveness of the proposed HV-IBC design in achieving high efficiency under wide range of load conditions.

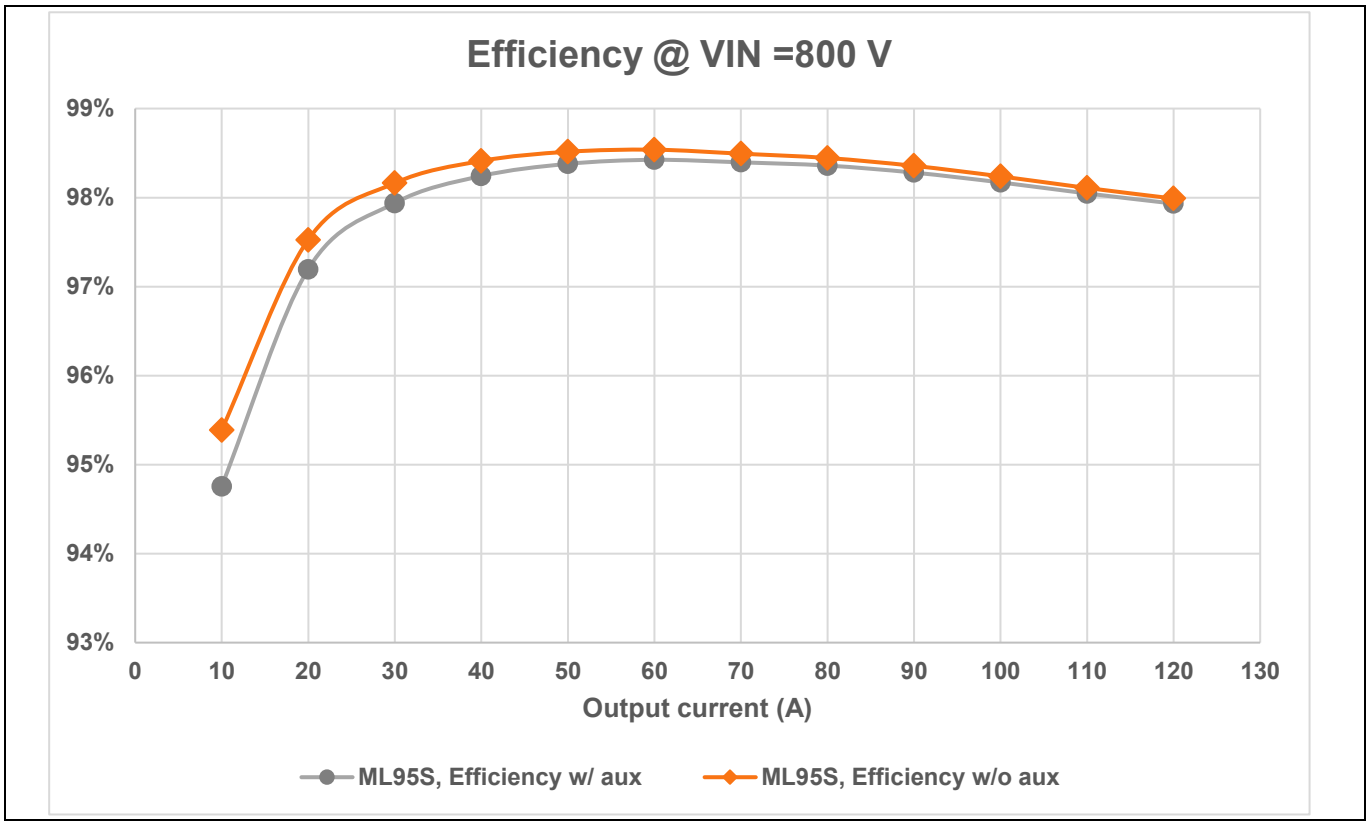


Figure 23 System efficiency curves (including/excluding auxiliary power)

4.2.6 Thermal performance

Figure 24 shows the measured thermal performance of the board, shown using a side-view thermal image captured under steady-state operating conditions. The temperature data is recorded after 30 minutes of continuous full-load operation to ensure thermal equilibrium. As observed, the transformer exhibits the highest temperature rise on the board, indicating it as the dominant thermal hotspot.

In addition, elevated temperatures are also observed at the switching devices located on both sides of the PCB. These results not only highlight the primary sources of heat generation but also demonstrate that the overall thermal management and heat dissipation of the system are effective under prolonged high-power operation conditions.

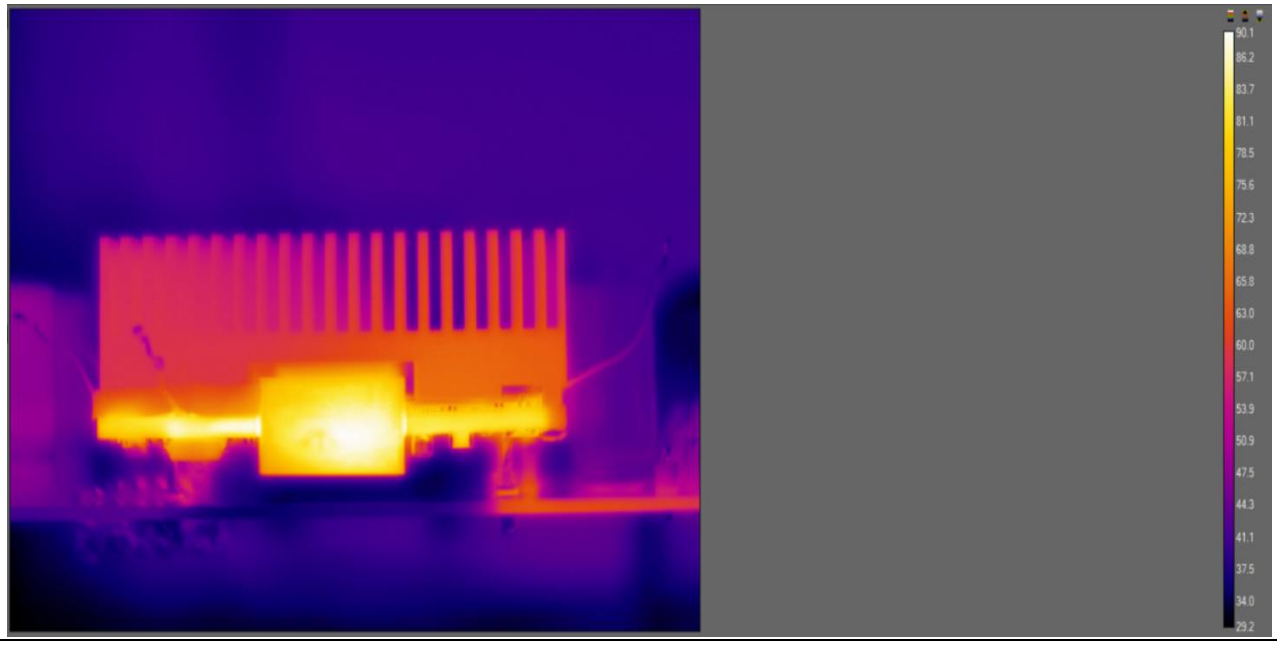


Figure 24 Thermal image of IBC module after 30 Mins of full load operation

5 Schematics

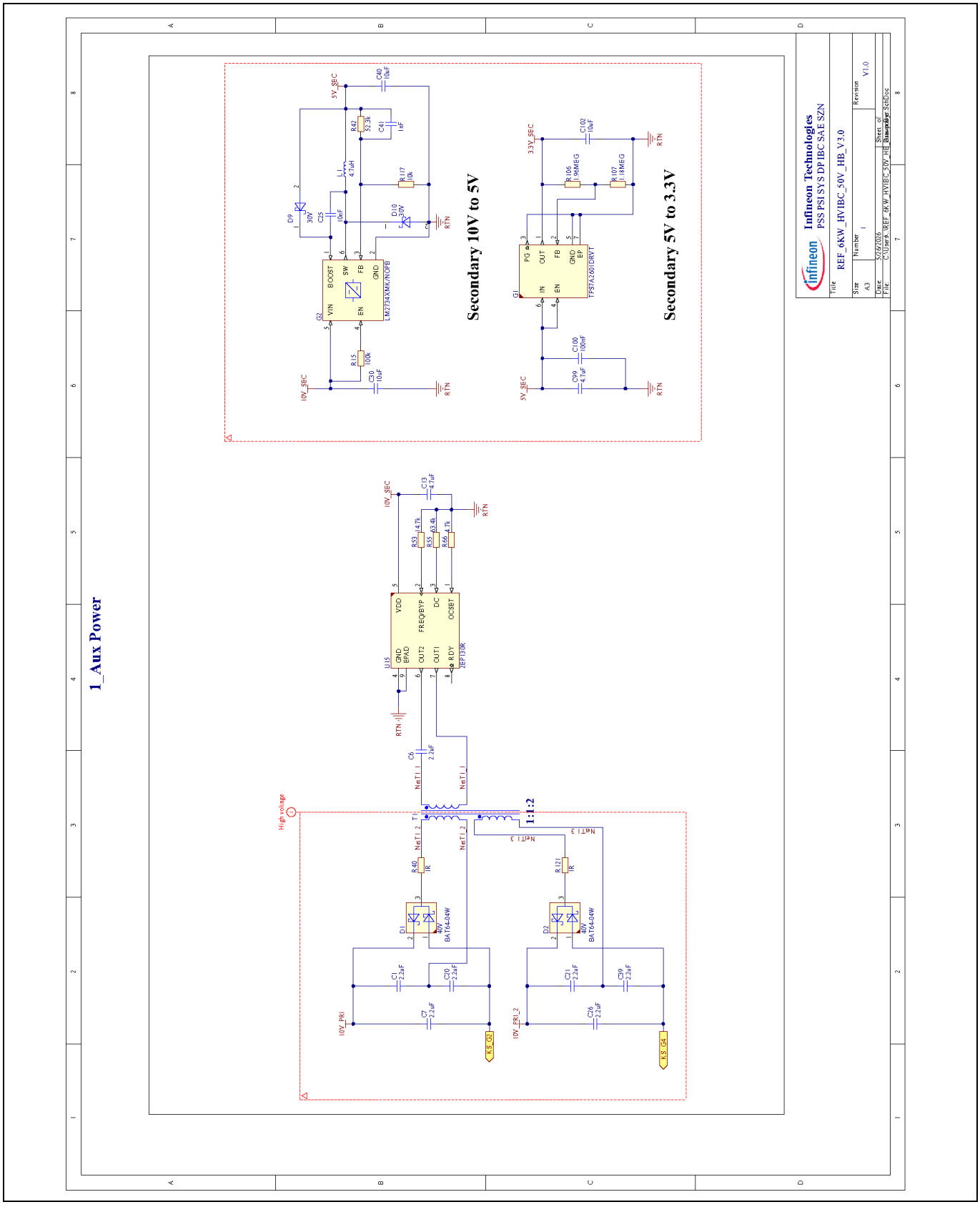


Figure 25 Auxiliary power

5 Schematics

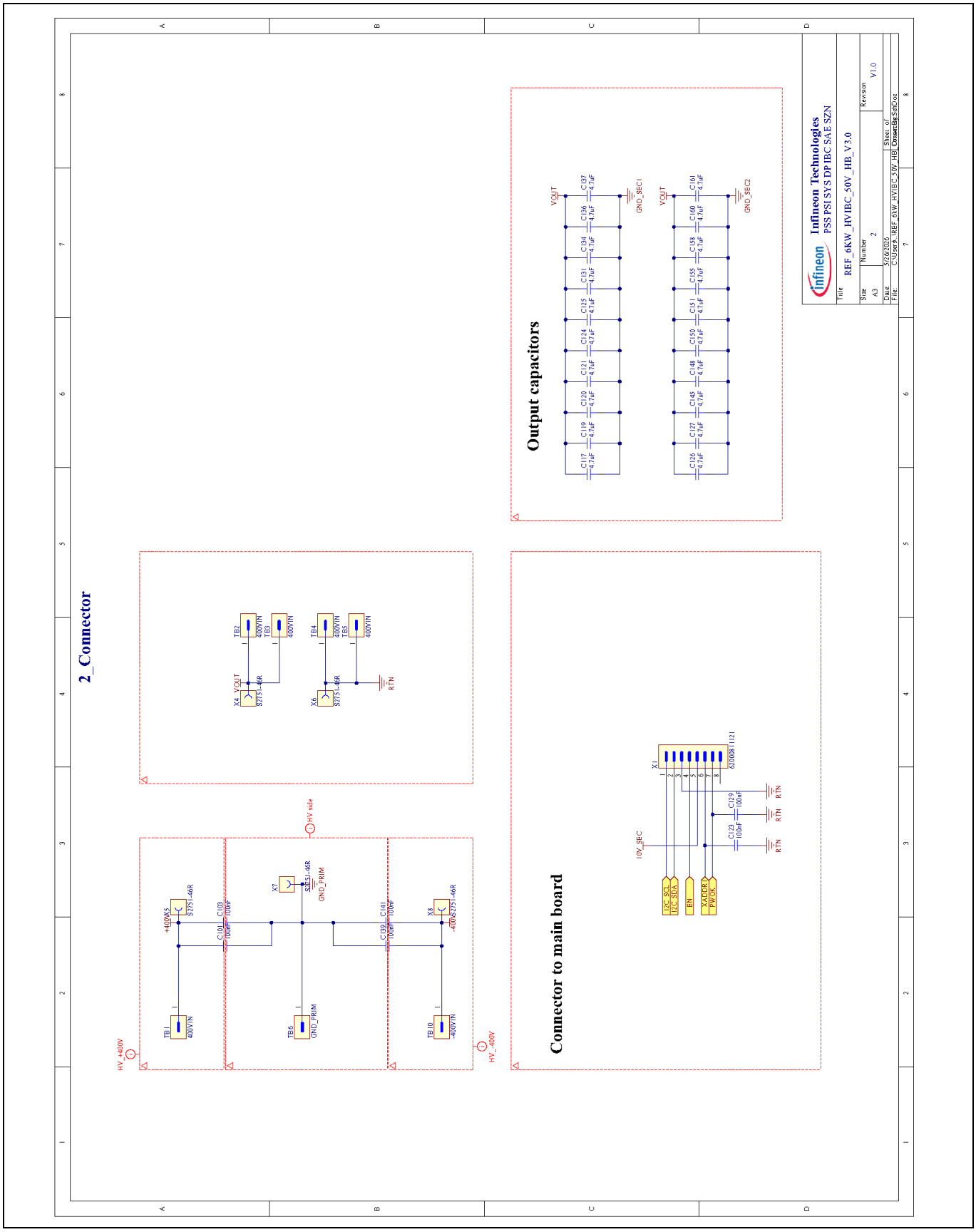


Figure 26 Connector

5 Schematics

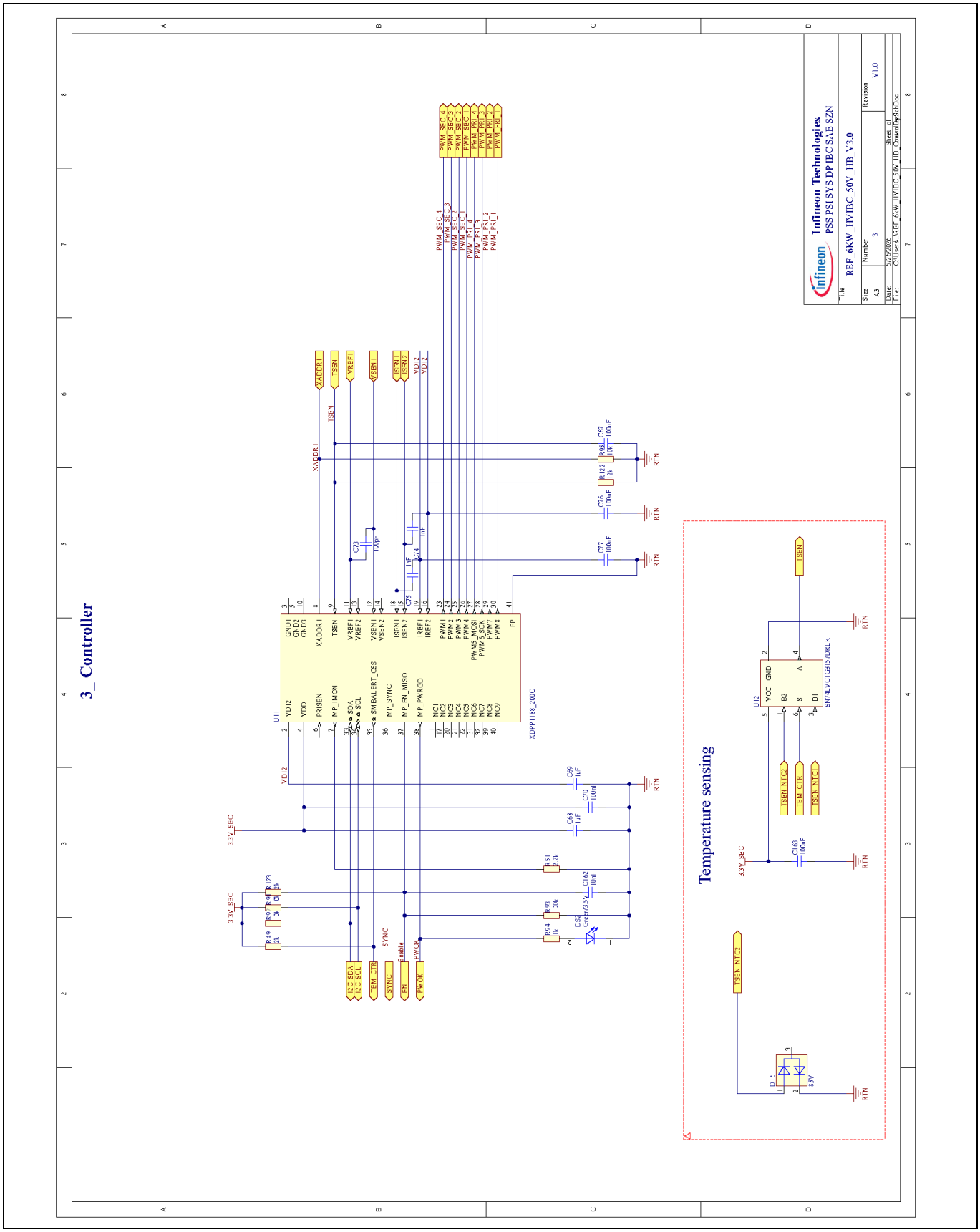


Figure 27 Controller

5 Schematics

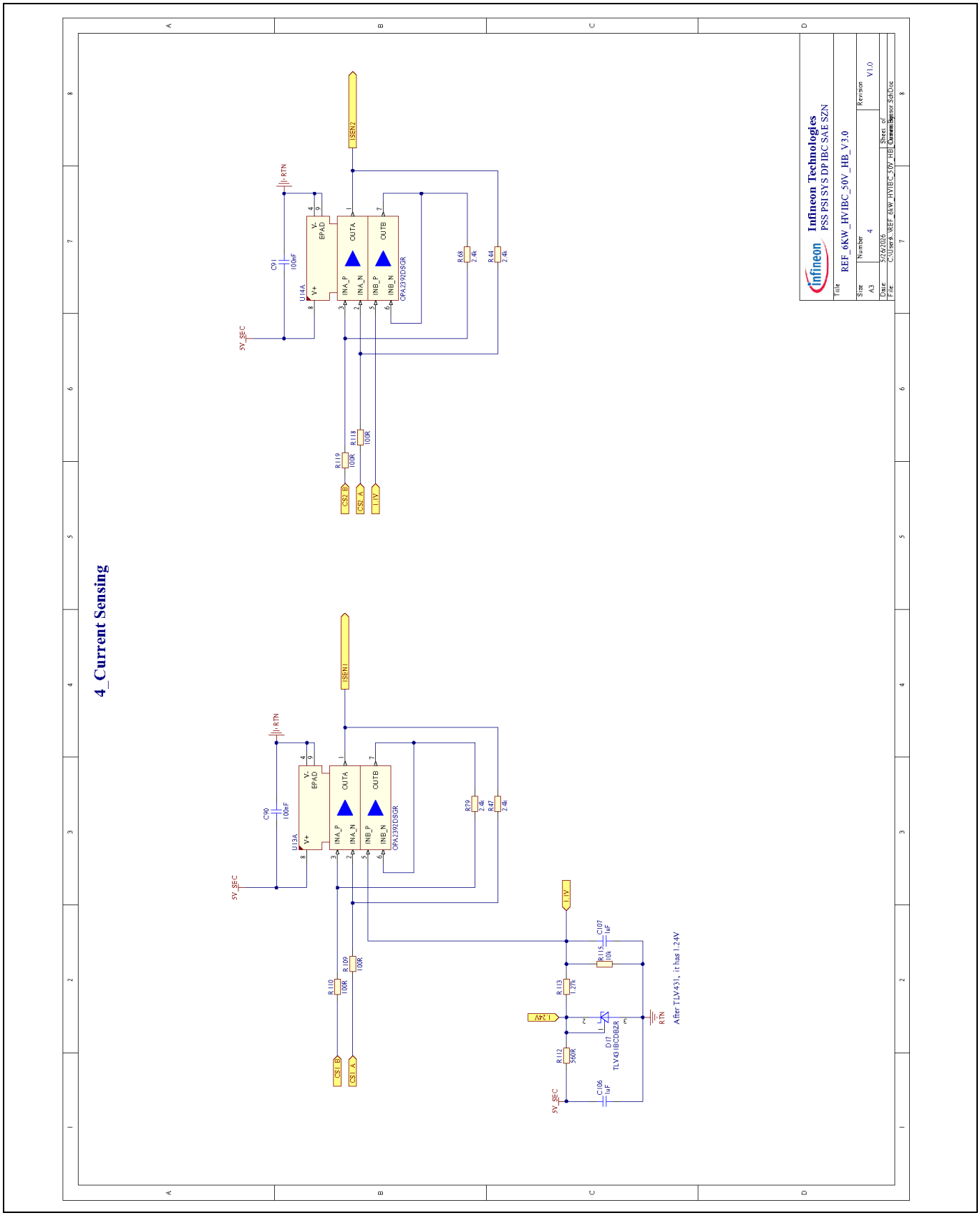


Figure 28 Current sensing

5 Schematics

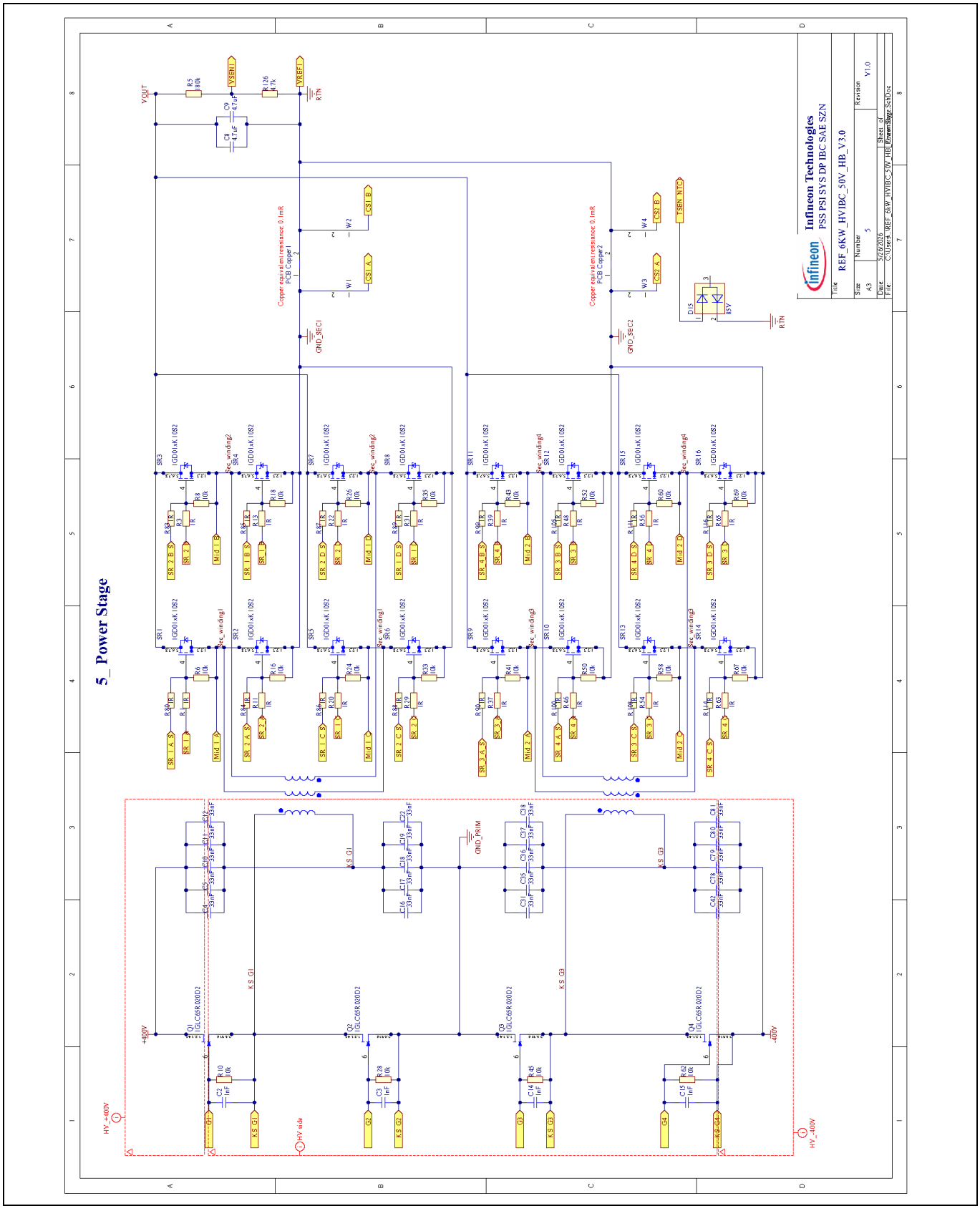


Figure 29 Power stage

5 Schematics

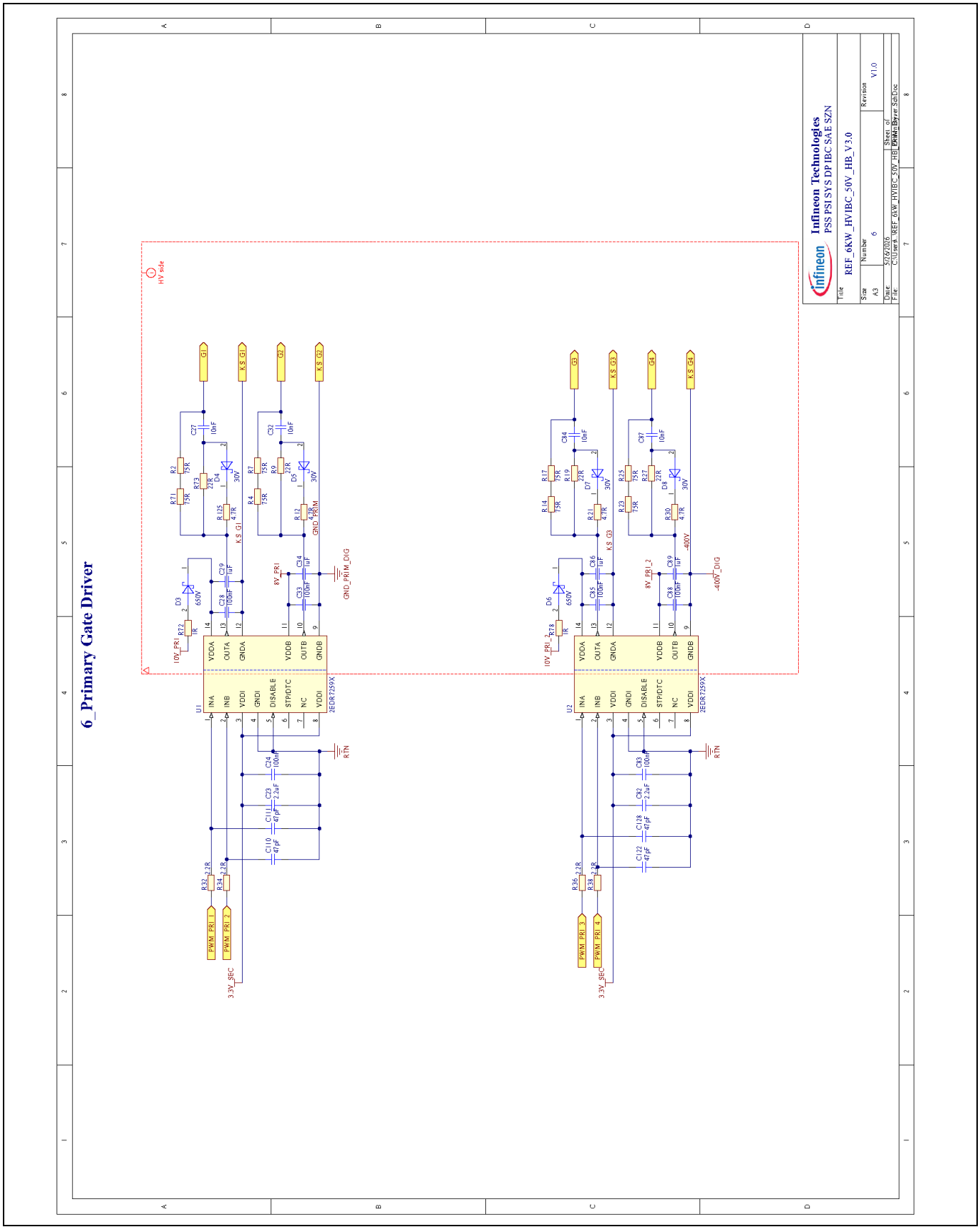


Figure 30 Primary gate driver

5 Schematics

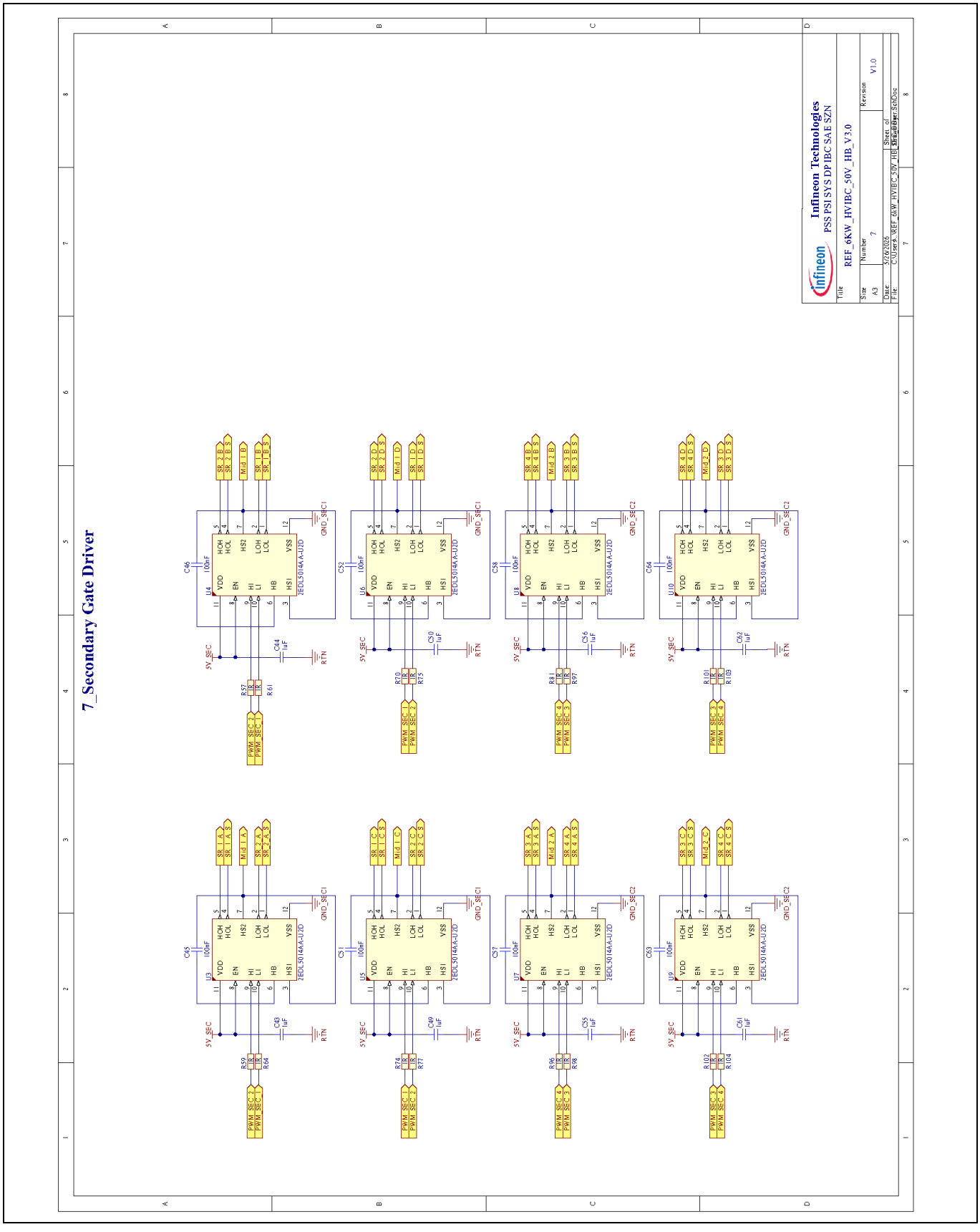


Figure 31 Secondary gate driver

6 Bill of materials (BOM)

The complete bill of materials is available on the download section of the board webpage. A log-in is required to download this BOM.

Table 5 BOM for the REF_6KW_800V_50V_HB

Designator	Description	Vendor	Qty
C1, C6, C7, C20, C21, C26, C39	CAP / CERA / 2.2nF / 25V / 10% / X7S (EIA) / -55°C to 125°C / 0603(1608) / SMD	Murata	7
C2, C3, C14, C15, C41	CAP / CERA / 1nF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0402 (1005) / SMD	Murata	5
C4, C5, C10, C11, C12, C16, C17, C18, C19, C22, C31, C35, C36, C37, C38, C42, C78, C79, C80, C81	CAP / CERA / 33nF / 630V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 1210(3225) / SMD	TDK Corporation	20
C8, C9, C117, C119, C120, C121, C124, C125, C126, C127, C131, C134, C136, C137, C145, C148, C150, C151, C155, C158, C160, C161	CAP / CERA / 4.7uF / 100V / 10% / X7S (EIA) / -55°C to 125°C / 1206(3216) / SMD	Murata	22
C13	CAP / CERA / 4.7uF / 25V / 10% / X7S (EIA) / -55°C to 125°C / 0805(2012) / SMD	Murata	1
C23, C82	CAP / CERA / 2.2uF / 25V / 10% / X5R (EIA) / -55°C to 85°C / 0402(1005) / SMD	Murata	2
C24, C28, C33, C83, C85, C88, C90, C91, C100	CAP / CERA / 100nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0402(1005) / SMD	Murata	9
C25, C162	CAP / CERA / 10nF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0402 (1005) / SMD	Murata	2
C27, C32, C84, C87	CAP / CERA / 10nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0402(1005) / SMD	Murata	4
C29, C34, C86, C89	CAP / CERA / 1uF / 50V / 10% / X5R (EIA) / -55°C to 85°C / 0402(1005) / SMD	Taiyo Yuden	4
C30, C40	CAP / CERA / 10uF / 25V / 10% / X7S (EIA) / -55°C to 125°C / 0805 (2012) / SMD	Murata	2
C43, C44, C49, C50, C55, C56, C61, C62, C68, C69, C106, C107	CAP / CERA / 1uF / 16V / 10% / X6S (EIA) / -55°C to 105°C / 0402(1005) / SMD	Murata	12
C45, C46, C51, C52, C57, C58, C63, C64, C67, C70, C76, C77, C123, C129, C163	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0402(1005) / SMD	TDK Corporation	15
C73	CAP / CERA / 100pF / 50V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0402(1005) / SMD	Murata	1
C74, C75	CAP / CERA / 1nF / 25V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0402(1005) / SMD	Murata	2
C99	CAP / CERA / 4.7uF / 16V / 20% / - / -55°C to 105°C / 0402(1005) / SMD	Murata	1

6 Bill of materials (BOM)

Designator	Description	Vendor	Qty
C101, C103, C139, C141	CAP / CERA / 100nF / 630V / 10% / X7R (EIA) / -55°C to 125°C / 1210(3225) / SMD	Murata	4
C102	CAP / CERA / 10uF / 16V / 10% / X5R (EIA) / -55°C to 85°C / 0603(1608) / SMD	Murata	1
C110, C111, C122, C128	CAP / CERA / 47pF / 25V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0402(1005) / SMD	Murata	4
D1, D2	Dual Schottky Diode Symbol 3 Pins, 1 Anode1 , 2 Cathode2, 3 Anode2, Cathode1	Infineon Technologies	2
D3, D6	Gen 3 Power SiC Merged PIN Schottky Diode, 650V, 2A	Vishay	2
D4, D5, D7, D8	Diode, Schottky Barrier Rectifier, 30V, 1A	Diodes Incorporated	4
D9	Schottky Barrier Diode, 30V, 1A	Toshiba	1
D10	Low VF High Current Density Surface Mount Schottky Barrier Rectifiers, 1A, 350mV	Vishay	1
D15, D16	Surface Mount Low Leakage Diode, 85V, 125mA	Diodes Incorporated	2
D17	1.24V Adjustable Precision Shunt Regulator, 0.5% Reference Voltage Tolerance	Texas Instruments	1
DS2	WL-SMCW SMT Mono-color Chip LED Waterclear, Green, 515nm	Würth Elektronik	1
G1	LDO, Ultra Low IQ, Low Dropout Linear Voltage Regulator with Power-Good	Texas Instruments	1
G2	Regulator, 1-A Load Step-Down DC/DC	Texas Instruments	1
L1	IND / Fixed Inductor / 4.7uH / 800mA / 20% / -55°C to 125°C / 288mR / 0805 (2012) / SMD	Murata	1
Q1, Q2, Q3, Q4	IGLC65R020D2, CoolGaN™, 650 V, 27 mΩ, 82 nC, –55°C to 150°C, VHSON-10	Infineon Technologies	4
R1, R3, R11, R13, R20, R22, R29, R31, R37, R39, R46, R48, R54, R56, R57, R59, R61, R63, R64, R65, R70, R74, R75, R77, R80, R81, R83, R84, R85, R86, R87, R88, R89, R90, R96, R97, R98, R99, R100, R101, R102, R103, R104, R105, R108, R111, R114, R116	RES / STD / 1R / 100mW / 1% / 200ppm/K / -55°C to 155°C / 0402(1005) / SMD	KOA Speer Electronics Inc.	48
R2, R4, R7, R14, R17, R23, R25, R71	RES / STD / 75R / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD	Vishay	8
R5	RES / STD / 180k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R6, R8, R10, R16, R18, R24, R26, R28, R33, R35, R41, R43, R45, R50,	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Panasonic	24

6 Bill of materials (BOM)

Designator	Description	Vendor	Qty
R52, R58, R60, R62, R67, R69, R91, R92, R95, R115			
R9, R19, R27, R73	RES / STD / 22R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD	Vishay	4
R12, R21, R30, R125	RES / STD / 4.7R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD	Vishay	4
R15, R93	RES / Resistor Chip / 100kR / 63mW / 1% / 100 ppm/K / -55°C to 155°C / 0402 (1005) / SMD	Yageo	2
R32, R34, R36, R38	RES / STD / 2.2R / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	4
R40, R72, R78, R121	RES / STD / 1R / 100mW / 1% / 100 ppm/K / -55°C to 155°C / 0603 (1608) / SMD	Vishay	4
R42	RES / STD / 52.3kR / 100mW / 1% / 100 ppm/K / -55°C to 155°C / 0603 (1608) / SMD	Vishay	1
R44, R47, R68, R79	RES / STD / 2.4k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	4
R49, R123	RES / STD / 2k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	2
R51	RES / STD / 2.2k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R53	RES / STD / 14.7k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R55	RES / STD / 63.4k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R66	RES / STD / 4.7k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R94	RES / STD / 1k / 630mW / 1% / 50ppm/K / -55°C to 175°C / 0402(1005) / SMD	Vishay	1
R106	RES / STD / 1.96MEG / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R107	RES / STD / 1.18MEG / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R109, R110, R118, R119	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Panasonic	4
R112	RES / STD / 560R / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R113	RES / STD / 1.27k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1
R117	RES / Resistor Chip / 10kR / 63mW / 1% / 100 ppm/K / -55°C to 155°C / 0402 (1005) / SMD	Vishay	1
R122	RES / STD / 12k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Vishay	1

6 Bill of materials (BOM)

Designator	Description	Vendor	Qty
R126	RES / STD / 4.7k / 63mW / 1% / 100ppm/K / -55°C to 155°C / 0402(1005) / SMD	Yageo	1
SR1, SR2, SR3, SR4, SR5, SR6, SR7, SR8, SR9, SR10, SR11, SR12, SR13, SR14, SR15, SR16	CoolGaN™ transistor 100 V G5, IGD01xK10S2, 100V, 0.9 mΩ, 90 nC, –55°C to 150°C, WRTFN-9	Infineon Technologies	16
T1	Custom EI core, DMR95	–	1
TB1, TB2, TB3, TB4, TB5, TB6, TB10	Solder Mount PCB Pin, Brass Alloy, Gold Over Nickel	Mill-Max	7
U1, U2	2EDR7259X, dual-channel gate driver ICs, reinforced isolation, 5 A/9 A, DSO14-300 mil	Infineon Technologies	2
U3, U4, U5, U6, U7, U8, U9, U10	2EDL5014AA-U2D, high-side and low-side GaN driver IC, 120 V, 4 A/4 A, 2 mm × 2 mm, TSNP-12	Infineon Technologies	8
U11	XDP™ XDPP1188-200C, digital power supply controller, 5 mm × 5 mm, VQFN-40	Infineon Technologies	1
U12	SN74LVC1G3175DRLR, Single-Pole Double-Throw Analog Switch, SOT32	Texas Instruments	1
U13, U14	OPA2392DSGR, Dual, low-offset(10uV), low-noise(4.4nV/rtHz@10kHz), WSON-8	Texas Instruments	2
U15	2EP130R, 5 W, 20 V full-bridge transformer driver, 50 kHz~695 kHz, 10%~50% duty, TSSOP-8	Infineon Technologies	1
X1	WR-PHD THT Straight Single Pin Header, 8 Pins, 2.00 mm Pitch, 200VAC, 2A	Würth Elektronik	1
X4, X5, X6, X7, X8	Test Point, Surface Mount, Finish- Tin Over Nickel	Harwin	5

References

[1] Infineon Technologies AG: *XDP™ digital controller XDPP1188 datasheet*; Available online

[2] Infineon Technologies AG: *EiceDRIVER™ 2EDR7259X datasheet*; Available online

[3] Infineon Technologies AG: *EiceDRIVER™ 2EDL5014AA-U2D datasheet*; Available online

[4] Infineon Technologies AG: Whitepaper – *Why use GaN SR in LLC converter?*; Available online

[5] Infineon Technologies AG: Whitepaper – *Gate drive configurations for GaN power transistors*; Available online

Abbreviations and acronyms

Table 6 Abbreviations and acronyms

Abbreviation	Expansion
BOM	Bill of materials
EMI	Electromagnetic interference
EN	Enable
ESD	Electrostatic discharge
FET	Field-effect transistor
GaN	Gallium nitride
GUI	Graphical user interface
GND	Ground
GPU	Graphics processing unit
HB	Half-bridge
HV	High voltage
HV-IBC	High-voltage intermediate bus converter
I2C	Inter-Integrated Circuit
IBC	Intermediate bus converter
IC	Integrated circuit
ISOP	Input-series output-parallel
LDO	Low dropout regulator
LLC	Inductor-inductor-capacitor
OCP	Overcurrent protection
OTP	Overtemperature protection
OVP	Overvoltage protection
PCB	Printed circuit board
PG	Power good
PMBus®	Power Management Bus
PPE	Personal protective equipment
PWM	Pulse-width modulation
SR	Synchronous rectifier
TPU	Tensor processing unit
UVP	Undervoltage protection
VIN	Input voltage
VOUT	Output voltage

Revision history

Document revision	Date	Description of changes
V 1.0	2026-06-09	Initial release

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