Non-isolated 400 W synchronous buck converter user guide

Featuring the IGC025S08S1 CoolGaN™

About this document

Scope and purpose

This user guide provides an overview of the DEMO_48V12_400W_GaN buck configuration demo board with CoolGaN™ power transistor IGC025S08S1 and LTC7891 controller suitable for gallium nitride (GaN) transistor power stages. The board can be used for testing and assessing the performance of the products in half-bridge applications such as DC-DC conversion.

DEMO_48V12_400W_GaN board serves as an easy-to-use, practical design, showcasing what can be achieved within constrained spaces by utilizing the IGC025S08S1 CoolGaN™ transistor in conjunction with a well-optimized PCB layout.

A detailed description of the analog controller LTC7891 is available online [3] as well as the datasheet for the IGC025S08S1 [1]

Intended audience

This document is for power electronics engineers and developers of power electronic systems who are interested in small form factor, simple and high-power density PCB designs, using low-/medium-voltage CoolGaN™ transistors

About this product group

Target applications

Infineon's CoolGaN™ solution offers unmatched quality that operate at higher switching speeds resulting in lower power losses, higher efficiency paving the way for smaller and lighter power supplies with the same power supplies with the same size but increased power capability.

CoolGaN™ target applications include:

- Consumer electronics
- Information and communication technologies
- Robotics
- Energy Storage Systems
- Renewables

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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 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.*

Table of contents

1 Introduction

The DEMO_48V12_400W_GaN board shown in Figure 1 is a half-bridge buck converter design featuring an onboard analog controller. The core design measures 18 mm x 29 mm, while the total board size, including mounting brackets is 47 mm x 43 mm. Operating switching frequency is set to 500 kHz but adjustable by changing a resistor if needed. The board supports an input voltage range of 24 V to 60 V. DCR current sensing of the inductor is implemented to sense the output current for the controller. The output is set to 12 V, and the maximum power can go up to 400 W or higher depending on the cooling conditions. Multiple features of the controller can be explored by changing passives on the bottom side of the board. A 3-pin header is available to enable or disable the operation of the board. This board is utilizing optimal layout techniques recommended for MV GaN transistors mentioned in [2] by minimizing overall loop size as well as parasitics.

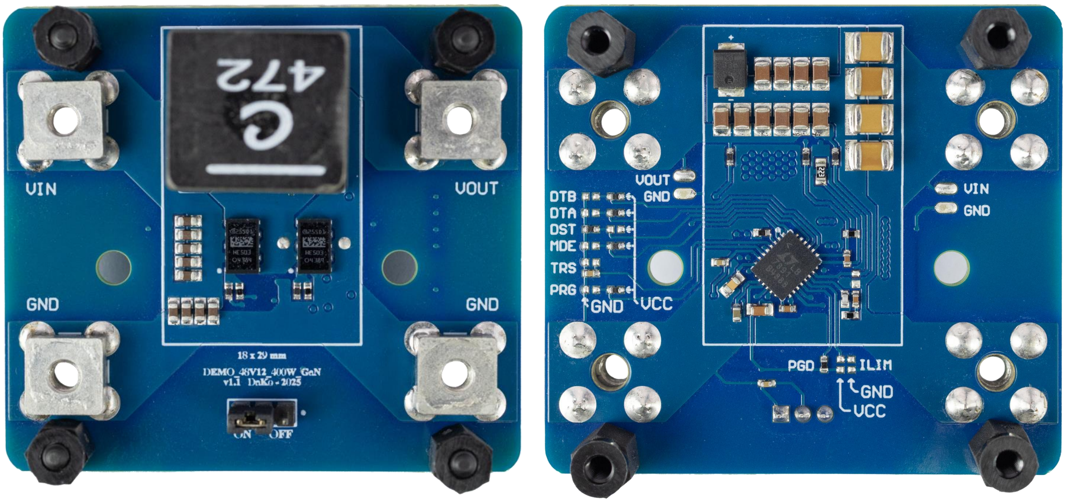

Figure 1 DEMO_48V12_400W_GaN demo board

1.1 CoolGaN™ transistor

The DEMO_48V12_400W_GaN demo board is using the 80 V CoolGaN™ power transistor IGC025S08S1 [1]. It comes in a 3 mm x 5 mm PQFN package, as shown in Figure 2, with very low inductance in the pH range, as well as dual-side cooling with an exposed thermal pad on the top side of the transistor. They can be operated at high switching frequencies and short dead-times due to its fast-switching transitions and low switching loss. This enables reducing the size of output filter, capacitors, and heatsinks in the application to improve power density and the overall system efficiency.

Figure 2 CoolGaN™ power transistors IGC025S08S1

1.2 LTC7891 Synchronous Step-Down controller

LTC7891 is a high-performance, step-down, DC-DC switching regulator controller that drives N-channel synchronous GaN FETs from input voltages up to 100 V. Features like burst mode, forced conduction mode (FCM), pulse skipping mode, dead time control etc. are provided by the controller and can be altered easily by the board's interface.

1.3 DEMO_48V12_400W_GaN demo board

The main parts of the DEMO_48V12_400W_GaN demo are:

- CoolGaN™ G3 power transistor IGC025S08S1 in a half-bridge configuration
- LTC7891 Synchronous Step-Down Controller for GaN FETs

Gate driving as well as PWM generation is done internally by the controller. Designed as an easy-to-use solution, the board allows users to customize key parameters such as switching frequency, dead times, input/output voltages and operating mode to meet specific application requirements. This flexibility makes the board adaptable for a variety of testing and evaluation scenarios. Figure 3 provides a detailed schematic diagram of the board's key components.

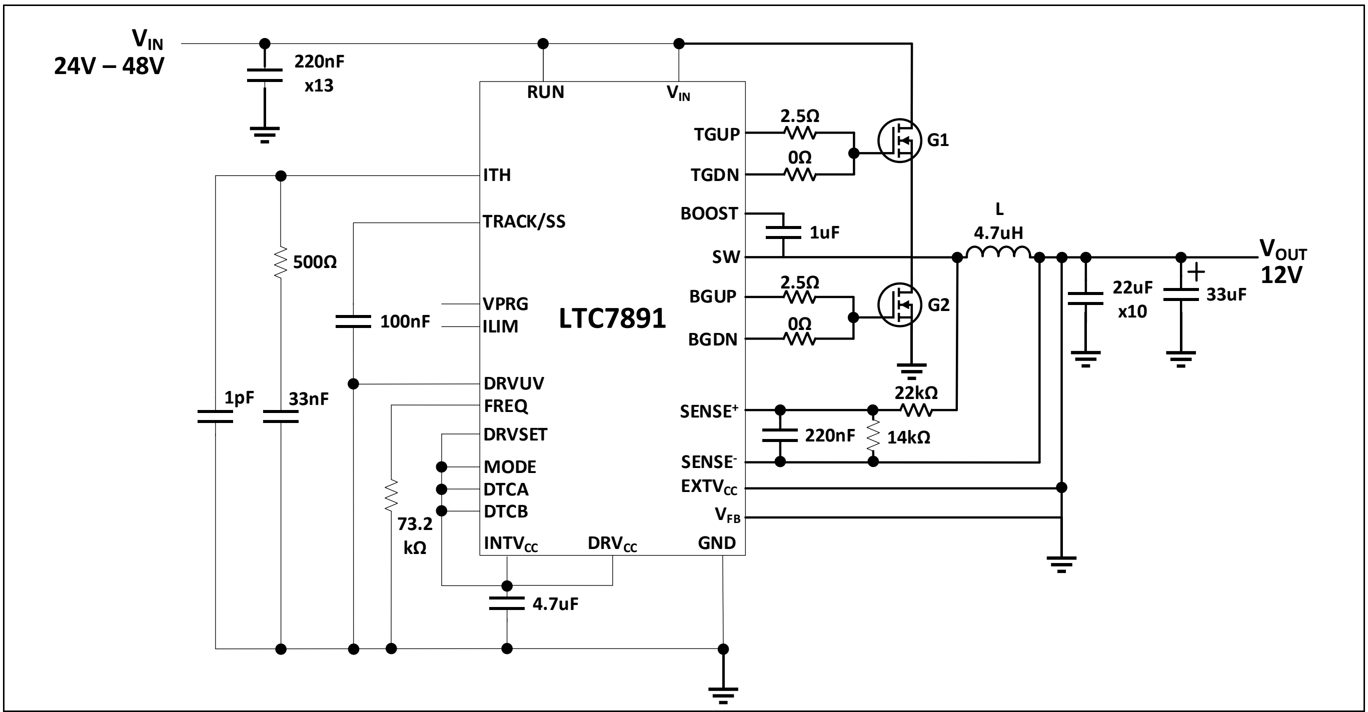

Figure 3 DEMO_48V12_400W_GaN schematic diagram

A DC power supply and load can be connected to the four power connectors labeled as "VIN", "VOUT", and "GND". Proper decoupling of the input voltage is highly recommended, particularly in situations where the board is located at a significant distance from the power supply.

1.4 Board specifications

Table 1 Recommended operating conditions

Parameter	Values			Unit	Note
	Min	Typ	Max		
Input Voltage (V_{in})	24	–	72	V	According to the voltage rating of the GaN transistor
Output Voltage (V_{out})	-	12	16	V	Maximum output voltage limited by output capacitor voltage ratings
Programmable dead-time range	7	–	60	ns	Smart near zero delay (default setting) allows for ~ 0 ns of dead-time if selected
Programmable frequency	0.1	0.5	3	MHz	Default switching frequency is set to 500 kHz
DC input/output current	–	–	34	A	With top-side heatsink and 5 m/s airflow. Output current limited by the cooling conditions

1.5 Main board features

The main features of the DEMO_48V12_400W_GaN half-bridge demo board can be found below:

- The LTC7891 dead-time delays can be programmed from near zero to 60 ns by configuring DTCA and DTCB pins of the controller [3], labelled as DTA and DTB (see Section 2.2). The DTA setting programs the dead time associated with the bottom FET turning off and the top FET turning on. The DTB setting programs the dead time associated with top FET turning off and the bottom FET turning on
- The board can be operated in high efficiency burst mode, constant frequency pulse skipping mode, or FCM at light load currents while also offering adjustable output voltage and peak current settings. Additional details can be found in Section 2.2
- In this board current sensing is done utilizing the DCR resistance of the inductor, allowing the highest possible efficiency at high load currents. In case a different inductor is used, careful consideration must be given in the time constant of the RC network attached to $SENSE^{+}$ and $SENSE^{-}$ differential pins [3]
- Overvoltage and overtemperature features are also included with the LTC7891. As such, the controller has an overvoltage comparator that guards against transient overshoots as well as other more serious conditions that can cause output overvoltage. On the other hand, in cases where the internal power dissipation causes excessive self-heating, internal overtemperature shutdown circuitry shuts down the controller
- A custom heatsink is provided that can be mounted on the top side of the board for cooling the half-bridge. Steps to assemble the heatsink are described in Section 2.4

2 Overview and functional description

This section provides a brief overview of the DEMO_48V12_400W_GaN demo board, focusing on its core components, features and initial setup procedure. Furthermore, the section also features the available measuring points along with the heatsink attachment process.

2.1 Overview of the DEMO_48V12_400W_GaN demo board

Figure 4 illustrates both sides of the DEMO_48V12_400W_GaN demo board, highlighting its key circuit components.

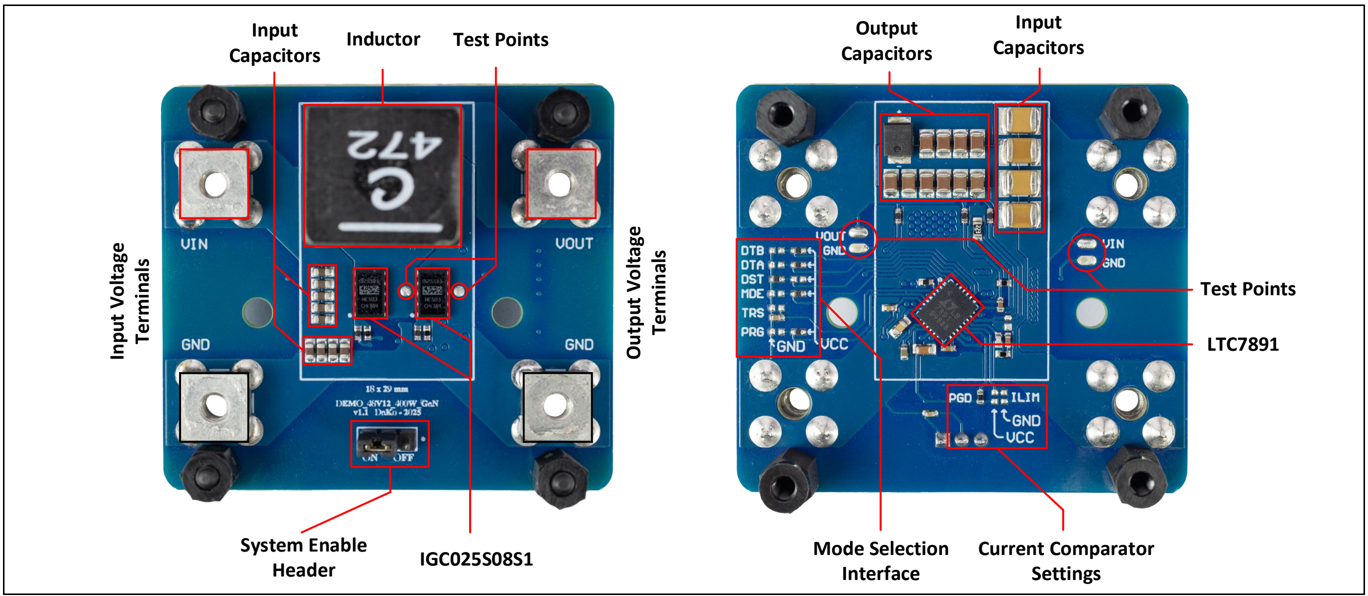

Figure 4 **Top (left) and bottom (right) side pictures of the DEMO_48V12_400W_GaN board highlighting various crucial board components**

Respectively, Figure 5 highlights the total board area dedicated to the circuitry of the buck converter, showcasing the compactness of its design. As previously mentioned, the total size of the buck converter, which includes the controller, CoolGaN™ devices, input/output capacitors, and inductor, is constrained to a relatively small footprint of 18 mm x 29 mm, while the total board size remains larger due to the wire mounting points and the additional feature selection interface.

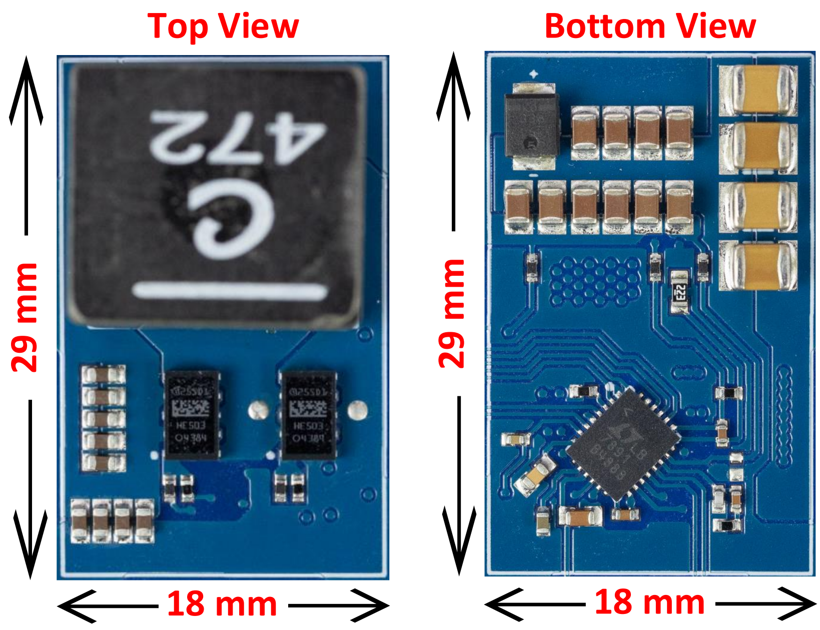

Figure 5 **Zoomed-in image of the converter's size**

2.2 Settings/feature interface

The board offers a simple and easy to use interface regarding its features, as mentioned in Section 1.4. Figure 6 illustrates the interface where the user can choose the preferable options accordingly. As such, the role of every feature can be found below:

- **DTB/DTA (dead time control setting):** Connect DTB to GND to program an adaptive dead time delay of approximately 20 ns. Connect DTB to INTVCC to program a smart near zero delay between SW falling and BGDN rising. Connect a 10 kΩ to 200 kΩ resistor between DTB and BGND to add additional delay (from 7 ns to 60 ns). By default, the dead time is set to smart near zero setting
- **DST (INTVCC voltage level setting):** Connect DST (DRVSET pin) to GND to set INTVCC to 5 V. Connect DST to INTVCC to set INTVCC to 5.5 V. Program voltages between 4 V and 5.5 V by placing a resistor (50 kΩ to 110 kΩ) between DST and GND
- **MDE (mode setting):** Connect MDE (MODE pin) to GND to enable burst mode operation. An internal 100 kΩ resistor to GND also invokes burst mode operation when MDE is floating. Alternatively, if MDE is pulled up to INTVCC the converter is forced into continuous inductor current operation (FCM). Connecting MDE to INTVCC through a 100 kΩ resistor selects the pulse skipping operation. By default, the controller operates in FCM mode
- **TRS (ramp time setting):** Connect a capacitor between TRS (TRACKSS pin) and GND to set the ramp time to the final regulated output voltage. The ramp time is equal to 1 ms for every 12.5 nF of capacitance
- **PRG (output voltage mode setting):** Floating PRG (VPRG pin) programs the output from 0.8 V to 60 V with an external resistor divider, regulating VFB to 0.8 V. Connecting PRG to INTVCC or GND the output is programmed to 12 V or 5 V, respectively, through an internal resistor divider on VFB. By default, PRG is connected to INTVCC
- **ILIM (current limit setting):** Connect ILIM to GND or INTVCC or leave it floating ILIM to set the maximum current sense threshold to one of three different levels, 25 mV, 75 mV, and 50 mV, respectively. The default configuration is set at 50 mV (floating)

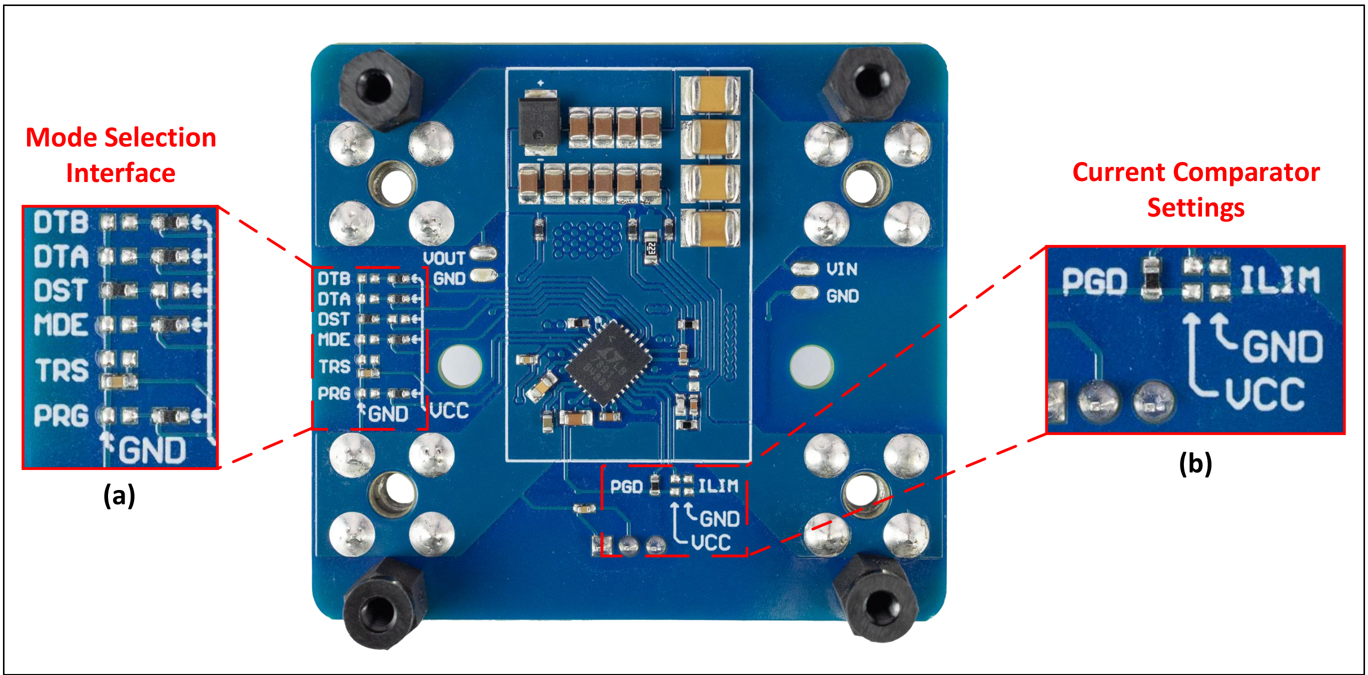

Figure 6 (a) Board's mode selection interface, (b) current comparator settings (bottom side)

2.3 Connection and measuring points

Power supply and load should be connected as Figure 7 indicates, to operate the board. Exposed copper pads are also added to support further measurements on the board as previously mentioned in Section 2.1. Those measuring points are located on the top side (switch node) as well as on the bottom side (V_{in} and V_{out}).

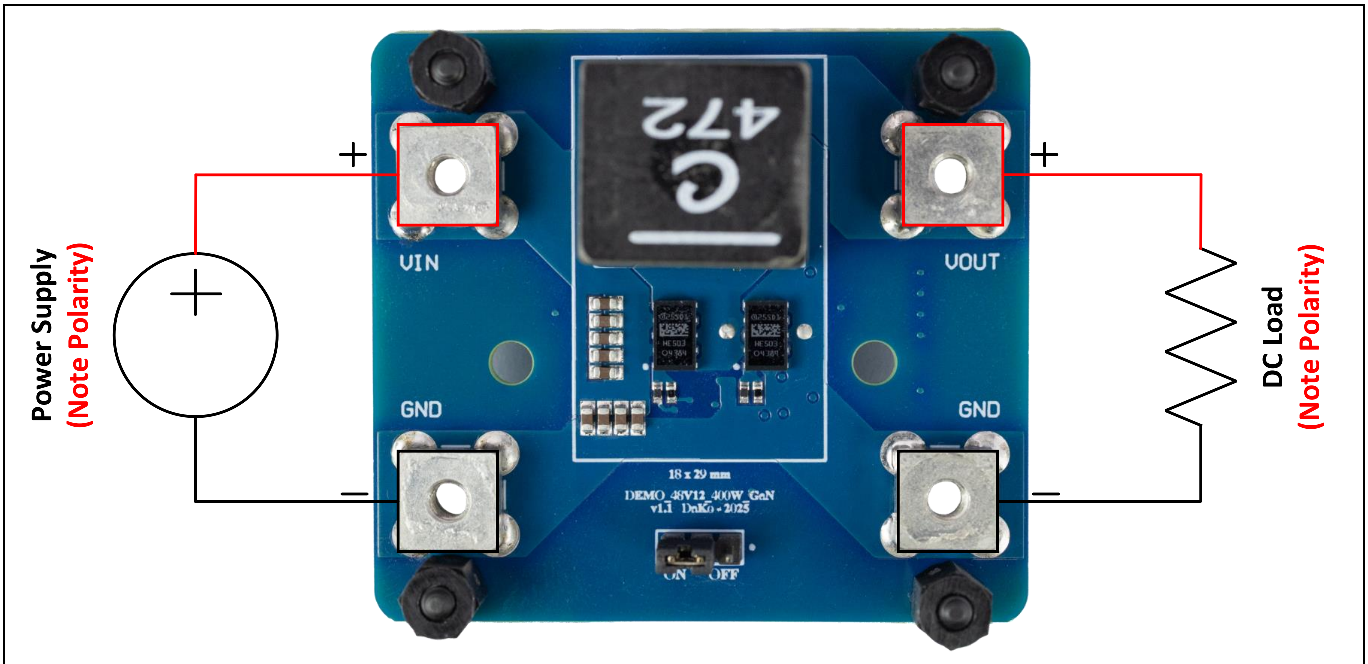

Figure 7 Power connections of the DEMO_48V12_400W_GaN demo board

2.4 Initial start-up procedure

The DEMO_48V12_400W_GaN demo board offers a straightforward way to assess the performance of IGC025S08S1 GaN FETs. By first ensuring that the connection and measurement setup steps outlined in earlier sections are followed carefully, the procedure to operate the board is described below:

1. Connect the input power supply between V_{in} and GND, as indicated by the markings on the solder mask. A shunt resistor can be mounted in series with the positive supply to measure the input current
2. Connect the load (e.g., an electronic load) between V_{out} and GND, as labeled. A shunt resistor can also be placed in series to measure the output current
3. Move the jumper to the “ON” position to enable the controller
4. While the board is powered off, additional wiring can be soldered to the exposed copper pads for proper waveform monitoring or data acquisition. To measure the performance of the IGC025S08S1, ensure that the long ground wire of the oscilloscope’s probe is replaced with a low-inductance spring. This minimizes loop inductance and improves measurement precision
5. Turn on the power supply and measure the output voltage. The output should be 12 V
6. Turn on the load and carefully observe the temperature of the GaN FET. Ensure that the load does not exceed the current limits specified in Table 1. The temperature of the components must not exceed the values provided in the datasheets [1]
7. Perform measurements and collect data with different voltages and current configurations. Verify that all operating parameters remain within the specifications outlined in Table 1
8. Shut down the load and gradually decrease the input power supply voltage to 0 V to safely turn off the board

Note: *Always monitor the temperature of critical components, including the inductor, GaN FET, and heatsink, before making any changes to the board.*

2.5 Heatsink attachment

The provided heatsink comes with a preinstalled thermal interface material (TIM) pad of T-Global TG-A1780, which is an ultra-soft galvanically isolated TIM pad with a thermal conductivity of 17.8 W/m·K and a thickness of 0.5 mm. Recommended TIM pads from t-Global include TG-A1780, TG-A1660, TG-A1450, TG-A1250, depending on the preference for cost vs. performance.

The heatsink can only be installed on the topside of the PCB for top-side cooling, as shown in Figure 8.

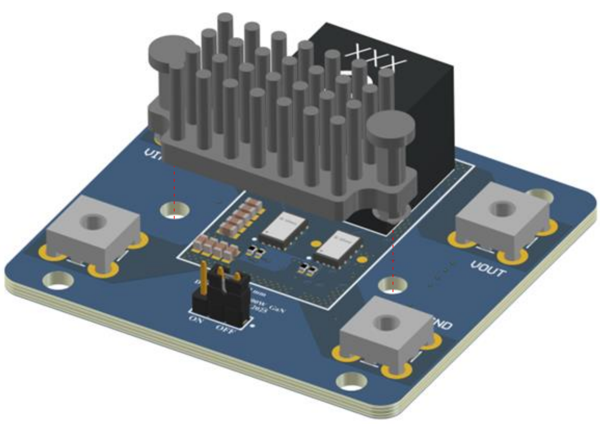

Figure 8 3D view of the heatsink on the top side of the DEMO_48V12_400W_GaN demo board

Install the heatsink

1. Remove the plastic protective tape from the TIM pad
2. Position the heatsink at the desired location
3. Press down on both the spring pins at the same time

Note: *Use two flathead (slotted) screwdrivers or similar tools to avoid finger injuries on the pin fins.*

2.6 Changing the CoolGaN™ power transistor

The evaluation board comes with CoolGaN™ power transistor IGC025S08S1 in a 3 mm x5 mm PQFN package assembled. Alternatively, IGC033S10S1 [3] rated at 100V, comes in the same package and can be used in the final system depending on the targeted input voltage range (e.g., 72 V), frequency, and output power as its package is footprint compatible. Therefore, the change of the power transistor is a simple one to one replacement. Finally, gate turn on resistors should be adjusted accordingly due to the slightly higher gate charge of the IGC033S10S1.

3 Experimental results

3.1 Example experimental efficiency and power loss

Efficiency and power loss results are shown for the board operating in three different switching frequencies of 250 kHz, 500 kHz, and 750 kHz as well as three different input voltage levels 24 V, 36 V, and 48 V. In each case the output voltage is regulated at 12 V.

First, Figure 9, Figure 10, and Figure 11 show the results for an XGL1313 – 472 4.7 uH inductor from Coilcraft with the heatsink attached on the top side of the board and with 5 m/s of airflow. Figure 12 and Figure 13 showcase the efficiency comparison when the XAL1580 – 302 3 uH inductor is used. Finally, regarding the latest comparison, power losses are indicated in Figure 14.

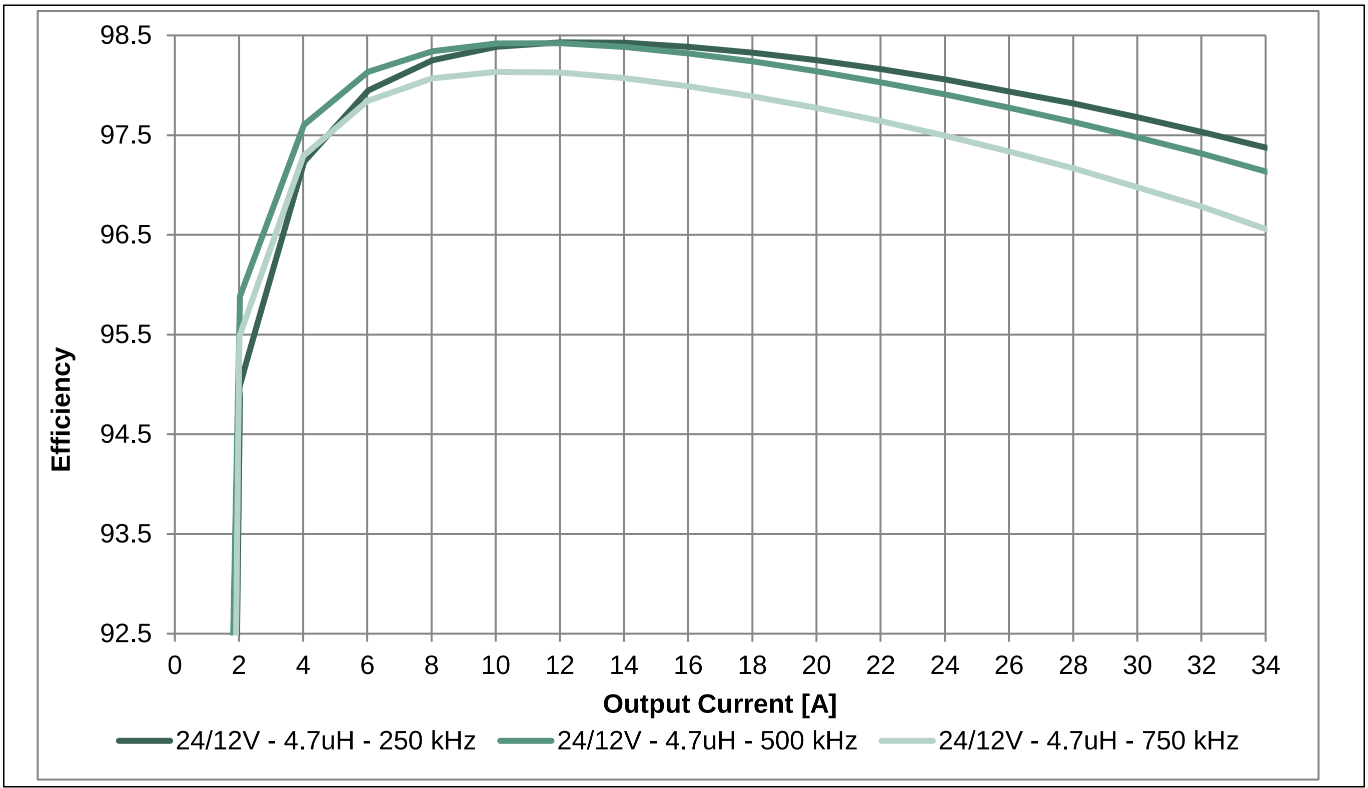

Figure 9 **Efficiency results at different switching frequences, 24 V input, 12 V output, 4.7 uH inductor. The heatsink is placed on the top side, and 5 m/s of airflow is used**

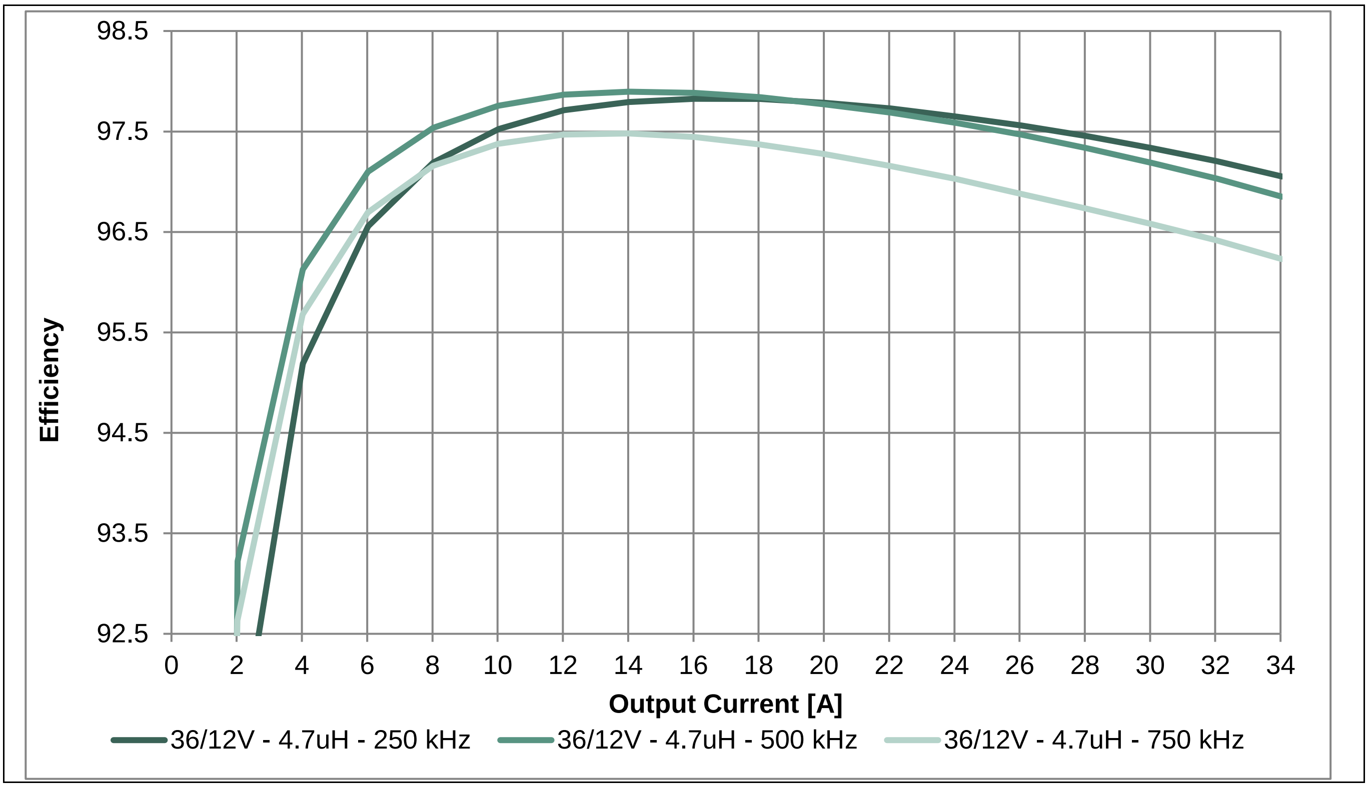

Figure 10 Efficiency results at different switching frequences, 36 V input, 12 V output, 4.7 uH inductor. The heatsink is placed on the top side, and 5 m/s of airflow is used

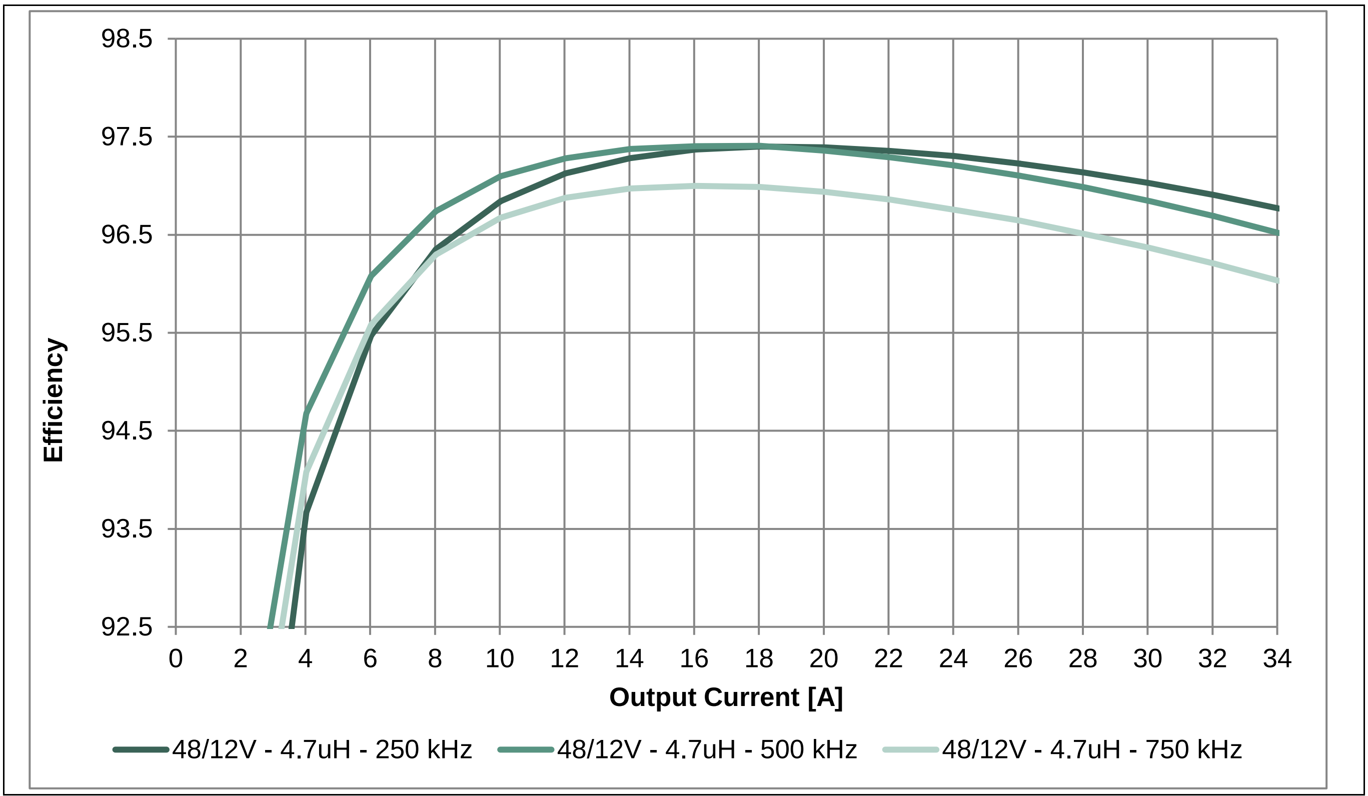

Figure 11 Efficiency results at different switching frequences, 48 V input, 12 V output, 4.7 uH inductor. The heatsink is placed on the top side, and 5 m/s of airflow is used

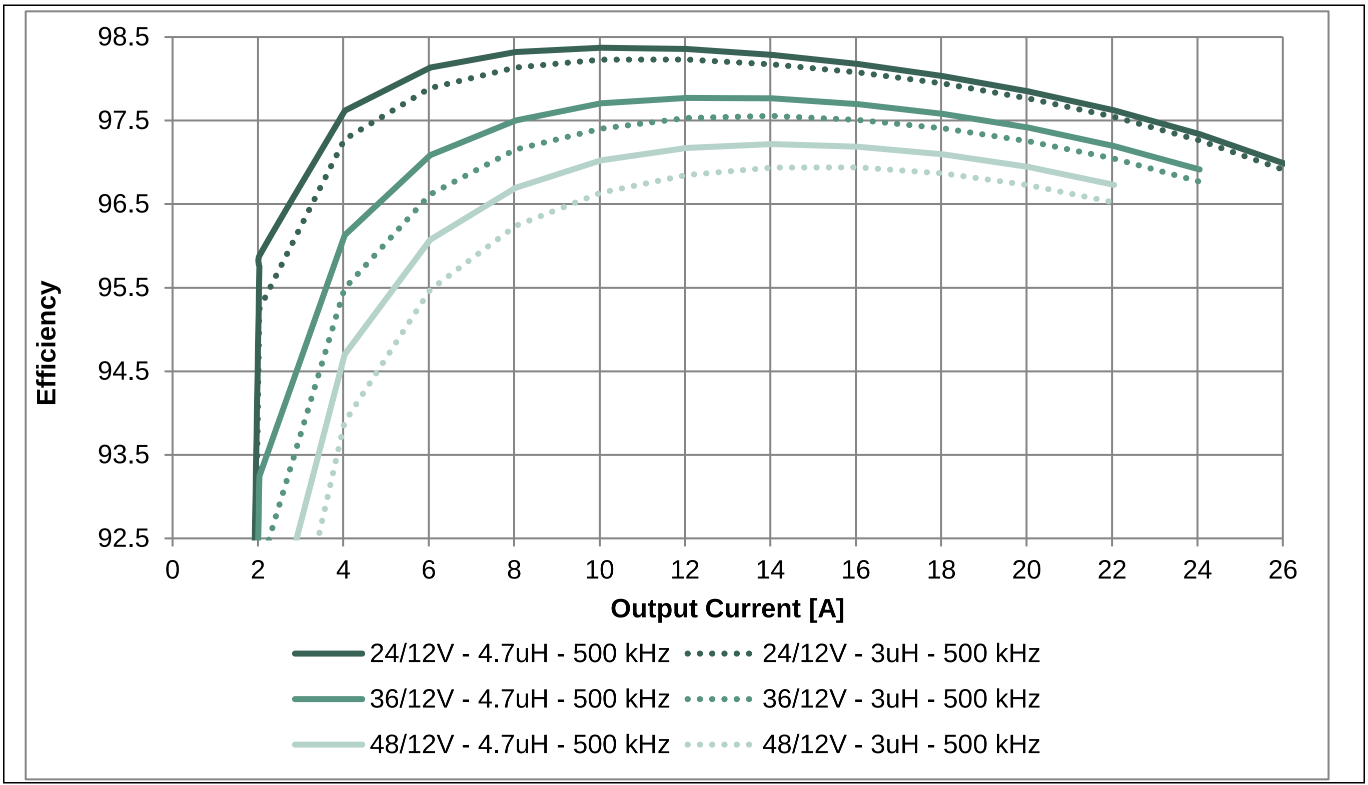

Figure 12 Efficiency results at different input voltage levels and different inductor values. Neither airflow nor heatsink is used

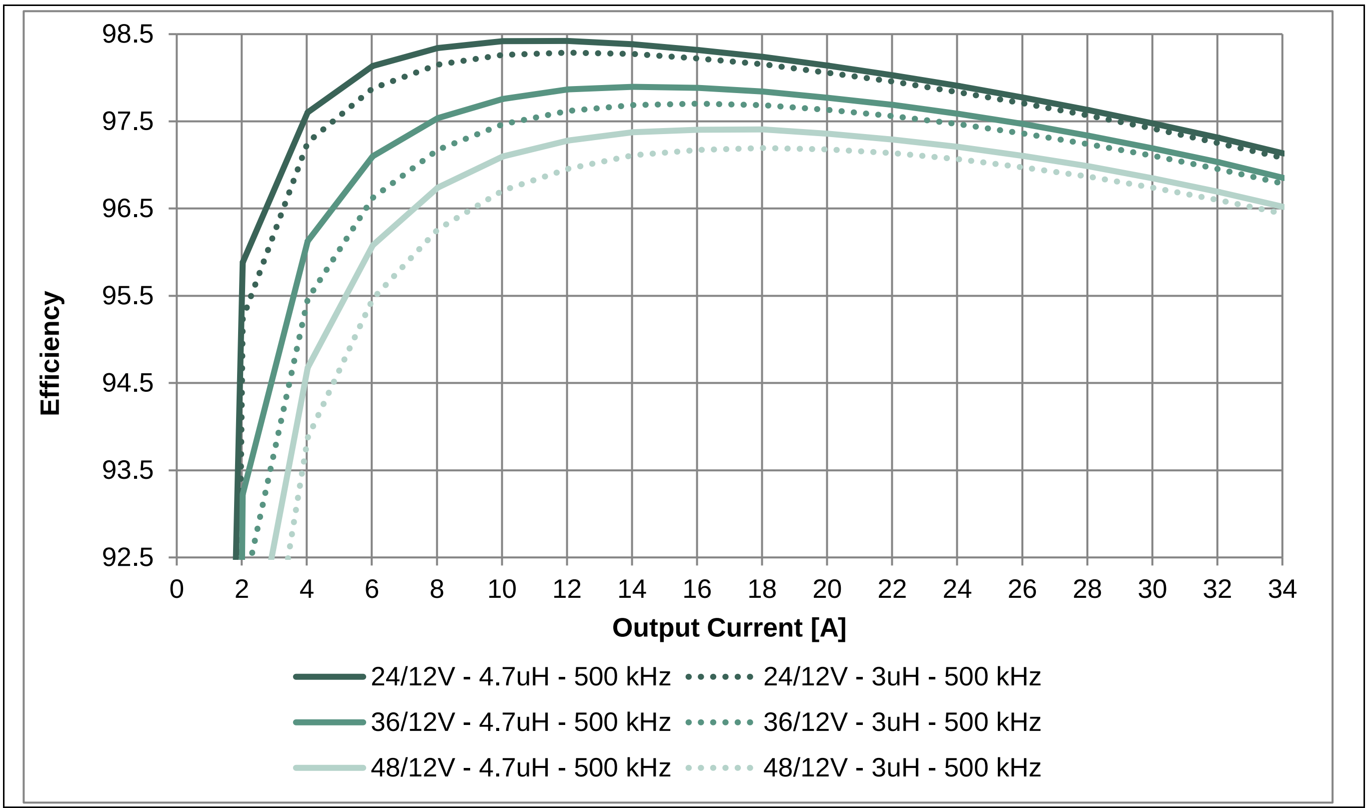

Figure 13 Efficiency results at different input voltage levels and different inductor values. The heatsink is placed on the top side, and 5 m/s of airflow is used

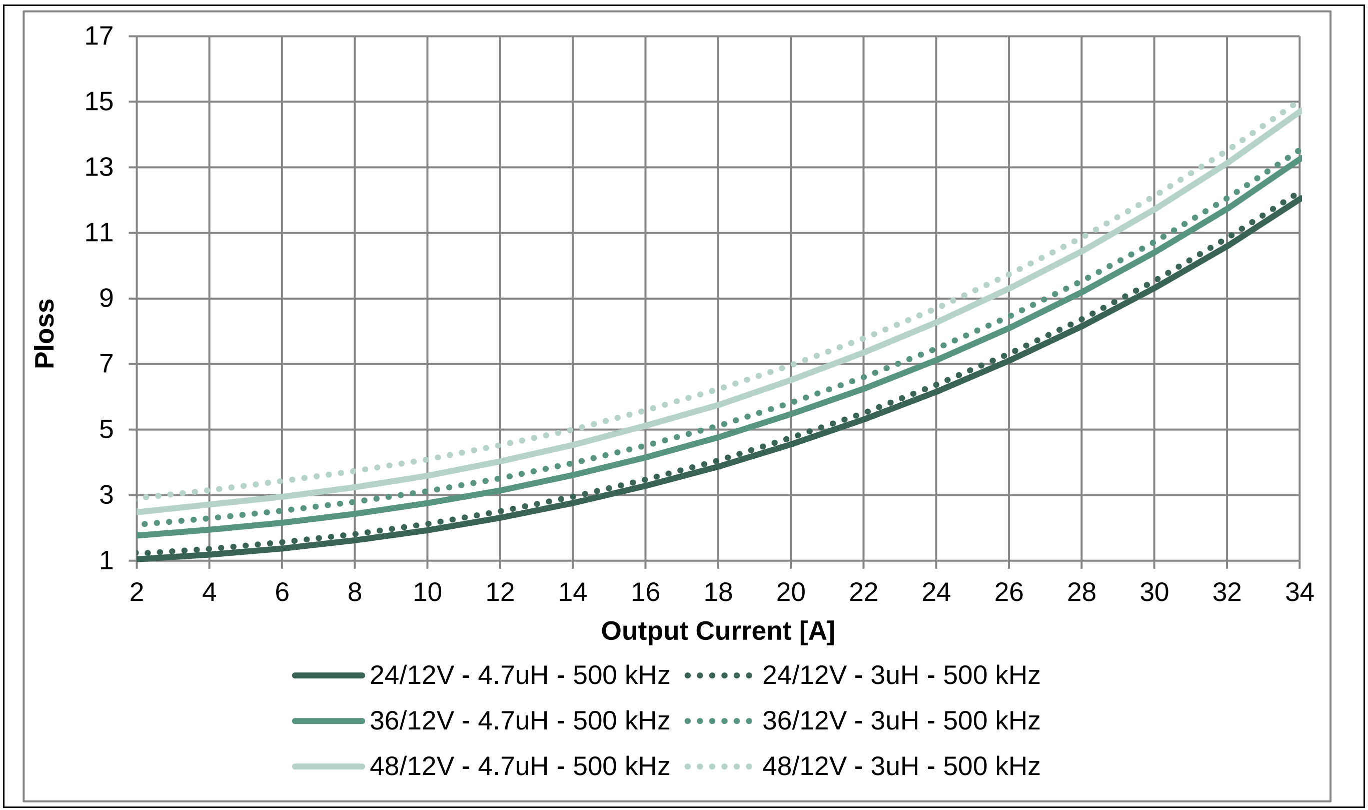

Figure 14 **Power losses at different input voltage levels and different inductor values. The heatsink is placed on the top side, and 5 m/s of airflow is used**

3.2 Example waveforms

Figure 15 shows the low-side Drain Source voltage at turn-on and turn-off of the high-side device. The switching is set in order to not exceed 64 V at 48 V input of the converter. If less overshoot is of preference the high-side gate resistor value can be increased. This reduces turn-off dv/dt of the low-side Drain Source voltage and furthermore the overshoot with little increase of switching losses.

In Figure 16 the transient response of the converter is shown at a load step on the output with 48 V input and 12 V output voltage. A load change from 5 A to 20 A, the controller is able to regulate the output voltage without a significant drop in output voltage.

As a third example waveform the startup of the converter is shown at 48 V input voltage. The set output voltage of 12 V is reached within less than 10 ms as shown in Figure 17.

Both the transient response as well as the startup time can be adjusted at the controller side as described in the datasheet of the controller.

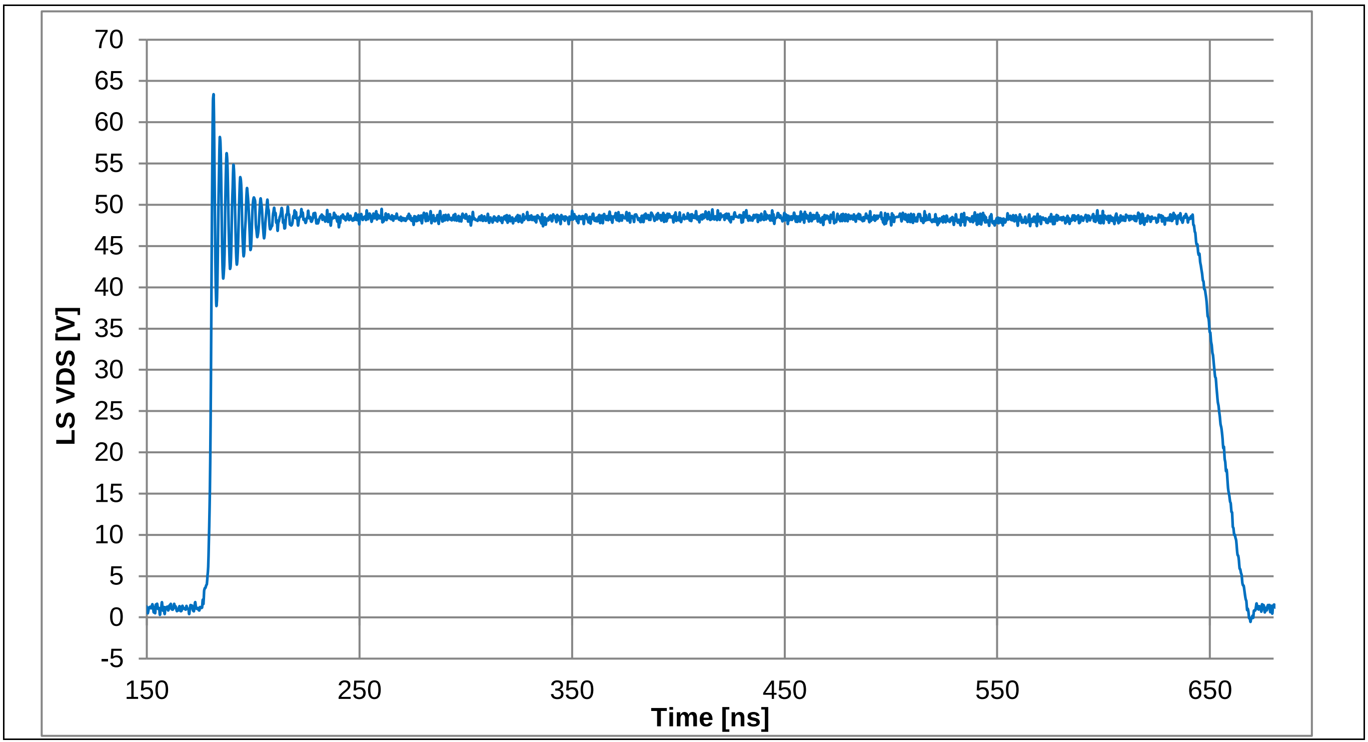

Figure 15 **Measured switch-node voltage waveform of the DEMO_48V12_400W_GaN demo board operating at 48 V input and 12 V output**

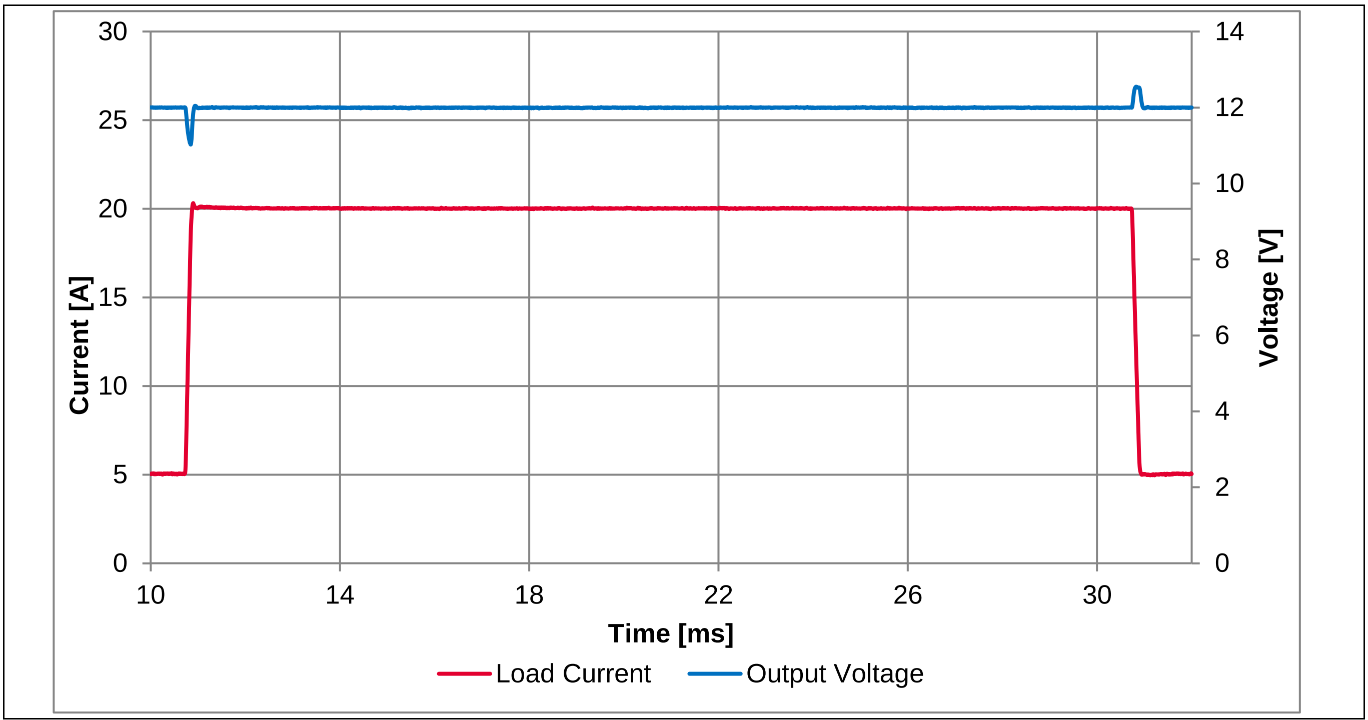

Figure 16 **Measured transient waveform of the DEMO_48V12_400W_GaN demo board operating at 48 V input, 12 V output and with a load step change from 5 A to 20 A**

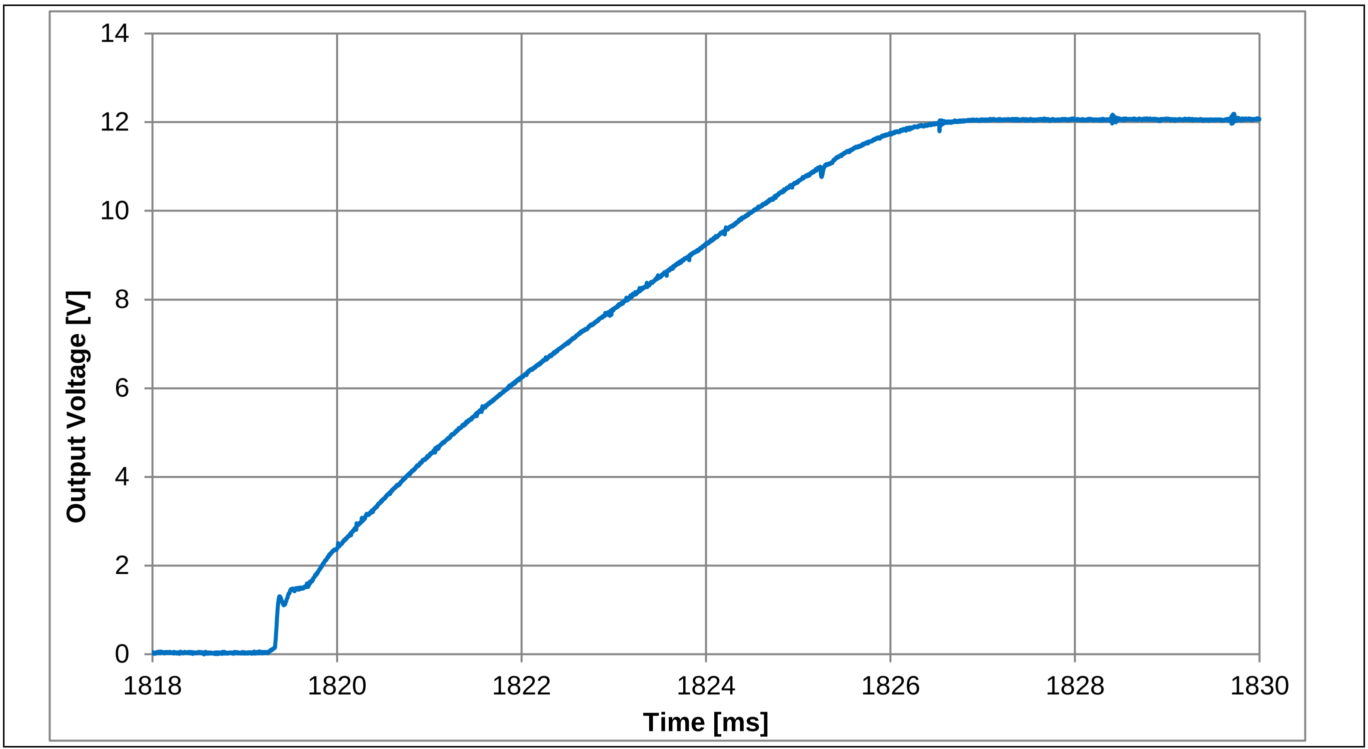

Figure 17 **Measured start-up waveform of the DEMO_48V12_400W_GaN demo board operating at 48 V input, 12 V output**

3.3 Thermal performance

To showcase the excellent thermal performance of GaN used in this buck configuration, example temperature figures are provided. In Figure 18 thermal imaging results of the board operating at different switching frequences, 24 V input, 12 V output, and 20 A output are shown without airflow and heatsink.

As the switching frequency is increasing by 250 kHz in every step, the thermal image reveals that the increase on the device's temperature remains rather low, while at the same time the inductor temperature is dropping noticeably. This is a great indication that CoolGaN™ transistors can increase theirs switching frequency without significantly suffering.

Another example is given in Figure 19 to showcase the thermal performance of the board with a heatsink connected to the top and forced air at different input voltage levels.

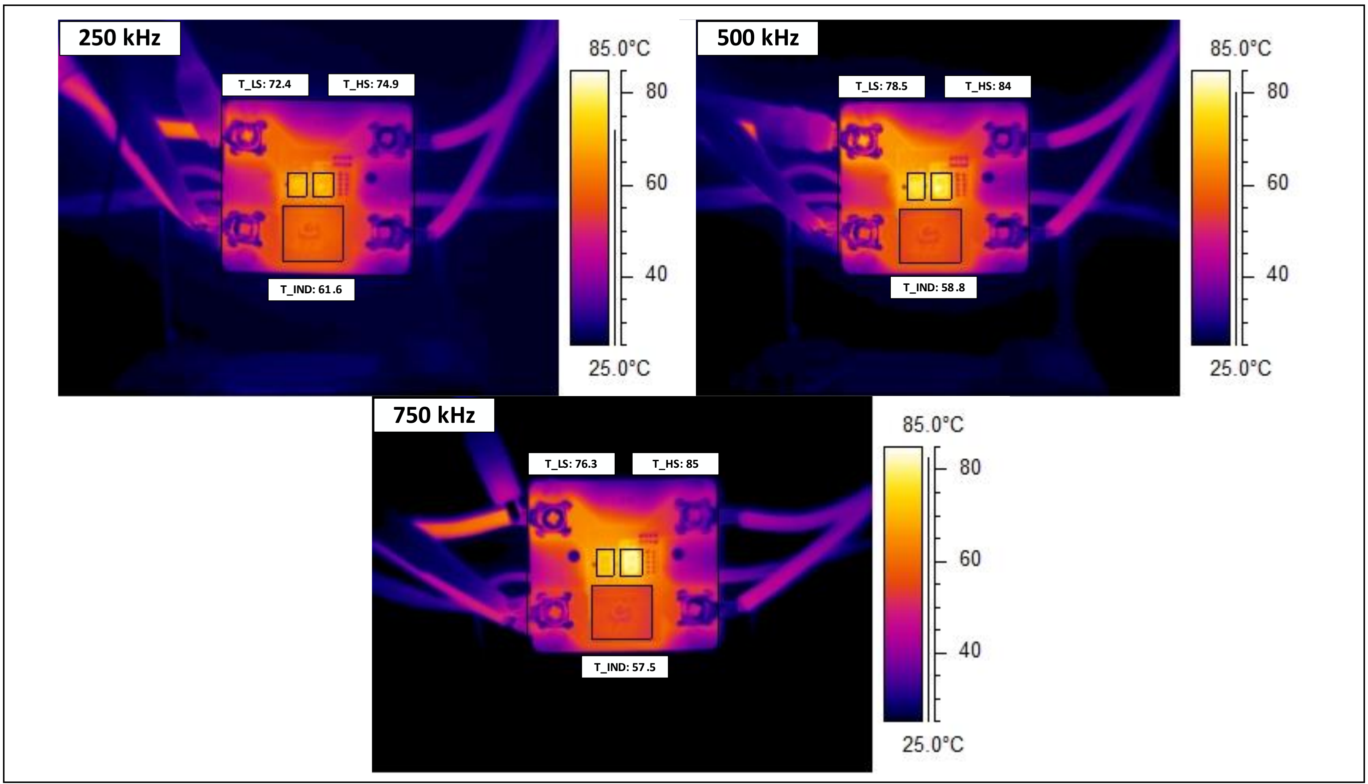

Figure 18 **Thermal imaging results of the board operating at different switching frequences, 24 V input, 12 V output and delivering 20 A into the load, neither airflow nor heatsink is used**

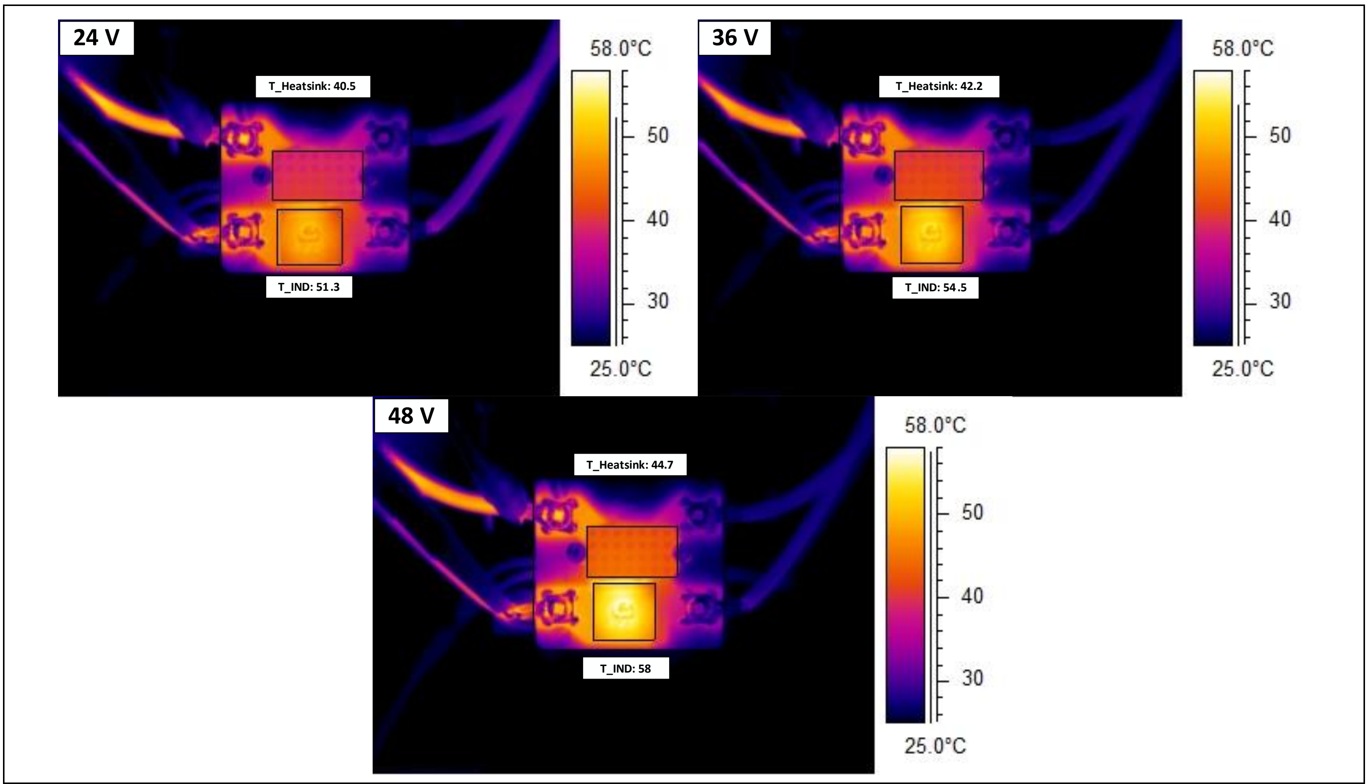

Figure 19 **Thermal imaging results of the board operating at 500 kHz, 24/36/46 V input, 12 V output and delivering 30 A into the load, the heatsink is placed on the top side, and 5 m/s of airflow is used**

4 Board documentation

In this section detailed information about the schematic (Figure 20), PCB layout (Figure 21 to Figure 23) and bill of material (Table 2) of the DEMO_48V12_400W_GaN demo board will be showcased. Finally, connectors details are summed up in Table 3.

4.1 Schematic

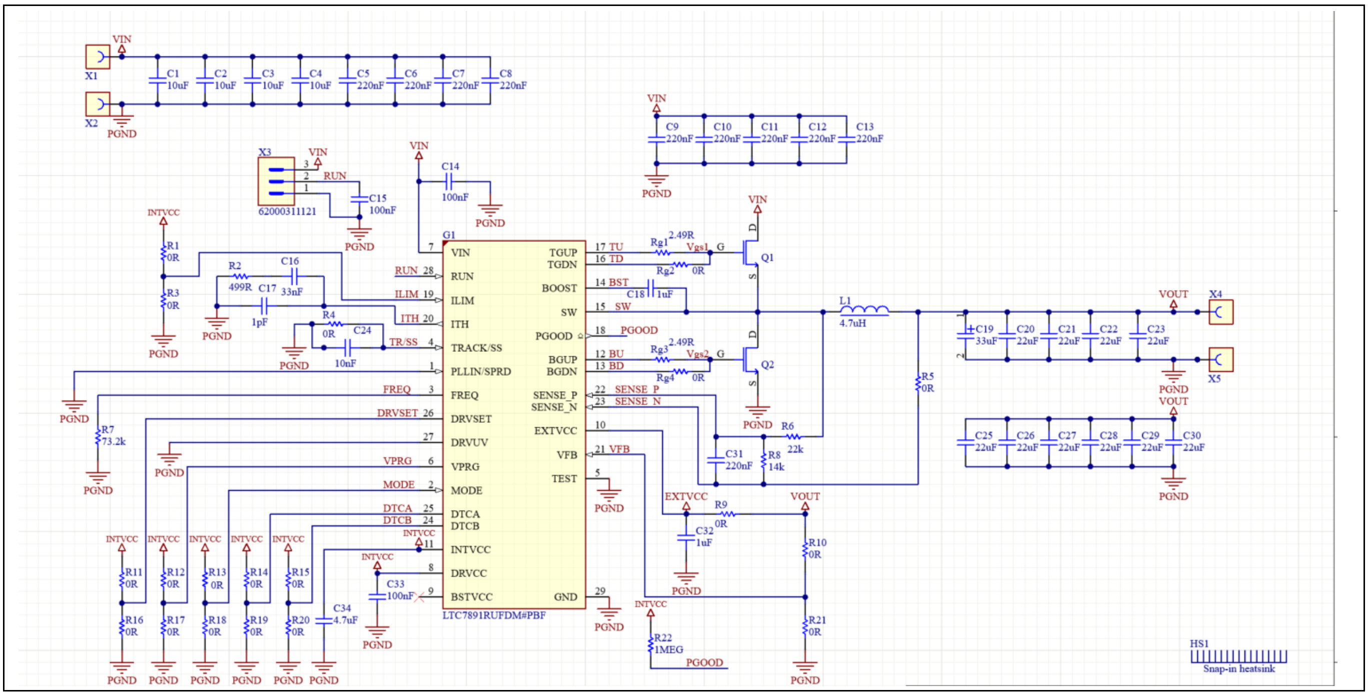

Figure 20 DEMO_48V12_400W_GaN schematic

4.2 Layout

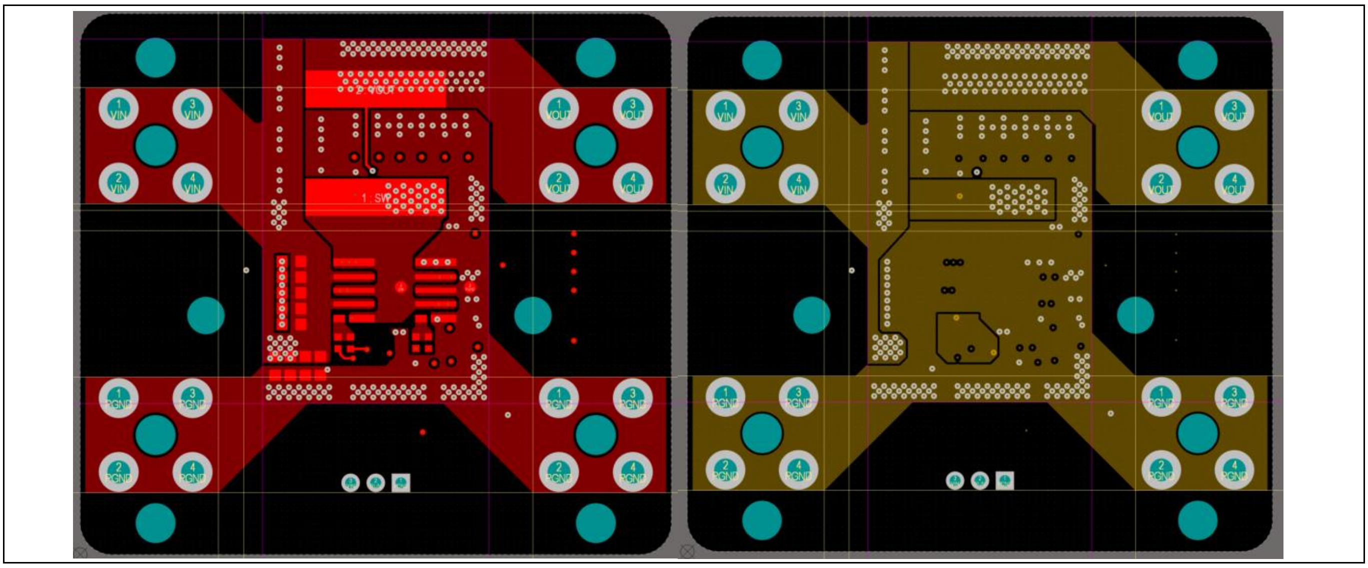

Figure 21 PCB layout top layer (left) and mid-layer 1 (right)

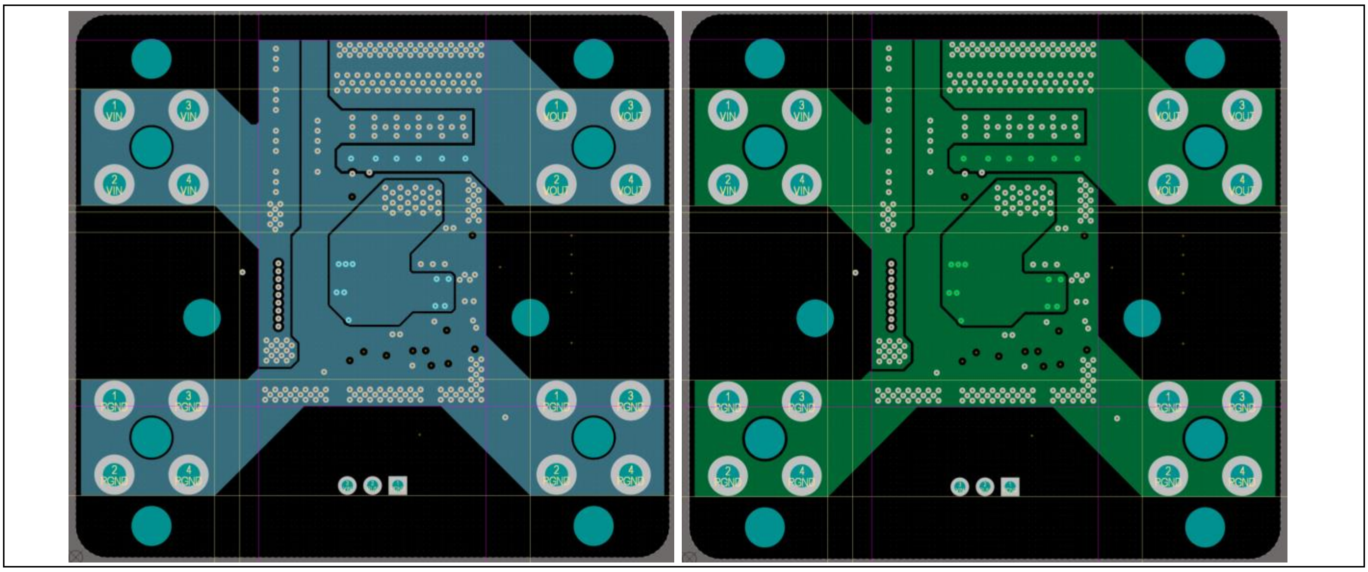

Figure 22 PCB layout mid-layer 2 (left) and mid-layer 3 (right)

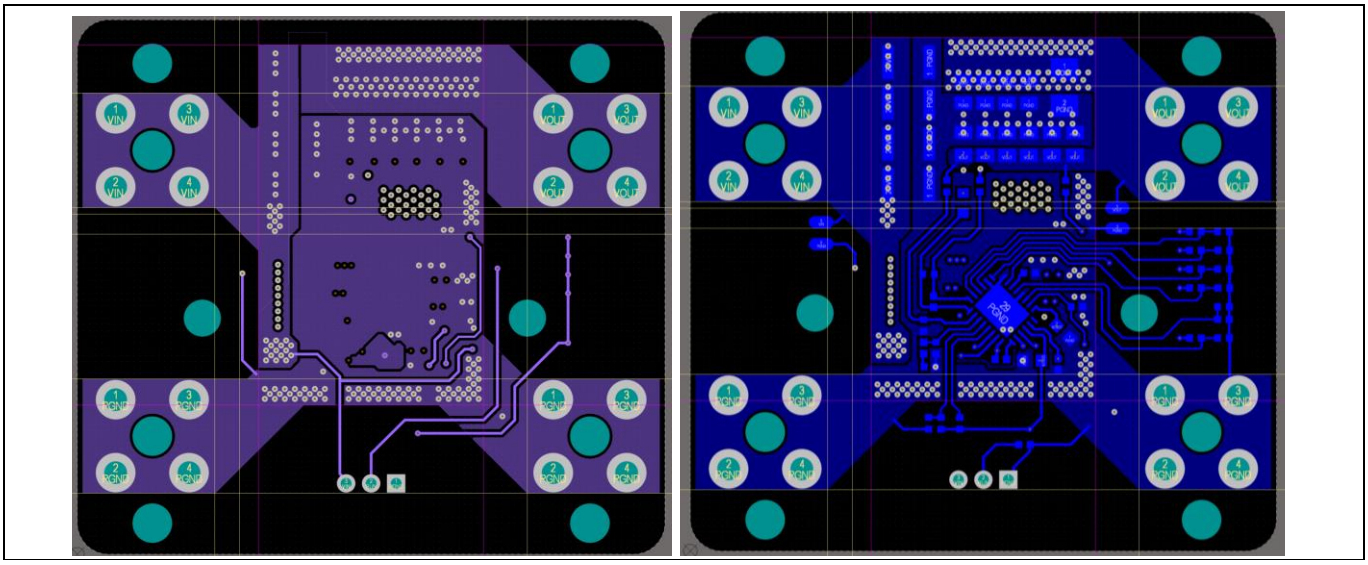

Figure 23 PCB layout mid-layer 4 (left) and bottom layer (right)

4.3 Bill of material

Table 2 Bill of material

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N	Populated
1	C1 ~ C4	10uF / 100V	Murata	GRM32EC72A106KE05L	Yes
2	C5 ~ C13	220nF / 100V	Taiyo Yuden	MCASH168SC7224KTCA01	Yes
3	C14, C15	100nF / 25V	Samsung	CL05B104KA5NNNC	Yes
4	C16	33nF / 50V	TDK	CGA2B3X7R1H333K050BB	Yes
5	C17	1pF / 25V	Murata	GRM1555C1E1R0BA01	Yes
6	C18	1uF / 25V	Murata	GRM155C81E105KE11D	Yes
7	C19	33uF / 16V	KEMET	T525B336M016ATE090	Yes
8	C20 ~ C30	22uF / 25V	Murata	GRM21BR61E226ME44L	Yes

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N	Populated
9	C24	10nF / 25V	TDK	GRM155R71E103KA01	Yes
10	C31	220nF / 25V	TDK	CGA2B3X7R1E224K050BB	Yes
11	C32	1uF / 50V	Taiyo Yuden	UMK105CBJ105KV-F	Yes
12	C33	100nF / 25V	Würth Elektronik	885012206071	Yes
13	C34	4.7uF / 25V	Murata	GRM188R61E475KE11D	Yes
14	G1	Synchronous Step-Down Controller for GaN FET	Analog Devices	LTC7891RUFDM#PBF	Yes
15	L1	4.7uH / 36.7A	Coilcraft	XGL1313-472MED	Yes
16	MP1	Jumper	Würth Elektronik	60800213421	Yes
17	Q1, Q2	E-Mode GaN FET 80V	Infineon	IGC025S08S1	Yes
18	R2	499R	Vishay	CRCW0402499RFK	Yes
19	R5, R9, R10, R12 ~ R16	0R	Panasonic	ERJ-2GE0R00X	
20	R6	22k	YAGEO	RC0603FR-0722KL	Yes
21	R7	73.2k	Vishay	CRCW040273K2FK	Yes
22	R8	14k	Vishay	CRCW040214K0FK	Yes
23	R22	1M	Vishay	CRCW04021M00FK	Yes
24	Rg1, Rg3	2.49R	Vishay	RC0402FR-072R49L	Yes
25	Rg2, Rg4	0R	Yageo	RC0402FR-070RL	Yes
26	X1, X2, X4, X5	REDCUBE	Würth Elektronik	74650073R	Yes
27	X3	Header, 3 pins	Würth Elektronik	62000311121	Yes

Table 3 Connectors

Pin	Label	Function
1	Vin	Input voltage (+) from power supply
2	GND	GND reference of the power supply
3	Vout	Load (+) connection
4	GND	GND reference of the load

5 Related resources

- Infineon CoolGaN™ GaN webpage
- Infineon CoolGaN™ Evaluation Boards
- Infineon CoolGaN™ application note

References

[1] Infineon Technologies AG: *IGC025S08S1 datasheet*; Available online

[2] Infineon Technologies AG: *Half-bridge evaluation board with 100 V CoolGaN™ power transistor and EiceDRIVER™ 1EDN7136U gate driver user guide*; Available online

[3] Infineon Technologies AG: *IGC033S10S1 datasheet*; Available online

[4] Analog Devices: 1*00 V, Low IQ, Synchronous Step-Down Controller for GaN FETs*; Available online

Revision history

Document revision	Date	Description of changes
V 1.0	2025-08-22	Initial release

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