# Scalable regulated intermediate bus converter with CoolGaN™ 100 V power transistors

## REF_IBC_1600W_GAN

### About this document

#### Scope and purpose

Provide how-to's on the operation and configuration of the multiphase buck GaN IBC reference board, as well as example test results.

#### Intended audience

Power supply designers and early adopters of Infineon CoolGaN™ 100 V technology.

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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 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.* |
| | **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:** *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.* |

# Table of contents

# 1 REF_IBC_1600W_GAN board at a glance

Figure 1 shows a picture of the REF_IBC_1600W_GAN, as well as input and output power connections, I²C header, auxiliary 3.3 V and 5 V supply selection header and buck/boost selection header locations.

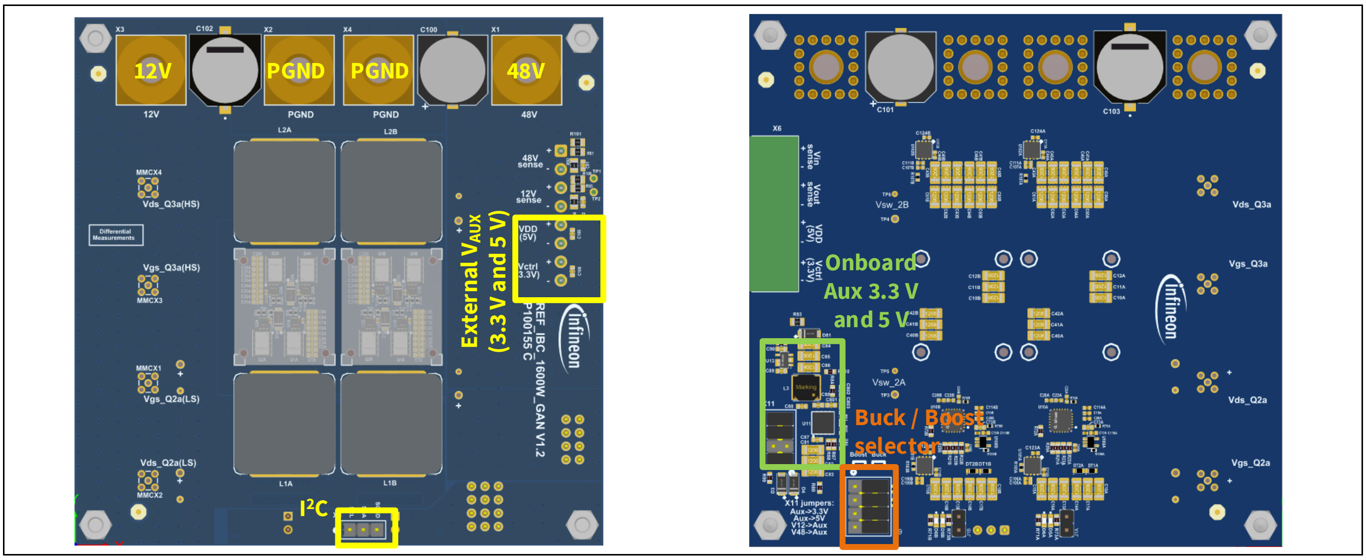



**Figure 1 Images of the REF_IBC_1600W_GAN with major connections highlighted**

## 1.1 Main features

- Infineon CoolGaN™ 100 V IGC033S10S1: 2.4 mΩ typical in 3 mm x 5 mm PQFN package with dual-side cooling
- Infineon EiceDRIVER™ 1EDN7136U: 1.8 mm x 1.8 mm gate driver IC optimized for GaN, truly differential input
- Infineon XDPP1148-100B controller: 4 mm x 4 mm digital power controller with firmware and configuration GUI
- Vishay IHLP7575 inductors: 7 mm height
- Onboard housekeeping power supply for easy evaluation: 3.3 V and 5 V

## 1.2 Board parameters and technical data

This board can be operated in buck or boost modes, selected by the header and jumpers shown in Figure 2. The boost mode is a future experimental feature and is currently not supported by the default controller configuration.

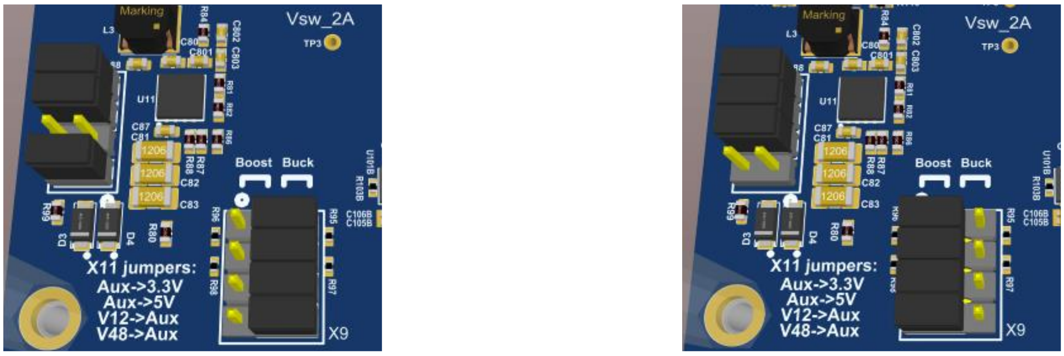



**Figure 2** X9 and X11 jumper positions for buck (left) and boost (right) configuration

All board parameters are summarized in Table 2 at $T_a$ = 25°C, 1000 LFM airflow unless otherwise specified.

**Table 2** Parameters and recommended operating conditions

| Parameter | Symbol | Values | | | Unit | Note/test conditions |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Operating input voltage | $V_{in}$ | 36 | 48 | 60 | V | Buck |
| | | 10 | 12 | 14 | V | Boost |
| Start-up voltage threshold | $V_{in(on)}$ | – | 16 | – | V | Buck |
| | | – | 10 | – | V | Boost |
| Output voltage set-point | $V_{out,nom}$ | 10 | 12 | 14 | V | Buck, adjustable setpoint |
| | | 36 | 48 | 60 | V | Boost, adjustable setpoint |
| Output current | $I_{out}$ | – | – | 134 | A | Buck |
| Input current | $I_{in}$ | – | – | 134 | A | Boost |
| Output power | $P_{out}$ | – | – | 1600 | W | – |
| Efficiency | η | – | 96.1 | – | % | $V_{in}$ = 48 V, $V_{out}$ = 12 V, $P_{out}$ = 1600 W |
| Power dissipation | $P_{diss}$ | – | 65 | – | W | $V_{in}$ = 48 V, $V_{out}$ = 12 V, $P_{out}$ = 1600 W |
| Output voltage ripple (peak-to-peak) | $V_{out,ac(pp)}$ | – | – | 50 | mV | Buck, continuous switching |
| Output voltage regulation (load) | $\Delta V_{out(load)}$ | – | – | 10 | mV | $V_{in}$ = 48 V, $V_{out}$ = 12 V, 0 - 100% of $I_{out,max}$ |
| Output voltage regulation (line) | $\Delta V_{out(line)}$ | – | – | 10 | mV | $V_{in}$ = 36 - 60 V, $V_{out}$ = 12 V, $P_{out}$ = 1600 W |
| Dynamic load response<br>• Output voltage deviation<br>• Settling time | <br>$\Delta V_{out(tr,load)}$<br>$t_{tr(load)}$ | – | – | <br>±600<br>80 | <br>mV<br>µs | $V_{in}$ = 48 V, $V_{out}$ = 12 V, 10% to 100% of $I_{out,max}$ at 10 A/µs |
| Switching frequency | $f_{sw}$ | – | 500 | – | kHz | – |
| Junction temperature | $T_J$ | – | – | 125 | °C | – |

# 2 Operational setup

## 2.1 Getting started

The evaluation board is preconfigured in the buck mode.

***Attention:*** *Check the X11 jumpers before powering on the board to prevent damage.* ***Three jumpers are factory-configured to enable onboard housekeeping power supply. Make sure that all the three jumpers are in place according to Figure 2 to use onboard housekeeping supply.*** *If using external 3.3 V and 5 V supply, remove all three jumpers.*

Note: *Input and output aluminum polymer/electrolytic capacitors are required for stable operation of the converter. Do not attempt to operate the converter without these capacitors.*

Note: *The control loop has been optimized for the output capacitance preinstalled onboard. Any additional output capacitance will become a part of the board control loop, changing the regulation properties accordingly.*

To prepare the board for operation:

1. Connect power supply (PSU) and electronic load to 48 V, GND, 12 V, GND terminals according to Figure 1.
2. Turn on the PSU, either slowly increase, or directly step to a desired value that is within the limits of Table 2.

## 2.2 Description of additional functional blocks

Additional measurement/probe points, jumpers, and external auxiliary power supply locations are highlighted in Figure 3.

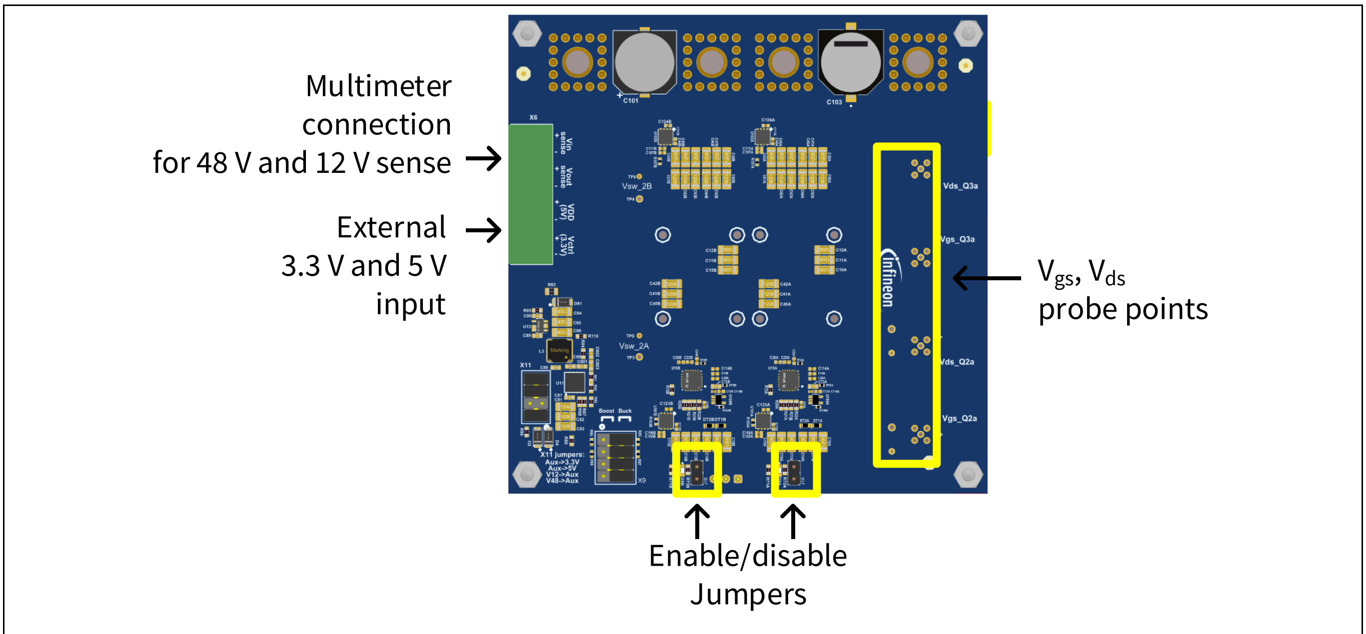



**Figure 3** **Measurements and probe points, enable/disable jumpers, and phoenix contact locations for externally applied AUX**

## 2.3 Basic operation

The board becomes ready for operation by following the procedure in Section 2.1.

The two enable/disable jumpers should be left floating for normal operation. Installing a jumper will cause the corresponding XDPP1148 to shutdown, thus disabling the module.

## 2.4 Operation with externally applied 3.3 V and 5 V AUX

Three jumpers are factory installed inside housekeeping power supply. To disable the onboard housekeeping power supply:

1. Remove all three jumpers on X11
2. Connect external 3.3 V and 5 V to the appropriate Phoenix contact terminal blocks
3. Make sure 3.3 V and 5 V are on before turning on PSU
4. Turn on the PSU

# 3 System design

## 3.1 Schematics

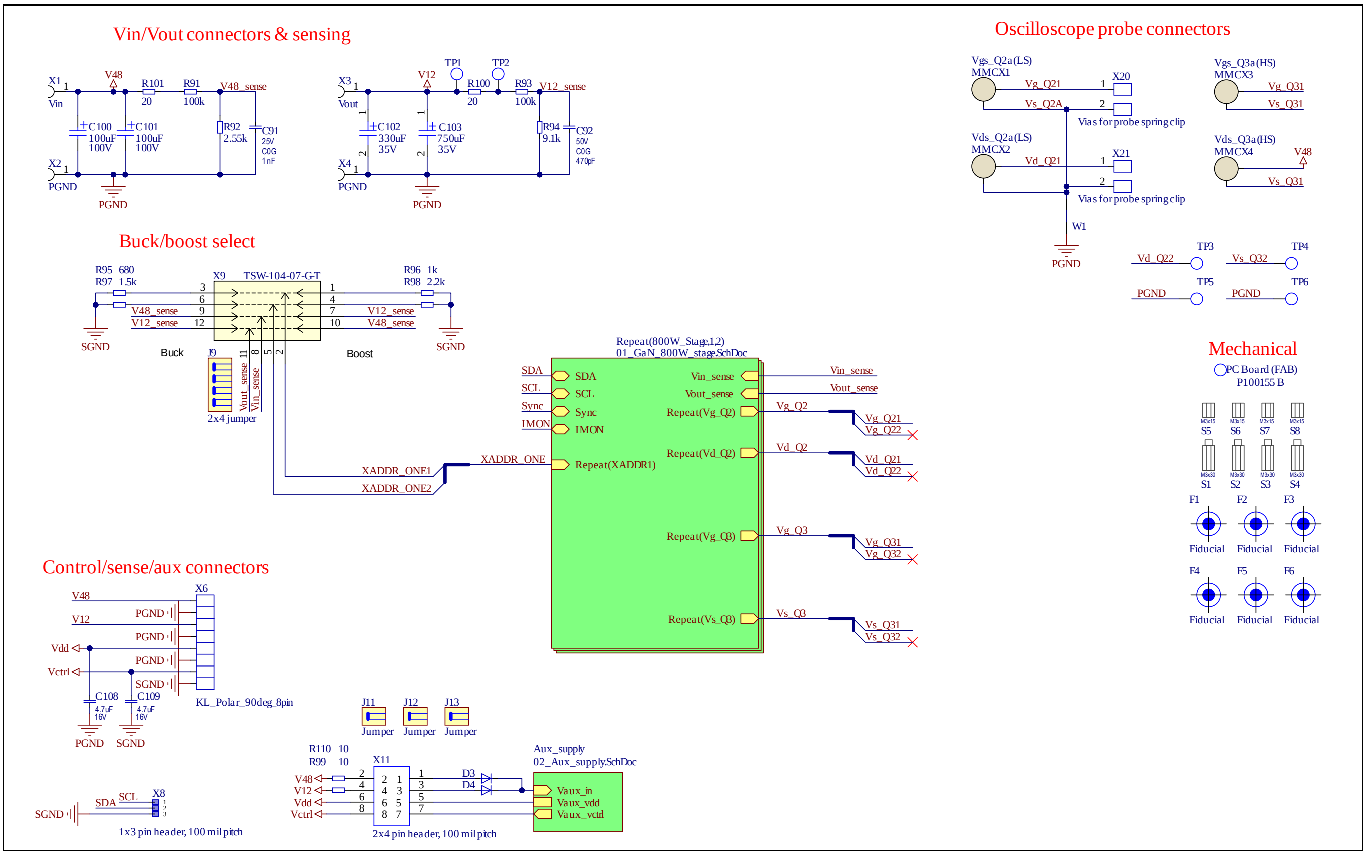



**Figure 4** Main schematic

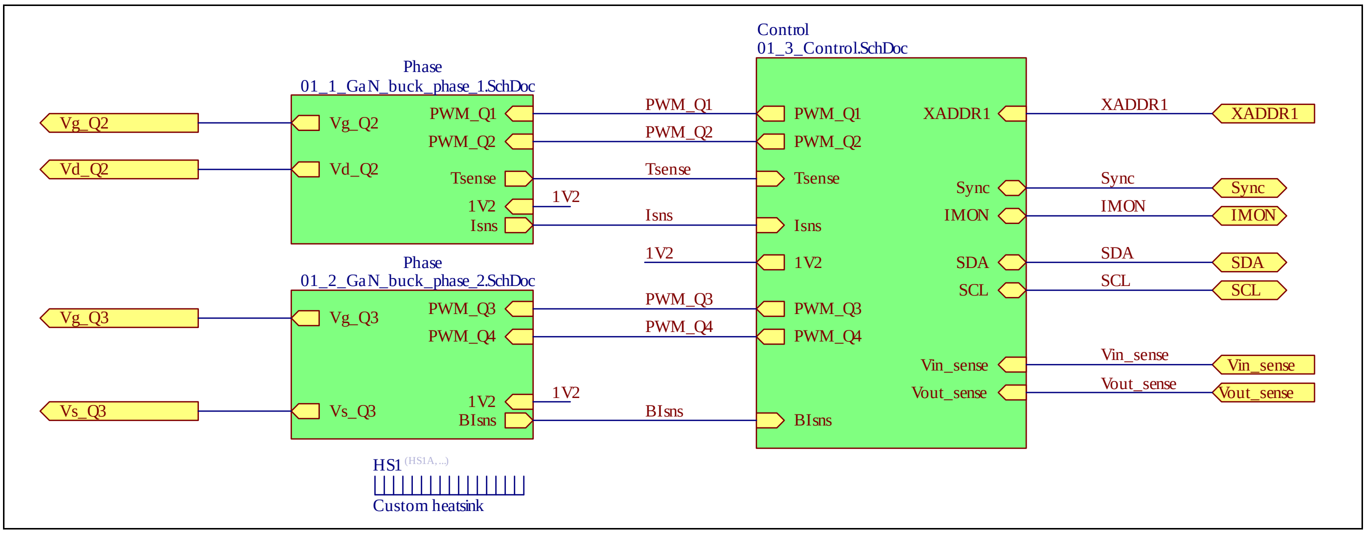



**Figure 5** Power stage schematic (top hierarchy)

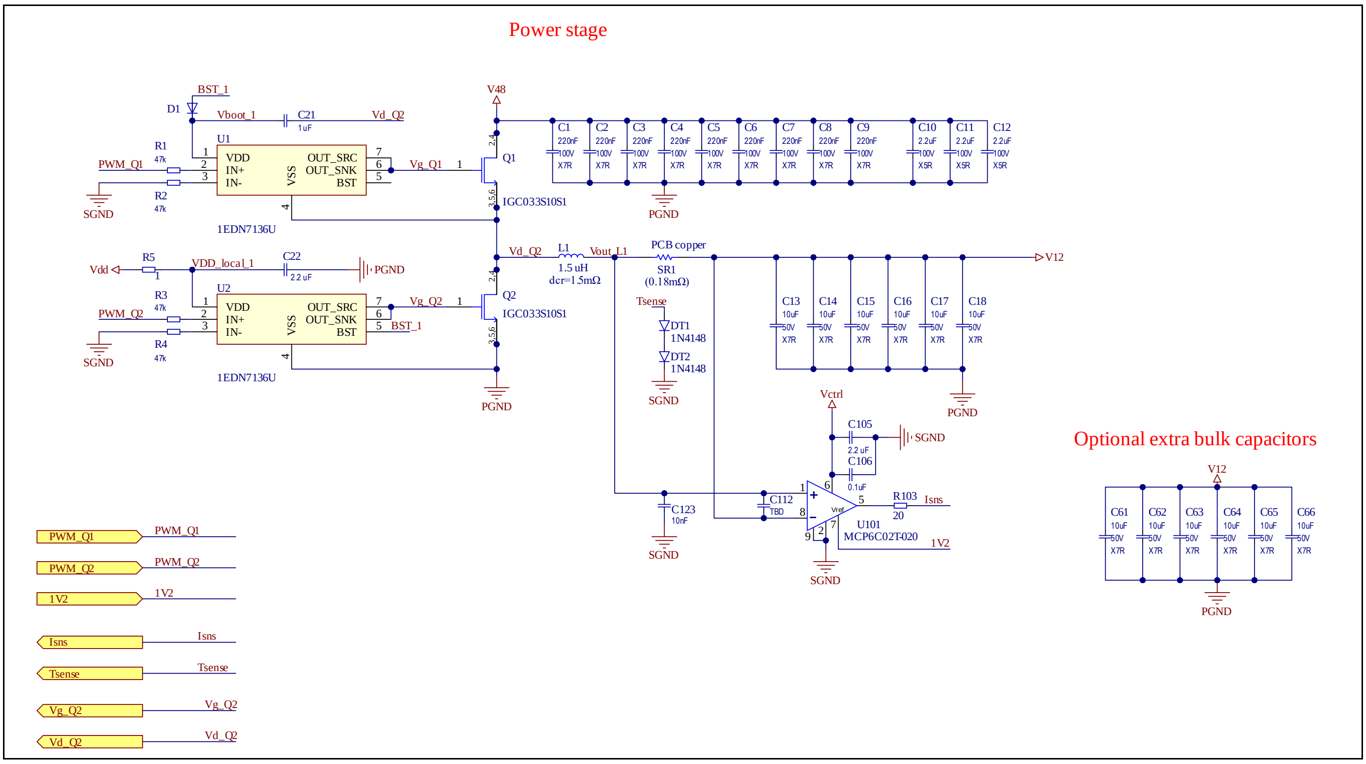



Figure 6 Phase 1 schematic

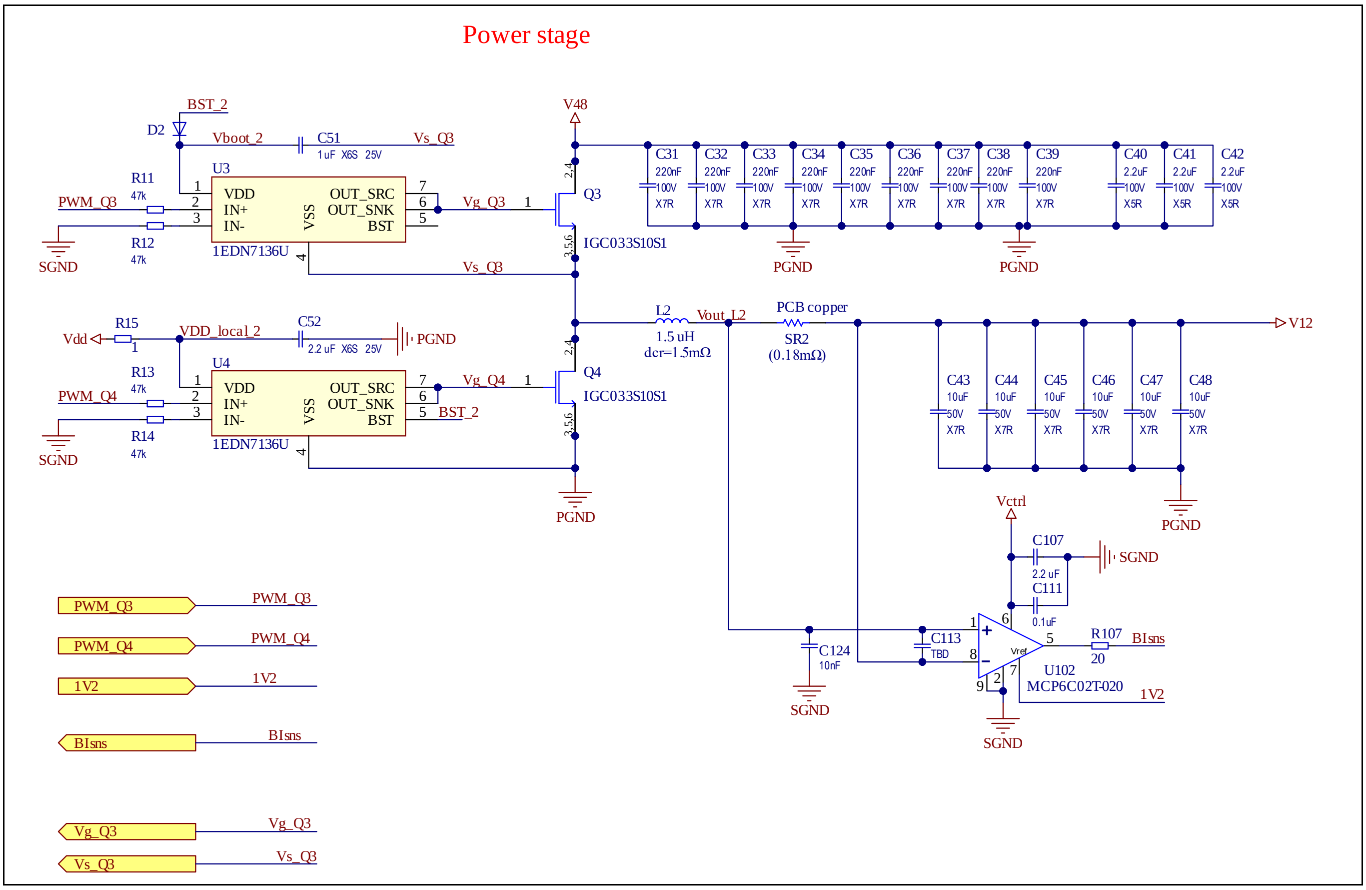
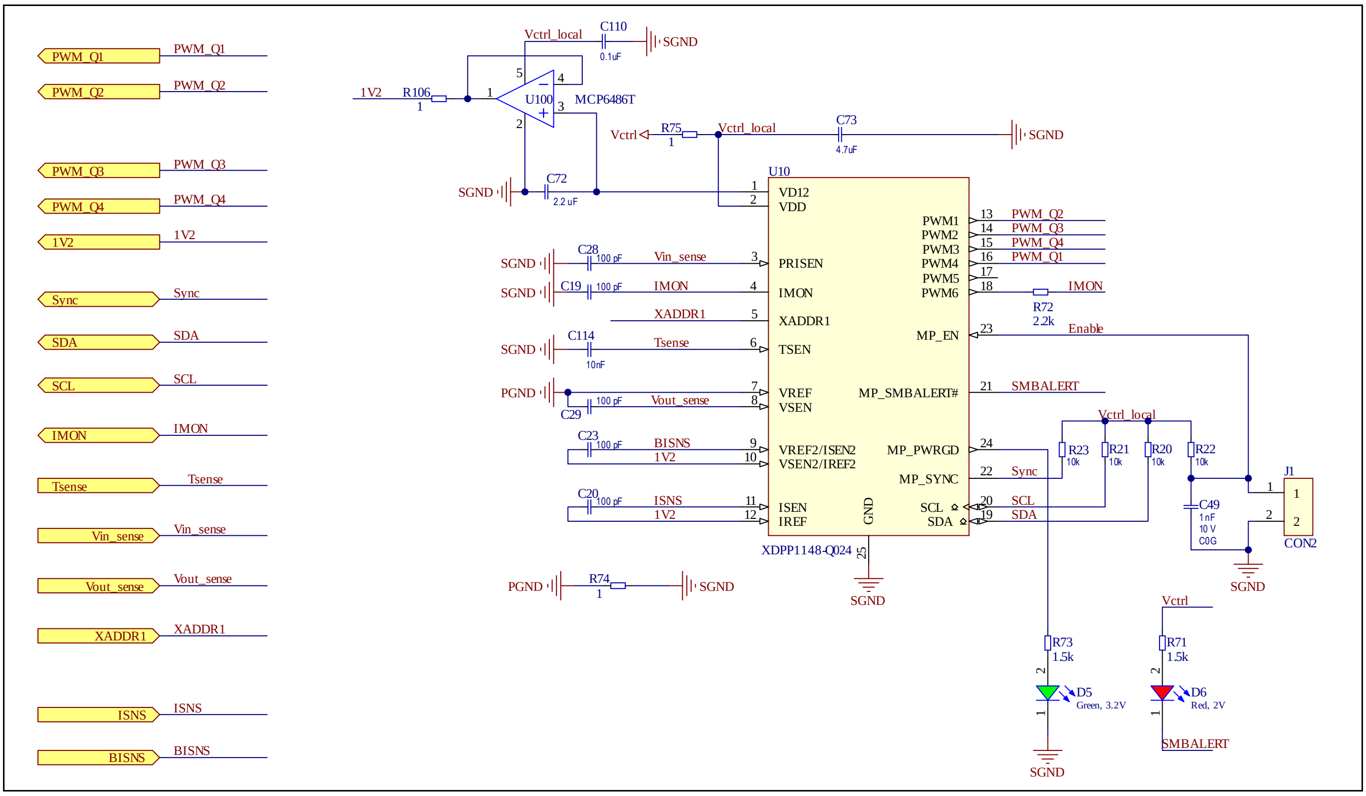
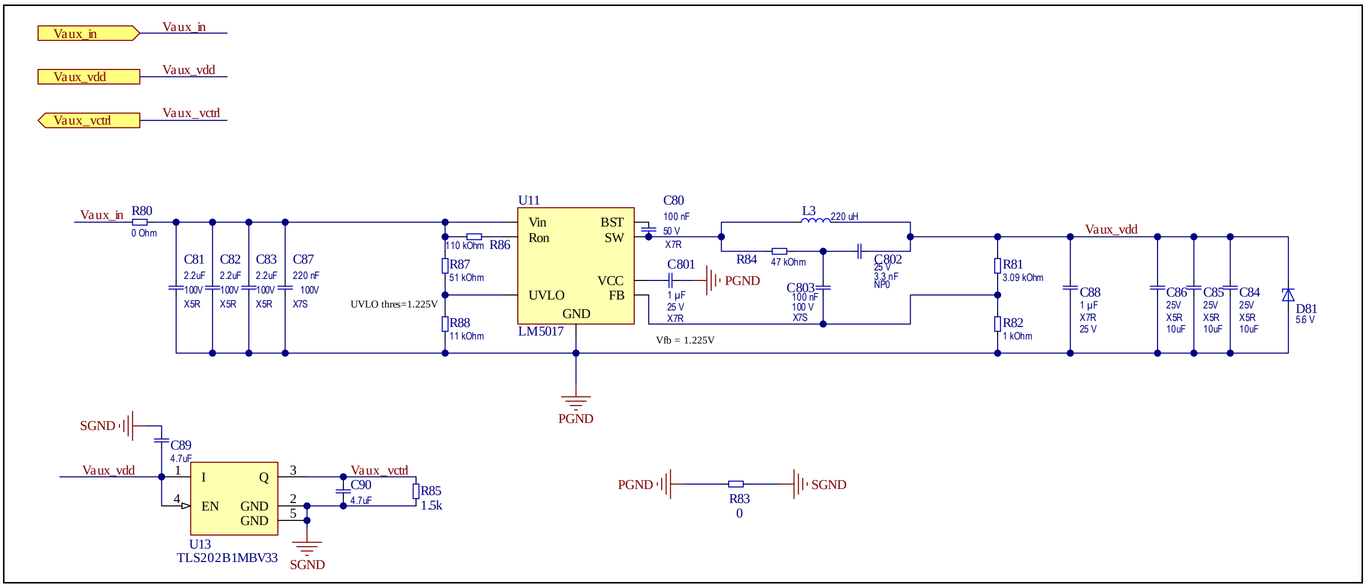



Figure 7 Phase 2 schematic




## Figure 8 Control schematic




## Figure 9 Housekeeping power supplies schematic

## 3.2 Layout

Figure 10 shows an excerpt of the layout for a single-phase of the power stage.

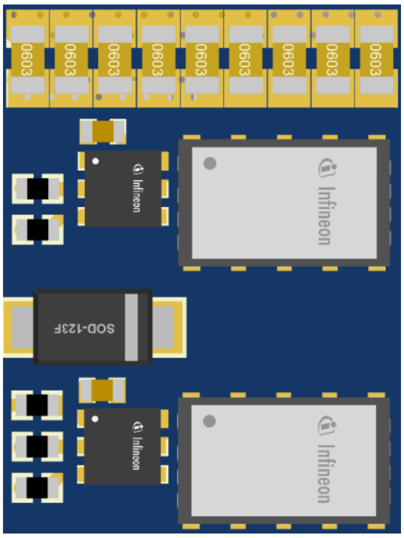
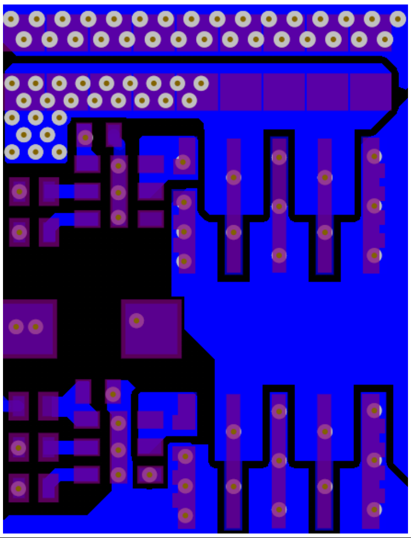
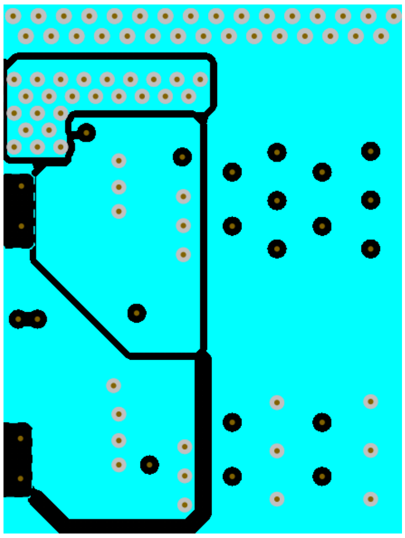
| **100 V CoolGaN™ half-bridge**<br>3D view | **Top layer**<br>70 µm copper + pads | **First inner layer**<br>(~80 – 100 µm dielectric) |
|---|---|---|
|  |  |  |

**Figure 10 PCB layout for the power stage**

# 4 XDPP1148 configuration

The XDPP1148 devices can be configured from XDP™ Designer GUI [1]. The built-in design tool helps simplify the configuration from topology selection to loop control and protection setups. The XDP™ Designer also offers firmware support and debugging tools which includes loading firmware patches and storing user configurations into the OTP.

The XDPP1148 devices are preprogrammed and no additional configuration or software is necessary for basic operation. XDP™ Designer is needed to communicate with XDPP1148, to change the configuration or to access telemetry data.

## 4.1 Hardware connection

A typical setup is shown below:

- The computer with XDP™ Designer installed connects to the USB dongle USB007A via the USB port. USB007A connects to the system board that has the XDPP1148 chip over $I^2C$.
- The system board provides 3.3 V bias to XDPP1148 to allow communication through the housekeeping supply or the externally applied 3.3 V. The reference board REF_IBC_1600W_GAN provides the necessary connections to the dongle (header X8).

# 5 Test results – 1600 W

## 5.1 Measurement reference

Onboard probing points (Figure 11) for GaN half-bridge gate-to-source and drain-to-source voltages, are provided for ease of use.

*Note:* *Although the probing points are differentially routed, their placement is far from the GaN half-bridge and impacts the signal integrity (e.g., ringing and higher overshoots are recorded). It is recommended to use the probing point only for a functional evaluation of the power stage. Precise measurements on the power stage must be carried out with probes placed as close as possible to the switches (ideally with short, 30 AWG tightly twisted pairs).*

*Note:* *More probing points are given only for Module A and not Module B. Probing points for the LS switch are routed to Module A, Phase 2. Probing points for HS switch are routed to Module A, Phase 1. Only switch node voltage probing points are provided for Module B.*

*Note:* *To perform high-side measurements, a differential, high performance (BW, slew rate) probe MUST be used. Infineon recommends the Tektronix TIVP1 IsoVu probe.*

***Attention:*** *Do not attach passive probes to high-side probe connectors. Doing so will short the circuits and damage the board.* ***Only differential probes are recommended for high-side measurements.***

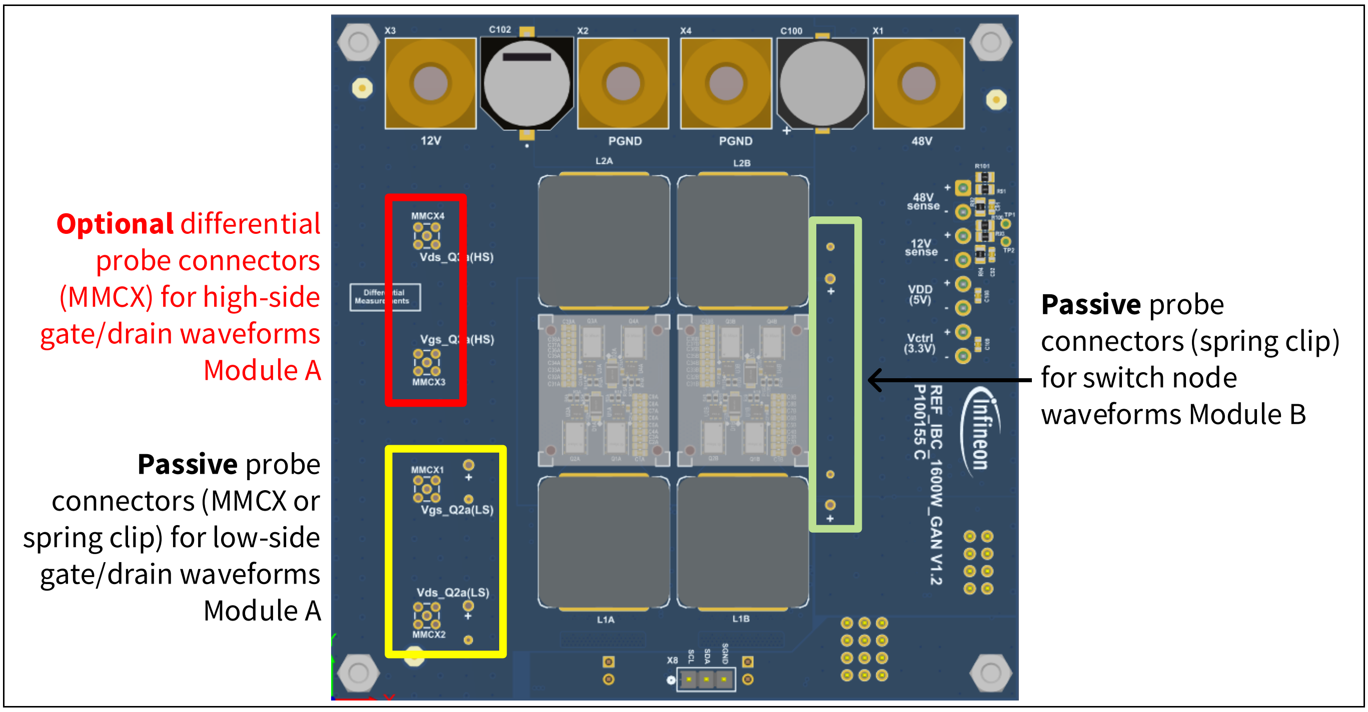



**Figure 11 Probing point locations**

### 5.1.1 Oscilloscope and probes

The recommended bandwidth for all voltage probes and oscilloscopes is minimum 1 GHz.

### 5.1.2 High-side measurements

In general, high-side voltage waveforms are challenging for a GaN-based half-bridge circuit, due to the high dv/dt and di/dt involved. The most accurate measurement scheme comes from a high-bandwidth optically isolated probing system, for example the IsoVu TIVP1 probe from Tektronix shown in Figure 12(a).

Other fiber-based optically isolated probing systems are available from other measurement vendors, and these solutions may also be acceptable, but they have not yet been validated for this measurement.

In addition to the bandwidth of the probing system, the probing loop connectivity is absolutely critical. An MMCX tip adapter for high-side measurements is very important for an accurate measurement with highest fidelity and the lowest signal degradation.

### 5.1.3 Low-side measurements

Any passive probe can be used to measure low-side (ground-referenced) voltage waveforms for GaN transistors, but they should have a suitable bandwidth and connectivity.

The loop between the probe tip and the measurement points (both + and – sides) should be within 10 mm, preferably shorter. One example of a recommended probing solution is Tektronix TPP1000 with MMCX tip adapter 206-0663-xx, as shown in Figure 12(b), which guarantees the tightest possible probing loop for this tip. As a secondary option, a spring clip probe tip shown in Figure 12(c) may be employed, but this does degrade the measurement fidelity to some degree.

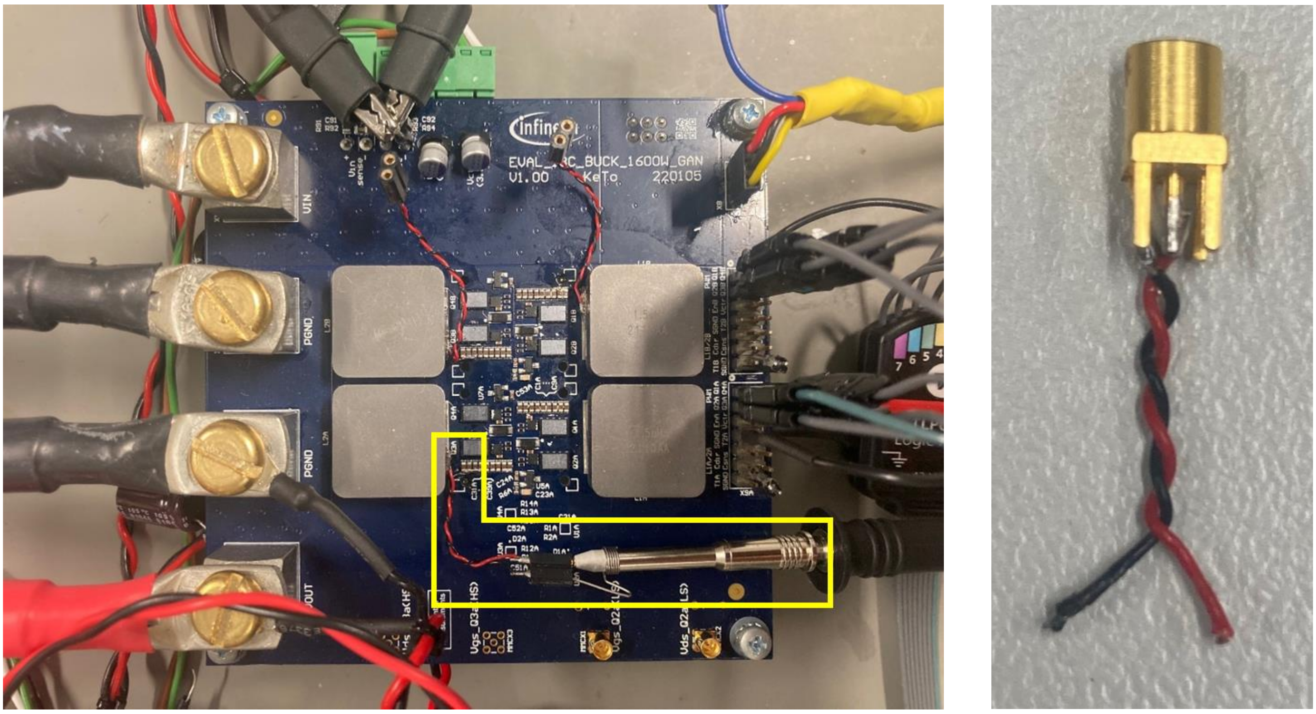

(a) (b) (c)

**Figure 12 Probe options for measuring high-side (a) and low-side (b), and with a spring clip probe(c)**

### 5.1.4 Measuring other signals/waveforms

To probe other signals, please make use of tightly twisted copper pairs (e.g. PVC insulated 30 AWG). Solder the pairs at the desired location. Keep the leads as short as possible. For the best performances, terminate the twisted pairs on MMCX connectors and attach a proper probe.

In case MMCX connectors are not available, terminate the twisted pairs on 2.54 mm pitch female headers and use a probe with ground spring, as shown in Figure 13.



**Example: measuring switching nodes with the aim of twisted pairs and passive probes with a ground spring**

**Twisted pair terminated on MMCX connector (best practice)**

**Figure 13 Placement of additional probing points**

### 5.1.5 Temperature measurements

The board is equipped with two onboard PCB temperature sensors, placed near the PCB current shunt for current telemetry compensation and protection purposes. It is recommended to use a contacting thermocouple solution or an infrared thermal camera to more accurately capture the temperature of GaN transistors, as well as the power inductor.

When using a thermal camera, it is highly recommended to paint all target surfaces with a matte-finish paint (white or black is commonly used) to ensure that the emissivity is consistent for all temperature measurements. An example of painted switches and inductor is shown in Figure 14.

*Note:* *The thermal design assumes the operation of the board with the heatsink mounted. To capture the temperature of the switches using a thermal camera, always provide sufficient amount of airflow and keep the case temperature under control.*

*Note:* *The applied paint would most likely affect heat transfer. Please clean the surfaces before applying the TIM and heatsink.*

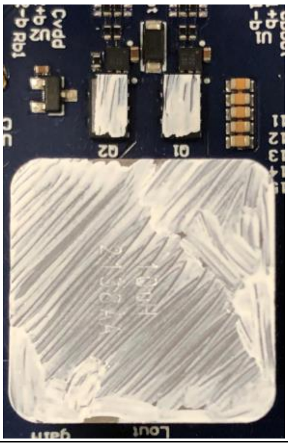


**Figure 14** **Painted switches and inductor**

## 5.2 Efficiency and power losses

Efficiency and power losses were measured at three different input voltages: 36 V, 48 V, and 60 V. The load current varies from 0 A to 134 A. Onboard housekeeping supplies were disabled and losses from external 3.3 V and 5 V supplies (0.465 W) were added to the calculation. Switching frequency is 500 kHz; inductor is 1.5 µH in each phase.

*Note: Efficiencies have been captured with a dwell time of 3 s, not at thermal steady state.*

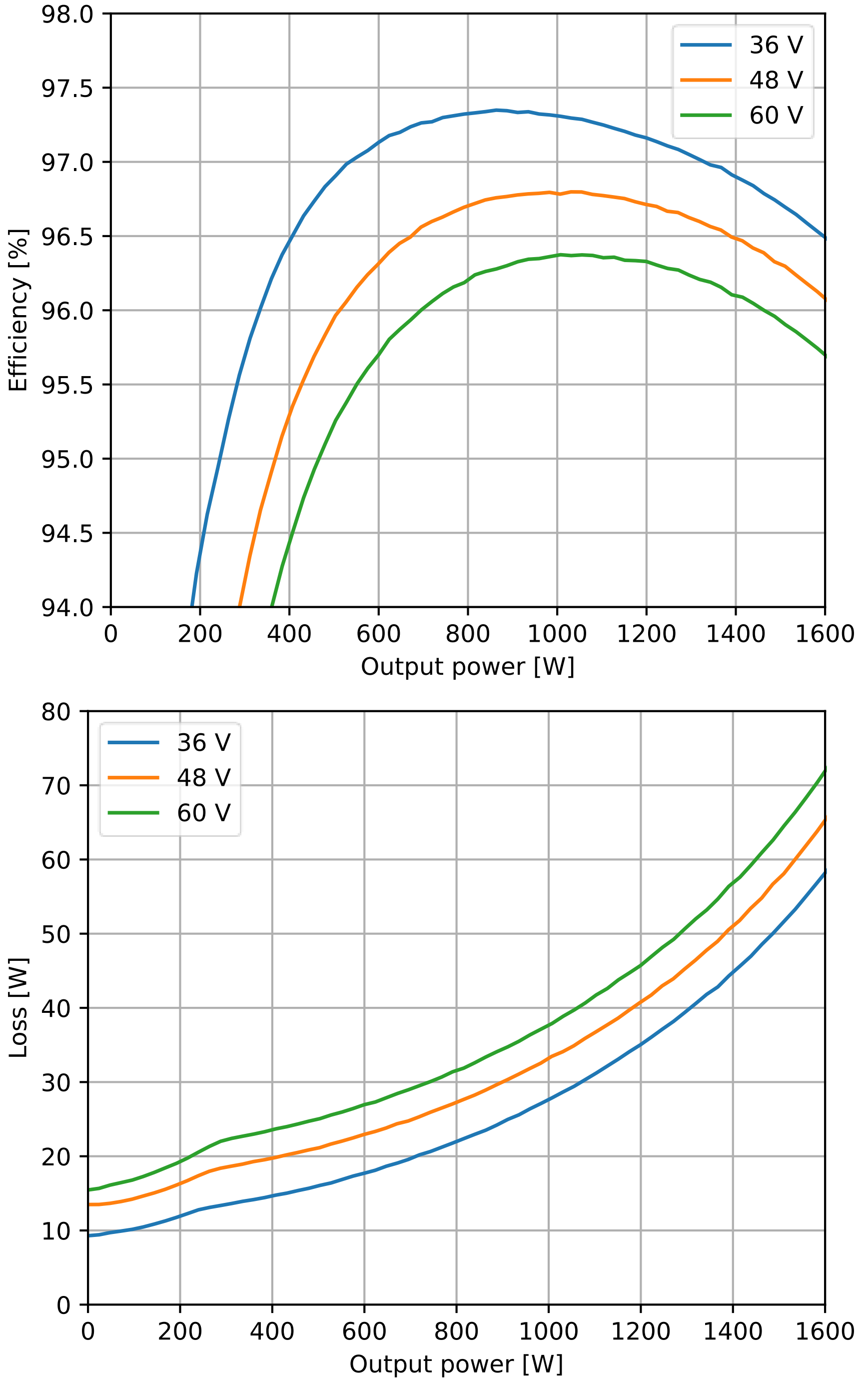



**Figure 15 Measured efficiency and loss at 36 V, 48 V, and 60 V input voltages**

## 5.3 Steady-state waveforms

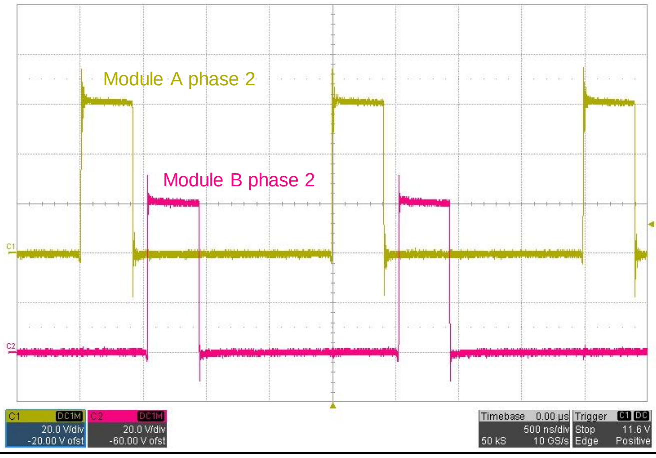



**Figure 16 Switching node waveforms: 60 Vin, 12 Vout, 134 A out**

## 5.4 Start-up waveforms

In buck mode, the total Vout ramp time from 0 V to 12 V is configured to 10 ms. The current sense amplifier has a specified minimum common mode voltage of 3 V. The step response of the current sense amplifier at Vout near 3 V could trigger overcurrent protection (OCP) of XDPP1148. Therefore, Module B is programmed to turn on 5 ms after Module A. This means the output for Module B has a pre-bias of 6 V. This also verifies the current sharing function during startup ramp.

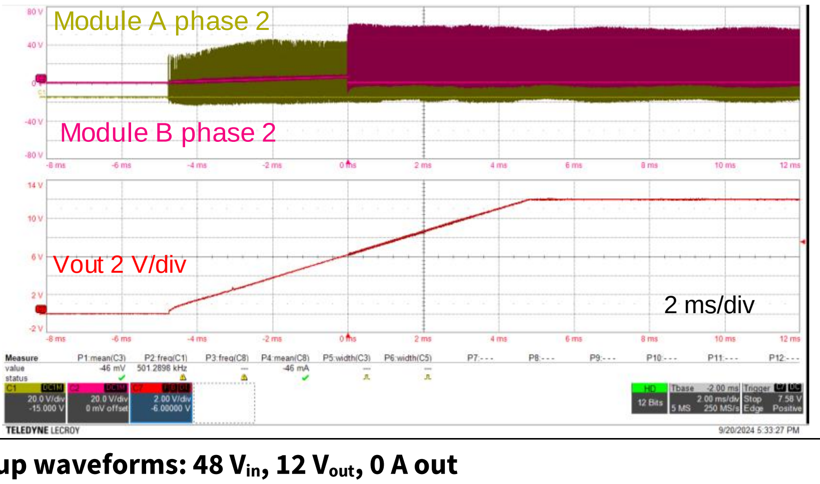



**Figure 17 Start-up waveforms: 48 $V_{in}$, 12 $V_{out}$, 0 A out**

## 5.5 Load transient response

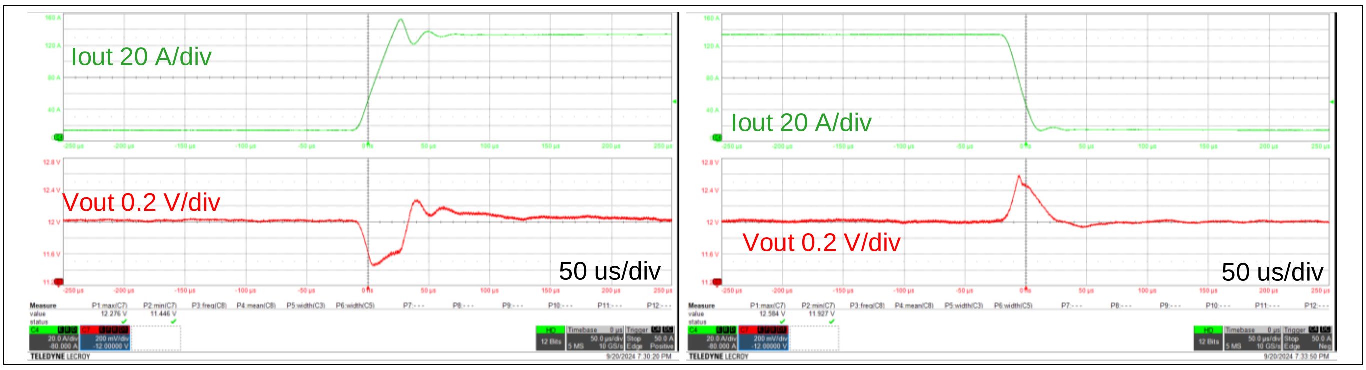



**Figure 18 Load transient response: 48 $V_{in}$, 12 $V_{out}$, 13.4 A to 134 A and 134 A to 13.4 A, 5 A/µs slew rate, $V_{out}$ error within ±5%**

## 5.6 Line transient response

The input voltages for line transients are 36 V/60 V, with a slew rate of 0.3 V/µs, limited by the power supply's maximum drive capability and input capacitor, at a load current of 20 A. With input feed forward enabled, the overshoot and undershoot are within ±4%, as shown in Figure 19. Without feed forward, the overshoot exceeds 2 V and triggers overvoltage protection (OVP).

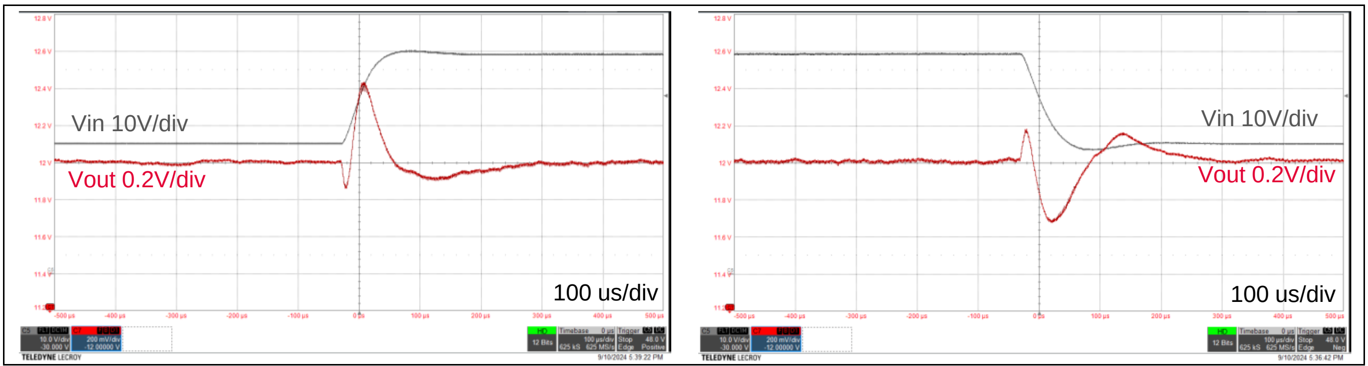



**Figure 19 Line transient response: 36 $V_{in}$ to 60 $V_{in}$ and 60 $V_{in}$ to 36 $V_{in}$, 12 $V_{out}$, 20 A output, 0.3 V/µs slew rate**

## 5.7 Thermal performance

Thermal images are recorded using a FLIR A700, at 48 $V_{in}$ and 12 $V_{out}$, 134 A. The airflow is about 5 m/s (1000 LFM), and the dwell time is 5 minutes. The module closer to the fan shows a lower temperature.

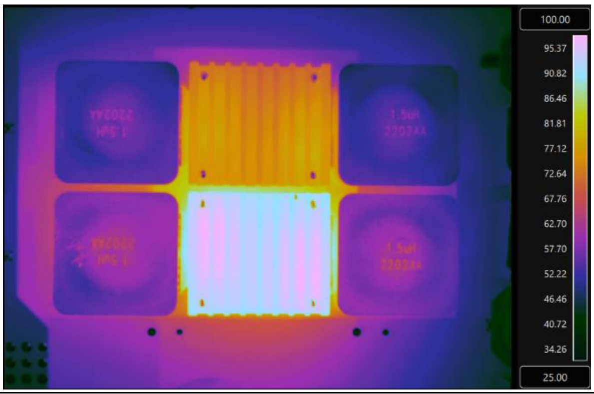



**Figure 20 Thermal image for 48 $V_{in}$ and 12 $V_{out}$, 134 A**

# 6 Test results – 2400 W

***Attention:*** ***This section contains results from the old PCB version. Only the virtual design is available.***

Since the board design is modular and scalable, the 2400 W version of the evaluation board is very similar to the 1600 W version, but with an extra module, as shown in Figure 21. The power connectors, I²C port, external 3.3 V and 5 V auxiliary connectors, measurement and probe points are the same.

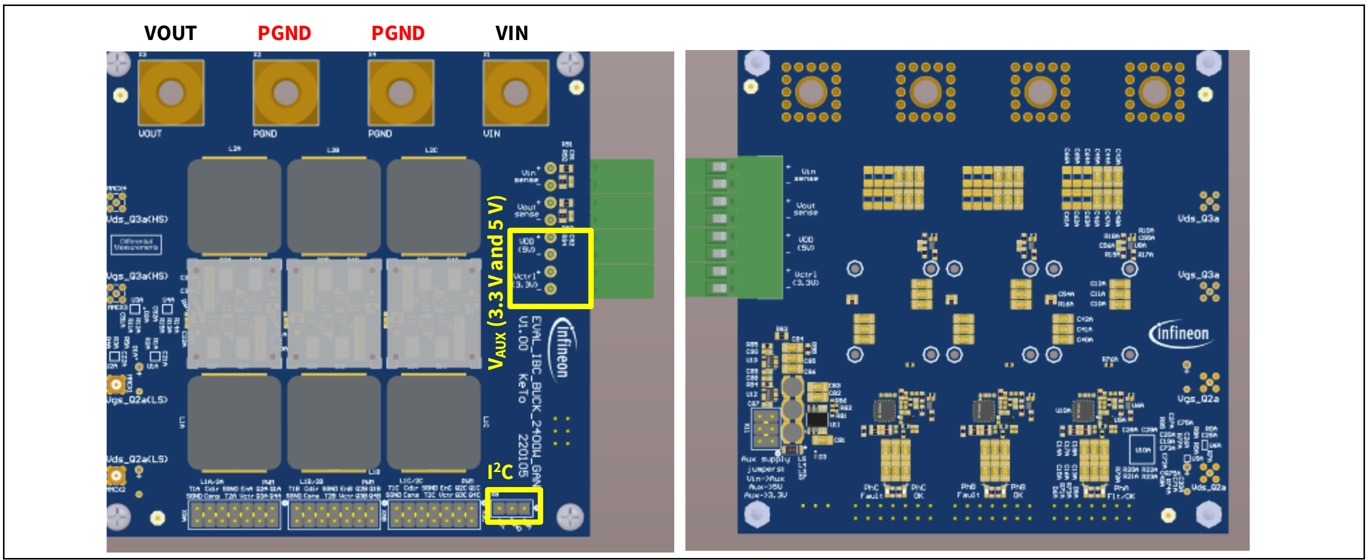



**Figure 21 Picture of the GaN IBC board – 2400 W version**

## 6.1 Efficiency and power losses

Efficiency and power losses were measured at three different input voltages: 36 V, 48 V, and 60 V. The load current varies from 0 A to 192 A. Onboard housekeeping supplies were disabled and losses from the external 3.3 V and 5 V supplies (0.681 W) were added to the calculation. Switching frequency is 500 kHz; inductor is 1.5 µH in each phase.

*Note:* *At 36 V, output power was limited due to the input power supply's maximum output capability.*

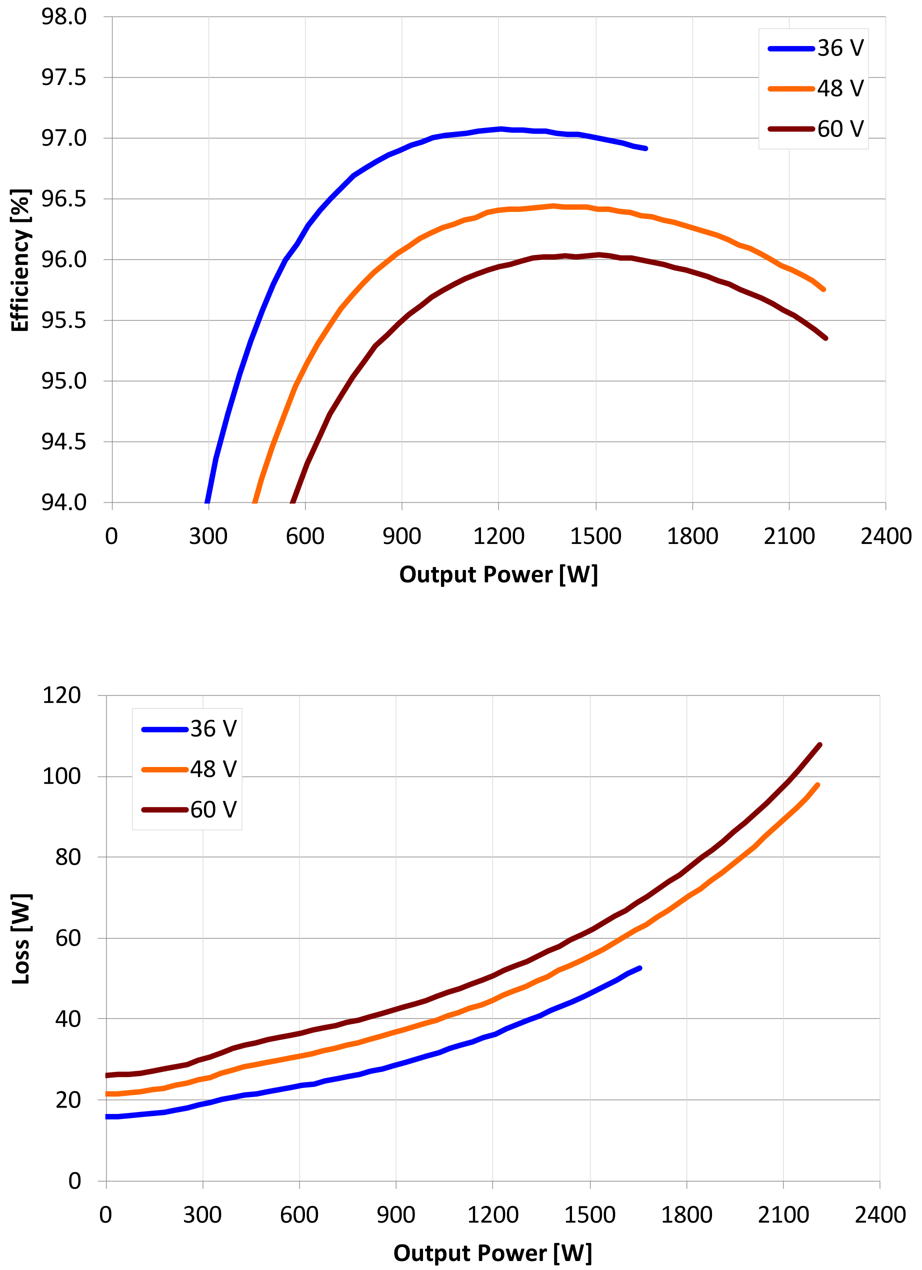



**Figure 22 Measured efficiency and loss at 36 V, 48 V, and 60 V input voltages – 2400 W version**

## 6.2 Steady-state waveforms

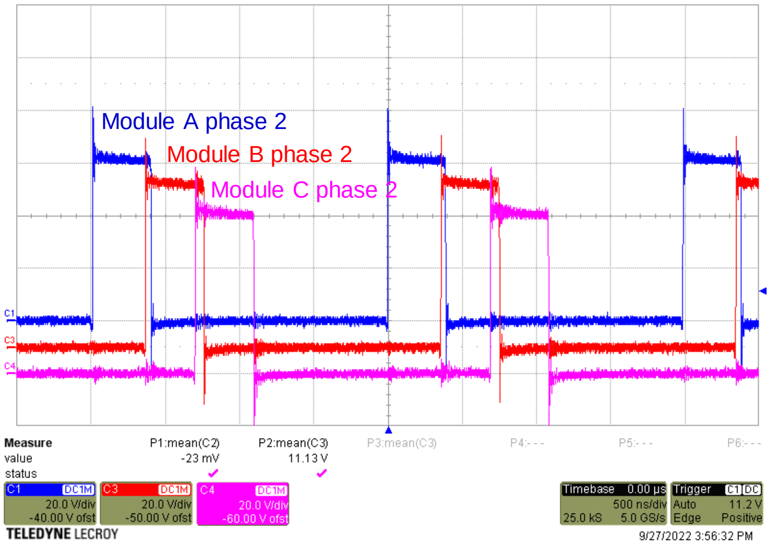



**Figure 23 Switching node waveforms: 60 $V_{in}$, 12 $V_{out}$, 192 A out**

## References

[1] Infineon Technologies AG: *Infineon Developer Center*; 2024; Available online

## Revision history

| Document revision | Date | Description of changes |
|---|---|---|
| 1.0 | 2024-10-31 | Initial release |

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